Editing Engagement: Visions of Science, Democracy, and Responsibility in Gene Editing Discourse

by

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ABSTRACT

This dissertation investigates how ideas of the right relationships among science, the public, and collective decision-making about science and technology come to be envisioned in constructions of public engagement. In particular, it explores how public engagement has come to be constructed in discourse around gene editing to better understand how it holds together with visions for good, democratic governance of those technologies and with what effects.

Using a conceptual idiom of the co-production of science and the social order, I investigate the mutual formation of scientific expertise, responsibility, and democracy through constructions of public engagement. I begin by tracing dominant historical narratives of contemporary public engagement as a continuation of public understanding of science's projects of social ordering for democratic society. I then analyze collections of prominent expert meetings, publications, discussions, and interventions about development, governance, and societal implications human heritable germline gene editing and gene drives that developed in tandem with commitments to public engagement around those technologies.

Synthesizing the evidence from across gene editing discourse, I offer a constructive critique of constructions of public engagement as expressions and evidence of scientific responsibility as ultimately reasserting and reinforcing of scientific experts' authority in gene editing decision-making, despite intentions for public engagement to extend decision-making participation and power to publics. Such constructions of public engagement go unrecognized in gene editing discourse and thereby subtly reinforce broader visions of scientific expertise as essential to good governance by underwriting the legitimacy and authority of scientific experts to act on behalf of public interests. I further argue that the reinforcement of scientific expert authority in gene editing discourse through public engagement also centers scientific experts in a sociotechnical imaginary that I call “not for science alone.” This sociotechnical imaginary envisions scientific experts as guardians and guarantors of good, democratic governance. I then propose a possible alternatives to public engagement alone to improve gene editing governance by orienting discourse around notions of public accountability for potential shared benefits and collective harms of gene editing.

DEDICATION

To my parents, who first taught me how to do hard things.

This was a hard thing.

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In many ways, writing a dissertation is an incredibly solitary task of countless hours spent by oneself with one's own thoughts. It would quite forgivable, then, to mistake the PhD as an individual achievement. Though this dissertation is a product of my labor, who *I* am is product of the people who have believed in me and prepared the way ahead of me. There are too many people to thank, but I will make an earnest attempt.

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AN INTRODUCTION TO PUBLIC ENGAGEMENT IN GENE EDITING DISCOURSE: SCIENCE AND DEMOCRACY IN THE MAKING

The purpose of this dissertation is to investigate how ideas of the right relationships among science, the public, and collective decision-making about science and technology come to be envisioned by critically examining constructions of public engagement as part of democratic governance. Though the full extent of such relationships is itself a sprawling topic, this dissertation is, at its core, motivated by the questions that we ask (and systematically do not ask) about science and technology and how we attempt to answer them. How ought we make decisions about science and technology? What is at stake in the ways that we do or do not develop and use them? How ought we govern them? And who ought to decide?

As science and technology continue to become ever more integrated and enmeshed in most every aspect of modern life, so, too, do the questions of how we ought to make decisions about science and technology become ever more consequential. From the food we eat, the medicines we take, the children we have, the families we raise, the places we live, work, and play; how we educate our young people, how we communicate with one another, how we move from place to place, how we care for our sick, aging, and vulnerable; to how we start businesses, hold elections, make laws, defend ourselves, enact policy, and pursue justice—how we build and uphold the whole world—the reach of the impacts of science and technology leave no person or facet of life untouched. In one sense, these are deeply personal and individual questions about how one navigates increasingly complex and dynamic landscapes of varying social and technoscientific worlds. And yet, such questions are at the same time questions for all of us. They are questions about how we—we as collectives, communities, nations, and humanity—ought to navigate those same landscapes.

Though science and technology often are thought of as holding the promise of progressively better, freer, and fairer futures, the potential risks and benefits, the realized or not yet realized harms and gains of science and technology are not at all equally or evenly distributed. Accordingly, questions of the potential risks and benefits, harms and gains of the applications of science and technology are inseparable from the choices we make, as individuals and as collectives, about if and how we use them, for what purposes, and who decides. Notions of the public good are necessarily intertwined with science and technology. To ask, "what is the public good?" is also, in part, to ask about the nature, relationships, goals, and actions of scientific and technological systems and agents.

Such questions, fundamentally, are also matters of governance. Who is authorized to make decisions on whose behalf, upon what basis, and with what authority? The answers to such questions also necessarily bring with them particular normative visions of the good—the right ways to make sense of the world, our place in it, and the responsibilities and obligations we have to one another. In other words, questions about the use and governance of science and technology are also always questions about how the world ought to be.

If we are invested in democracy as a preferable form of governance, then ostensibly, the “who” in questions of “who governs” is each of us—we the people or we the consenting governed. To be clear, I do not mean democracy primarily in the common but narrow sense of a formal system of government with institutions like a congress or parliament made up of representatives of a particular demos through free and fair elections as opposed to some other form of government—monarchy, autocracy, or otherwise. Rather, I mean democracy, in a more fundamental sense as a set of social and political relations that enable the resolution of differing and conflicting individual and communal interests (Dewey 1927). In a Rawlsian sense, I mean democracy as a political culture comprised of an assemblage of institutions and publics and a shared social space for public reason and deliberation as a basis for legitimate governance (Rawls 2001). In other words, democracy is governance of societies, in some sense, by publics.

By publics, I refer to social and political units of collective decision-making which have formed around particular issues of concern. I approach publics not as merely aggregations of individuals and individual interests, but as collectives that are more or less organized around a sense of shared, communal interests. In the language of John Dewey, it is the "indirect, extensive, enduring and serious consequences of conjoint and interacting behavior [that] call a public into existence having a common interest in controlling these consequences" (1927). Though such formulations of publics emphasize publics formation around preventing or mitigating negative effects on shared interests, publics also form in response to the potential to realize a positive effect on shared interests (or said another way, publics form around avoiding the negative effect of *not* manifesting some beneficial outcome). Publics around issues of science and technology, in particular, exhibit this pattern of avoiding negative consequences and realizing potential benefits, with publics having shared interests and therefore legitimate standing in the outcomes of their governance.

And yet, the technical complexities and years of specialized, advanced education and training associated with understanding science and technology seems to require some expertise to navigate it. There is a sense in which sufficient and salient knowledge about the technical is thought of as a prerequisite for good governance of science and technology. To be able to make reliably good decisions about science and technology, one must also understand that which one is making decisions about, or so the rationale goes. Such understanding goes beyond that which is present or could be reasonably expected of every person, and thus some deference to expertise is necessary, even if such deference is in tension with principles of governance of and by the people.

But such deference of publics to experts is at least somewhat in tension with ideas of democratic governance. After all, democracy is seldom idealized as governance of the people, by the experts. How, then, is the tension between the seeming epistemic necessity of expertise and the democratic legitimacy of public participation or consent in governance to be resolved? What are the desirable ties that bind experts with publics, science and technology with democracy?

This dissertation contributes to scholarship on public engagement with science and technology and the rightful place of scientific expertise and public participation in the democratic governance of emerging science and technology. It explores how public engagement has come to be constructed in discourse around gene editing to better understand how it holds together with visions for good, democratic governance of those technologies and with what effects. The central claim of this dissertation is that in the arena of gene editing. constructions of public engagement have been expressions and evidence of scientific responsibility, expressions which ultimately reassert and reinforce the authority of scientific experts. As a result, in the gene editing debates, calls for public engagement have generally reinforced broader visions of scientific expertise as essential to good governance by underwriting the legitimacy and authority of scientific experts to act on behalf of public interests, envisioning them as guardians and guarantors of good, democratic governance.

The goal of this dissertation is not to object to the idea or aspirations for publics to be more engaged with science and technology governance, nor is it merely meant to criticize public engagement or those who strive to develop such practices. On the contrary, my intention is to constructively add critical insights into how the idea of public engagement comes to be understood, invoked, and deployed in emerging science and technology governance.

My aim is to call attention to social, epistemic, and power dynamics associated with calling for greater public engagement with science and technology vis-à-vis scientific expert authority and public participation that might otherwise go overlooked and unexamined. These patterns, when unrecognized and unaddressed, undermine sincere aspirations of public engagement to improve the governance of science and technology to better promote public interests through deliberative, democratic means. Thus, this dissertation is a constructive critique of particular constructions of public engagement and uncritical approaches to promoting greater public engagement with science and technology with the express purpose of enabling better, clearer thinking about good, democratic governance and the role of scientific expertise and public participation. I show how calls for public engagement to enhance democratic governance of emerging science and technology are part of a broader discursive landscape of epistemic and normative authority, and that, even when sincerely intended, calls for public engagement have potential to exacerbate perceived problems of technocratic decision-making while also potentially obscuring those very problems.

Background

The formulation of the public and its relation to science and technology are well-trodden conceptual territory in historical and science and technology studies (STS) scholarship (Martin and Richards 1995; Rowe and Frewer 2005; Wynne 2006, 2008; Bucchi and Neresini 2008; Wickson, Delgado, and Lein Kjølberg 2010; Jones 2014). STS scholars have spent considerable effort theorizing publics and technoscientific decision-making. Who constitutes the relevant and appropriate public or publics? What are the right relations of scientific experts and publics, particularly in democratic society? Who should make decisions about science and technology and their governance and with what authority and accountability?

Emerging technologies in particular often raise issues that are both technically and socially complex and affect broad and diverse societal domains. Because of the uncertainty and rapidity with which emerging technologies develop, the challenges they present also often invite controversy about whether and how to proceed with developing and deploying them (Rotolo, Hicks, and Martin 2015). Increasingly, the broad, societal impacts of emerging technologies bring related discussions of science and governance into more public forums. To those forums, technical experts as well as laypeople bring heterogeneous values, norms, and ways of knowing to bear on emerging technology issues. As one might reasonably expect, perspectives often do not neatly align. Tensions can build not only over the proper responses to the challenges of emerging technologies but also over the proper framing of those challenges. The combination of technical complexity, uncertainty of impacts, and contested framings of challenges make discussions surrounding emerging technologies a useful locus for studying the relationships between science and publics.

The stakes are high (or at least, are often construed as being high) for how those discussions unfold. Emerging technologies often come with significant hype promising immense and widely distributed societal benefits. Though at the same time, concerns about the potential risks or the unintended consequences of emerging technologies build with seeming commensurate attention. The questions of how to govern emerging technologies to maximize benefits while also minimizing risks, then, are consequential, not only because of their potential to affect diverse sectors of society, but also because of the growing scale of publics those emerging technologies stand to effect.

One prominent thread in the scholarly literature over the past several decades that attempts an answer to such questions of technoscientific governance has been a general move toward greater public engagement. Public engagement with science and technology has become increasingly upheld as an essential component of good governance and the democratization of science and technology governance (Wynne 1993; Jasanoff 2003a; Giddens 1998; Leach, Scoones, and Wynne 2005; Callon, Lascoumes, and Barthe 2001; Stilgoe, Lock, and Wilsdon 2014). These appeals for greater public engagement with science and technology appeal to democratic principles of governance as a way to improve the quality and outcomes—principles like transparency, legitimacy of outcomes, and expanding the array of included perspectives brought to bear on issues of whether and how to move forward with particular aspects of science and technology (Guston and Sarewitz (eds.) 2006; Barben et al. 2008; Stirling 2005; Stilgoe, Lock and Wilsdon 2014).

Public engagement with science and technology has become a first principle of sorts such that "increased participation and interactive knowledge-making may improve accountability and lead to more credible assessments of science and technology" (Jasanoff 2003a, 243). Likewise, public engagement has become a practical imperative for scientific experts as part of responsible scientific practice as well as promoting public trust in science (Leshner 2003, 2006). However, despite the significant attention given to public engagement in-practice and in the literature, precisely what public engagement entails—who it involves, by what processes, and toward what ends—lacks unified consensus (Delgado, Lein Kjølberg, and Wickson 2011).

This non-consensus prompts questions not only of who constitutes the public, how they are to be engaged, by whom, and to what ends, but also how public engagement itself has come to be understood as a way of answering questions of technoscientific governance. By looking closely at public engagement around emerging technologies, one has the opportunity to scrutinize how science and publics interface in decision-making about the development and use of those technologies and how their relationships come to be formed, disrupted, or reinforced. Public engagement around emerging technologies also gives a view to the kinds of individuals, groups, institutions, expertise, and evidence that come to shape modes of science and technology governance.

Representing Publics

Calls for greater public engagement in the governance of science and technology are simultaneously assertions that publics have legitimate standing to participate in that process. Direct participation of all individuals in society is often not realistically feasible, so commitments to public engagement are also inherently commitments to some form of representation. The representation implicated in calls for public engagement is in two distinct senses. First, there is the degree to which subsets of publics or "mini-publics," however divided, come to be recognized as corresponding to and sufficiently reflective of the features of the broader public at-large of which they are taken to be representative (Goodin and Dryzek 2008). In that sense, the means and criteria by which publics are constructed and justified as being representative are the primary contested points of contingency.

The second is the authority, legitimacy, and responsibility of those delegated as officials or spokespersons to act on behalf of the publics whom they represent (Dewey 1927; Thorpe 2007). For issues of governance of science and technology, scientific experts often adopt a role of representing publics through official advisory positions within governmental bodies or through assertions of a generalized scientific responsibility to society. A central tension in the second sense is the degree to which the public decision-making is organized as open and participatory or closed and technocratic (Stirling 2005). Though commonly described as a spectrum of more participatory to more technocratic forms of governance (Marres 2007), the range of formulations of public engagement should not be understood as a sliding scale of being more or less democratic. The representation entailed in calls for public engagement is an innate, requisite feature of democratic governance. Regardless of whether public engagement is more participatory (e.g., Brown 2009) or more deferential to technical experts (e.g., Durant 2008), at issue is not an “ersatz of direct democracy” against a genuine one (Callon, Lascoumes, and Barthe 2001). What is at stake in the representation of public engagement is the particular formations of democracy and the imagination of the right relations between science and society thereby asserted.

