A case for experimental and speculative political ecologies

Dylan M. Harris[1]

Dan Santos

University of Colorado Colorado Springs, USA

Australian National University, Australia

Abstract

One of political ecology's main strengths is its emphasis on critique, and, through critique, its ability to better understand nature-society relations. Recently, calls have been made from within the sub-discipline – and from the social sciences more broadly – to move beyond critique, to engage nature-society relations more experimentally. Experimental approaches to nature-society relations invite new techniques and methods to study issues as they emerge, as opposed to those that have already happened. To this end, much has been written about the limits of human reasoning and understanding in the face of large-scale environmental crises like climate change. Complementing experimental sensibilities, speculative approaches to nature-society relations engage directly in the politics of expanding imaginative, perspectival, and political capacity in the face of these changes. The aim of this article is threefold. First, we will highlight scholarship that informs already existing approaches to experimental and speculative political ecologies, tying these threads together to elucidate a larger research agenda. Second, by way of example, we will discuss two case studies – solar's role in Colorado's 'just transition' and speculative climate futures and CRISPR-based gene drives and environmental management – to inform our discussion. Finally, this article serves as the introduction to a Special Section, in which we will outline and connect three articles that point towards how political ecology can be done with an eye more explicitly trained towards the future.

Keywords: speculation, experimentation, genetic engineering, solar energy, climate change

Résumé

L'une des principales forces de l'écologie politique est l'accent qu'elle met sur la critique et, à travers elle, sa capacité à mieux comprendre les relations nature-société. Récemment, des appels ont été lancés au sein de la sous-discipline – et plus largement dans les sciences sociales – pour aller au-delà de la critique, afin d'engager les relations nature-société de manière plus expérimentale. Les approches expérimentales des relations nature-société font appel à de nouvelles techniques et méthodes pour étudier les questions émergentes, par opposition à celles qui ont déjà eu lieu. On a beaucoup écrit sur les limites du raisonnement et de la compréhension de l'homme face à des crises environnementales de grande ampleur comme le changement climatique. En complément des sensibilités expérimentales, les approches spéculatives des relations nature-société s'engagent directement dans la politique d'expansion des capacités imaginatives, perspectives et politiques face à ces changements. L'objectif de cet article est triple. Tout d'abord, nous mettrons en lumière les études qui éclairent

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[1] Dylan M. Harris is an Assistant Professor in the Department of Geography & Environmental Studies at the University of Colorado Colorado Springs, Colorado Springs, CO 80918, USA. E-mail: dharri14@uccs.edu. His research focuses on the stories we tell (and don't tell). about climate change, energy, debt, and labor, focusing on the intersections of these issues as they relate to climate and energy justice. Dan Santos is a Postdoctoral Fellow in the Centre for the Public Awareness of Science at the Australian National University, Acton 2601, A.C.T., Australia. His research is broadly concerned with the dynamics between political economic processes and public engagement, especially with respect to emerging biotechnologies. Acknowledgements: We want to thank to all the participants and attendees from our panel on 'Speculative and experimental political ecologies' at the 2019 Annual Meeting of the American Association of Geographers who helped push and shape this conversation, which has evolved over the past few years to inform this article. We are also grateful to Simon Batterbury for allowing us to edit this Special Section, and for his encouraging editorial guidance. Similarly, we are thankful for three anonymous reviewers for their thoughtful and generative feedback. Any mistakes are, of course, our own.
This is the introduction to Dylan Harris and Dan Santos (eds.) 2023. "Speculative and experimental political ecologies" Special Section of the *Journal of Political Ecology*, 30.

les approches déjà existantes des écologies politiques expérimentales et spéculatives, en reliant ces fils pour élucider un programme de recherche plus large. Ensuite, à titre d'exemple, nous discuterons de deux études de cas – le rôle de l'énergie solaire dans la " transition juste" du Colorado et les futurs climatiques spéculatifs, et les lecteurs de gènes basés sur CRISPR et la gestion de l'environnement – pour éclairer notre discussion. Enfin, cet article sert d'introduction à une section spéciale, dans laquelle nous décrirons et relierons trois articles qui montrent comment l'écologie politique peut être réalisée avec un œil plus explicitement tourné vers l'avenir.
Mots-clés: spéculation, expérimentation, génie génétique, énergie solaire, changement climatique

Resumen

Uno de los principales puntos fuertes de la ecología política es su énfasis en la crítica. Recientemente, se ha hecho un llamamiento para ir más allá de la crítica y abordar las relaciones naturaleza-sociedad de forma más experimental. Esto requiere nuevas técnicas y métodos para estudiar los problemas a medida que surgen, en contraposición a los que ya han sucedido. Los críticos han cuestionado los límites del razonamiento y la comprensión humanos ante crisis medioambientales a gran escala como el cambio climático. Los enfoques especulativos de las relaciones naturaleza-sociedad amplían nuestras capacidades imaginativas, perspectivas y políticas para hacer frente a los rápidos cambios. Este artículo desvela en primer lugar lo que entendemos por ecologías políticas experimentales y especulativas. En segundo lugar, a modo de ejemplo, analizaremos dos estudios de caso: la energía solar en la "transición justa" de Colorado, y los impulsores genéticos basados en CRISPR y la gestión medioambiental. Por último, presentamos una Sección Especial, que conecta tres artículos que muestran cómo la ecología política puede orientarse hacia el futuro.
Palabras clave: especulación, experimentación, ingeniería genética, energía solar, cambio climático

1. Introduction

According to the newest report from the Intergovernmental Panel on Climate Change, the world is on track to reach 1.5°C of average global warming beyond the pre-Industrial baseline by 2040 in nearly every possible emissions scenario (IPCC, 2021). This degree threshold signals, for many, a point of no return, moving into a world characterized by dangerous climate change, a world in which previously known or understood climatic processes become unknown and unknowable. Scientists write with a sense of foreboding, arguing that now is the time to act in order to avoid a dire planetary future. In all this writing, there is a sense of anticipation, language loaded with the future perfect tense, implying that the worst of climate change is yet to happen. This work is necessarily *pro*spective (as opposed to *retro*spective) (Harris, 2020), and as such carries with it an inherent element of speculation, such as using the best cutting-edge science (e.g., modeling, multivariate data synthesis, etc.) to make informed hypotheses about the future. While this work is invaluable, it is important to consider that the future is always political, a site of struggle and contestation built upon the legacies of the past and present.

