



Engagement for genetic modification technologies in conservation: For whom, how, and for what ends?

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ABSTRACT

Questions of engagement loom large for the use of genetic modification technologies in conservation. As scientific teams rapidly move towards implementing changes that will fundamentally alter entire species, concerns are regularly raised that associated engagement activities are inadequate. It is therefore vital to take stock of recent social research that critically examines how engagement is being enacted: who is engaged and by whom, how and on what terms, and for whom or what those processes serve. Despite a rise in calls for engagement, our review shows emergent gestures towards engagement by developers and regulators lean strongly towards narrow instrumental approaches that reinforce knowledge hierarchies and existing power imbalances. It contributes to engagement practices that are often vague and tokenistic, and focused on one-way education and snapshots of opinion, rather than mutual reciprocity and dialogue. To counter these undercurrents, our review draws attention to the ways social researchers are seeking to reorient engagement for genetic modification towards its more substantive and democratic possibilities, through articulating process, amplifying plurality, and acknowledging contestation.

1. Introduction

The development of genetic modification technologies like gene drives has opened a range of possibilities for their use in conservation. Techniques like CRISPR are lauded as providing a step change in conservation efforts by altering the likelihood of specific genes being passed down within a species. Through spreading in wild populations this intervention could help manage pests or other biosecurity threats that contribute to biodiversity loss or alternatively bolster native species (e.g. Bier, 2022; Macfarlane et al., 2022). At the time of writing, only a few interventions are in development for conservation, but multiple speculative applications are being explored (Dearden et al., 2018). The technology is also being considered in a range of other applications, including to limit vector diseases like malaria, in agriculture, and to prevent some human diseases (Gusmano et al., 2021; Taitingfong et al., 2023).

Genetic modification is ethically fraught and socially contentious on many fronts, however. In editing life, it has the scope to alter entire

species and transform human and nonhuman relationships that form the basis for life-sustaining conditions, ties of kinship and connection, and livelihoods (Burrall, 2018; Jasanoff and Hurlbut, 2018). Regular warnings have been made about the potential for techniques like gene drives to create imbalances in already fragile ecosystems and profoundly impact our relationships with nature (Kofler et al., 2018; Sarewitz, 2015). Field tests and models suggest these technologies will transcend political boundaries and generations, as well as having ‘spill-over’ and ‘slippery slope’ implications for plants, animals, and humans that are difficult to fully anticipate (Gusmano et al., 2021; Rabitz, 2022).

Given these wide-reaching possibilities, engagement is increasingly seen as critical to genetic technology governance. An influential report by the National Academies of Sciences, Engineering, and Medicine (NASEM, 2016) suggested that the outcomes of engagement may be as crucial as scientific outcomes for genetic modification. In their review of governance documents related to gene drives in conservation, Hartley et al. (2022) identified the most widespread emerging principle to be the need for inclusive, broad, and empowered engagement. Engagement is

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also a key concept in codes of ethics for gene drive research (Annas et al., 2021) and risk assessment (Hartley, Kokotovich, and McCalman, 2023).

Despite wide-spread calls for engagement, emerging practices of engagement for genetic modification in conservation, and in other applications, appear insufficient. Critics note that the speed and trajectory of development are primarily determined by those leading scientific innovations, rather than the aspirations and concerns of wider publics (Burall, 2018; Dryzek et al., 2020; Jasanoff and Hurlbut, 2018). While developments rapidly forge ahead, warnings have been raised that engagement can be tokenistic and focused on ‘selling’ the technology (Russell et al., 2022). Governance systems have also not kept pace with the science in a systematic manner, leaving fractured decision-making frameworks that rely heavily on self-regulation by developers (Hartley et al., 2022) and regulatory gaps that allow for ‘ethics dumping’ (Schroeder et al., 2017). A *Nature Editorial* (2018, p. 414) alluded to this gap between the promise and practice of engagement for genetic modification, calling for it to “become more about consultation and democracy, and less about the marketing of science.” More forcefully, scholars and activists have argued that without meaningful engagement, genetic modification holds the potential to perpetuate and amplify existing injustices and practices of colonisation, imperialism, and capitalism (Taitingfong and Ullah, 2021; Van Dyck et al., 2022).

It is therefore timely and necessary to foreground critical perspectives on engagement: that is, to ask questions of who is engaged and by whom, how and on what terms, and for whom or what those processes serve. We approach this critical review as interdisciplinary scholars interested in strengthening the governance of genetic modification. We consider engagement to be vital to governance as the decisions being made are fundamentally political, in that they are normative and values-laden, and therefore should be open to inclusive societal deliberation (also Jasanoff, 2005; Kofler et al., 2018; Sarewitz, 2015). We also see engagement as a power-laden practice. Engagement can be a buzzword or a ‘slippery’ concept (Schairer et al., 2019) that holds vague meaning and is open to various interpretations, while nevertheless having meaningful impact on practice. We therefore understand engagement to be conceptualised and performed in multiple ways by different actors, in a range of contexts, for a variety of ends that are connected to, and informed by, broader political constellations (Felt and Fochler, 2010; Wynne, 2007).