At stake in calling for greater public engagement with science and technology are also foundational questions of democratic governance. And at their core, calls for public engagement are calls for more democracy, not less. Thus, questions of who ought to be responsible for what decisions about science and technology, through what procedures, with what justifications, and with what accountability are at the heart of science and technology governance. They are foundational questions of who rules. Such questions are consonant with the stakes for the resilience and future of democratic institutions to withstand the incessant pressures, disruptions, and stresses that technoscientific innovations inflict upon them. Therefore, the imagining of both science and democracy in society is front and center in the construction of public engagement.

Constructing Public Engagement

Over the past several decades, imaginations of the public have shifted from the deficit portrayals of the public as ignorant, uninterested, or distrusting of science (Wynne 1991; Ziman 1991; Evans and Durant 1995). One of the major areas in public engagement research has been around constructions of “the public” not as a singular, monolithic group but as a plurality of multiply realizable publics with diverse interests, values, and attitudes towards technoscientific issues (Wynne 1992a; Jasanoff 2012). However, recognition of a plurality of publics has done little to settle questions of who exactly constitutes distinct characterizations of those publics, how they are formed, and upon what basis.

In-practice, publics often form through the solicitation from convening institutions around technoscientific issues. The formation of "mini publics" (Goodin and Dryzek 2008) as units of democratic deliberation about science and technology has been analyzed more in terms of "invited" and "uninvited" publics (Irwin 2001; Stilgoe 2007; Wynne 2007; Felt and Fochler 2010; Krzywoszynska et al. 2018). Invited publics come pre-formed by the conveners' conceptualizations not only of who is included in constructions of relevant publics, but also of how public engagement ought to take place and public input taken up (Irwin and Michael 2003; Wynne 2007). Similarly, the framings of technoscientific issues around which publics are formed can "open up" or "close down" (Stirling 2008) discussions and constructions of publics. The "framing battle" (Wynne 1996; Goven 2003; Irwin 2006; Nisbet 2009) that can then ensue shapes what is highlighted or backgrounded, what evidence is deemed relevant or extraneous, and what publics are included and which are not.

Answering the question of who constitutes "the public" or "publics," therefore, is a messy task of boundary work done by both public engagement actors and analysts (Gieryn 1983). Publics qua publics cannot be taken as preexistent entities in the world, nor can the mechanisms by which they are organized or the criteria by which they are distinguished self-evident. As STS scholar Sheila Jasanoff observes, "publics are not all alike but are guided by culturally conditioned 'civic epistemologies'"(2014). Differing civic epistemologies explain the diversity and heterogeneity of how publics come to be constructed across various criteria, issues, and cultural contexts (Jasanoff 2005; Macnaghten and Guivant 2011; Zhao et al. 2015). Moreover, it illustrates that the construction of publics is thoroughly a social and generative activity, not one of isolating and identifying some naturally occurring category. Accordingly, "the public" may be better understood less as an aggregate of publics "out there" in the world and more as a shared, societal space within which publics are socially constructed and contested in substance and as analytical category at every turn.

Likewise, what precisely constitutes engagement with publics is not *a priori* obvious, clear, or in-practice, widely agreed upon. In the first place, review of the scholarly literature about public engagement scholarship shows how widely variable the use of the term "participation" rather than "engagement" is used to describe publics' involvement in science and technology discussions.[1] Though some have drawn sharp distinctions between notions of participation versus engagement (Wynne 2007), their use more commonly appears without clear differentiation as "synonyms of uncertain equivalence" (Rowe and Frewer 2005). Moreover, a variety of distinct and often contradictory notions of what constitutes engagement are the rule rather than the exception, from one-directional, educational and deficit model-styled interventions to bi-directional or more participatory ones (Wilsdon and Willis 2004; Rowe and Frewer 2005; Barben et al. 2008; Burgess 2014).

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[1] Over the past decade, "engagement" has become the more widely used term in the literature over "participation" to describe the involvement of publics in decision-making about science and technology (Stilgoe et al. 2014). This chapter uses "public engagement" to refer to that conceptual territory without making specific claims to its difference or synonymity with "public participation."

Much of public engagement work in-practice has centered on understanding the methods, mechanisms, and modes of designing, implementing, and evaluating public engagement interventions in-practice (e.g., Irwin 2006; Gustona 2014; Kleinman, Delborne, and Anderson 2011; Tomblin et al. 2017; Rowe et al. 2008; Carr, Yung, and Preston 2014.; Neuhaus 2018). Normative questions of whether, in general, public engagement with science and technology is desirable or beneficial for decision-making have largely been set aside. Instead, the prevalence of institutional uptake of public engagement around science and technology governance serves as a starting point for asking more narrow, evaluative questions about the development public engagement methods, best practices, and outcomes, consonant with admonitions from responsible research and innovation (RRI) and reflexivity literatures (e.g., Stilgoe, Owen, and Macnaghten 2013; Guston 2014a). What is left out in not interrogating the normative facets of engagement, however, is conceptual clarity of the public involvement entailed by engagement and what it aims to achieve. That gap in theoretical work about public engagement is reflective of a common pattern in more outcome-oriented research in which “the *how* trumps the *why*” (Stilgoe, Lock, and Wildson 2014, italics in original).

Public Engagement and a Normative Gap

As STS scholarship of public engagement has followed a “deliberative turn” in democratic theory (Parkins and Mitchel 2005), there have also been disputes as to its normative value for democratic governance. Greater public involvement has been argued to produce normatively better and more democratic governance outcomes (Rowe and Frewer 2000, Hamlett 2003; M. Brown 2009), though whether that description of outcomes is redundant is unclear. Public engagement is also not without skepticism as to whether institutional methods for its design and implementation will deliver on its promises (Wynne 2006, 2016; Pidgeon and Rogers-Hayden 2007) or if publics are themselves even invested in public engagement initiatives (Sturgis 2014).

In particular, Brian Wynne notes that the tensions between public engagement and democracy are more than just matters of cynicism, but that “there prevails an acute contradiction between, on the one hand, the post-2000 ‘enlightenment’ of public engagement and dialogue with science, thus “listening” to publics in a two-way fashion, and, on the other, the coincident treatment of publics as threats to sacrosanct principles of modern ‘science-founded, democratic’” order (Wynne 2016). The difficulty and infrequency with which public input has been incorporated into policy in-practice further complicates commitments to public engagement as instrumentally effective or desirable (Hansen and Allansdottir 2011). Similarly, the asymmetry in science-public interactions to set agendas, identify stakes, and contribute perspectives suggests that merely having more public inclusion may not meaningfully alter how topics are framed, discussed, or settled (Hurlbut 2017).

Furthermore, elsewhere Wynne (2016) has argued explicitly, and others in similar spirit (Blue 2018; Chilvers and Kearnes 2020) that the moves toward public engagement, responsibility, and democratic rhetoric are attempts to enforce public reasoning and political authority through science. My intent is to build on the instinct that public engagement is linked with the authority of science, but to center public engagement as part of a scientific repertoire by and for science and not the state per se. My aim is to focus on how public engagement holds together with those scientific imaginations of democratic governance of science and technology based on the rationales scientists provide for doing public engagement as part of the responsibilities of science to society.

Some STS scholars have also raised concerns about whether and under what conditions would increasing public engagement in decision-making about technical matters be desirable for democratic societies (e.g., Rip 2003; Bijker 2003; Collins, Weinel, and Evans 2010; Durant 2011). Some have questioned whether the case for participatory public engagement is as straightforward as the rationale that “the technical is political, the political should be democratic, and the democratic should be participatory” (Moore 2010). Illustrative of these tensions in the literature is the significant debate between Sheila Jasanoff (2003, 2005) and Brian Wynne (2003, 2007) on the side of more participatory, deliberative involvement of publics in science and technology governance and Harry Collins and Robert Evans (2002, 2008) who have argued that deference to technical experts on the basis of specialized knowledge are both justified and necessary for democratic societies to avoid unworkable identity politics or populism.

Collins, Evans, and their supporters (Collins and Evans 2008; Durant 2019) take issue with cautions against experts as epistemic authorities in democracy. They reject arguments that expertise may be dangerous or deleterious for the quality of democratic governance if not kept within a narrow area of delegated authority to render expert judgements (Jasanoff 2009) or that the power of experts undermines the potential for extended discussion outside of technoscientific frameworks (Wynne 1992a, 2016). They argue that normative commitments to public engagement lack robust understanding of political theories of participatory democracy (de Vries 2007) and are underdetermined by constructivist critiques of scientific expertise, leaving a normative gap between those criticisms and commitments to public engagement as imperative for democratic governance of science and technology (Collins and Evans 2008).

In other words, that expertise is itself socially constructed does not imply that experts ought to have similar epistemic footing as lay persons in technoscientific decision-making. Experts with specialized, technical knowledge, by virtue of that knowledge being relevant to technical matters, ought to have privileged status in democratic deliberations. The participation of publics is necessary only insofar as they have a kind of relevant expertise, experience, or knowledge to bring to bear on particular technoscientific issues that otherwise would not be considered. Moreover, Collins, Evans, and colleagues maintain that their skepticism of public engagement as a democratic panacea has been further validated in light of developing cultural narratives in which trust in experts is described by some as in decline in the wake of rising anti-science, anti-intellectual movements in democratic societies (Collins, Evans, and Weinel 2017).

By contrast, Jasanoff and Wynne, have argued the bright lines between laypersons and experts that Collins and Evans lean upon are not just socially contingent and constructed, but indicative of value-laden pre-determinations of who the experts and lay publics are. While expertise has been commonly used to differentiate between “ordinary citizens” (Powell et al. 2011) and experts with specialized, technical knowledge and credentials, Wynne has long complicated attempts to use scientific expertise as a line of demarcation, noting how publics generate their own forms of expertise with distinct experiences and specialized knowledge that traditional scientific experts lack (1996).

Jasanoff and Wynne have contended that such privileging of the perspectives of scientific and technical experts is misguided when the question of who ought to be included in those processes is precisely the point of dispute. Further, their contention is less about the inherent virtue of publics in decision-making and more about recognizing the precariousness in how appeals to expertise render expert judgments as naturalized, objective knowledge and not as subjective matters to which experts can be held accountable. Public engagement as an opportunity for deliberative reflection on science and technology, they argue, and serves as a necessary democratic and epistemic check on technocratic power (Jasanoff 2003a, 2005; Wynne 2003, 2007).

My intention is not to plant my flag on one side of these disputes or the other, as others have done (Durant 2008; 2011; Sismondo 2017), nor to offer a full-throated defense or attack on public engagement as such. Rather, I want to call attention to the contested nature of the category of public engagement, both epistemically and normatively. That contestation substantively cuts across how publics are constructed, with what modes of engagement, and with what aims as a democratic intervention in the governance of science and technology.

And yet, despite the unsettled epistemic and normative status of public engagement, there remain strong calls for public engagement in the governance of emerging technologies from scientists, policymakers, and STS scholars alike. Public engagement as a term and concept has become widespread and recognizable in the rhetoric of science and technology governance and institutional practice. How, then, do the constructions of public engagement hold together with associated notions of publics, expertise, and democratic participation around issues of science and technology policy and governance in the midst of vigorous contestation?

Public Engagement and Gene Editing Discourse: An Exemplary Case

To investigate the constructions of public engagement around emerging technology governance, this dissertation focuses its analysis on recent discourse surrounding gene editing technologies. Gene editing is a specific kind of genetic engineering that pertains to a collection of tools and techniques to alter genetic molecules, from whole genomes to short sequences of isolated DNA, by adding, removing, or otherwise modifying genetic elements. Over the past decade, gene editing has gained significant scientific, governmental, and public attention in no small part due to recent advances in molecular biology, namely CRISPR technologies and CRISPR-Cas9 in particular.

Based on the clustered regularly interspaced palindromic repeats (CRISPR) in regions of bacterial genomes involved in viral defense mechanisms, CRISPR enables modification of the genetic material with unprecedented speed and precision. Gene editing has come to be closely linked with CRISPR-based technologies, in particular CRISPR-Cas9, as the flagship technology and archetype for gene editing (Jinek et al. 2012; 2013). CRISPR technologies are exemplary of the techniques involved and potential applications of gene editing, but gene editing need not use CRISPR-based techniques to make genetic alterations (e.g., Kim, Cha, and Chandrasegaran 1996; Smith et al. 2006; Joung and Sander 2013). Nevertheless, the focus on CRISPR and CRISPR-Cas9 in particular as a linchpin technology for gene editing has had a unifying effect to include the various applications of CRISPR technologies in considerations of gene editing as a whole.

Since its development in 2012 as a molecular biology tool (Jinek et al 2012), CRISPR has quickly inundated scientific research, journals, and broader discussions, prompting some to label the new addition to biologists' toolkit the "CRISPR Revolution" (Barrangou 2014; Doudna et al. 2017). In 2015, Science dubbed CRISPR the "Breakthrough of the Year" (Travis 2015), and in March of 2016, *Nature* headlined CRISPR as a technology marking the "dawn of the gene-editing age" (Nature Eds. 2016). CRISPR has been called a "disruptor" both to the scientific and societal status quo in biological research (Ledford 2015a), and in 2020, the Nobel Prize in Chemistry was awarded to creators of CRISPR, Jennifer Doudna and Emmanuelle Charpentier.

Because it is faster, cheaper, and easier compared to previous gene editing techniques, CRISPR has a wide reach of applications both in and out of the laboratory (Ledford 2015a). CRISPR-based gene editing presents new opportunities in agricultural biotechnology for the development of genetically engineered crops and livestock (Khatodia et al. 2016; Carlson et al. 2016; Niu et al. 2017). Similarly, CRISPR holds promise as a tool to treat or cure genetic diseases or to enhance human capabilities (Ledford 2016a). CRISPR also has potential to combat vector-borne infectious diseases such as malaria (Ghorbal et al. 2014), or to better control populations of pest or invasive species (Owens 2017). Despite the possible benefits, the ability of gene editing technology to make genomic changes swiftly, efficiently, and accurately across most species, gene editing also has concerned many, including scientists, about the potential risks of such technologies (e.g., Lanphier 2015; Ledford 2015a; Doudna 2015).