As Andrew S. Mathews and Jessica Barnes (2016, p.21) point out, "Futures are not easily made, nor are people easily persuaded to believe in them. As both material and imaginative objects, always in motion, futures are open to challenge." Implicit in the act of speculation is an element of the unknown, gaps that are rarely innocent of social and political realities. In the same way that much of Western science fiction writing implies that the future is invariably Western and white (Whyte, 2018), the unknown unknowns of speculative analysis, left unchecked, replicate the inequalities of the past and present. Further, the predominant focus on collapse undermines any possibility of critical analysis of the factors that led to the cusp of catastrophe. Bruce Erickson (2018, p.111) writes, "the threat of collapse forecloses the future as a site of creatively reimagining the social relations that led to the Anthropocene." He argues, the "relationship between environmentalism and the settler state in the Anthropocene reminds us that the universal discourse of the Anthropocene is intertwined with the attempt to sustain whiteness into the future" (Erickson, 2018, p.111). Importantly, as writers like José E. Muñoz (2009) and Kara Keeling (2019) remind us, the future is a space of possibility, of radical political and social potential, where the failing, systemically unequal institutions of the present do not have to persist. J. K. Gibson-Graham (2006) shows us that a world after capitalism is possible, and projects like the Petroculture Research

Group's (2015) *After Oil* create critical space to encounter and overcome what appears to be an impasse for more sustainable, equal, and diverse futures.

However, these futures do not make themselves. Therefore, we argue that speculation, though necessary, should be intertwined with criticism. Further, and more to the point of our intervention in this article, more emphasis should be put on analyses and research that intentionally aims to create different futures. In this respect, experimentation is key, although it is rarely applied to the future, especially within the social sciences which tend to focus on events in the past or that are happening in the present. This emphasis would include efforts to understand critically informed experimental initiatives undertaken by others, and interventions designed and implemented by researchers themselves. In many ways, speculation and experimentation are viewed negatively in social science research because of their less-stable claims to knowledge production. However, to avert catastrophe – to avoid a self-prophesied future wrought with the inequalities of the present – we argue that both critical speculation and experimentation are imperative. More specifically, we argue that political ecology, with its emphasis on historical power relations, attention to social inequalities, and critique, is especially well-suited to addressing many of the pressing issues of the present and future. While much of political ecology, like social sciences more broadly, has focused largely on the past, in this article and associated Special Section, we ask, following Donna J. Haraway's call (2016) to 'stay with the trouble' of ongoing, intertwined crises of the present: *how can political ecology help us avoid or preempt the trouble? Further, how might political ecology help us envision and enact more sustainable, radically creative, and diverse futures?*

To date, there have been several interventions in the field that deal with elements of speculation and experimentation, which seem to be increasing in light of future-facing crises stemming from climate change (e.g., potential sea-level rise; geoengineering, etc.). However, they have not necessarily been brought into conversation with one another in terms of their engagement with speculation and experimentation. Our first goal in this article is to outline how these interventions have already begun the process of making political ecology more speculative and experimental, noting specifically how political ecology's roots and historical emphases on issues of power, politics, and environment are crucial for more critical studies of the future. Second, this article will focus on two case studies from our research that highlight how speculation and experimentation are already at play in many of the issues that political ecologists study. The first case focuses on the development of one of the largest solar projects in the United States, located in Southern Colorado, and its potential socioecological impact on the region. The second case focuses on the development of gene drives for use in environmental management, specifically noting the participatory issues that arise with using novel genetic engineering technologies. Then, we will shift our focus to the three other articles that make up this Special Section, noting how, together, they offer an important intervention in the way we think of and do political ecology scholarship. Finally, we conclude by sketching broad contours for an emerging research agenda that emphasizes, rather than avoids, speculation and experimentation.

2. Speculating and experimenting with political ecology

We see speculation and experimentation as working hand-in-hand, and, while we aim to discuss them in relation to one another, we also want to acknowledge that the two offer different avenues for analysis. In this section, we discuss each in turn; however, we will also discuss them as interrelated and intersecting concepts. Broadly, we define speculation as the work of critically considering, imagining, and creating conditions for more just and equitable futures. We see speculation as a tool that helps clarify important questions of potential that are often dismissed because they are not as empirically legible as typical political ecology scholarship that, again, tends to focus on issues in the past and the present. If speculation can be considered the work of creating conditions for more just futures, we see experimentation as the means by which we can create those futures. Experimentation can be defined in a number of ways, in our work and otherwise. However, in short, we see experimental research as trying something new, regardless of whether it fails. Though we explore more traditional senses of experimentation (e.g., lab coats, scientific method, etc.) below, we are also aiming to evoke an understanding of experimentation more akin to something like experimental art

or music, which is to say we are hoping to combine well-trodden and emerging theories and methods in ways that inspire new modes of thinking, studying, and doing political ecology.

Speculating

In response to an article about 'anticipatory adaptation' to climate change (see also Ross, 2011; Kuruppu and Liverman, 2011), Laura Pulido (2012) argues that, while she agrees with the general idea of anticipatory adaptation, "The truth is, triage is *already* happening *de facto* in various places across the globe. This is not something that may come in the future — the future is now and we have shown ourselves perfectly capable of ignoring the suffering that climate change has caused others." She goes on to point out, rightfully, that climate-related tragedies are rarely due only to climate change. There are a multitude of intersecting factors that inform disasters, which are never 'natural', and these disasters impact people of color disproportionately. While so much of climate planning focuses on the future, Pulido (2012) is quick to remind us that "the future is now." The plasticity of time, and specifically the scales of time, have been central to geographical knowledge for decades (Massey, 2001), and Pulido's insight that 'the future is now' adds another layer of complexity to the way temporal scales are typically discussed in geography and in political ecology by extension. Whereas temporality typically refers to the timescales at which events have happened or could happen, Pulido shows us that time scales happen simultaneously, thus reinscribing the notion that the future is always in motion and is always political (see also Jeffrey and Dyson, 2020). It is critical, then, to bring the future squarely into the purview of political ecology.