Our focus in this review is on genetic modification in conservation, while noting overlap with fields like disease vectors and biosecurity that also deal with modification of nonhumans. The implications of this application are contested. As Russell et al. (2022) note, genetic modification in conservation holds a non-profit, ‘public good’ ethos with no clear expectations of future delivery through commercial mechanisms. Such an ethos could be seen to sit apart from the history of genetic modification that is ridden with the expansion of corporate interests and intellectual property rights (Schurman and Kelso, 2003; Wynne, 2001). Some activists and scholars are unconvinced with this seeming break with the past, instead emphasising the potential for recent developments in genetic modification to be complicit in the enactment and extension of (bio)colonialism and neoliberal capitalism (Montenegro de Wit, 2020; Van Dyck et al., 2022). One caution is that using genetic modification to achieve conservation goals may be a ‘trojan horse’ that opens the technology for agribusiness (Boëte, 2018). Nevertheless, Barnes and Delborne cautiously suggest that there may be an “uneven politics of biotechnologies”, as they may be formulated in ways that help “revive ecosystems while acknowledging biological complexity, respecting the genetic commons, and empowering human communities.” If genetic modification is to realise different political possibilities, then an important task is to take stock of how engagement practices are unfolding.

We undertook a several stage process to systematically build a corpus of literature. An initial pool of literature was derived from a Scopus search using a broad set of terms: “TITLE-ABS-KEY (gene* AND tech* OR gene* AND mod* OR syn* AND bio* OR gene AND drive OR crispr) AND

TITLE-ABS-KEY (engagement OR public* OR democra* OR consult* OR communit*). The subject area was limited to social sciences and humanities to reflect the focus of this review and publications were only selected from January 2012 to August 2024 to encompass the period following the announcement of CRISPR. The first pool of literature (n = 193) was then screened by reviewing titles and abstracts. Papers selected for further analysis included those that: (a) discussed engagement for genetic modification; (b) involved a significant humanities or social research component, and; (c) included a general perspective or focus on conservation or related fields like disease vectors. Exclusions included articles with a specific focus on human genome editing and bioweapons. From this second pool of literature (n = 58), articles were sorted into high relevance articles that had a core focus on engagement, and lower relevance articles related to perception studies, ethics, and governance. A snowball approach was then used by reviewing reference lists and citation records of the high relevance articles to identify literature that was missed in the first search. High relevance articles were then sorted by application context. The final corpus for detailed analysis was 76 papers, 15 specifically related to conservation, 23 in applications like vector control, and 38 involving general discussion of engagement for genetic modification. Like the scholarship that is included in this review, we draw on and connect our analysis with long-standing literature on engagement within political studies, environmental justice, and science and technology studies.

Through this review, we seek to advance critical dialogue on engagement for genetic modification in conservation by bringing explicit attention to its power-laden dimensions. Following Chilvers and Kearnes (2016, p. xv), we consider this analysis a foundation for remaking engagement in more reflexive and transformative ways. In the first part, we review social research that critiques how engagement is being enacted, noting the persistence of exclusionary practices and the dominance of instrumental rationales. The second half then draws attention to how scholars have sought to strengthen and reorient engagement within power-laden contexts.

2. Exclusion and engagement

The term engagement, as Bensaude-Vincent reflects, points to a pre-existing state of exclusion that is to be superseded by move towards inclusion. Exclusion has arguably characterised much of the development of genetic modification, reflecting wider patterns in science and technology (Jasanoff, 2005; Wynne, 2001). The initial trajectories of genetic modification were primarily shaped by concentrated teams of experts with highly specialised scientific knowledge, largely situated in western research institutions, and often responsible to funder priorities and corporate interests. As Jasanoff and Hurlbut (2018, p. 436) summarise, “the questions asked, the forms of expertise called upon, and the definition of stakes for science and human life were all shaped by those communities most aggressively advancing the research.”

In the field of genetics, issues of exclusion were made stark when genetically modified organisms (GMOs) ‘hit the ground running’ in the 1990s. Implementing GMOs in agriculture resulted in strong civil society resistance that challenged the biotechnology industry on economic, environmental, cultural, and moral grounds (Schurman and Kelso, 2003). Despite storylines about poverty alleviation, critics pointed to the favouring of agrochemical corporations and large-scale, industrialised farming systems (Bronson, 2015). Notions of democracy rarely featured in this first generation of genetic modification and what minimal efforts were made towards engagement failed to influence design or technological content in the face of strong expert cultures and corporate interests (Montenegro de Wit, 2020; Wynne, 2001).