In light of those uncertainties, risks and concerns, and potentially transformative benefits, many have emphasized the need for dialog, discussion, and deliberation among experts, policymakers, and publics (Jasanoff, Hurlbut, and Saha 2015; NASEM 2016; 2017; NAM, NAS, and The Royal Society 2020; Nuffield Council on Bioethics 2018; German Ethics Council 2019; Rosemann et al. 2019). The uncertainties and disputes over whether and how to pursue CRISPR-enabled gene editing technologies situate the technical and societal challenges as examples of "post-normal science" (Funtowictz and Ravetz 1993) and also as "trans-science" (Weinberg 1972) in which scientific facts, knowledge, or expertise alone did not hold the fullness of answers (Sarewitz 2016). These discussions among scientists, scholars, policymakers, and publics serve as a foundation for my analysis.

Similar investigations of the construction of public engagement as part of science and technology governance discourse could identify and focus on other emerging technologies to productive effect. Indeed, many scholars have done precisely that. The subfield of public engagement scholarship, in many ways, has been built upon studies of public engagement around nanotechnology (e.g., Delgado, Lein Kjølberg, and Wickson 2011; Macnaghten, and Guivant. 2011; Lotte and Mulder 2015). Likewise, others have successfully directed their analytical attention to public engagement around emerging technologies such as geoengineering (Stilgoe, Watson, and Kuo 2013), artificial intelligence (Brundage 2016), autonomous vehicles (Cohen, Stilgoe, and Cavoli 2018; Stilgoe 2020), and synthetic biology (Marris et al. 2015; Heather et al. 2017; Delborne and Kokotovich 2020). My focus on gene editing aims to add to this growing domain of research on the formations of public engagement and technoscientific governance.

I have chosen to focus my analysis on gene editing discourse in particular because it displays patterns of constructing public engagement around emerging technologies in ways that make it an especially good case to study the patterns of public engagement construction in science and technology governance discourse. Approaches to biotechnological governance, in particular, have shifted in recent years from being primarily about "experiments of concern" to "groups of concern" in which publics themselves have become the site of deliberation, consideration, and intervention rather than only the technologies themselves (Marris et al. 2017). The publics implicated in governance of biotechnologies are less in the sense of groups formed around shared interests regarding "life itself" (Rose 2001), as individuals with shared biological features—their bodies, genetics, or potential progeny—in specific geographic or temporal environments. Instead, the publics are constituted in the sense of "biosociality" in that "groups of concern" come to be formed on the basis of a shared experience of or exposure to the biological effects of biotechnology rather than the effects on their biology itself (Rabinow 1996). In other words, the "affected publics" salient to biotechnologies such as gene editing are "bioconstituted" (Jasanoff 2011a) as those who stand to be the potentially biologically affect-*able*, even if they are not (yet) the affect-*ed*. Thus, the sort of publics implicated in gene editing are distinctly configured not merely in terms of national civic identities or other social or political "imagined communities" (Anderson 1983), but as co-constituted with hopes and fears for the future of gene editing technologies themselves.

Accordingly, gene editing presents distinct configurations of the stakes, risks, and benefits that are often treated as "a game that is constantly played in the future in order to generate the present that enables the future" (Rajan 2006, 34). As a result, past moments in biotechnology governance, such as the deliberations about recombinant DNA at Asilomar in 1975, come to be remembered, repackaged, and redeployed in contemporary gene editing discourse. Past events in biotechnological decision-making are remembered in ways such that the present moment serves as a sort of self-fulfilling prophesy or a "just-so story" of the appropriateness of the structures, procedures, and formulations of the stakes of the past as the right sort to continue to use to realize similarly desirable futures. Gene editing follows in this historical patterning in which the roles of experts, publics, and the stakes come to be largely taken for granted, reaffirmed, and reasserted (Hurlbut 2015). As a result, gene editing provides unique opportunities to problematize how specific governance choices and normative visions for science and society go systematically unquestioned and unasked.

Gene editing, then, is an emerging technology that has come to be recognized by many as having significant stakes for broader society and biodiversity in its technical applications and societal implications. Around such considerations, public engagement has become a core conceptual component of how decisions ought to be made about its development, use, and governance. As such, gene editing discourse provides an insightful example case to study constructions of public engagement and related visions for the relationships among scientific expertise, publics, and democracy.

Driving Questions and Methodological Approach

In this dissertation, I aim to explore how public engagement comes to be constructed such that it holds with imperatives for good, democratic governance of complex technoscientific issues as well as configurations of the right relationship between science and the public (Irwin 2001; Jasanoff 2005; Chilvers 2008). I take public engagement—as a concept deployed by discourse actors—as my primary object of study and approach gene editing discourse as an example case of science and technology governance discourse in which public engagement has featured prominently and with salience for constitutive visions of science and democracy.

Accordingly, the driving questions for the dissertation are:

1. How has public engagement been constructed in gene editing discourse?
2. What work do calls for public engagement do in visions of the right relationships among science, publics, and democratic governance of gene editing technologies?

The first question is, in part, meant to be a descriptive one of what has occurred in gene editing discourse vis a vis public engagement construction as an actors' category, meaning as the figures in the example cases construct public engagement (Latour 2005; Collins 2008). As previously discussed, the collection of things called "public engagement" is highly varied and different particular notions of public engagement emphasize differently the relationships between experts and publics, typologies of engagement practices, engagement objectives, and normative commitments to democratic governance (see Rowe and Frewer 2005; Stilgoe, Lock, and Wilsdon 2014). Rather than choosing a particular kind of public engagement ahead of time, my analysis takes public engagement as constructed and deployed by actors in gene editing discourse. It is focused on identifying and explaining the processes by which public engagement has come be part of gene editing discourse in the way that it has. Accordingly, the answers to my driving questions ought not be understood as necessarily extending fully to every manifestation of "public engagement." But insofar as other forms of public engagement are recognizably similar to public engagement as constructed in gene editing discourse, the findings of this dissertation may give cause for those other formation of public engagement to be similarly studied and scrutinized.

The second question is more analytical and complex. I am interested in how understandings of public engagement align (or do not align) with envisioned social orders of technoscientific governance, scientific responsibility, and democracy. Specifically, I want to understand the work that calls for greater public engagement do to create and maintain particular sociotechnical visions. When I ask, "what 'work' do calls for public engagement do?," I approach calls for greater public engagement as a potent discursive move, as distinct from particular practices of public engagement themselves. I mean specifically: How do particular constructions of public engagement in gene editing discourse hold together with and contribute to the creation, maintenance, and reformation of those visions? How do the constructions of public engagement in gene editing discourse in particular ways (as opposed to other ways) frame the challenges, problems, and stakes of gene editing governance such that public engagement is understood as responding to them? And how do they matter for how good, responsible gene editing governance comes to be imagined?

Therefore, I do not take public engagement as a known or a priori knowable entity in terms of what it is or does (or what it ought to be or do). Rather, what comes to be recognized as public engagement and how it matters for gene editing discourse is precisely what I aim to answer, in part, in this dissertation. Thus, this project is not one of evaluating public engagement in terms of its effectiveness in achieving some particular end, but one of asking more foundational questions of how public engagement comes to be co-produced with the normative goals of democratic science and technology governance.

Furthermore, I use the concept and term "discourse" to refer to a loosely-bounded collection of written and spoken language, ideas, and structured social relations united around particular phenomena (van Dijk 1993). Said another way, discourse is "an ensemble of notions, ideas, concepts and categorizations through which meaning is allocated to social and physical phenomena" (Hajer 2009). In the case of gene editing discourse, I mean the collection of scientific papers, reports, meetings, media publications, interviews, and archival documents pertaining to gene editing technologies and public engagement as part of their governance.[2] Thus, public engagement is part of the attempts to "collectivize" decision-making around gene editing technologies and thereby also legitimize and democratize their governance.

In this dissertation, I specifically analyze particular examples of gene editing technologies, namely heritable germline gene editing and gene drives. But these ought not to be understood as disconnected from one another, but as part of a shared discursive space, linked by their reliance on the same underlying CRISPR-based gene editing

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[2] Throughout this dissertation, I use the terms "gene editing discourse" or "gene editing governance discourse" interchangeably. I intend no sharp distinction between them; discourse on the governance of gene editing is broadly what the focus of this dissertation is. Similarly, in multiple chapters I focus on specific gene editing technologies and refer to "germline gene editing discourse" or "gene drive discourse." (Those also may or may not include the "governance" designation. Again, no distinction is meant.) Both "germline gene editing discourse" and "gene drive discourse" ought to be thought of as constitutive of "gene editing discourse," though not equivalent or interchangeable with one another.

techniques and their relative co-occurrence and simultaneity with one another. Also, these examples of particular gene editing discourse that I have selected are not intended to contain every instance or manner of construction of public engagement. Rather, these cases are emblematic of a pattern of public engagement construction that is prominent and reflected across broader gene editing and science and technology discourse. These examples are illustrative, not exhaustive, but they are nevertheless comprehensive in the ways that they capture the patterns of co-production between public engagement and gene editing governance.

Throughout this dissertation, I adopt the idiom of co-production (Jasanoff 2004) to explain the construction of public engagement and scientific knowledge. This approach enables analysis of the construction of scientific knowledge and democracy simultaneously in terms of epistemic and normative stakes for society. Co-production holds a fierce commitment to a symmetrical analysis of science and society (Bloor 1976) and avoids privileging scientific knowledge, technical facts, and related notions of expertise as somehow more real or true accounts (e.g., Collins and Evans 2008; Collins, Evans, and Weinel 2017). In so doing, I aim to avoid tacitly re-inscribing scientific norms and rationales as the de facto epistemic authority when the creation and legitimation of epistemic authority is precisely what is at stake in constructions of public engagement.

My analysis takes publics—who constitutes the public, what it means for them to be engaged, and about what issues—to be contingent, contested entities which are built concurrently with notions of public engagement. Although in discussions of science and technology governance lay-expert distinctions are often made in-practice on the basis of specialized knowledge, my analysis takes those articulations of publics as definitionally non-experts, not as a natural category nor one corresponding to an essential epistemic core of facts, but as contingent actors' construction of publics in particular contexts. I take seriously injunctions that distinctions between publics and experts are not ready-made nor self-evident along lines of expertise, nor are the features of "relevant" expertise (Collins and Evans 2002) given in advance of the negotiation of those categories. Rather, they are socially and culturally erected, policed, and disputed by interested actors (Wynne 1996). I maintain that the criteria and rationale for describing publics in particular ways are inseparably wrapped up in the social values of who ought to have political grounds to participate in decision-making processes.

Likewise, this dissertation approaches science and technology as socially constructed entities (Fleck 1935; Pinch and Bijker 1984; Hacking and Hacking 1999) that are nevertheless potent and central to the formation and stabilization of society (Jasanoff 2005; Jasanoff and Kim 2015). [3] Science and technology are particularly implicated in formations of democracy, as collective witnessing through performances of experiments and representation similarly underwrite claims to both scientific authority and democratic legitimacy (Shapin and Schaffer 1985; Ezrahi 1990; Hilgartner 2000; Jasanoff 2004; 2011b). Insofar as issues of the epistemic authority of science and scientific knowledge

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[3] This dissertation frequently refers to "science and technology" as a dyad as well as "science" and "technology" separately. This is not to emphasize any sharp distinction between them nor to suggest that they are synonymous or interchangeable. Rather, my usage is reflective of the ways that many have argued that "science and technology are not sufficiently well defined and distinct for there to be any determinate relationship between them" (Sismondo 2010). Accordingly, I approach science and technology as commonly co- occurring designations for a shared conceptual territory in which both science and technology are more than merely tools of inquiry, but ways of understanding the world (Heidegger 1977; Hickman 1990). I take science and technology, then, to be a composite system "comprised of artifacts, social practices and systems of knowledge" (Fox, Johnson, and Rosser eds. 2006) about which publics form (Dewey 1927) and not as distinct modes of ordering knowledge from one another.

are at stake, so too, are issues of democracy and political, decision-making legitimacy (Laurent 2017).

Public engagement with science and technology, then, as a means of "linking science with politics" (Nowotny 2014), sits squarely at the site of scientific and forms of democratic decision-making. I do not take public engagement, however, as merely a reproduction of the constructions of publics. Rather, I take public engagement as a social construction extending from requisite constructions of both publics and engagement, though not fully reducible to either. Public engagement does not only encapsulate the particular groups recognized as salient and the means by which they are related to decision-making of scientific and technological concern, but also refers to a set of epistemic and sociopolitical arrangements in which notions of expertise, representation, and democracy are implicated. Public engagement overtly invokes a necessity and legitimacy of involvement of a public to inform, underwrite, or otherwise contribute to collective decision-making. Accordingly, I approach public engagement, notions of democracy, and the visions of the future as entities "in the making" (Chilvers and Kearnes 2016; Krzywoszynska et al 2018).

My analysis of how public engagement comes to be constructed in relation to science and technology governance draws upon what Jasanoff and Kim (2015) term "sociotechnical imaginaries." They describe sociotechnical imaginaries as "collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology" (Jasanoff and Kim 2015, 4). Said another way, sociotechnical imaginaries or visions are part of societies' collective consciousness about how the world ought to be, visions which increasingly are inseparably linked with the understandings and applications of science and technology. Further, they are the generative source of the rationales—or civic epistemologies—that direct attempts to realize those futures, drawing together the social and the technical visions of the good and underwriting the moral imperatives to pursue it (Jasanoff 2015, 6).

In discourse around technoscientific governance, imaginaries mobilize social and cultural resources, persons, and institutions to create and uphold particular configurations desirable democratic futures vis a vis advances in science and technology (Jasanoff, Kim, and Sperling 2007, Hilgartner 2015). Potent imaginaries often link technological and societal progress, reenacting memories of the past that reinforce the cultural and epistemic power of science (Hurlbut 2015). Imaginaries, however, do not go uncontested as understandings of the world. Prevailing elite imaginations of science as saving society from the woes of current and future modernity through technological innovation elicit other counter-imaginations of "contingent progress" in the advancement of technoscience and social order (Smallman 2018, 2020). Such imaginaries are deeply formative of the discursive landscape in terms of the logics and framings of both stakes and stakeholders in science and technology governance. The growing institutionalization and stabilization of public engagement as a core component of technoscientific decision-making is testament to the impact and influence of such imaginaries.