Critiques of capitalism are central to political ecology, but, as Povinelli (2016) notes, capitalist development is future-oriented, looking toward the future and new possibilities as it de-territorializes and re-territorializes frontiers of production, leaving behind the wake of inequality that political ecologists often study. This strategy can be seen in the wave of venture capitalists vying for 'climate-tech' contracts in light of the newest IPCC report on the dire state of the global climate (Rathi, 2021; IPCC, 2021). With some notable exceptions where the future has been the frame of analysis (see Mansfield *et al*., 2015; Braun, 2015b; Holifield & Schuelke, 2015; Collard *et al*., 2015; Robbins, 2020; Lawhon *et al*., 2021; Paulson, 2021), much of political ecology tends to avoid speculating about the future directly. Yet, the future, almost as a specter, has been central to much recent political ecology scholarship (McCarthy & Thatcher, 2017; Paprocki, 2018; Buck, 2015; 2019; Surprise, 2020). Rather than only anticipating the worst of future capitalist development, our intention here is to highlight how speculative inquiry and analysis, much of which is already happening, can be tuned towards outpacing or preempting the fallout of capitalist development. In other words, we argue it is possible – perhaps necessary – to take political ecology's strengths and apply them with the understanding that the 'future is now.'

In the introduction to a special issue of the *Annals of the American Association of Geographers,* 'Futures: Imagining socioecological transformation', Bruce Braun (2015b, p. 239) comments on "the discipline's inability to imagine alternatives in its widespread and principled rejection of prescriptive or normative approaches to political or ecological change and its widely held suspicion of utopian thought." And yet, as Tom Perreault *et al*. (2015) note, it is precisely a commitment to normative and prescriptive claims that make political ecology unique. However, we argue that suspicion of utopian thought persists in political ecology, despite the field drawing from several writers and thinkers whose work touches on utopianism. In her 'cosmopolitical proposal', Isabelle Stengers (2005) articulates a need for political ecology, at least a version of it, to be more speculative and open to possibility. This approach to knowledge production is echoed by other nature-society scholars who envision the element of the unknown in speculative thought as a form of praxis (Ogden *et al*., 2013; Kirksey *et al*., 2013; Kirksey, 2015).

Anna L. Tsing writes about the possibilities of life in the ruins of capitalism (2016), building upon insights from Gibson-Graham (2008) who utilize the notion of prefigurative politics – of creating the conditions for a viable future in the present – to think through, and create, possibilities for life after capitalism. The proliferation of literature examining the realities of structural racism and racial inequalities in the present, with an eye towards implications for the future, also signals the importance of work that focuses squarely on the politics of speculative utopianism as a matter of analysis rather than something to avoid (Krupar & Ehlers,

2016; Smith & Vasudevan, 2016; Heynen, 2018). Following the footsteps of scholars like Zoi Siamantha (2021) and Laura Zanotti *et. al*. (2020), we argue that it is both possible and useful to blend political ecology's emphasis on historical power relations and capacity for making normative claims about environmental injustices with the ability to consider and create more viable futures.

We are drawn to Alexander Dunlap's conceptualization of an "insurrectionary political ecology", which calls for a practice of "viral subversion" – a "lived, subtle and continuous practice that creates unmediated socio-ecological relationships to restore ecosystems through free political practices" (2020: 1005). In other words, Dunlap is calling for a proactive, anti-authoritarian stance to both political and ecological relations that simultaneously undermines destructive and exploitative socioecologies while also laying the foundation for counter-hegemonic socioecological futures. He calls for scholars and activists to "break our separation from 'nature' and unite our radical theories with a practice built on experimentation [more on that below], joy, freedom from institutions, friendship and mutual aid" (2020: 1009). This work is reminiscent of David Graeber's (2014) essay, *What's the point if we can't have fun?* that asks readers to consider the prospects of joy and play as formative elements of evolutionary theory, highlighting a potential for socioecological relations to be anything but oppressive and pointing towards a future where pleasure rather than power is a driver of change. Ongoing efforts to block the building of 'Cop City' – a proposal to build the largest police training facility in the U.S. in the Welaunee Forest (stolen Muscogee land) near Atlanta, Georgia – exemplifies insurrectionary political ecology. Activists have been organizing rave-protests to protect the forest, creating autonomous spaces of resistance and actively speculating and building visions of an abolitionist future (Beery, 2022). Similarly, rather than focusing on what ought not happen in the future (e.g., a wariness of large-scale geoengineering) (Buck, 2019; Surprise, 2020), perhaps it is possible for political ecologists to focus more on what *ought* to happen. In addition to honing our ability to imagine just futures, we also need to be more comfortable with creating the conditions to make them possible. It is time, we argue, for political ecologists to study and stage interventions – speculating and building – and to examine their outcomes as a means of creating the world we would like to see.

Experimenting

To stage interventions, experimentation is key. In its many possible guises and modalities, it offers an especially useful lens, sensibility, and approach to imagining and enacting alternative futures. It is useful to study experimentation more generously, keeping criticism in mind while also leaving conceptual and analytical room to learn from others' mistakes. For example, it is easy and useful to be critical of geoengineering experiments. However, as Holly J. Buck (2019) points out, these experiments are happening regardless, and, as such, it behooves critical researchers to better understand where and how these experiments take place as a means of highlighting, and perhaps even shaping, their outcomes. Additionally, it is useful to actually stage experiments of our own, seeing what works or does not work in the hopes of creating more just environmental futures, actively embracing failure as a part of the necessary process of knowledge production. In arguing for more experimental approaches in political ecology, we take an expansive and open view of what 'experimentation' may involve. Our intention is not to prescribe or impose any singular definition, but instead to encourage others to work through and with the meanings and possibilities afforded by experimental approaches, and to consider the futures at stake in enacting them, both by others and ourselves.