From the twenty-first century greater attention was given to engagement in genetic modification development and governance. In part, this interest was catalysed by fierce opposition to GMOs and growing awareness in scientific and policy circles that receiving regulatory approval is not in itself adequate to ensure favourable conditions

for technology uptake (Montenegro de Wit, 2020). Other processes also came to play as part of a wider ‘participatory turn’ across science policy (for discussion see Chilvers and Kearnes, 2016). Long-standing social movements and environmental justice scholarship underscored the significance of engagement to confront epistemic violence, particularly for Indigenous and other marginalised communities for whom the wielding of ‘expert’ knowledge in research and policy acted to oppress and harm (George et al., 2019; Taitingfong and Ullah, 2021). Related analysis challenged claims that science and policymaking are objective (Hartley et al., 2023; Stirling et al., 2018). It brought efforts to address knowledge hierarchies within scientific practice and science-policy governance, including through engagement (Irwin, 2014; Wynne, 2007). Growing distrust in scientific and political elites within western liberal democracies in a ‘post-truth’ era, as well as concerns of political polarisation, also brought calls for engagement to help ‘repair’ relationships between society, science, and the state (Chilvers and Kearnes, 2020).

Lofty – but also somewhat conflicting – ideals underpin the growing interest in engagement. For genetic modification in conservation, engagement is often justified on three grounds that draw from a well-established literature on participatory democracy (e.g. Hartley et al., 2022; NASEM, 2016). From a ‘democratic’ stance, engagement reflects the rights people hold to influence decisions that will affect them and provides avenues towards more just and equitable decision-making. ‘Substantive’ arguments focus on the potential for engagement to result in improved decisions, including opening alternate viable policy responses through involving people with rich and pluralistic knowledges, experience, and identity. ‘Instrumental’ perspectives emphasise that engagement can build acceptance, trust, and legitimacy in decision-making, and in doing so can help minimise conflict and build consensus.

These ideals have brought some promising steps towards inclusion in genetic technology development and governance. A growing number of scientists hold aspirations to change their practice in response to public input (Taylor and Woods, 2020) and seek substantive collaborations with social researchers (Ledingham et al., 2023). Engagement with local communities is standard practice for many genetic modification applications (Russell et al., 2022). Emergent practices of engagement are beset by lack of clarity, however. Schairer et al. (2019) examined 28 engagement activities across 14 projects in vector control genetic technologies and found that even when formal documentation of engagement was available, it was difficult to identify who was involved and what was done. Likewise, in gene drive risk assessment, Hartley et al. (2023) reviewed guideline documents and found that, with only one exception, the documents prescribe a vague, narrow, or completely absent role for engagement. As they argue, this vagueness is concerning as it makes it likely that engagement will take the easiest, cheapest, or least threatening form vis a vis the status quo.

The need to carefully consider what falls under the umbrella of ‘engagement’, and associated concepts of participation, consultation, and consent, has long been recognised. The idea that participation could fall into a spectrum was reflected in Arnstein’s (1969) seminal ‘ladder of participation’ that extends from ‘empty rituals’ involving tokenism, through to arrangements that redistribute power. For gene drives, Russell et al. (2022) suggest a spectrum between engagement that involves ‘closing down’ and ‘opening up’ opportunities to shape outcomes. These descriptors allude to the potential for engagement activities to be superficial and effectively exclude, despite claims to the contrary.

The significance of persistent exclusion, despite the rise of ‘engagement’, is particularly apparent for Indigenous, Global South, and other marginalised communities. As Taitingfong and Ullah (2021, p. 75) identify, the “vast majority of scientists, ethicists, and philanthropic or corporate funders working to develop genetic engineering technologies are in the Global North and aim to trial and eventually implement these technologies in the Global South.” This dynamic is stark in the case of malaria gene drive trials in parts of Africa, where – despite publicised engagement activities – locally available information is scarce,

transparency and regulatory oversight is lacking, and elites dominate discussions and decisions (Hartley et al., 2024). Taitingfong (2020) also identifies that Pacific islands are being positioned as ideal ‘laboratories’ for gene drive trials by western research teams, a framing with connotations of settler colonialism and military experimentation. Such practice is complicit in a long history of injustice and imperialism that treats islands and their residents as dispensable to the risks and unintended consequences of experimentation (ibid.). It therefore matters, as Hartley et al. (2023) summarise, that discussions move beyond questions of whether to conduct engagement for genetic modification, and instead ask why and how engagement might take place.

3. The goals of engagement and the persistence of instrumental rationales

In their analysis of engagement for disease vectors, Schairer et al. (2019) argue that the first question to ask of engagement is ‘why?’ Asking ‘why’ queries the underlying rationales of engagement. These motivations can be broad and conflicting, reflecting the range of democratic, substantive, and instrumental justifications often given for engagement. It also draws attention to desired outcomes that often go without clear articulation. Being explicit about the goals of engagement demonstrates whether and how engagement processes are connected to decision-making power – what Schairer et al. (2019) describe as the ‘power to act’ (also Smith et al., 2021). If engagement is to open decision spheres to those previously excluded, then there needs to be a meaningful connection to decision-making power. However, Schairer et al. (2019) caution that the widely used language of ‘engagement’, ‘consultation’, and ‘perception studies’ is often vague as to whether there is any such connection. Engagement that connects publics to decision-making power is relatively rare, even if many might consider it the ideal (ibid.).