I use sociotechnical imaginaries and metaphor of visions and envisioning[4] as a conceptual framework to theoretically ground my analysis of how public engagement around gene editing interfaces with other notions of knowing or imagining possible or inevitable futures for gene editing in society. Doing so enables me to make sense of how public engagement both comes to be a part of gene editing governance discourse as a well as the work that it does in configuring visions of the right relations of science and society. In other words, using a framework of visions and imaginaries provide me with tools to analyze public engagement around gene editing as a site in which not only are scientific experts' and publics' relationships actively being made but also one in which visions of possible and alternative configurations of science, responsibility, and democracy are in the making.

Dissertation Roadmap

This dissertation is organized as a collection of related papers and essays that are united in their analytical aims to explore different aspects of my driving questions in a shared conceptual territory. Each chapter is written to be able to stand on its own as a complete argument and intellectual work, though the chapters clearly draw upon, reference, and reinforce the arguments of one another. As a result, there are areas of overlap and resonance between this introductory chapter and the introductions of the

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[4] In this dissertation, I often use the term "vision" or "envision" to refer to sociotechnical imaginaries to emphasize how they are, in emerging technology discourse, often implemented in the sense of foresight, anticipation, and even manifesting of the future. This is not to be confused with other ways of metaphorically "seeing" or "making legible" particular features of the world for the purposes of knowledge, calculation, and dominance (Scott 1998).

body chapter in which I highlight the literatures and discourses in which I situate the individual chapters. Likewise, while there are resonant themes across them, each chapter does not make the same arguments precisely across different example cases. Rather, each is an attempt to illuminate and explain how public engagement has come to be constructed as part of gene editing governance discourse as it has and the work it does in shaping imaginations of science-society relationships. In the conclusion chapter, I draw together the thematic and analytical resonances for the body chapters in synergistic ways to provide more comprehensive answers to my driving questions and arguments for the dissertation as a whole.

In Chapter 2, I investigate the development of public engagement as a core part of science and technology governance discourse broadly to provide historical context for my analysis of particular examples cases of constructions of public engagement about gene editing technologies in subsequent chapters. I recount how the dominant narratives of the contemporary public engagement describe it as developing out of and distinct from public understanding of science. Such accounts frame public engagement as a shift from public understanding of science’s approaches to science-public relationships as matters of public knowledge deficits to matters of public participation and democratic governance. However, I argue that those accounts of public engagement omit and underexplore how public understanding of science was itself explicitly a normative project of ordering the relationships between science and society through notions of promoting *public appreciation of science*. I show how the development of public engagement was not a shift *from* a primarily epistemic project *to* a project of participatory governance. Rather, public engagement is a continuation of public understanding of science’s projects of social ordering that reinforce the position and authority of scientific experts in science and technology governance as essential for democratic society.

Chapter 3 explores further the development of gene drive technologies, in particular early discourse around the development of gene drives and gene drive organisms, alongside notions of public engagement and the scientific experts' responsibilities to society regarding those technologies. I follow early scientific discourse on the responsible development and governance of gene drive technologies beginning from the first CRISPR-based gene drive papers in 2014 through the US National Academies of Science, Engineering, and Medicine report on gene drive technology in 2016, and subsequent institutional uptake of public engagement as part of broader gene drive governance frameworks. I argue that framings the stakes for gene drive technologies in ethical terms also framed public engagement, as an essential part of commitments to good governance, a moral imperative for scientific experts as part of their responsibilities as scientists. In so doing, public engagement underwrote scientific experts not only as epistemic authorities for gene drive governance, but also as normative ones. The constructions of public engagement as a core part of scientific responsibility also further reinforced the position of scientific experts by rendering local engagement and global stakes for gene drives commensurable.

Chapter 4 appears in this dissertation in the same form it does in the forthcoming edited volume *Nature Remade* (Campos et al. (eds.) 2021) which explores ideas, rationales, and attempts to engineer life across biological scales. The chapter explores initiatives led by scientist Kevin Esvelt to engage with indigenous Māori communities in Aotearoa New Zealand around the potential use of gene drive technologies for the control of invasive species as an example case in which principles of public engagement around gene editing are constructed and intentionally enacted. I show how commitments to and practices of public engagement function as expressions of scientific responsibility for the development of gene editing technologies by including local, affected communities. Yet, that same engagement also enables scientific approaches, like that of mechanistic biology, to dominate and constrain understandings of what it means to control gene drive. I argue that the dominant, mechanistic approaches in modern biology, particularly around notions of controlling life, envision the use and governance of gene drive technologies in ways that center scientific expert perspectives on what is technically and socially salient for good, responsible development of gene drive.

Chapter 5 explores prominent expert discussions on the technical, governance, and societal implications human heritable germline gene editing, as an example case of gene editing governance discourse in which public engagement features prominently. In particular, I follow constructions of public engagement across international summits on human gene editing convened by US, UK, and China national academies of science in 2015 and 2018 through the controversies of the birth of the first genetically edited humans, and subsequent reports and calls for moratoria on heritable human germline gene editing. I show how scientific experts' calls for public engagement as part of a commitments to the governance of heritable germline gene editing framed public engagement as a way to navigate and resolved societal controversy about the potential uses of the technology. Scientific experts constructed public engagement as part of a vision heritable germline gene editing governance as being "not for science alone" in which public engagement underwrote development of heritable germline gene editing in terms of *how* to move forward with the technology, rather than *if*. In that framing, scientific experts set the stakes for heritable human germline gene editing and the terms for requisite public engagement, effectively expanding the range of publics on whose behalf they assumed responsibility and ultimately reinscribed their authority in gene editing decision-making.

In Chapter 6, I return to answer my driving questions, synthesizing arguments across the previous chapters. I argue that public engagement in gene editing discourse has been constructed as an expression and evidence of scientific responsibility, which has ultimately reinforced the authority of scientific experts in decision-making by expanding the range of publics that on whose behalf scientific experts may legitimately act. I argue that the reinforcement of scientific expertise through public engage also centers scientific experts in visions of democratic governance of gene editing in a sociotechnical imaginary that I term “not for science alone.” This imaginary envisions scientific experts as guardians and guarantors of good governance and societal prosperity through science and technology, evidenced by demonstrations of scientific responsibility through commitments to public engagement. I also show how this reinforcement of scientific experts does not require any intentionality on the part of those experts calling for public engagement around gene editing. Rather, it is precisely because of their earnestness and sincerity that the reinscribing of scientific authority goes largely unrecognized as such. Moreover, I argue that these patterns ought not be fully surprising, given the linked histories of public engagement and public appreciation of science as overtly science-supporting aspirations. I conclude with considerations of whether or not public engagement with gene editing is something that should be done and reflections on future directions for improving engagement and democratic governance of science and technology.

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CHAPTER 2

LEGACIES OF PUBLIC UNDERSTANDING OF SCIENCE IN THE UK AND US: VISIONS OF SCIENCE AND DEMOCRACY FOR PUBLIC ENGAGEMENT

Over the past two decades, the idea that publics ought to be more engaged with science has become a recurring, prominent feature of societal and scholarly discourse of decision-making about science and technology (Wynne 1992b; 2006; Rowe and Frewer 2005; Bucchi and Nersisni 2007; Irwin 2014; Jones 2014; Stilgoe, Wilsdon, and Lock 2014), ushering in a veritable “age of engagement” (Delgado, Lein Kjølberg, and Wickson 2011). Similarly, public engagement has become a continued refrain and imperative from scientific institutions as an essential part of doing good, responsible science that promotes public interests. (AAAS 2006; Leshner 2003; 2006; National Academy of Science 2018). The emphasis on need for public engagement has been particularly strong around the challenges surrounding emerging technologies (Sturgis 2014; O’Doherty and Einsiedel, 2013). Such calls for public engagement largely aim to promote inclusion of the public in deliberations about science, increased transparency in scientific practice, better governance and decision-making regarding science issues, and greater public trust in science broadly.

While in recent years public engagement has received significant attention as a site where the right relationships between science and society are negotiated, such discussions are not themselves new. Nor is public engagement itself is a new taxon for science-public interactions (Balogh 1991; Berg 2008; Boyer 1985; Elster 1998). So, where did contemporary ideas of public engagement originate? How did they develop to be as they are? To understand how public engagement is characterized and leveraged in contemporary science discussions, one must also understand how it has developed over time, where its principles and distinctives have their foundations, and how specific features of public engagement have come to be as they are.

Contemporary ideas of public engagement find their conceptual predecessors in prior notions of the public understanding of science. Scholars have closely studied and mapped the emergence of contemporary public engagement, tracing its origins to ideas of public understanding of science that rose to prominence as scientists and scientific institutions grew more concerned about the sustainability of public support for science (Evans and Durant 1995; Gregory and Miller 1998; Gregory and Lock 2008; Davies 2013).[5] The standard narrative goes that rising criticism of the inaccuracy and ineffectiveness of "cognitive deficit models" used in approaches to public understanding of science to improve public trust in or support for science eventually gave way to more deliberative, participatory, and democratic inflections to the relationships between science and publics (Millar and Wynne 1988; Ziman 1991; Martin and Richards 1995; Irwin and Wynne 1996; Wilsdon and Willis 2004; Bauer, Allum, and Miller 2007). While some describe the development of public engagement from public understanding of science in relatively tidy, linear terms (Tlili and Dawson 2010), such accounts ultimately

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[5] These histories specifically trace the development of public engagement in the context of the United Kingdom, which has long been a hub for public engagement scholarship and practice (e.g., Wynne 1992a; 1992b; 1996; Stilgoe 2005; 2007; Bowman and Hodge 2007; Gregory and Lock 2008), and the transitions from public understanding of science to public engagement were sharp, if heterogeneous (Davies 2013). In part, the sharpness stems from particular features of a UK-specific civic epistemology in which expert science advice has a particularly intimate relationship with governmental decision-making (Jasanoff 2004), though Davies notes that the general pattern of moving away from public understanding of science and toward public engagement, however, is still present in other centers of public engagement scholarship in the United States and elsewhere, which I explore in part in this chapter.

belie the more piecemeal, iterative, and heterogenous process by which what is recognized as public engagement has come to be (Wynne 2006; Davies 2013).[6]

Whether as an object of critique or inspirations, public understanding of science has been widely identified as the main historical and conceptual forerunner to public engagement. Many scholars have explored how conceptualizations of publics, knowledge and trust deficits, and relevant expertise have been configured differently in public engagement than in public understanding of science (Rowe et al. 2005; Wynne 2006; Bauer, Allum, and Miller 2007; Bucchi 2008; McCallie et al. 2009). Others have pointed out that despite ostensible differences in framings of public engagement (Nisbet 2009), there remains a tendency for public engagement to recreate public understanding of science deficit models and assumptions (and subsequently, a rediscovery of the need to reform them (Wynne 2006). Moreover, as in public understanding of science efforts, many invested in conceptual projects about public engagement also remain occupied with the configuration of the relationship between lay publics and scientific experts in collective decision-making in democratic societies (Wynne 1992b; 2016; Jasanoff 2003b; 2014; Collins and Evans 2008, Durant 2019). In particular, the shift from public understanding of science to public engagement also denoted a reclassification of what constituted good decision-making about science and technology from being a matter of right knowledge to being one of right governance, specifically participatory, democratic governance (Gregory and Lock 2008; Burgess 2014).

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[6] Despite the variations in public engagement practices and developmental histories, characterizations of public engagement have nevertheless stabilized around a "dominant model" (Hilgartner 1990) in which public engagement pertains more to matters of participation, deliberation, and democratic inclusion in science and technology decision-making rather than a matter of publics' knowledge or ignorance of scientific facts, processes, or methods of inquiry.

These familiar accounts of public engagement stemming in various ways from a tradition of public understanding of science largely trace their conceptual origins to the mid-1980s, primarily, though not exclusively, among science and technology studies scholars in the United Kingdom (e.g., Thomas and Durant 1987; Millar and Wynne 1988; Davies 2013; Stilgoe, Wilsdon, and Lock 2014). According to such histories, the key inflection point for public understanding of science to public engagement was the shift from an emphasis on public knowledge to public participation. However, the term and concept of public understanding of science existed for decades prior, going back to at least the mid-twentieth century (Tripp 1943; AAAS 1946; Davis 1948; Piel 1955; Wolfle 1957; Killian 1959; Shils 1974; Lewenstein 1992). By starting their narratives of how public engagement came to be as it is understood today in the 1980s, these accounts leave unexamined more than they actually examine. As a result, they inadvertently paint out how public understanding of science was just as concerned about public attitudes and values—public *appreciation* of science—as it was about public acquisition or deficits of scientific knowledge. As a result, the influence of public understanding of science as a project of affect and shaping public attitudes, and how scientific experts' perceptions of whether the public did (or did not) sufficiently appreciate science are largely lacking in these genealogical narratives. [7] Likewise, the legacy of public understanding of science as

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[7] Research explicitly focused on public understanding of science and public appreciation of science is relatively scarce. Notable exceptions include the work of Lewenstein (1992) and Evans and Durant (1995). Related scholarship by Cooter and Pumfrey (1994) and Knight (2006) has more been in regard to science communication approaches than it is about public engagement as part of collective decision-making about science and technology. Other branches "public appreciation of science" research uses surveys of public appreciation alongside understandings of scientific processes and facts (e.g., Etzioni and Nunn 1974, Bauer 2008), though this is more about assessing public attitudes about science broadly.

also public appreciation of science as it pertains to contemporary ideas of public engagement also remain underexplored.[8]

This chapter attempts a modest contribution to build upon the body of existing scholarship by following an overlooked continuity of *public understanding of science as appreciation* in narratives of the development of public engagement. I aim to draw together continuities in the histories of public understanding of science itself and scholarship on the development of contemporary engagement from public understanding of science movements. I draw inspiration from Bruce Lewenstein's (1992) account of mid-twentieth century United States public understanding of science efforts as having been equated with increasing public appreciation of science as a starting point for analyzing how public understanding of science as appreciation has influenced notions of public engagement. My contribution is not merely *that* public understanding of science was, in fact, functionally about the public appreciation of science. My point is that, in being equated to appreciation, public understanding of science *also* brought with it a specific, normative vision of right social ordering in which scientific expertise had an elevated and esteemed societal position that was recognized by members of the public.