Experimental approaches to understanding nature-society relations have proliferated in recent years. A few examples will suffice to demonstrate their varied contexts, conceptualizations, and approaches. Stuart Lane *et al.* (2011) describe an experiment in undertaking flood management differently in England and Wales, defining their experiment in relation, and contrast, to existing and dominant approaches. Their "radical scientific method" was designed around the co-production of knowledge between experts and publics from the outset, such that their experiment "became as much about creating a new public capable of making a political intervention in a situation of impasse, as it was about producing the solution itself" (p. 15). Vanesa Castán Broto and Harriet Bulkeley (2013, p. 1934) understand urban climate change experiments as "purposive interventions that seek to reconfigure urban sociotechnical systems to achieve low-carbon and resilient cities." While the initial stages to establish experiments are important, they also posit the need to examine and

understand how experiments are maintained over extended periods of time. Finally, in telling stories about urban water voles in the UK, Steve Hinchliffe *et al*. (2005) explore urban wilds and political ecologies and consider the sorts of 'cosmopolitical' possibilities that arise when thinking through how the nonhuman matters, in myriad ways. While they do not define 'experiment' explicitly, they adopt an experimental sensibility that foregrounds openness and a lack of closure: "the things, spatialities, and working practices that we are interested in cannot be adjudicated upon once and for all" (p. 644). With their varied empirical foci and understandings of experimentation, each has grappled with novel forms of environmental politics and governance and have tried to make sense of new modes of knowledge production, collaboration, and intervention. Collectively, these varied engagements with the experimental show an orientation towards grappling with complex problems that require imaginative forms of governance, and the need to remain open to learning new lessons in an ongoing way.

Drawing on these examples of experimentation, the following insights are by no means exhaustive. Instead, we focus here on useful sensitizing concepts and perspectives drawn from Science and Technology Studies (STS), a field in which experiments and experimentation have been a longstanding topic of interest. While there have been insightful examinations and critiques of the intersections between political ecology and STS around ontological (Lave, 2015), epistemological (Goldman and Turner, 2011) and political economic dimensions (Lave, 2012), we see 'experimentation' as enabling further conceptual traffic between the two fields in multiple ways.

Firstly, an ecological experiment is simultaneously a political experiment – that is, the ecological and the political, the scientific and the social, are co-produced (Jasanoff, 2004). The formation or creation of new (environmental) knowledge is rarely, if ever, separate or distinct from questions about how to use such knowledge. When analyzing or enacting experimentation, we are not only learning about new ways to know the world, but we are also fashioning, epistemologically and materially, the very worlds that we desire and believe are necessary (or, to be avoided). A key question to consider and unpack in adopting an experimental sensibility could be: what forms of nature, and what forms of governance, do we want to explore and realize to address urgent and complex environmental problems?

With respect to the former – the question of nature and technoscientific knowledge – it is important to remember experiments not only attempt to generate new knowledge and technologies, they also actively generating information about what we do not know. Experiments reveal new forms of uncertainty and ignorance such that "what makes the physical, technical, and procedural basis for an experiment work is that it is deliberately arranged to generate surprises" (Gross, 2010, p.5). These surprises may be just as significant as positive knowledge because they do not provide stable grounds on which to make decisions and act, and thus demand more negotiated, and potentially contested, approaches to developing appropriate responses. Nevertheless, those designing experiments generally want to remain "open to surprises but at the same time [be] eager to control the surprising even as a basis for learning" (Gross, 2010, p.29). These two dualities – knowledge and surprise, control and openness – mean that learning and adaptability are critical for experimentation.

There are central questions that merit consideration around who can participate in the experiment, who can design it, and whose lessons are learned from it. In many technoscientific matters, there are important differences between 'experts' and the 'public', and there are often unequal power relations between them. In order to move towards more balanced relations and decision-making, it is important to avoid perceiving the 'public' as a stable, pre-existing entity that merely responds to a technoscientific controversy. Instead, there are always multiple publics with potentially overlapping and conflicting interests, and each of these emerges from and is associated with a specific issue in a particular context (Marres, 2005). If issues may create publics, then experiments which create new knowledge (and issues) also create new publics, such as 'hybrid forums' of diverse groups of engaged participants who discuss how to manage new technoscientific possibilities and forms of risk (Callon, Lascoumes & Barthe, 2011). Furthermore, these groups need not only be composed of human actors; non-humans may be significant actors within experiments, participating in myriad ways to shape the contours and outcomes of these experiments in significant ways (Lorimer and Driessen, 2014). Collectively, these ways of thinking about what publics are and how they emerge, open questions about the power relations that may affect the design of future-oriented experiments.

Work on experimentation, participation, and democracy has generated several useful insights for applying experimental approaches in political ecology. Conventional, routinized approaches to soliciting public perspectives and participation on technoscientific questions are insufficient. Alexander Bogner (2012) contrasts two forms of participation: 'protest participation' and 'lab experiments.' While the former is initiated and mobilized by concerned publics, the latter are organized by professionals and experts (including academics) who design, monitor, and evaluate participation activities as 'experiments', under "controlled conditions" which are, ironically, "without reference to public controversies, political participant demands, or individual concerns" (p. 510). These 'lab experiments' include relatively common types of participation activities like citizens', or consensus, conferences. These utilize public deliberation as research praxis, were initially developed in Denmark and have been primarily applied in Western contexts (Einsiedel and Eastlick, 2000). Lay people may be invited to participate, but as these lab experiments are externally organized and framed, order and control predominate over openness and possibility, undermining the chance that more radical potentialities may emerge from such engagement exercises. If the crux of experimentation is "fostering and controlling surprises in a modularized manner" (Gross, 2010, p.79), then many externally developed and designed participation 'experiments' focus too much on the latter. More exploratory and emergent approaches to experiments are needed, especially ones that are more attuned to broader political and democratic contexts.