Two practices are often critiqued for providing ‘thin’ engagement that perpetuates exclusion in genetic modification decision-making, despite claims to the contrary. One tendency is for engagement to lean towards one-way informing and educating people or communities about technological developments, in ways that have little to no impact on scientific or policy communities. Techniques like CRISPR are often described in very technical terminology that is not accessible to a wide audience, requiring a high degree of training or editorial effort to demystify the language (Stirling et al., 2018). Independent communication is crucial to redress knowledge asymmetries particularly for communities that have limited scientific literacy or access to science media (Hartley et al., 2024; Ledingham et al., 2023). Studies like MacDonald et al. (2020) and Hartley, Stelmach et al. (2023) note the significance of communication that does not focus on providing ‘more scientific information and facts’, but instead offers opportunities for publics to negotiate genetic modification on their own terms.

While this communication is vital, the problem is when activities that claim to be ‘engagement’ do not go further than one-way transmission of information from scientific experts to publics. Such an approach maintains a ‘deficit’ understanding of communities, in which they are primarily defined in negative terms as ignorant, lacking the ‘right’ information, and therefore in need of education (Irwin, 2014; Van Dyck et al., 2022). It perpetuates a perceived divide and hierarchy between expert and lay knowledge, where expert knowledge is framed as grounded in reality, while lay knowledge is considered “politically real but intellectually unreal” (Wynne, 2001, p. 452). The focus becomes how to communicate developments in a way that will build acceptance of a technology, rather than opening possibilities for publics to shape the direction of developments.

A second, related concern is that engagement for genetic modification can become a one-off ‘tick box’ exercise with little or no follow-up. Such an approach relies on the premise that there is a set of unchanging perspectives ‘out there’ waiting to be identified about a predetermined technology, focusing on public attitudes in relation to a single

technological solution in a neutral setting (for discussion see [von Schomberg and Blok, 2023](#)). Engagement exercises become a method to generate a particular form of evidence (opinion/public perception) that can become part of a perceived linear and rational decision-making process. Like approaches that seek to educate, such forms of engagement are likely to have minimal impact on decision-making. As [Smith et al. \(2021, p. 743\)](#) argue, it risks “merely reiterating long-demonstrated findings about public perceptions of emerging technologies without providing routes to fully embed those lessons in science policy.” A snapshot approach also shuts down consideration of alternatives within particular contexts or the potential for politically negotiated solutions (*ibid.*).

The reason often given for the dominance of these ‘thinner’ forms of engagement in genetic modification is that the overriding rationale is instrumental. From an instrumental stance, engagement is a means to an end; it primarily provides a mechanism for reinforcing the credibility of pre-existing scientific pathways ([Stirling et al., 2018](#); [Wynne, 2007](#)). Instead of ‘opening up’ decisions for input from publics, instrumental engagement ‘closes down’ the possibility of straying from a pre-determined technological pathway ([Russell et al., 2022](#)). The science involved might be open-ended and uncertain, but engagement is seen as a means to pave the way towards a relatively fixed outcome ([Delborne et al., 2020](#)). Claims that various forms of engagement will help ‘sell’ a technology, socialise an idea, build acceptance, foster trust, provide legitimacy, manage blame, and minimise conflict all potentially hold this instrumental dimension ([Smith et al., 2021](#)).

Instrumental approaches to engagement have long been seen in genetic modification (e.g. [Wynne, 2001](#)), as well as in other controversial technologies ([Gunster and Neubauer, 2019](#)). Conservation science, too, often approaches engagement instrumentally, for instance in claims that engagement can help ‘fast-track’ pre-determined conservation ‘solutions’ (e.g. [McAfee et al., 2021](#)). These dynamics appear to be replicated for recent gene drive developments. For example, [Russell et al. \(2022\)](#) examined the perspectives of developers towards engagement in Australia and Europe for gene drives in conservation, biosecurity, and disease vectors. They identified the instincts of developers were primarily to view engagement as a way to ‘sell’ gene drive technology, build acceptance, and ‘prime’ publics for release. Developers enacted these instrumental aims by emphasising the severity and urgency of the challenge, disassociating gene drive with contentious applications of genetic modification, and presenting gene drive as the ‘best’ solution to a problem (*ibid.*).

A long-standing concern with instrumental engagement is its potential to manifest and maintain power imbalances. Instrumental rationales perpetuate a deficit model of communities that frames them as the ‘problem’, taking attention away from the ethical or moral dimensions of the technology at hand ([Irwin, 2014](#); [Wynne, 2007](#)). Societal acceptance become seen as a hurdle to be overcome and unruly publics a liability to be managed. It lends itself to risk management strategies to pacify civil society, alongside use of ‘just enough’ consultation practices and public relations methods to claim societal acceptance ([Delborne et al., 2020](#)). For example, [Van Dyck et al. \(2022\)](#) demonstrate how public refusal of genetic modification is often dismissed by developers and regulators as being irrational or ignorant. They note that the language used to reassure the public – emphasising precision, innovation, safety, and control – ultimately delegitimises refusal and implies that the future of technology is predetermined. Further, [Welsh and Wynne \(2013\)](#) identify the paradox that increased calls for engagement with science has coincided with intensified state surveillance and policing of social movements engaging with issues of genetic modification.