My aim is not to provide an exhaustive account of public understanding of science nor to suggest that its expression in the national context of the United States is the standard by which to be compared. The ways of making sense of what constitutes scientific knowledge, authoritative expertise, relevant publics, and good, legitimate

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[8] Other linkages between public understanding of science and public appreciation of science as part of discourse on the governance of science and technology have emerged (Hvidtfelt Nielsen 2005), but in a distinctly different national context (Denmark) than this chapter explores.

governance in the context of the United States are surely distinct from those elsewhere.[9] However, what I identify are instances in which public understanding of science came to be understood as public appreciation of science that I argue are illustrative of broader patterns in the configuration of science-public relationships. In other words, this chapter examines cases in which advocates for the public understanding of science cast visions not only of what publics ought to know, but also how they ought to relate to science and scientific expertise and vice versa.

To do this, I show how patterns of public understanding of science existed in the United States for decades prior to familiar narratives of public understanding of science of the mid-1980s, in both the United States and United Kingdom that underpin contemporary public engagement. I then show that earlier constructions of public understanding of science were always also a matter of public appreciation of science. Thus, histories of the development of public engagement as a shift from knowledge deficits to participation and deliberation are only partial. Central to those transitions are also scientific experts' attention on publics' affective attitudes toward science and broader visions of science and democracy.

I conclude by arguing that contemporary expressions of public engagement are a continuation of prior ideas of public understanding of science that equated understanding of science with appreciation of science. Those framings of public understanding of

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[9] Science and technology studies scholar Shelia Jasanoff terms these ways of sense-making "civic epistemologies." She observes that across various national, cultural, and historical contexts "publics are not all alike but are guided by culturally conditioned 'civic epistemologies'" (Jasanoff 2014). Accordingly, my use of examples of public understanding of science in the United States alongside that in the United Kingdom is not a commensuration of their respective publics, but as indicative of a pattern of framing visions of science, expertise, and publics that is common to both.

science also shaped enduring visions of the right relationship among scientific expertise, publics, and governance.[10] Furthermore, framings of public understanding of science as appreciation were not neutral but were explicitly concerned establishing social orders which elevated the position of science and scientific expertise in society. Likewise, public engagement has come to embody similar aspirations for the place of scientific expertise and authority in decision-making about science and technology. In so doing, public engagement ultimately reinscribes the aspirations of public understanding of science as appreciation by envisioning scientific expertise and authority as essential for democratic social orders.

Early Visions of Public Understandings of Science for Society

While the common narratives of the origins of public engagement with science and technology begin with ideas of public understanding of science that became prominent in the 1980s, public understanding of science itself, as both a term and concept, did not originate with the renewed interests in the topic at that time. The term public understanding of science had already been used in similar ways for at least forty years prior in both the UK and the United States. In those prior uses, public understanding of science was associated, not with publics' knowledge (or ignorance) of scientific facts, processes, or ways of knowing. Rather, the "understanding" of public

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[10] The focus of this chapter is on the how the relationships between scientific experts and publics have been envisioned by constructions of public engagement and public understanding of science as part of broader imaginations of social and political arrangements. Often, this is in the context of government agencies or actors, but this chapter is not focused on the of scientific experts as advisors to governments, per se (Jasanoff 2009), but more broadly about the position of scientific experts relative to publics.

understanding of science was meant in the sense of recognizing and appreciating the value of science and scientific expertise for society.

To illustrate the pattern of public understanding of science as public appreciation of science, I briefly point to examples of the framings of public understanding of science and its aims from science advocacy organizations in the UK and United States in the mid-twentieth century. Though these examples are not the only ones, nor necessarily even the first,[11] they are broadly illustrative of the relating of public understanding of science with notions of appreciation of science and broader imaginations of the right relationships between science and publics in national. contexts that have historically dominated public understanding of science discourse.

One influential example of the pattern of public understanding of science as the appreciation of the societal value of science I examine is the work of the British Science Association (BSA) in the mid-twentieth century. The BSA, founded in the first half of the nineteenth century, was a prominent advocate and popularizer of science in British society. In particular, in 1943, the Division for the Social and International Relations of Science of the BSA published a report entitled "Science and the Citizen: The Public Understanding of Science" that detailed proceedings events of conference they held in March earlier that year. The purpose of the conference and the report was to "consider ways and means for increasing public understanding and appreciation of science" (Tripp 1943, 382). Public understanding of science and public appreciation of science, in this

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[11] Ideas about public understanding of science (though not always by that name) also had existed for further decades prior, in ideas of the "popularization of science" (Burnham 1987; Broks 2006). Yet, even in earlier formulations, the aims for publics' relationship to science were "to stimulate, not so much the acquisition of scientific knowledge, as the appreciation of its value…in affairs of every kind" (The British Science Guild 1904).

framing, were closely coupled, a pairing that linked together a cognitive apprehension of science with a positive assessment of its value.

However, the kind of understanding that was sought for citizens of the British public was not that of scientific knowledge per se, but of fostering recognition of the "spirit and service of science" (Tripp 1943, 382). Public understanding and appreciation of science were described as being primarily about the capacity of science to be valuable to society. Members of the BSA reasoned that both public understanding and appreciation of science were necessary because they were "living in an era in which the discoveries of science are becoming an essential constituent of our everyday life, and an understanding of the spirit and service of science is of the utmost importance for the people and its leaders if our civilization is to survive" (Tripp 1943, 382).

According to the BSA's framing, at stake for public understanding of science was not only the reputation or public perception of science, but society itself. [12] The primary goals of BSA to increase public understanding and appreciation of science as essential for British society demonstrated the extent to which commitments to public understanding of science embodied more than just expressions of support for science. They also reflected aspirations for the well-being of the whole of British society, aspirations that depended upon scientific discovery for the quality, prosperity, and safety of everyday life. Therefore, widely held public understanding and appreciation of the valuable service that

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[12] No doubt, when the conference proceedings were published in 1943, the memory of bombing raids on London and other British cities a couple of years prior and the continued turmoil of WWII resonated profoundly with the incredibly high stakes for public understanding of science as the survival of civilization. Though perhaps expressed to an extreme, the pattern of setting the stakes for public understanding of science as being for the prosperity, safety, and future of a nation continued to be repeated, especially in the United States, over the following decades.

science provided to society was a necessary component for visions of British society and their relationship to and attitude toward science.

Soon after in the United States, the BSA's counterpart, the American Association for the Advancement of Science (AAAS), expressed similar constructions of public understanding of science as public appreciation of science. Like the BSA, AAAS was a prominent science advocacy organization whose longstanding mission had been to coordinate scientific efforts across the country that prioritized providing general direction for scientific research, securing resources for scientific work, and developing the "wider usefulness" of science to society (AAAS 1856; 1874; 1920).

In 1946, shortly after the conclusion of World War II, AAAS adopted a new constitution that laid out the organization's goals for American science going into the second half of the twentieth century. Their new constitution outlined specific objectives for the organization, reaffirming its historic commitments to furthering the work of scientists across the country. However, it also notably included new additions focused on promoting public understanding of science in service of broader society. It stated that "The objects of the American Association for the Advancement of Science are to further the work of scientists, to facilitate cooperation among them, to improve the effectiveness of science in the promotion of human welfare, *and to increase public understanding and appreciation of the importance and promise of the methods of science in human progress*" (AAAS 1946, emphasis added).

Improving public understanding of science and public appreciation of science were both listed as primary aims for AAAS on part with the organization's goals for the prosperity of science in the United States. Importantly, the objectives for publics' understanding and appreciation of science were linked to its “promise” for society. AAAS’s aim was not to boost publics’ comprehension of scientific ways of thinking or their acquisition of scientific knowledge. Rather, what was sought by public understanding of science and public appreciation of science was a change in public affective attitudes toward science—to recognize the vital role that science played in advancing “human progress.” In that construction of public understanding of science and public appreciation of science was an aspirational vision not only for American science, but, at the same time, the future of American society. It was not only the activities of science itself aided in “the promotion of human welfare,” but also greater public understanding and appreciation of science were necessary to enable and generate fundamental social progress.

The co-occurrence of the language of public understanding of science and public appreciation of science in AAAS documents three years after the BSA expressed notions may not be causally related to one another (though it would have been unlikely for members of AAAS to be utterly unaware of BSA proceedings in general, even if they were not familiar with them in particular). Regardless, the point is not a causal one but an evidentiary one. The repeated framing of public understanding of science alongside public appreciation of science as a core component of the aims for science and scientific organizations, despite the presence of other differences in culture, national context, or civic epistemologies, was indicative of some early coherence of how public understanding of science and the relationships between science and publics in particular were imagined on either side of the Atlantic in the mid-twentieth century.

Public understanding of science and public appreciation of science were therefore a matched set and a conceptual pair that national scientific organizations adopted as important goals for scientists to pursue. How those scientists constructed public understanding of science and public appreciation of science also envisioned a particular ordering of the relationships between science and society, relationships in which the stakes for increasing public understanding of science and public appreciation of science were at once for both the success of science as well as the welfare and progress of broader society. Even in its earlier instances, public understanding of science and public appreciation of science were not only projects of and for science, but also projects of and for society.

Appreciation Rather than Apprehension

Such patterns of framing public understanding of science as public appreciation of science are also consonant with broader arguments about public understanding of science in the United States during the years following World War II made by science communication scholar Bruce Lewenstein (1992). In brief, Lewenstein shows how, during the 1940s and 1950s, converging interests among scientific experts, government agencies in the United States, science publishers, and science journalists around promoting public valuing of science and its role in improving and upholding modern American society led to an equating of public understanding of science as public appreciation of science. He argues that "advocates of popular science who used the term 'understanding' were in fact seeking public *appreciation* of science. That is, they were seeking to improve the attitude of members of the public toward science as a body of knowledge, science as a way of knowing the world, scientists as individuals, and the particular requests for support and funding that came from scientific institutions" (1992, 45-46; emphasis in original).

Lewenstein makes the case that public understanding of science was not primarily about educating publics to be more like scientists in their thoughts, knowledge, or abilities. Instead, public understanding of science was concerned with changing public attitudes to recognize and value science as indispensable to modern society. As a result, public understanding of science, far from being about publics having particular beliefs about scientific *content*, was about publics' beliefs about the value of scientific knowledge and expertise itself for wider society.[13]

In part, the appreciation implied in public understanding of science entailed a kind of gratitude for the technological advances that science enabled. Public appreciation of science ascribed responsibility for advancements in medical therapies and drugs, new means of telecommunication and transportation, more efficient manufacturing materials and methods, computing, and most any other gadget that made modern life more convenient and comfortable to being possible thanks to the work of scientists.

However, more than just seeing science as a provider of new and better widgets, commitments to public understanding of science also situated science as a way (or rather, *the* way) of understanding the world rightly. Advocates of public understanding of

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[13] Notably, this notion of public understanding of science was not tied to publics' having specific beliefs about science apart from its general value to society. This stands in contrast to more recent controversies in which calls to believe, trust, or listen to science have focused on publics' acceptance of particular scientific claims or related policies about topics such as climate change, vaccines, evolution, the effectiveness of masks in preventing virus transmission, or the shape of the planet. It is not that the aims of public understanding of science were less political in their aims but located publics' affective attitudes toward science as the site of intervention rather than publics' epistemic capacities or commitments.

science also explicitly advocated for a societal arrangement in which science enjoyed both governmental funding and broad public esteem, cementing a position of legitimacy and authority for their particular forms of specialized knowledge in national-level governance and decision-making (Lewenstein 1992,61-62). Built into the aims of increasing public understanding of science was also an aspiration for a particular set of social relations between science and the public, namely, a vision of American society in which scientific experts occupied positions of significant power and authority for the sake of the public interest and well-being.

The framing of the public understanding of science as tantamount to the appreciation of the social value of science simultaneously asserted science as a progressive process that enabled greater and broader common good through both technological advancements as well as expert policy advice. Rather than as one tool out of the many enlisted to produce the public good, science was envisioned as a public good in and of itself. As the enterprise of science was critical to societal prosperity, so too was public recognition of that relationship. In that way, public understanding of science itself, as a project of improving public appreciation, also was in service to broader society.

Importantly, the project of improving public understanding of science was not framed as a responsibility of scientific experts alone, or even primarily. Rather, improving public understanding of science, and thus public appreciation, was a shared endeavor. Scientists, government agencies, and popular science media all engaged in large-scale and organized efforts to develop public understanding of science in the United States (Lewenstein 1992, 62). Though they pursued it with differing strategies, with somewhat different interests, and in different capacities, there were seldom sharp delineations between science as a research enterprise as distinct from the popularization of science with the general public or the communication of scientific ideas with a broad audience. As a result, public understanding of science was framed as a wider, more comprehensive societal project, rather than only a scientific one.

Commitments to the importance of improving public understanding of science as a societal imperative have long been part of discourse on the rightful place of science and society. Moreover, in the mid-twentieth century, the equating of public understanding of science as public appreciation of science was the rule, not the exception. Thus, public understanding of science was not only, or even primarily, a project of scientific knowledge-making among public groups but a social project of ordering the relations among science and publics in society. Furthermore, that social ordering had specific goals to secure and elevate the place of science and scientific experts in broader society that were stabilized through the efforts of scientific and governmental institutions.

Responsibility for Science and Democracy

Similar patterns of public understanding of science as public appreciation were also present in conceptions of public understanding of science in the 1980s, though they have largely not featured in the dominant narratives of the development of public engagement. In particular, these understandings of public understanding of science draw heavily from ideas and subsequent interpretations of the 1985 report on *The Public Understanding of Science* by the Royal Society (e.g., Gregory and Lock 2008; Stilgoe, Wilsdon and Lock 2014). The report was created by an ad hoc group of Royal Society scientists, chaired by Sir Walter Fred Bodmer, a geneticist at the University of Oxford who later became a prominent figure around the Human Genome Project (Bodmer and McKie 1997). The report attempted to respond to perceived waning public support of science and the dangers that posed to British society (Bauer 2008; Short 2013), and their emphasis on the need for greater public understanding of science grew out of the misgivings of scientific experts about public attitudes vis a vis the position of science in society.[14]

The Royal Society report was a highly influential and widely-cited document that was in many ways exemplary of a particular thought collective engaged with questions about the proper relationships between science and publics at that time, particularly in the UK (Millar and Wynne 1988; Miller 2001; Locke 2001; Stocklmayer and Bryant 2012; Meyer 2016; Wynne 2014; Cortassa 2016). However, whereas common narratives of public engagement have emphasized a shift of focus on public knowledge to public participation, "from deficit to democracy" (Irwin 2014), the public understanding of science of the 1980s and as expressed in the Royal Society's 1985 report was not exclusively concerned with deficits in publics' scientific knowledge (or their scientific ignorance). Rather, the report was concerned about publics' recognition of the value of science for society.