There are more experimental participatory modes. Anna Krzywoszynska *et al*. (2018) consider how publics and futures are simultaneously produced and argue that "when the aim of public participation is extending democratic influence over the shaping of the future, the question of *whose futures are constructed and examined in participation matters*" (p. 787; emphasis in original). Javier Lezaun *et al*. (2017) note the importance of materials in experimentation by positing that "deploying settings, devices and/or things experimentally makes it possible to curate novel forms of participation, eliciting expressions or accounts of public issues that would otherwise remain underarticulated or existing only *in potentia*" (p. 197; emphasis in original). Different forms of speculation can arise that deviate from the narrowly imagined approaches of Bogner's 'lab experiments.' Maintaining a critical and wary eye to make sure that experimental sensibilities do not become constrained or undermined is important, and political ecology's strengths in critique can be productively channeled towards ensuring that experimental sensibilities retain their open, emergent outlook.

In surveying existing work that has pioneered productive directions to conducting speculative and experimental work in political ecology, our goals are to highlight the ways in which such approaches can offer insightful and useful outlooks for forging new directions and paths for political ecology. Building on these existing insights, in the next section we demonstrate through two case studies what speculative and experimental approaches in political ecology could look like.

3. Speculating about the Transit of Colorado's "Just Transition"

In the United States, the State of Colorado is on the cusp of a renewable energy transition. The Martin Drake coal-fired generating station in downtown Colorado Springs, the state's second largest city, recently stopped burning coal as a means of weaning the state off fossil fuel dependence (Budner, 2021). Three-hundred miles northwest, the Hayden Generating Station, once the cornerstone of its community (providing nearly half of the tax base for the local school district), is slated to be transformed into a massive battery for renewable energy as it phases out burning coal by 2028 (Brasch, 2021). Nearly fifty miles (80km) south of Colorado Springs, one of the state's newest and largest coal-fired power plants, the Comanche Generation Station, is set to close by 2040, three decades earlier than expected (Otárola, 2021). Six miles (10km) northwest of the Comanche Generation Station lies the Big Horn Solar Project (BHSP), one of the largest on-site solar facilities dedicated to a single customer in the U.S. The BHSP, currently set to be online by the end of 2022, is being built through a partnership between Xcel Energy, an energy company serving 3.7 million customers electricity across eight states in the U.S. Midwest and West, and Lightsource bp[2], a recently re-branded partnership between Lightsource Renewable Energy and BP that is the third-largest solar developer in the world outside of China. The BHSP will provide energy to the EVRAZ Rocky Mountain Steel mill facility, ensuring that the

[2] https://lightsourcebp.com

mill, which has been a socioeconomic touchstone for the City of Pueblo since 1881, will continue producing steel, providing jobs, and enriching the city's taxbase for decades to come, all while producing the world's "greenest steel" (Kohler, 2021).

Each of these 'transition' projects aligns with Colorado's plans outlined in the recently published *Just Transition Action Plan* (2020), which reflects the 2019 Colorado General Assembly's "moral commitment to assist the workers and communities that have powered Colorado for generations" in light of a large-scale transition "away from coal as a fuel for generating electricity" (CDOLE, 2020, p.1). While much has been written about the need for a just transition – a large-scale shift in socioeconomic relations away from a society built around fossil fuels towards a society that is meant to be more equitable, more 'just', and built around more sustainable practices (energy being one of many) – much less is said about the 'transit' of transition, or, in other words, the discursive and material work of speculation involved in the project of shifting society towards something prescriptively 'better' to avoid the worst impacts of climate change (Wilson, 2018; Curley, 2018; White, 2019; van den Bold, 2021). In many ways, this brief case study of the BHSP brings to light the 'transit' of transition by raising the following questions: what exactly is being transitioned away from and to, and who stands to benefit (or lose) from such a transition? These questions are especially salient when considering the steel industry's historical legacy as a dirty industry.

To begin answering these questions, it is helpful to turn towards Jodi Byrd's (2011) conceptualization of transit. Though her framing of transit does not mention renewable energies, it speaks broadly to the social and ecological relations that underpin mainstream notions of a just transition. The transition to renewable energies, considering Colorado's *Just Transition Action Plan*, signifies a commitment to 'sustainable growth', ensuring a vision of 'Transition without Loss', as it is articulated by the Petrocultures Research Group (2015). In other words, mainstream ideations of the Just Transition align with a greener version of 'business as usual', which may, on the one hand, work to lessen greenhouse gas emissions. However, on the other hand, they are an evolution of the machinations of empire, or the perpetuation of patterns of power and powerlessness that, according to Byrd (2011), characterize the U.S.'s role as a settler state: "the Indian is left nowhere and everywhere within the ontological premises through which U.S. empire orients, imagines, and critiques itself" (Byrd, 2011, p. xix). Further, she writes, "What it means to be in transit, then, is to be in motion, to exist liminally in the ungrievable spaces of suspicion and unintelligibility. To be in transit is to be made to move" (2011, p. xv). Progress, for as long as the U.S. has existed, requires, as a precondition, the displacement and dispossession of Indigenous populations. Transition without loss, then, is simply not possible. Just a few miles away from where the BHSP is being built, a massacre of over 40 Ute people took place in 1854, only a few decades before the steel mill was established (Flores and Norton, 2019). Again, it is important to ask, considering these histories: what exactly is being transitioned away from and to, and who stands to benefit (or to lose) from such a transition?

To date, there have been many 'transition' projects around the world that have only served to perpetuate violence rather than to ensure just futures (Rignall, 2015; Avila-Calero, 2017; Siamantha, 2021). The 2016 murder of Honduran environmental activist, Berta Cáceres, who was organizing protests against a hydroelectric dam that would have been damaging to her community, puts this violence into stark perspective. Cáceres was even considered an 'enemy of progress' by the Honduran state for her actions (Reel, 2020). Context certainly matters, and the political realities of Colorado are different than in Honduras. However, the promise of solar energy specifically conceals the 'hidden costs' of the technology (Mulvaney, 2019). From the unjust labor practices to the environmentally destructive mining of rare materials necessary for the manufacturing of solar panels, these hidden costs are not on display at the BHSP.