4. Drivers of instrumental engagement for genetic modification

There are a range of explanations given for the dominance of instrumentalism in emerging engagement practices for genetic

modification, including in conservation. Many draw on longstanding analyses within science and technology studies which highlight the paradox that - despite calls for engagement - there are “powerful and largely obscured underlying dynamics of closure” that remove publics from the centres of power ([Chilvers and Longhurst, 2016, p. 7](#); also [Jasanoff, 2005](#); [Wynne, 2007](#)). In recent literature on genetic modification, these concerns have been echoed in the persistent dichotomy and hierarchy between expertise and ‘lay’ knowledges ([Taitingfong and Ullah, 2021](#)), the uninterrogated values embedded within promises of science-led progress, and inadequate institutional structures and dominant economic rationales ([Jasanoff and Hurlbut, 2018](#)). Indeed, it has been argued that engagement has become a successful concept in science-policy precisely because it is seen as a ‘harmless vehicle’ to facilitate the pursuit of established scientific, development, or economic interests (e.g. [Thorpe, 2010](#)).

The structures and processes of the state have also been a focus of analysis. Despite numerous experiments with engagement, scholars working in genetic modification, but also related fields, note a constant tendency towards ‘slippage’ that restricts the democratic possibilities of engagement ([Ledingham and Hartley, 2021](#)). Policymakers frequently fall back on entrenched ways of thinking through the ‘mess’ of policy-making and processes of lock-in and path dependency (e.g. [Smith et al., 2021](#)). As such, engagement is likely to be conducted using methods and thought patterns that occupy only a small area of the possible ‘institutional design space’ ([Fung, 2015](#)). Further, there are what [Wynne \(2007, p. 100\)](#) describes as ‘hidden choreographies’ during engagement processes; the “unstated and unseen default processes” that can silently reproduce the agency, interests, concerns, and identities of entrenched powerful actors. In addition, those who interpret the results of engagement can make it unlikely that the values and knowledges of different publics are properly portrayed ([Evans, 2020](#)). Together, these processes can act to ‘domesticate’ engagement to fit with entrenched ideas and less able to challenge the status quo ([Rothstein, 2013](#)).

Scholars have also begun to draw attention to the funding structures involved with genetic modification that contribute to instrumental engagement. One concern relates to potential ‘governance capture’ by a single group or organisation. In gene drives for malaria, [Hartley et al. \(2024\)](#) identify that reliance on the Bill and Melinda Gates Foundation across multiple stages - technology development, regulatory development, and public engagement - raises concerns about conflicts of interest. In the US, [Fajardo-Ortiz et al. \(2022\)](#) trace the increase in philanthropic and charitable organisations funding genetic modification and argue that it will likely limit democratic influence over the trajectory of the technology. They suggest changes in funding concentrates efforts from basic research to development of applications, shifting the direction of science and making instrumental forms of engagement more likely (*ibid.*). In addition, relatively little attention has been paid to the dominance of the US military as a funder of genetic technology development and the ways this funding structure shapes or constrains the aims of research and engagement carried out by its grant recipients. As of 2017, the Department of Defense agency, Defense Advanced Research Projects Agency (DARPA), was a top global funder gene drives, having mobilised at least \$100 million toward its ‘Safe Genes’ program, making it the largest government funder of gene drive in the world ([Callaway n.d.](#); [DARPA n.d.](#); [Neslen, 2017](#)).

Along these lines, there is concern that the dominance of instrumental approaches may reflect the co-option of engagement by economic interests. These dynamics are especially visible in debates about the terms ‘social acceptability’ and ‘social licence’, which are increasingly used in genetic modification ([Delborne et al., 2020](#)). The terms originally emerged during the 1980s from morally contentious projects and technologies believed to be of high economic potential, such as mining. In the wake of community opposition, social acceptability and social licence emerged as the “ultimate prize of good communicative, deliberative and managerial practices”, but have also been widely critiqued for approaching acceptance instrumentally as the more or less

effective adoption of a technology (Gunster and Neubauer, 2019, p. 710). The terms hold multiple interpretations and can be subverted and reimagined by communities (Gunster and Neubauer, 2019; Russell et al., 2022). Nevertheless, Delborne et al. (2020) express their unease with the recent intertwining of the ‘social licence to operate’ metaphor with engagement in synthetic biology, arguing its conceptual and political baggage makes it a liability in envisioning the responsible deployment of genetic technologies. Hartley et al. (2022) also note the concept operates in a western paradigm and may exclude Indigenous worldviews.

The persistent instrumentalism of engagement presents a challenge for social researchers. As Ledingham et al. (2023) discuss, social researchers are often excluded from, or relegated to the periphery of, science-led genetic modification research teams. Scientific development has often been preoccupied with the inclusion of stakeholders or communities, rather than epistemic inclusion in the structures of science itself (e.g. Koch, 2020). When social researchers are included, they can often be channelled into a ‘handmaiden’ role of facilitating uptake of scientific innovation (Ledingham et al., 2023). In the context of this exclusion, there are concerns that the forms of social research deemed ‘acceptable’ by science-led teams may inadvertently facilitate instrumental forms of engagement. For instance, Gunn and Jongma (2023) note the rise of engagement ‘specialists’ that design, operate, and market techniques to give voice to publics. They caution that part of ‘selling’ social research expertise can involve claims to bring about societal acceptance and reduced dissent that align with a pre-defined agenda (also Felt and Fochler, 2010). Despite these challenges, a growing body of critical scholarship has sought to reorient engagement for genetic modification towards its more democratic and substantive possibilities. We turn to that literature now.