In their report, the Royal Society described public understanding of science in quite broad terms. Public understanding of science was being about "not just the facts of

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[14] Such anxieties on the parts of experts were not new to discourse around public understanding of science but had grown for decades as science continued to be enmeshed with broader societal and political decision-making. Harvard physicist, Harvey Brooks, captured such sentiments in his reflection on the state of American science in an article published in *Science* saying that "the threats to the integrity of science, both from within and without, are probably greater than at any time in the past…because science is much more a part of the total social and political process" (1971).

science, but also the method and its limitations as well as an appreciation of the practical and social implications [of science]" (The Royal Society 1985, 6). While particular science facts, processes, and the nature of science were part of the Royal Society's aims, the "understanding" that they envisioned publics as needing to have was less a matter of knowing things more scientifically themselves, but of recognizing the value of scientific knowledge for society generally. Motivating the perceived need for greater public understanding of science was not public ignorance of science per se but the "erosion of public appreciation of science" (The Royal Society 1985, 14).

Moreover, the Royal Society's report explained that the stakes for public understanding of science were as high and reaching beyond the scope of science itself. Dwindling public understanding of science was "an issue that [was] important not only, or even mainly, for the scientific community but also for the nation as a whole and for each individual within it." (The Royal Society 1985, 5). The importance of public understanding of science was for "individual citizens, to participate in a democratic society" as well as for "those responsible for major decision-making in our society, particularly in industry and government, where few, if any, issues do not have a scientific or technical aspect" (The Royal Society 1985, 31). As such, the imperative to improve public understanding of science was not only a matter of scientific concern, but also much more foundational concerns of democracy. Thus, promoting the understanding of and appreciation of science was "an urgent task for the well-being of [society], requiring concerted action from many sections of society including, most importantly, the scientific community itself" (The Royal Society 1985, 6)

In framing the problems of public understanding of science as public non-appreciation of science, the Royal Society imagined scientific experts like themselves as having a unique responsibility as scientists to improve public understanding of science, not only for the sake of science but for the whole of society. The Royal Society report stated that their “most direct and urgent message [was] for the scientists--learn to communicate with the public, be willing to do so, indeed consider it your duty to do so” (The Royal Society 1985, 24). The report put this message succinctly saying, “**It is clearly a part of each scientist's professional responsibility to promote the public understanding of science**” (The Royal Society 1985, 24, emphasis in original). Furthermore, as part of that scientific responsibility, they argued that “scientists must learn to communicate better with all segments of the public” to ensure that publics sufficiently understood and appreciated science (The Royal Society 1986, 24).

As the knowledge experts, scientists themselves laid claim to being the conduit for the public to rightly understand science. Thus, improving the public understanding of science—and thereby public appreciation of science, too—became part of not only the aims of science, but also part of the responsibilities of scientists specifically. What it meant to be a good scientist included being a good science communicator that promoted the public understanding and appreciation of science. Whereas previous modes of promoting public understanding and appreciation of science were a multi-stakeholder endeavor, this reformation of the aims of public understanding of science was a task that science alone was uniquely equipped for.

The Royal Society’s report demonstrated how, in the mid-1980s, public understanding of science was not solely conceived of as a problem of public ignorance with regard to scientific facts or processes, but about public affective attitudes and evaluations of science. However, their report prescribed that the way forward to increasing this kind of public appreciation was increased and improved science communication. Though models of public knowledge deficits were certainly prevalent in strategies to go about increasing public understanding of science (Wynne 1991; Ziman 1991; Stocking and Holstein 1993; Miller 2001; Sturgis and Allum 2004), the motivations which animated those moves were concerned with publics' appreciation of science, not a narrower sense of understanding as publics' cognitive apprehension of science. Implicit in their reasoning was also a logic that if the public had better or more complete understanding and knowledge of science, then the public would also have a particular set of beliefs about science and its value to society that would translate into public support for science. More pointedly, the proper understanding of science was that which produced appreciation of science among the public. Therefore, proper public understanding of science—and thus appreciation—was as important for the production of societal benefits as sustained support of science and scientific practice were. This ideation presented not only science, but also improved public understanding of science itself as a societal goods.

Conclusions

In retracing histories of public understanding of science, I have aimed to show how the dominant narrative of contemporary public engagement developing out of prior notions of public understanding of science as primarily a shift in framing governance as matters of knowledge to matters of participation are incomplete. Though it is the case that public understanding of science as a conceptual precursor to public engagement was deeply influential, articulations of public understanding of science that anchor those narratives largely leave out the ways that public understanding of science was equated with public appreciation of science.

As a result, the explicit political and social aims of the advocates of public understanding of science as public appreciation go underrecognized. What is lost in those accounts is how public understanding of science has consistently been a more complex social project of molding and managing public attitudes and not as much public knowledge. Efforts to improve public understanding of science were at the same time explicitly advocacy efforts to elevate and maintain the position of science and scientific expertise in society through the generation of public appreciation of the value of science to society. In doing so, particular norms of science—scientific independence, relative autonomy from public direction and oversight, and self-regulation—were also perpetuated and stabilized as part of normative visions for both science and democracy.

By recollecting the histories of public understanding of science as appreciation into narratives of the development of public engagement, one can better recognize how contemporary expressions of public engagement continue patterns of reasserting the rightful place of science in society, in which scientific experts both diagnose the problems and prescribe the solutions for challenges of democratic governance of science and technology.

The consonance between public understanding of science as appreciation with public engagement also show how public engagement, like public understanding of science, is not a socially or politically neutral activity. Rather it is one that envisions more technocratic forms of governance that maintain a position for scientific experts to be a source of authoritative knowledge. Such aims of public understanding of science have not been jettisoned in the transitions from deficit models of public understanding of science to more participatory ones in public engagement. If anything, they have been strengthened by the claiming of public understanding of science and public engagement as especially the responsibility of scientific experts qua scientific experts.

The framing of improving public understanding as scientific responsibility permeates framings of public engagement as well. Alongside the rhetorics of democracy that underwrite doing public engagement in the first place, constructions of public engagement as a special responsibility of scientific experts launder the technocratic projects of public understanding of science in a rhetoric of more inclusive, participatory democracy. Moreover, failing to include the lingering legacies of public understanding of science as public appreciation elides a shift where decision-making authority and responsibility have been located. It enables the explicit aims of public understanding of science to secure and uphold the place of science in society to be obscured by a rhetoric of participation that present public engagement as an enhancement of a priori democratic norms of governance instead of a site in which the democratic governance of science and technology is itself being made.

Contemporary public engagement, then, is not a significant departure in conceptual aim from public understanding of science with regard to the relationships between science, the public, and decision-making. Instead, public engagement, like public understanding of science, implicitly elevates scientific experts to a preeminent role in that process. Part and parcel of public engagement is a simultaneous assertion of the legitimacy of scientific expertise for decision-making in the public interest. This places public engagement in tension with the democratic aspirations and rhetoric that often accompanies contemporary invocations and prioritizations of public engagement as essential for the good governance of emerging science and technology.

Public engagement often is couched in language of democratic principles and ideals, focused on expanding the range of voices involved in scientific decision-making. Despite the insistence on public inclusion, deliberation, or participation, public engagement embodies a hierarchy that enshrines scientific experts as the de facto leaders. In effect, the inclusion of publics functions as a legitimation of scientific expert authority and influence rather than a democratic check on them. Public engagement, thus, should be understood not as a project of scientific communication, democratizing science, or even of responsible science. Rather, public engagement is a project of democracy itself: how it is envisioned, constituted, and rendered legitimate. In other words, public engagement with science and technology is itself a site of democracy in the making.

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CHAPTER 3

ENGINEERING RESPONSIBILITY: EXPERTS, ENGAGEMENT, AND ENGINEERED GENE DRIVES

Public engagement has become a conceptual thread increasingly interwoven into international discourses concerning emerging science and technology and its governance. Commitments to the democratization of science and technology have often employed public engagement as a way to give structure and form to their claims to produce preferable governance outcomes (Wynne 1993; Giddens 1998; Jasanoff 2003a; Leach, Scoones, and Wynne 2005; Stilgoe, Lock and Wilsdon 2014). Public engagement has been instrumentalized as a critical means of increasing decision-making transparency, securing political legitimacy of deliberative outcomes, promoting public trust in science, including a wider array of values and perspectives, and providing a counter-weight to more technocratic forms of governance (Jasanoff 1990, 2005; Guston and Sarewitz 2006; Barben et al. 2008; Stirling 2005; Stilgoe, Lock and Wilsdon 2014).

As a result, public engagement has become one of the mainstays of democratic visions for the governance of technoscience (Jasanoff 2003a; Wilsdon and Willis 2004; Guston 2014a; Chilvers and Kearnes 2015). Such visions not only encompass specific understandings of the appropriate development and use of technologies, but also reflect prescriptions for the right configuration of relations among science, technical experts, publics, and spaces of collective political decision-making and corresponding notions of credibility, legitimacy, and authority (Jasanoff 2004). Especially around emerging science and technology in which the pertinent scientific facts, societal values, political implications, and moral stakes are not settled, public engagement has been portrayed as a tool in a larger repertoire of decision-making strategies for navigating uncertainty in and around technological developments and outcomes. Public engagement with science attempts to respond to questions of how decisions about science and technology ought to be made, who ought to be included, and toward what ends.

At the same time, public engagement has also become an integral part of discourse on what it means to pursue responsible science. While responsible science itself may reasonably be understood as an "essentially contested concept" (Gallie 1955), scholarship on responsible research and innovation generally situates it as having something to do with configuring the right relations between scientific enterprise and broader society, with an emphasis on democracy, collective, reflexive practices, and obligations to public good (Owen et al. 2013; Von Schomberg 2013). Public engagement, then, has been framed as a component of negotiating the relations between science and publics in pursuit of responsible scientific practice (Bucchi and Neresini 2008; Stirling 2008; Barben et al. 2008).

Such calls for public engagement have been especially pronounced around the emergence of engineered gene drives.[15] At the most basic level, gene drives are a genetic biotechnology that enables the spread of selected genetic elements through species populations by significantly increasing the likelihood of a gene's inheritance in subsequent generations. Proposed gene drives apply recent advances in genome editing,

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[15] In this chapter, I use the term "engineered gene drives" and "gene drives" interchangeably to refer to the biotechnology, as distinct from naturally occurring instances of super-Mendelian inheritance that are called "gene drive." Generally, I use the plural in recognition that multiple mechanisms and type of engineered gene drives exist with different potential applications, risks, and benefits at different scales (Noble et al. 2016; Esvelt and Gemmell 2017; Buchman et al. 2018; Min et al. 2018), with exceptions for reference to individual gene drive systems or used in adjectival form.

such as CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats)-based tools, to create a self-propagating system of genetic modification that, in principle, could spread throughout a reproductively-connected population. The power and scalability of gene drives to alter entire species populations has lent itself to speculative ecological engineering applications ranging from prevention of vector-borne diseases such as malaria to conservation efforts and the control of invasive species (Esvelt et al. 2014a). Gene drives have come to be recognized in international governance discourse as a technology with far-reaching, potentially irreversible, biosphere-altering effects, significant global stakes for human and environmental well-being, as well as profound implications for local communities who stand to be most affected by uses of gene drives.

Calls for public engagement around gene drives have been widespread across scientific and governmental institutions as a normative imperative to ensure their responsible development and the democratic governance of their potential use (Esvelt et al 2014.; Benedict et al. 2014; Akbari et al. 2015; NASEM 2016; Emerson et al. 2017; Esvelt 2017; Braverman 2017a; African Union 2018; James et al. 2018; Long et al. 2020). Similarly, there is no shortage of scientists and science and technology studies scholars using public engagement as a practical intervention in scientific practice and discourse around genetic engineering (e.g., Kleinman et al. 2011; Delborne et al. 2018; Buchthal et al. 2019; Brossard et al. 2019). Such interventions also often take as a starting point the belief that public engagement in some form is part and parcel of democratic and responsible science. Focus has been on developing strategies and evaluations for public engagement with regard to what it ought to entail, who it ought to include, and how it might best be done. Less attention has been directed toward understanding the ways that public engagement itself has come to be constructed as part of a decision-making repertoire for democratic and responsible visions of science and technology. Similarly, some have observed that calls for public engagement themselves have often produced a "reductive rendering of engagement as the right thing to do or as a way to secure public acceptance," rather than more substantive reflections on what public engagement in-practice adds to decision-making about gene drives (Hartley et al. 2019).

My interest in public engagement is not as a set of practices or interventions per se, but as an aspiration and motivation that underwrites imagined practices and interventions of public engagement as salient and crucial to technoscientific governance discourse. I want to understand how commitments to public engagement as a necessary and embedded feature of discussions of technoscientific governance operates in that discourse—how is it framed, leveraged, and deployed as part of a regime of values, commitments, and aims for visions of science, democracy, and society.

At stake in gene drive discourse are notions of responsible science and the rightful role of science and publics in collective decision-making in democratic societies. Accordingly, public engagement is a site where both science and democracy are "in-the-making" (Chilvers and Kearnes 2015; Laurent 2017). Knowledge claims about gene drives are co-produced with normative claims about the right relations and relative power of scientific experts and publics in technoscientific decision-making about them (Jasanoff 2004). Engineered gene drives bring to the fore of technoscientific governance discourse concerns and aspirations for the intentional redesigning, repurposing, and reconfiguring of "life itself" in natural and social worlds alike (Rose 2001).