While the newly revamped facility, which has a long history of labor disputes (Personal Communication, 2022), is set to provide over a thousand 'green' jobs to an area struggling with low employment rates (Kohler, 2021), and with high rates of energy poverty and histories of environmental injustice, there are hardly any considerations, at least publicly, of what else could be built in its place. Further, while the EVRAZ facility will now use solar energy for its electric arc furnace to produce steel (as opposed to the fossil-fuel intensive blast furnace method) (IEA, 2020), it is important to consider what ideologies – of progress and growth – are implicit in the push towards a just transition. Beneath the veneer of progress and 'green' growth are more complex, often unseen politics – for example, who benefits from closing a coal-fired power plant in

terms of taxation (Tapp & Kay, 2019)? Additionally, according to a former EVRAZ employee, the facility is the largest single user of electricity in Colorado (Personal Communication, 2022). Even if the BHSP can manage to produce enough energy to power the entire facility, the amount of power required still raises questions of consumption and growth that are rarely discussed in mainstream just transition policies and literature (Velicu & Barca, 2020). It is also important to consider that the EVRAZ facility recycles scrap steel, much of which has historically been acquired in the U.S. (Personal Communication, 2022). But it also imports some steel – in the form of pig iron – from countries like Russia and Ukraine. The production of pig iron is the most emissions-intensive element of the global steel industry, which produces nearly eight percent of the world's CO_2 emissions and consumes nearly fifteen percent of its coal (Mikulka & Exley, 2022). Although the BHSP will provide several meaningful benefits, economically and environmentally, it is also important to keep in mind that the 'greening' of the facility, on its own, will not guarantee a truly just energy transition.

As Mulvaney (2019) rightly points out, critiquing a just energy transition to renewables is not to stymie the process but to shed light on a history of unjust socioecological relations, in order to make sure they do not continue. Avoiding unjust futures is part of a longer-term project studying the 'transit' of Colorado's Just Transition. Rather than working with communities to prescribe a 'better' future, this project aims to build visions of the future collaboratively through critical speculation, or what Ogden (2021, pp.12-13) calls speculative wonder: "…an experimental approach to engaging and representing those worlds." She writes "Thought experiments are the nudge that helps us ask, *What if*?", allowing an expansiveness that "helps nudge concepts that feel stagnant (2012, p.13)." By bringing histories of dispossession into perspective in a present characterized by energy poverty and warming temperatures, building on the strengths of political ecology, the project works alongside communities impacted by the BHSP to ask, *what if*? What if, instead of replicating these histories (albeit from a 'greener' approach), we experiment together to envision and enact creative futures? Here, the role of speculation is key, of analytically and methodologically entering the 'transit' of transition, to imagine and prefigure just outcomes, rather than studying the aftermath of failed policies. As Colorado, and the U.S. more broadly, push for a just transition, it is imperative to create spaces of and conditions for engagement in the process of transit, speculating about the future while experimenting with the means to ensure it. The past lives in the present, and the present lives in the future (Sharpe, 2016; Keeling, 2019). Regarding a just transition in Colorado, speculation is a powerful, necessary tool for engaging in the 'transit' of transition, which is to say the material and discursive politics of socioecological and sociotechnical change, as projects like the BHSP go online.

4. Experiments in environmental governance with gene drives

In the last decade there have been rapid advancements in the capabilities of genetic engineering technologies. This has led to substantive discussion about how to use these technologies to address environmental and health problems. At the forefront of these biotechnological developments has been CRISPR-based genome editing. Adapted from a naturally occurring viral defense system in bacteria and archaea, CRISPR-based genome editing comprises a set of techniques allowing scientists to make precise, targeted edits to the DNA of virtually any species, thereby wielding unprecedented control at the genetic level (Doudna & Steinberg, 2017). One of the more prominently discussed biotechnological applications in environmental management has been gene drives.

There are naturally occurring gene drives, but much of the recent discussion and debate has revolved around gene drives constructed using CRISPR-based genome editing. While several types of gene drive have been developed (see Min *et al*., 2018 for a detailed overview), in general they firstly involve genetically editing individuals in a target population to have a particular desired trait and the means to pass on that trait at higher rates than normal to their offspring. This can subsequently lead to the trait being inherited – 'driven' – throughout the population so that most, or even all, members of a population have it. There have been efforts to develop variations of this basic premise (for example, gene drives designed to be more 'local' in scope and reach; see Esvelt and Gemmell, 2017). Nevertheless, through gene drives, scientists are now not only able to edit the genomes of particular species, but can also ensure that the trait is inherited, over several generations, at much higher rates than normal.

In terms of potential applications, numerous possibilities have been touted (NASEM, 2016). One set of applications revolves around improving public health outcomes, involving the modification of organisms (such as mosquitoes and rodents) to contain and reduce the spread of infectious diseases. Another set of applications focuses on novel tools for ecosystem conservation, and would include initiatives to, on the one hand, manage and even entirely remove invasive species, and on the other hand to modify threatened or endangered species to increase their adaptability and resilience in changing environments. Finally, there are potential applications in agriculture to modify organisms that spread harmful diseases or that ecologically outcompete valued crops. These applications are being considered in a variety of contexts, requiring attention to multi-scalar dynamics ranging from national regulation to the cultures and needs of local communities; see Genetic Literacy Project (2020) for information about gene drive initiatives around the world in development and the associated regulatory contexts.

There have been several efforts to critically think through and anticipate the issues involved with gene drives. Many of these efforts raise issues and concerns that are prominent in political ecological thought. Zahra Meghani (2021), focusing on proposals to genetically modify mosquitoes to combat malaria in sub-Saharan Africa, critiques the ways in which the scientific 'biologization' of what is an inextricably social, political, and economic public health issue diverts attention from broader structural dynamics. With the support of prominent NGOs like the Bill and Melinda Gates Foundation, gene drives may come to embody a "high risk, high-tech, market-based intervention for malaria [...] rooted in [a] neoliberal orientation" (p. 436). As such, patented gene drives may be invested in for their profit potential and become prohibitively expensive for the countries where they may be most beneficial, undermining or significantly constraining positive health-oriented outcomes (Meghani, 2021) As the basis of another set of critiques, islands, because of their isolation, have often been forwarded as ideal sites for initial gene drive experiments. However, Riley Taitingfong (2019) draws parallels between this rhetoric and historical nuclear testing on Pacific islands, arguing that such histories, and their continuing contemporary consequences, foreground the importance of including Indigenous peoples as significant stakeholders in whether, and how, gene drives are used.[3] Proposals regarding the participation of local communities made by others. For example, Dalton George *et al*. (2019) have explored how 'free, prior and informed consent' might be legitimately obtained from affected communities, although what 'consent' might mean for future generations remains a challenging, underexplored problem.