5. Reorienting engagement through articulating process

In response to concerns that engagement practices are often vaguely defined and driven by instrumental goals, some scholars have sought to clarify how engagement ‘should’ unfold. Discussed in scholarship and increasingly encapsulated in some governance documents, these accounts provide models, guides, procedures, or instruments that provide a normative ideal of engagement (e.g. Barnhill-Dilling et al., 2021; Hartley et al., 2023). This approach to engagement has been critiqued for the assumption that there is a pre-existing ‘good practice’ that can be deployed across different contexts and cultures (see Chilvers and Longhurst, 2016). Most scholarship for genetic modification for conservation, however, acknowledges the need for flexibility, while using the structuralism of the approach to counter the vagueness and tokenism that dominates existing practice.

A focus of the literature has been questions of ‘when’ engagement should take place, seen in calls for engagement to be moved ‘upstream’ and to be ‘early and often’ (e.g. Barnhill-Dilling et al., 2021; Hartley et al., 2022). Moving engagement ‘upstream’ is intended to provide publics with greater influence over the trajectory of technical and political decision-making before it is fixed and finalised. The metaphor of a river has been critiqued for reproducing a unidimensional and instrumental logic that a technology will inevitably be accepted downstream (Hartley et al., 2023). The precise timing of ‘how early’ is difficult to identify, as engagement undertaken too soon can mean that the issue is too abstract and less likely to be a matter of concern (Barnhill-Dilling et al., 2021). Nevertheless, the importance of early engagement is underscored by scholars and activists from a range of Indigenous and other marginalised communities who identify that the burdens of potentially irreversible environmental effects and locked-in technologies often fall most heavily on people who are already most excluded (George et al., 2019; Taitingfong and Ullah, 2021).

Various models have been proposed to integrate engagement into successive stages of decision-making for genetic technologies. For instance, Stirling et al. (2018) suggest a three-stage process to ‘open up’ problem framing: first, various publics need to agree that the problem at

hand is real; second, consideration is given to the extent a problem might be addressed with alternate practices or technologies; and third, discussion examines whether a novel technological solution is worth contemplating, including possible benefits or harm (ibid.). Another example is Barnhill-Dilling et al. (2021) who propose a model to integrate engagement across successive stages of genetic technology development. Drawing on concepts from science and technology studies and adaptive management, they suggest a three-phased approach – during research and development, regulatory review, and deployment and management – to build in responsiveness and social learning (ibid.).

Engagement that is ‘early and often’ has also been discussed specifically in the context of risk assessment. It has long been identified that when genetic modification encounters social questions, almost the only form of public issue recognised by policymakers and scientific experts is that of ‘risk’ (Wynne, 2001). Through perceived objective methods, risk assessment processes can sidestep the often uninterrogated values and assumptions that guide science and innovation (Hartley et al., 2023). As scholars like Smith et al. (2021) argue, it is often the cultures producing science and technology, and the knowledges that are (un)recognised, that are the focus of public concerns. As such, Hartley et al. (2023) underscore the importance of prescribing engagement at all stages of risk assessment. In their review of gene drive risk assessment guidelines, they note that while there is increasing awareness of engagement at the problem formulation stage, less attention has been given to integrating engagement in other steps of risk assessment.

6. Amplifying plurality: developers, publics, knowledges

Another way that scholars have sought to reorient engagement is to demonstrate the plurality of people and institutions involved, both in terms of those initiating engagement and those participating in it. Similar to questions of timing, some of this scholarship follows a normative approach of suggesting who should be involved and how, drawing from democratic theory and concepts in environmental justice. Much of this scholarship, however, has focused on empirically evaluating existing engagement activities, partly to critique exclusionary practices, but also to demonstrate the pluralism in current practice. In shedding light on this variation that can otherwise go unacknowledged, such accounts identify and amplify openings for more democratic practice.

One example is a study by Russel et al. (2022) that demonstrates variation in how gene drive developers view engagement. While noting that most developers take a ‘closing down’ approach to engagement (i.e. an instrumental stance), they also identify exceptions that involve ‘leaving ajar’ or ‘opening out’ engagement. Those that take a ‘leaving ajar’ approach still maintain an aspiration to implement gene drives but ‘pragmatically’ recognise the need to listen to publics and adapt their technology to be more acceptable. As such, this stance holds some flexibility in the future of gene drives, at least to a limited degree, even if it is still geared towards deployment. Approaches that enable ‘opening out’ of engagement go much further by enabling public deliberation about gene drives and input in decision-making. This stance involves early engagement, willingness to respect diverse perspectives and reactions, and to go beyond risk and discuss novel characteristics of gene drives and their broader implications in particular contexts. Importantly, ‘opening out’ approaches acknowledge that gene drive may be only one possible solution and are open to abandoning the technology altogether. Within the cases examined by Russell et al. (2022), they note the ‘opening out’ approach was present primarily in the context of conservation, although it was not assured in that context.