Therefore, gene drive discourse enables analysis of public engagement as a component concept of broader notions of responsible science and forms of democratic governance. It presents a case in which prominent and international scientific and governmental institutions are implicated. While not exhaustive, I argue this case to be nevertheless representative and influential of broader discursive patterns. It also presents a case in which both global and local publics, stakes, and engagement are entangled, enabling points of comparison across scales and geographies. Moreover, gene drive discourse enables a more complete following of public engagement from its construction as a conceptual category, through its uptake and deployment as a set of commitments and practices.

This chapter follows constructions of public engagement as a conceptual category across gene drive discourse, with an emphasis on US and related international contexts. I begin by following the emergence of public engagement as part of gene drive discourse from circa 2014 and the first paper to describe a feasible, engineered gene drive (Esvelt et al. 2014a)[16] through the US National Academies of Science, Engineering and Medicine consensus report on gene drives (NASEM 2016) as a distinctive, prominent document that spotlighted public engagement. I then trace public engagement through its uptake, repackaging, and deployment in "on-the-ground" interventions as a morally-laden, imperative for the responsible development and democratic governance of gene drives.

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[16] Although there were earlier proposals of engineered gene drives (e.g., Burt 2003; Trivers and Burt 2009; Chan et al. 2013) as well as advisory documents recommending public engagement as a prerequisite to their use in nature (Benedict et al. 2008), the 2014 paper of CRISPR-based gene drives (Esvelt et. al) marks a significant shift in the technical feasibility of gene drives and, therefore, their subsequent consideration as an emerging technology of governance concern.

In this chapter I argue that public engagement works to reinforce the authority of scientific expertise by establishing scientists as responsible actors by imbuing public engagement and the stakes for gene drives with moral imperatives to act in specific ways. By constructing and framing public engagement as a marker of what it means to do responsible science, gene drive discourse sets up scientific experts not only as epistemic authorities but also normative ones insofar as they are committed to public engagement practices. The extension of scientific experts' purview to the realm of moral stakes-setting enables them to outline the agendas and framings of what constitutes public engagement, and thereby, also what constitutes good governance of gene drives. That construction of public engagement constrains possible avenues of critique for gene drives by counterposing narratives of responsible development of gene drives with those of imagined, irresponsible, and inevitable uses. The imparting of moral imperative onto public engagement also underwrites a rationale in which local and global publics are rendered commensurable. Scientists' appeals to localized instances of public engagement are leveraged to support the use of gene drives elsewhere globally on the basis of linked moral stakes of gene drives. This linkage is enabled and legitimized through assertions of the epistemic as well as the normative authority of scientists as responsible agents in developing and governing gene drives.

Public Discussion and Responsible Gene Drives

In July of 2014, a team of scientists from the Wyss Institute for Biologically Inspired Engineering, Harvard Medical School, and the Harvard School of Public Health published a landmark scientific paper describing the design and possible use of a genetically engineered gene drive (Esvelt et al. 2014a). The lead author on the paper was Kevin Esvelt, a charismatic geneticist and co-inventor of CRISPR-based gene drives. Over the following years, Esvelt would come to be a central figure in regional and international gene drive discourse as one of the technology's most prominent advocates, publishing further articles developing ideas both of gene drive techniques as well as how to do so responsibly, giving numerous media interviews and appearances, and personally engaging with local communities where gene drives might be used.

While previous research had long theorized the possibility of a human-designed gene drives (Craig et al. 1960) and even proposed genetic engineering techniques to realize them (e.g., Gould et al. 2008; Trivers and Burt 2009; Deredec, Godfray, and Burt 2011), the distinguishing feature of the 2014 paper was that the gene drives posited relied on recent advances in CRISPR-Cas9 gene editing to construct gene drives. CRISPR-Cas9 gene editing had significant advantages over other genetic engineering techniques for building gene drives. CRISPR-based techniques were faster to design, easier to implement, and cheaper to use than other methods of genetic alteration, making an engineered gene drive technically feasible and, more widely accessible for scientists to research and develop.

The findings of the 2014 paper marked a shift in scientific discourse around gene drives from being a technically difficult, cumbersome, largely-theoretical technology to a rapidly emerging technology with near immediate areas of application "relevant to human health, biodiversity, and ecological science" (Esvelt et al. 2014). Rather than a technology of some far-off future, gene drives as presented by Esvelt et al. were a technology placed on humanity's doorstep that required a response.

And a response they recommended. In the paper, Esvelt et al. made it clear that gene drives had the potential to offer “substantial benefits to humanity and the environment” (Esvelt et al. 2014a, 1). At the same time, they cautioned that the use of gene drives could have unwanted ecological or public health consequences that necessitated careful review and consideration before their use. They argued that it was of paramount importance that if research and development of the technology were to be done, it must be done *responsibly*. Central to their call for the responsible development and use of gene drives was a simultaneous call for “thoughtful, inclusive, and well-informed public discussions” prior to the deployment of gene drives in field trials or even in a laboratory setting (Esvelt et al. 2014a, 16). They argued that “the responsible development of…gene drive is best served by full transparency and early engagement with the public” (Esvelt et al. 2014a, 2).

The gene drive paper published by Esvelt et al. in 2014 also primed and framed subsequent gene drive discourse in several important ways. First, the paper conceptually linked gene drives and public engagement about possible uses of the technology. By virtue of the high stakes for gene drives to both deliver benefits and introduce risks for human and environmental well-being, the authors argued that gene drives required a distinctively responsible path of development towards use. Responsible scientific practice would protect against imagined irresponsible development of gene drives that insistence on responsible development implied. It would also provide the kind of time and deliberative space needed for appropriate regulatory approaches and the ultimate good governance of gene drives. Public engagement was a central part of that vision of responsible governance.

In part, the association of responsibility with publics was surely reflective of the personal beliefs of the authors about the responsibilities of science to society. But also, it was a testament to the extent to which notions of public engagement were already a legible concept to them as mattering for the arrangement of science, publics, and technoscientific governance. The already present ideas of public engagement with science suggested that they were not novel to gene drives in particular, nor the scientists themselves, nor even of a broader cultural moment in science at-large. Rather, the features and values associated with public engagement both predated and existed apart from the specifics of the case of gene drives, which was one iteration in a longer conceptual history of the relations between science and publics.[17]

Second, Esvelt et al. placed public engagement not only as necessary for responsible gene drives, but also as part of the responsibility of scientists qua scientists to society.[18] In describing the need for public discussion and transparency about gene drives, Esvelt et al. specified that "as scientists developing these technologies, it will be our responsibility to make all empirical data and predictive models freely available to the public in a transparent and understandable format. Above all else, we must openly share our level of confidence in these assessments as we determine how to best proceed" (Esvelt et al. 2014a, 17). The framing of open, transparent research as part of the remit of

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[17] Public engagement as a conceptual category became more prominent in the vocabulary of scientists and science discourses after the so-called "deliberative turn." The "deliberative turn" in political theory and the social studies of science shifted focus to study the formation of democracies in discursive spaces and deliberation rather than formal procedures of representative or direct democracy beginning at the end of the twentieth century and continuing into the twenty-first (e.g., Habermas 1996; 2001; Cohen 1997; Parnkins and Mitchel 2005, Bucchi and Neresini 2007).

[18] Note that the responsibility described here was distinct from previous accounts of gene drives and responsible development in which responsibility was more about regulatory compliance and sufficient governmental research oversight rather than pertaining to the ethics or right actions of scientists themselves regarding the applications of gene drives (see Benedict et al. 2008)

scientists attempted to circumscribe responsibility for the broader societal implications of gene drives within the boundaries of scientific expertise.

At the same time, they described the conditions for open, transparent discussion to be predicated on "independent scientific assessment" (Esvelt et al. 2014a: 16), data, models, and scientists' own levels of confidence in the technology such that "well-informed" public discussion could take place. Moreover, they insisted that "the decision of whether or not to utilize a gene drive for a given purpose should be based entirely on the probable benefits and risks of [each] specific drive. That is, each drive should be judged solely by its potential outcomes" (Esvelt et al. 2014a: 16-17). In other words, well-informed discussion meant technical discussions of gene drives and centered on the risks and benefits of its applications—as reviewed, assessed, and articulated by scientists. This further inscribed the responsibility to facilitate and provide the content for fully inclusive, well-informed public discussions about gene drives as within the purview and on the terms of scientific experts.

Third, Esvelt et al. conceptualized publics in rather vague terms. When discussing the need for public engagement, they described who constituted the "public" to be engaged as "the general public," a group that was "fully inclusive" (Esvelt et al. 2014a: 16), or more commonly simply as "the public" (Esvelt et al. 2014a: 17). Notably, the regulatory commentary in S*cience* collaboratively published at the same time as and in collaboration with the research paper by Esvelt et al. was even vague regarding who exactly constituted the public to be included or engaged, only using the term "public" adjectivally to describe the kind of discussions that would need to take place (Oye et al.

2014).[19] There was not yet a concrete vision of who constituted or was representative of "the public" or their interests in the stakes of gene drives. Instead, a generalized notion of "the public" served as a stand-in for the broad societal implications and considerations that animated the calls for responsible science and gene drives through public engagement. That publics were not clearly differentiated in terms of "relevant publics" (Irwin 1995), localized or global groups, affected communities, or specific stakeholders organized around specific issues or applications (Dewey 1927; Irwin and Michael 2003; Rowe and Frewer 2005; Goodin and Dryzek 2006;Wynne 2007) set up publics and what it meant to engage them as a markedly important, but also open category yet to be imbued with meaningful substance, which subsequent gene drive discourse actors could later fill.

Lastly, Esvelt et al. constructed public engagement itself as primarily an activity of scientific experts educating or presenting information to publics in order to elicit support from publics for the use of gene drives. To that end, they argued that before any development or trial use scientists must first bring the possible risks of various applications of gene drives to the scientific community and the public "prior to their realization in the laboratory" (Esvelt et al. 2014a, 17). Only by doing so, they continued, could the necessary kinds of "transparent, inclusive, and well-informed discussions concerning the responsible evaluation and application of [gene drive]" take place (Esvelt et al. 2014a, 17).

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[19] The vagueness in the use of the term "public" connotes that the emphasis on "public-ness" was more a differentiation from more private scientific discussion taking place behind closed doors rather than suggesting a more radical, participatory mode of decision-making.

The intentional pausing of laboratory work on gene drives, they imagined, would create the time and space necessary to have public discussion around gene drives. Moreover, it also constructed public engagement as primarily a task for scientists and their allies to undertake. The aim of public engagement was the cultivation of “public consent” as a prerequisite to development of gene drives and use (Esvelt et al. 2014a: 16). However, the linking of such public engagement with public consent framed instrumentalized public engagement as the method to secure public non-opposition to gene drives. In so doing, the importance of public engagement around gene drives was solidified as an obligatory point of passage (Callon 1984) for scientists wanting to press forward with the technology.

In the weeks immediately following the publication of their paper, Esvelt et al. published a popular science media piece in *Scientific American*, as well as an article with an expanded group of other scientists in *Science*, both of which emphasized the high stakes for gene drives and therefore the need for “broadly inclusive and well-informed public discussion” (Esvelt et al. 2014b; Oye et al. 2014) in order to make decisions about whether and how to move forward with applications of gene drives.

The emphasis on engaging with the public about gene drives prior to their realization in the laboratory and the insistence of Esvelt et al. (2014b) and Oye et al. (2014) on transparency presented a distinct vision of responsible science. Both papers pushed against scientific norms of keeping research projects and progress secret until final results could be published. Both papers also advocated for the inclusion of some non-scientist input into the research process as a vital, guiding component. They tied together the methods and attitudes of scientists with consideration of the broader societal implications and contexts in which development of gene drives and use would occur. In so doing, both papers were among the first to explicitly situate gene drives within longstanding discourses about the responsibility of scientists to society. More importantly, they also linked ideas of open science and public engagement to what it meant to do science responsibly.

Heightened Moral Stakes

The 2014 gene drive paper by Esvelt et al. and the simultaneously published paper by Oye et al., along with their corresponding popular media articles, set important precedents for gene drive discourse in the following years. The scientists behind the papers, especially Kevin Esvelt, would come to be some of the strongest proponents of gene drives and public engagement as the way to ensure its responsible development and eventual use to deliver on the promises of benefits to human and environmental health. The influence of these early publications for regional and international discourses about the governance of gene drives, laid the groundwork for public engagement to become not only a core part of gene drive discourse, but also to become understood as being a primary site for ensuring that any gene drive research and use was, in fact, done responsibly.

Despite the focus on public discussion as central to the development of gene drives presented in the initial papers by Esvelt et al. and Oye et al., conceptually, public engagement as such did not figure obviously in the gene drive discourse that immediately followed. In the months following the paper's publication, the majority of science (Akbari et al. 2015; Ledford 2015b; 2015c) and popular media coverage (Langin 2014;

Begley 2015; Bonsall 2015; Zhang 2015; Stein 2015) focused on gene drives as a fundamentally scientific matter for scientists, broadly construed, to sort out. To be clear, Oye et al. previously argued for an extension of the broader groups in discussions about gene drives to *not* be only by natural scientists and to include social scientists (2014). However, this nuance largely was not taken up in the initial science or popular media coverage of gene drives, which resulted in a variety of degrees of attention paid to matters of publics and engagement. That is not to say that no one was thinking about the place of non-natural scientists in gene drive discourse. The NASEM committee on gene drives clearly was, as evidenced by its composition including social scientists, humanities scholars, and legal experts, selection of ethicist Elizabeth Heitman as committee co-chair, and the arguments for a place for social science in their report (2016). However, the extension to include these other experts did not necessarily imply an expansion to non-scientist or non-expert publics.

As a result, mentions of public engagement or inclusive discussion about whether and how to move forward with the technology were largely absent. When the public was mentioned, it most often was a passing reference to the implications of gene drives for broader society that scientists would need to take into consideration. Publics were framed more as additional variables to be accounted for in a decision-making process that was *de facto* led by experts, and among those experts, scientists appeared to lead the way.