Some of these critiques are about structural conditions, and therefore difficult to change, at least in the short-term. The emergence of the modern biotechnology industry in the 1970s was closely intertwined with the rise of neoliberalism and remains so, and its political economy is pervaded by logics of privatization, patents, and profit (Cooper, 2008). Combined, for example, with the increasing prevalence of neoliberal approaches to conservation and environmental management (Arsel & Büscher, 2012), gene drives could become yet another example of how "environmental (and other) crises increasingly are themselves opportunities for capitalist expansion" (Büscher *et al*., 2012, p. 7). Here, gene drives as a techno-fix could be deployed in the 'disciplining of dissent' (Büscher *et al*., 2012). However, even within existing structural dynamics that may guide gene drives along or within particular trajectories, there is room for negotiating their applications to be more just and equitable. Investing critical thought into working towards these more desirable futures is worthwhile. In light of the critiques just outlined, this would involve changing how science and scientists engage with the communities who will be significantly affected by gene drive applications.

Here, Kevin Esvelt's (2016) efforts to emphasize an 'open and responsive science' in developing and applying gene drives are worthy of scrutiny. Esvelt is a prominent scientist in developing gene drives, and he has been vocal about the need to engage local communities in decision-making about whether, and how, to use gene drives to address environmental problems. However, enacting this ethos has not been without missteps and controversy (Ross, 2021). For example, New Zealand has long grappled with the challenges of managing invasive species and mitigating their impacts on local environments. Looking forward, *Predator Free 2050* is an ambitious initiative to entirely eradicate many of the predators that continue to cause the most ecological harm. Gene drives are a potential tool in this endeavor. Esvelt has made concerted attempts to practice his 'open

[3] See Ross (2021). for similar arguments about colonial histories and Indigenous communities in the context of New Zealand.

and responsive science' by meeting with Indigenous and Māori communities and emphasizes the vital role they should play in discussions about what role, if any, gene drives could play. However, there was immediate pushback when Esvelt and a colleague published a manuscript for review suggesting that New Zealand could be an ideal site for testing gene drives without consulting local communities. Esvelt subsequently apologized and took responsibility. The seriousness of these errors in judgment should not be downplayed or trivialized, and more broadly the reductionist assumptions inherent in the logic of gene drives sit uneasily in the context of the relational ontologies upheld by many Indigenous communities (Ross, 2021). But these errors and tensions need not be essentialized as indications of an inevitable abuse afflicted by science. Enacting a more 'responsive' science requires reconsidering responsibilities, and it is likely that this will involve mistakes; what is important to retain is an 'openness' to learning and accountability.

Gene drives may well become significant tools in future efforts to address climate change and other environmental issues. Such possibilities rightfully warrant a critical eye. However, equally as importantly they do not warrant complete, preemptive rejection. Should particular communities see value in using gene drives, then efforts to critically highlight pathways that should be taken, or avoided, are important bases on which to collectively speculate and experiment with how such pathways could align with the needs and desires of these communities. Here, looking to other contexts where public engagement with emerging biotechnologies is happening in experimental ways could also be insightful. For example, there is now a global movement to democratize biotechnology, especially in community science labs where new publics can experiment and innovate with biotechnologies (Santos, 2021). These developments are experimental in that such public engagements with biotechnology are relatively novel; a much wider range of people can now materially engage with biotechnology than ever before. To be sure, this expanded access raises legitimate concerns about risks. But there are also productive possibilities – engagement, learning, innovation – and these should not be dismissed or outweighed outright. Instead, through careful consideration, there can be ongoing processes of collective learning, informed by cultures and norms specific to particular communities. In adopting more speculative and experimental outlooks, enacting and practicing openness, responsiveness and engagement will require thought and balance with respect to both the critiques we make and the possibilities we imagine.

5. Tying together threads – the Special Section overview

In each of our case studies, we utilize both speculation and experimentation, albeit in different ways. The State of Colorado is one of many undergoing some form of a just transition in the U.S. as federal-level discussions of something like a 'Green New Deal' continue gaining traction. In Colorado, the transition is already underway, though importantly it is still in its early stages, meaning there is room to redirect a potentially inequitable trajectory. Critique comes into play in the Colorado case study by providing a nuanced context – of histories of dispossession and environmental injustice in Southern Colorado – from which to begin speculating about both what should not happen, and what could happen. Experimentation, then, is the route through which what *could* happen comes into view. By working in collaboration with stakeholders who stand to benefit the most from a truly just transition, it is possible to develop ideas for what such a transition may look like. Using experimental methods like collaborative storytelling workshops opens doors for more creative, even playful engagement with an otherwise overtly technical and expert-driven discourse that recycles historic ideas of growth and progress that may or may not be what stakeholders want or need.

With regards to gene drives, it is difficult not to speculate about what could happen if the technologies are left unchecked. Given historical precedents, there is plenty of room and need for critique: based on the way contemporary biotechnology has developed in tandem with privatization and commercial interests, and the expert-public divides and dispossessions that have ensued. However, rather than assuming the worst about gene drives or rejecting them outright as viable solutions to addressing health and conservation problems, it is helpful to temper these critical impulses and allow a measure of open-mindedness. Striking such a balance will perhaps allow for more imaginative forms of speculation and experimentation that might pave the way to considering gene drives as a radically equitable technology, one that is not controlled by powerful elites but that is more democratized, similar to the way CRISPR-based genome editing has become more widely accessible. Given political ecology's well-reasoned historical hesitancy around newly emerging technologies

(see, for example, Moseley, 2017; Bergius & Buseth, 2019), we argue that experimentation allows us to walk a fine line between being critical and skeptical on the one hand and being open-minded on the other, specifically considering how emerging technologies may lead to just outcomes. It is with these multitudinous definitions of speculation and experimentation in mind that we turn towards the three other articles that make up this special section.