Scholars have also drawn attention to the plurality of people participating in engagement. As Hartley et al. (2022) identify, gene drive governance documents in conservation typically suggest some combination of ‘the public’ or ‘stakeholders’ to be engaged. Both these terms have been critiqued, however. As long identified in feminist research, the singularity of ‘the public’ erases difference. A number of

scholars have underscored the significance of this difference in the context of genetic modification, particularly since claims that ‘the public’ have been engaged can be used instrumentally by developers and regulators. For example, [Cheung et al. \(2020\)](#) highlights that the hegemony of English as the language of science means non-English speaking publics are often excluded from discussions of gene drives. [Taitingfong and Ullah \(2021\)](#) and [George et al. \(2019\)](#) also caution against generalising about Indigenous, Global South, or other communities. Moreover, claims that ‘the public’ have been engaged usually implies those within geographically defined communities, but those boundaries do not necessarily align with scalar-temporal dimensions of genetic modification that hold transboundary, intergenerational, and more-than-human implications ([Bural, 2018](#); [de Graeff et al., 2023](#)).

The term ‘stakeholders’ has also been questioned. There is a long-acknowledged politics of ‘invitation’ involved in determining who has a ‘stake’ in an issue, as it provides an implicit signal as to what publics and knowledges are considered salient ([Wynne, 2007](#)). A persistent concern is that the term stakeholder – particularly when coupled with instrumental views of engagement – normalises a narrow understanding of who has a stake to be those who already hold power, thereby reinforcing existing injustices. In the case of Indigenous peoples, the term stakeholder also fails to appreciate their unique status and historical marginalisation ([Taitingfong and Ullah, 2021](#)). Various alternatives have been suggested, such as ‘rights holders’ for Indigenous peoples ([George et al., 2019](#)), or ‘affected communities’ or ‘communities of relevance’ ([de Graeff et al., 2023](#)).

Threading through these discussions are questions of how different voices and knowledges might be included in engagement activities. Like the engagement literature generally, there is lively discussion of what forms it might take for genetic modification - whether at local, national, or global levels - particularly if engagement is to take a more deliberative form (e.g. [Dryzek et al., 2020](#); [Gusmano et al., 2021](#)). Some approaches argue for a ‘representative microcosm of the public’ through representative sampling (e.g. [Fishkin, 2021](#)), while others suggest discursive representation or a mix ([Dryzek et al., 2020](#)). [Hartley et al. \(2019\)](#) proposes ‘knowledge engagement’ as a pragmatic way to assist genetic technology developers and regulators to focus on substantive motivations for engagement and the different knowledges and experiences involved, to help shift beyond instrumental rationales. Because of the difficulty of involving larger numbers of people, more deliberative forms of engagement are underpinned by challenges of representation and accountability: of who claims to speak in the name of whom or what, and the responsibility that is carried for the outcome ([Gunn and Jongsma, 2023](#)).

Environmental justice is a crucial component of these discussions, particularly the importance of structurally including the views and expertise of those who are marginalised. [Taitingfong and Ullah \(2021, p. 74\)](#) argue that engagement for gene editing in the wild must go beyond the mere inclusion of Indigenous people to “ensure that the design, conduct, and analysis of those activities actively confronts and subverts power imbalances that marginalise Indigenous ways of knowing.” Also drawing on justice considerations, [Kofler and Grogan \(2021\)](#) argue for including the voice of nonhuman nature and future generations in gene editing decision-making. To ensure more just and safe decisions, they call for deliberations to encourage participants to consider the well-being of those outside their communities, including beyond the present and the human. Examining the potential wild release of a genetically modified chestnut tree in the US, [Barnhill-Dilling and Delborne \(2019\)](#) suggest reciprocal restoration as a framework to evaluate if a genetically modified species could support Indigenous restoration efforts.

Some scholarship has also suggested actively enabling plural narratives in genetic modification engagement activities. For example, [Chen and Burgess \(2021\)](#) highlight how storytelling can help articulate nuanced perspectives and invite people to access empathy and precaution in formulating collective positions. Similarly, [Wills et al. \(2021\)](#) call

for ‘narrative transparency’, which they describe as paying close attention to the collective narratives that animate understanding of humans’ relationship with nature and how it might be altered through genetic modification. In addition to encouraging mutual understanding of difference, they suggest it may proactively guard against ‘crafted narratives’ manipulated by powerful elites and concentrated economic interests.

7. Questioning acceptance and accepting contestation

A further way that scholars have sought to reorient engagement is to critically examine the concepts of acceptance and contestation. Acceptance is a key emerging principle of gene drive governance and is closely related to consent and consensus ([Hartley et al., 2022](#)). For instance, [Jasanoff and Hurlbut \(2018\)](#) suggest a critical question to ask is what is needed in terms of representation and deliberation for a genuinely broad societal consensus on gene editing. The dominance of instrumental engagement for genetic technologies, however, means claims of acceptance are often treated cautiously by scholars. Crucially, there is a lack of clarity of how and on what terms acceptance might be claimed, especially given the persistent vagueness of engagement activities discussed earlier (e.g. [Schairer et al., 2019](#)). As demonstrated across a range of controversial technological developments, the intangible nature of acceptance can afford developers and regulators considerable leeway in making the case that it exists, while also encouraging an approach that treats refusal as deviant ([Van Dyck et al., 2022](#); [Gunster and Neubauer, 2019](#)).

In this context, some scholars have emphasised the significance of being able to say ‘no’ within engagement processes ([Evans, 2020](#)). [Van Dyck et al. \(2022\)](#) suggest that refusal in the context of genetic modification can be understood as a “generative, deliberately strategic, and politically positive move.” Like other interventions in pluralistic democratic politics, they argue “refusal should be recognized as unobjectionable an act as [...] countervailing pressure to accept” (*ibid.*, p.1233). Similarly, [Arvin’s \(2019\)](#) notion of ‘regenerative refusals’ challenges assumptions that when Indigenous peoples opt out of particular genetic technologies or projects, they are engaging in negative, ignorant, or anti-science standpoints. Instead, she reads these refusals as “positive, future-oriented acts” that challenge settler logics and restore Indigenous ways of being in and relating to the world.

How developers and regulators navigate societal dissent is particularly relevant considering the legacies of GMOs debates. Trust in engagement processes is precarious among some publics. For instance, [Montenegro de Wit \(2020\)](#) notes that gestures towards engagement for genetic modification are treated suspiciously by many food justice activists, understanding them as fundamentally embedded in a corporate regime. This is coupled, as [Hartley et al. \(2024\)](#) note, with sensitivity among decision-makers towards political controversies and fear of public backlash following previous opposition to GMOs. It has prompted a distinct strand of thinking among some developers and communicators that associations of gene drives with GMOs must be quashed. However, others argue that avoiding those connections contributes to a political situation that, at best, is unlikely to facilitate constructive dialogue about genetic modification. For instance, [Russell et al. \(2022\)](#) note that some policymakers and developers are developing more sophisticated positions that publics are entitled to reach their own conclusions, including through proactively discussing what has been learnt from previous GMOs and how it has been addressed.

8. Conclusion

This review opened by noting growing calls for ‘engagement’ in genetic modification development and governance, including in conservation. The potential for these technologies to edit life and alter entire species makes engagement imperative. Yet despite this rhetoric, this review traced the many ways emergent gestures of engagement lean

strongly towards tokenistic and instrumental approaches that reinforce knowledge hierarchies and existing power imbalances. Engagement activities tend to be vague and poorly documented, focused on informing and educating rather than mutual sharing of knowledge, or provide one-off ‘snapshots’ of opinion that allow publics little influence over development trajectories. Although there does seem to be some exceptions in conservation in particular (e.g. Russell et al., 2022), such practices underscore concerns that genetic technologies may perpetuate and amplify existing injustices (Taitingfong and Ullah, 2021; Van Dyck et al., 2022).

Countering these prevailing undercurrents, this review has also demonstrated the ways critical social researchers are seeking to open space for more democratic and substantive engagement. Some have taken a more normative and prescriptive approach through articulating process, such as guides for engagement that is ‘early and often’ and across different decision-making arenas. Others have sought to demonstrate the existing plurality among developers, regulators, and publics, and to explore how their diverse values, experiences, and knowledges might be integrated in decision-making. Another line of analysis has underscored the significance of contestation within genetic technology futures.

As genetic technologies move rapidly towards implementation in conservation and related applications, it matters more than ever that engagement is approached critically as both a ‘slippery’ and power-laden concept. As engagement activities arise, we encourage scholars to ask questions of ‘who is engaged and by whom, how and on what terms, and for whom or what those processes serve’, giving particular consideration of the voices - human and nonhuman, present and future - that may be marginalised in the process. This review has also shown the potential of parallel scholarship that pragmatically seeks to shift developer and regulator perspectives of engagement beyond instrumentalism. As Russell et al. (2022) note, context-specific applications of techniques like gene drive can enable engagement to go beyond the abstract and explore implications of particular technologies in socio-political contexts and the multiple pathways it could take. This situated and relational analysis may also open further understanding of the socio-political features needed to support more democratic and substantive engagement, such as the significance of well-resourced independent media and public funding of multidisciplinary research.

CRedit authorship contribution statement

Riley Taitingfong: Writing – review & editing, Writing – original draft, Conceptualization. **Amanda Black:** Conceptualization, Funding acquisition, Project administration, Writing – review & editing. **Franca A. Buelow:** Conceptualization, Writing – review & editing, Writing – original draft. **Sylvia Nissen:** Writing – original draft, Conceptualization, Methodology, Formal analysis, Writing – review & editing.

Declaration of Competing Interest

The authors have nothing to declare.

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Data availability

No data was used for the research described in the article.

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