Håvaard *et al*. (2023) highlight how relatively vague and amorphous policy targets, in this case Norway's Zero Growth Objective, can manifest as meaningful policy outcomes if the conditions for these outcomes are created. In other words, rather than seeing another ambitious policy target go by the wayside, which so often happens, it is imperative to hold the speculative nature of policy to account by creating concrete pathways that enable progress towards equitable outcomes. In the case of Norway's Zero Growth Objective, Håvaard *et al*. show how the policy targets were helpful for mobilizing initiatives that could be held accountable, and that the outcomes of the targets may not have come to fruition without input and action from civil society (e.g., researchers, activists, etc.). They show how the speculative work of policy meshes with the critical speculative work of prefigurative politics to produce, over time, a constellation of conditions through which policy outcomes are produced.

Rusca *et al*. (2023) directly confront the work of unchecked speculation by creating an experimental model that explicitly discusses inequalities that are often glossed over in climate modeling. So much of climate modeling predicts what appears to be a grim future, curtailing more generative possibilities for enacting meaningful change to curb worst of climate change. Instead of disabling potentiality, Rusca *et al*. experiment with modeling to envision urban climate futures that are more equitable and diverse. By specifically taking hydroclimatic extremes into account, meaning possible scenarios where water shortages are made more common due to climate change, they actively create alternative modeling that prefigures futures that are more open-ended, where there is room to consider and collaborate on possible futures where water is abundant. These open-ended models present different scenarios for consideration, allowing for more collaborative knowledge production. Further, they discuss the disruptive potential of flooding, not as something necessarily desirable but rather as an event that creates conditions for a radical reconsideration of socioecological relationships.

Schramm (2023) similarly engages experimentation as a means for envisioning more equitable, potentially post-capitalist futures. She examines how active degrowth communities are creating conditions for a more vibrant future in the present by experimenting with different modes of 'growth' and progress. More specifically, she highlights how experimentation – with invasive cacti, for example – can open doors for multispecies collaborations that challenge typical 'growth' narratives. Rather than fighting the invasive cacti with pesticides or abandoning the land where the plants grow, the community is experimenting with different ways of cultivating cacti to create food and cosmetic products. These experiments point towards novel agricultural techniques that complement the region’s winemaking history while also pointing towards pathways forward that are more climate resilient.

These three articles and this introduction discuss only a handful of ways to engage in political ecology more speculatively and experimentally, though there are invariably many other pathways this research could take. Here, we hope to begin developing theoretical and methodological frameworks as a means of encouraging broader engagement with these forms of thought and praxis in future. We are eager to see what ideas and conversations develop from this Special Section, and we are excited about the prospects for a political ecology that is more future-oriented, intervention-based, and open-ended. Taking climate change as an example, it is possible to see how there are many issues on the horizon, while also keeping in mind that many vulnerable communities are already experiencing the consequences of a rapidly warming planet. Rather than anticipating the worst, waiting for policy decisions to fail, or seeing how technologies like gene drives or geoengineering make things better/worse, we argue it is imperative that we – as researchers who actively want to see and participate in creating just outcomes – begin to pivot towards a political ecology that embraces critique and doubles-down on its emphasis on normative politics as means of ensuring a more equitable future.

6. Conclusions

As we began writing this conclusion, climate scientists found that the Greenland Ice Sheet is melting much faster than previously expected, raising red flags about significant global sea-level rise this century (Box *et al*., 2022). Within a matter of weeks, unprecedented, catastrophic flooding engulfed nearly a third of Pakistan, giving rise to outbreaks of water-borne disease as well as threatening food security (Hassan, 2022; Goldbaum & ur-Rehman, 2022). Similarly, Somalia was enduring its "worst famine in half a century", as it is in a fifth year of historically low rainfall and increasing temperatures (AFP, 2022).

To draw attention to these intersecting and dire crises, in October 2022 two young climate activists threw cans of tomato soup on Vincent van Gogh's painting, *Sunflowers*. The action went viral, resulting in a storm of controversies about what kinds of climate action are more or less acceptable, what is actually 'working', and, ultimately, what the point of disruptive action is more broadly. In an interview, one of the activists, Anna Holland, responded to these critiques: "…all it took was two young people to throw soup at a painting to get people talking more than they have done in such a long time about the climate crisis" (Holland *et al*., 2022). Later in the interview, the other activist, Phoebe Plummer, states, "Our generation doesn't have the luxury of sitting on the side-lines, because our futures are at stake" (Holland *et al*., 2022). It is with this sense of urgency, knowing the present for many and the future for us all is at stake, that we put forward this call for more experimental and speculative approaches for scholarly work, and for political ecology scholarship specifically. Whether you agree with the activists' action, they succeeded in disrupting the status quo, bringing critical attention to the intersecting realities of climate change (all without damaging the painting). How can we – as academics, educators, and activists – disrupt the status quo, breaking the patterns of business-as-usual scholarly practice that, arguably, only stands to perpetuate conditions for an unequal future?

We understand these are big claims and requests, and we acknowledge that this Special Section is only a small facet of what we hope will be a much larger conversation about more actively engaged research. Suffice to say, we are living in a time of profound change but also of profound possibility. We are in the midst of a global reconciliation with fossil fuel reductions, for example, as nations look more towards renewable energies to sustain their economies. To us, this represents a break, a path through which we can stage interventionist research, reconfiguring and redirecting possible outcomes to genuinely equitable ends. Emerging biotechnology is fundamentally shifting all that we know about the human body and its relationship to the world around us. These shifts are terrifying and exciting in equal measure, and we, as researchers, get to help shape that narrative, ideally towards a future where biotechnological applications are inclusive and participatory. The possibilities are truly endless. We just need to lean into them, understanding – and appreciating – that we may not always be 'right' or 'perfect', but that, as Holland *et al*. (2022) state, none of us have the luxury of waiting any longer.

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