One major exception to the discussion of public engagement and gene drives, however, were interviews with Kevin Esvelt himself, in which he continued to hold to the priorities of open, transparent, and public-facing discussion about gene drives and their responsible development. That is not to say that Esvelt was the only one committed to public engagement. Public engagement with emerging science and technology generally has a sustained history of advocates, both in science and science studies communities (see Stilgoe, Lock, and Wilsdon 2014). Regarding genetic engineering and gene drives, at that time there were numerous others from various sectors of society calling for broadly inclusive, deliberative, and ethically-sensitive discussions (Favia 2014; Ramsey et al. 2014; Caplan et al. 2015; Kaebnick 2015; Roberts et al. 2015 Kofler et al. 2018). However, Esvelt's insistent support for public engagement was distinctive not only as a co-creator of the technology, but also as a consistent media figure around responsible development of gene drives (Esvelt and Oye 2014a; 2014b). This made Esvelt a discursive figure worth paying attention to, not as the ultimate measure or the only actor one might reasonably scrutinize, but as a distinctive standard bearer of a conceptual object and a vanguard vision (Hilgartner 2015) for gene drives, responsible science, and public engagement, one that persists through later uptake in regional and international discourse.

In addition to media interviews, Esvelt also articulated his vision for responsible gene drives and public engagement through his research group's website, *Sculpting Evolution* (Esvelt 2014a). The website hosted many of the activities of Esvelt's research colleagues including laboratory personnel, descriptions of their various research projects, news of published scientific papers, Esvelt's own scientific philosophy, and a blog by Esvelt which recorded some of this thoughts and reactions about his research.

In many ways, Esvelt's blog paralleled the substance and tone of his scientific publications. Timed with the publication of his gene drive paper in July of 2014, Esvelt wrote a blog post titled "On gene drives and publication timing" in which he rolled out very similar commitments to public discussions about gene drives in almost identical language to that in the scientific paper, writing, “As scientists, we have a professional responsibility to let people know about the consequences of what we're doing… By telling people about these possibilities in advance, we're hoping to initiate broadly inclusive and well-informed discussions to explore how we might collectively and responsibly use this technology for the betterment of humanity and the environment” (Esvelt 2014b).

As broader discussion about gene drives and their implications developed in the following months, Esvelt’s framing of public engagement about gene drives was almost immediately coupled with the high moral stakes for the technology. In a post in December of 2014 titled “Should we eliminate malaria?,” Esvelt’s rhetoric took on a strong, morally-intonated quality beyond the values and implicit virtue of open and transparent science. In response to a question about the post’s title, Esvelt wrote:

> …refraining from eliminating malaria isn't all that different from murdering half a million children and mildly poisoning two hundred million people every year. Is this a loaded statement with respect to the question of whether we should use gene drives to alter populations of malarial mosquitoes? Absolutely. Does that make it invalid? Not at all. It simply reflects the reality that the moral case favoring action against malaria is strong. Whether it is strong enough to overcome the many potentially valid arguments opposing the use of gene drives must be decided collectively by society - and especially by those currently living in regions afflicted with malaria (Esvelt 2014c).

Esvelt’s framing of the moral stakes for gene drives struck a markedly different tone than those in previous science and media publications, suggesting that not using gene drives to solve the public health problems of malaria was a moral negligence tantamount to murder and suffering measurable in millions of human lives. His articulation of what was at stake left little room for morally permissible bases of disagreement about the use of gene drives. So strong were his convictions that his caveats about the need for collective societal decision-making appeared to take for granted that society would agree with his moral assessment of the need to eliminate malaria. Esvelt's strong moral views regarding the imperative for scientists to act in the public persisted as an animus in his approach to his research responsibilities. In interviews with ethnographer Irus Braverman in 2016, Esvelt continued to valorize his position and goals as a scientist as directed at "urgently solving the problem of animal and human suffering" (Braverman 2017b). Braverman summarizes Esvelt's morally-charged attitudes toward gene drives saying, "The scientist thus emerges as the knight whose responsibility it is to govern nature and improve on it." (Braverman 2017b).

Moreover, Esvelt's consideration of who constitutes society, or rather whose society was to take part in that decision-making is largely taken for granted. A fully inclusive societal discussion that he previously had advocated for appeared to implicate simultaneously both those specifically and regionally affected by malaria, yet also sufficiently general to the point of abstraction to be encompassing of the whole of global humanity. Societal consent, then, was framed more as a necessary legitimation for an inevitable use of gene drives, as the option to not move forward with gene drives was construed as being morally untenable.

Esvelt's reflections on his position, not only as a scientist but as an individual moral agent, illustrated that, on his view, gene drives were not merely a scientific matter but a moral one. As a result, the kind of responsibility required for gene drives was not only one of avoiding the risks of potentially bad outcomes, but also a responsibility to realize its benefits, or else have the blood of millions of children on one's hands. The ability to potentially eliminate malaria, and thereby prevent death and suffering, according to Esvelt, brought a moral imperative to develop applications of gene drives in-full. There was not any room for any unnecessary delay to using gene drives to eliminate a disease like malaria. Expediting gene drive's deployment in the world was a necessary aspect of scientists' obligations to act responsibly. Therefore, public engagement, as a requisite component of realizing gene drives, was likewise a moral imperative for scientists to secure public consent and avoid societal controversy, which might delay gene drive's use. From the very inception of gene drive discourse, public engagement was intertwined with the broader ethical stakes, not only as being essential for responsible research practices, but also for the moral uprightness of scientists themselves.

Local Biosafety Risks and Global Concerns

Over the course of 2015, gene drive research continued to advance the technology, though not obviously along the prescriptive paths for caution, public discussion, and responsible science that Esvelt et al. had laid out the year prior. In March of 2015, the first demonstration of a gene drive engineered into an organism was published in a *Science* paper by University of California, San Diego (UCSD) scientists, Valentino Gantz and Ethan Bier (Gantz and Bier 2015). The UCSD researchers successfully created what they called a "mutagenic chain reaction," which was effectively stable and functional engineered gene drive in a laboratory population of fruit flies.

Their landmark research also prompted immediate interest and concerns from other scientists about the future development of gene drive organisms and the biosafety risks they posed (Akbari et al. 2015; Bohannon 2015; Lunshof 2015).[20] If gene drive organisms were to escape the laboratory into wild environments, the concern was that the genetically engineered organisms which, in principle, could propagate globally might cause rapid, unpredictable, and irreversible damage to local ecosystems, Such risks were not unrecognized by Gantz and Bier. They reasoned that pushing the boundaries of the technology was worth it to try to realize its potential to provide significant benefits. Gantz and Bier soon began collaborating with a geneticist, Anthony James, working at the University of California, Irvine to develop gene drive systems in mosquitoes to block the transmission of malaria and dengue (Fikes 2015; Gantz et al. 2015).

Among the scientists concerned with the biosafety controls of the newly created gene drive organisms was Esvelt himself. He found gene drive experiments in organisms, such as those at UCSD, potentially worrisome because they lacked sufficient physical and genetic counter-measures to halt or reverse the effects of a gene drive if it were to get outside of a controlled laboratory environment. Shortly after the publication of Gantz and Bier's findings, Esvelt and his research group published their own gene drive research paper which detailed several designs for the sort of controls for biosafety that Esvelt considered to be so essential to gene drive research (DiCarlo et al. 2015).[21]

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[20] Gene drives are not neatly separable from the particular organisms in which they are engineered, and the organism bearing a gene drive is typically the intended object of development and governance discourse (Long et al. 2020). When referring to engineered organisms in particular, this chapter uses the terms "gene drive organisms" or "GDOs," though I do not do so with sharp distinction from "engineered gene drives," which is the more common usage of the term in the scientific literature (e.g., Esvelt et al. 2014a; 2017; Oye et al. 2014; NASEM 2016; Braverman 2017; Brossard et al. 2019).

[21] Gantz and Bier later developed their own, more containable version of a gene drive system known as "split drives" (del Amo et al. 2019), which were similar to those developed by those in Esvelt's research group (Dicarlo 2015). However, the initial UCSD gene drive experiments did not use a "split drive" system, thus Esvelt's later cautions about keeping experiments "confined to the laboratory" (Ledford 2015c).

As he had previously claimed, for Esvelt, the moral stakes for developing gene drives in a responsible way were high. In an interview with *Nature* after the publication of his research group's paper responding to Gantz and Bier, Esvelt put it this way, "We have a responsibility to keep our experiments confined to the laboratory…If anyone messes up and a gene drive gets out into the wild, there will be a media circus…the message will be that scientists cannot be trusted to deal with the technology, and we will be set back by years" (Ledford 2015c). As he had done before, Esvelt laid out the stakes for gene drives in terms of public perceptions of the technology and trust in scientists to responsibly use them. Without that trust, scientists risked delaying the deployment of gene drives and the health and environmental benefits it promised to bring.

Importantly, part of the rationale underwriting Esvelt's claims for greater biosafety measures was to ensure that "we don't blow it in the meantime and obviate the chance to talk about all of this" (Ledford 2015c). In other words, a central aim of developing appropriate biocontainment practices for experimental gene drive organisms was to enable broader discussion about gene drive's uses to take place. Public discussions were a critical means to secure the consent and support for gene drives that Esvelt's vision of responsible science required. As a result, it was the perception of scientists like Esvelt of the need for public acceptance, or at least uncontroversial non-opposition, to gene drives which animated insistence on greater technical, biosafety controls of gene drive laboratory experiments. Responsible gene drive research required biosafety containment and control precisely because responsible science also entailed the rapid development of gene drives to fulfil a moral imperative to save lives (Braverman 2017b).

Combined with the strong normative framing with which Esvelt had argued for the continued development of gene drives toward eventual use, it became evident that Esvelt's reaction to the UCSD researchers' experiments was not merely a case of academic rivalry or primarily about the biosafety risks of escaped genetically engineered fruit flies, per se. Rather, Esvelt identified their research on gene drives as being less than what he considered to be fully responsible and, therefore, as a possible threat to the use of gene drives in the world to address problems like malaria and environmental degradation. On his view, gene drives required a responsible scientific approach to ensure that its eventual use and acceptance by society would not be unnecessarily delayed.

In his claim that scientists "have a responsibility to keep our experiments confined to the laboratory" (Ledford 2015c), the word "responsibility" functioned in two distinct registers. First, it suggested that scientists have a responsibility to the local communities and environments proximal to the laboratories where experimental gene drive research would take place. That responsibility entailed not exposing local geographies and ecosystems, either accidentally or deliberately, to any gene drive engineered organism from the laboratory until the technology's safety and controllability could be wholly assured. More importantly, it also implied that scientists had a responsibility to broader society and global communities to contain gene drive organisms in the laboratory so that the life-saving and environmental-restoring benefits of gene drives might be realized without any unnecessary delay caused by mistaken or irresponsible releases. In other words, scientists had a responsibility to a generalized, globally-reaching public to actualize applications of gene drives which simultaneously entailed a tandem responsibility to develop localized laboratory biosafety measures.

The development of a gene drive organism in fruit flies at UCSD was an influential event in how broader discourse about gene drive research, use, and governance would unfold in the years to follow. As a technical first, Gantz and Bier laid groundwork for future gene drives to be built in other organisms, particularly in mosquitoes (Hammond et al. 2016). However, that precedent was in contrast to the public consultation that other scientists like Esvelt had insisted must take place prior to that sort of research. These distinct approaches to gene drive research and broader societal discussions illustrated unresolved contestation of what constituted scientific responsibility vis a vis gene drives and what the right relations between scientists and publics was. As a result, Gantz and Bier's work also served as a site in which scientific communities would assemble around the need for responsible gene drive—both as a matter of biosafety and of public engagement.

The UCSD gene drive research also illustrated how notions of scientific responsibility regarding the local biosafety risks and containment of gene drives was also wrapped up with morally-laden visions for the use of gene drives globally. Global deployment of gene drives to eradicate malaria or eliminate invasive species was predicated on societal non-opposition to its research and use. Any accidental laboratory containment breach or premature field trial locally was a threat to that societal non-opposition to gene drives globally. As local biosafety containment of gene drives came to be associated with the aims to use the technology globally, it also became entangled with the ethical imperatives to develop and use gene drives to ameliorate global health and environmental harms. In so doing, notions of the scientific responsibility needed in advancing gene drives reinforced scientists themselves not only as technical, epistemic experts but also as normative authorities to navigate the local and global gene drive moral landscapes. The ultimate responsibility for the societal adoption or opposition to gene drives rested with scientists.

Calls for public engagement about gene drives, then, also began to be entangled with scientific concerns about public trust in the autonomy and authority of science to act in the interest of society as well as with the ethical stakes implicated by the potential benefits of the technology. Engaging with publics—broadly construed—as a necessary part of securing public consent for gene drives was, therefore, also part of the remit of scientists who would fashion themselves as responsible. Thus, the emphasis on the need for public engagement enabled scientists as technical experts and moral authorities to move more freely between local and global contexts and stakes for gene drives as a public demonstration of their own practices of responsible science.

In addition to Esvelt's and others' concerns, the UCSD researchers' work also prompted the National Institutes of Health (NIH) and the Foundation for the National Institutes of Health to commission the US National Academies of Science, Engineering and Medicine (NASEM) in 2015 to form a consensus Committee on Gene Drive Research in Non-Human Organisms[22] which they tasked with reviewing the state of the science of gene drives, evaluating the technology's potential risks and benefits, and providing research and governance recommendations on how to best proceed (Ledford

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[22] While NIH and FNIH formally commissioned the NASEM gene drive committee and resulting study, the Defense Advanced Research Projects Agency (DARPA), The Bill & Melinda Gates Foundation, and the National Academy of Sciences Biology and Biotechnology Fund provided the funding to NIH and FNIH to support the committee's study (NASEM 2016). This combination of military, non-profit, and scientific funding bodies indicates the broad array of interests and stakeholders around gene drives after the events at UCSD that were nevertheless directed, in part, at engaging publics as part of gene drive's development and governance.

2015c). The activities of the NASEM committee and their resulting report on gene drives would become among the most influential and cited analyses in regional and international gene drive discourse. Their findings also bore many resemblances to the UCSD controversy. In particular, they shared a tight linking of scientific responsibility with notions of technical performance and safety alongside societal acceptance and public trust of gene drives. Moreover, in each the mechanism to ensure that acceptance and trust was by fostering societal discussion and engagement with various publics.

A Committee on Gene Drive Research in Non-Human Organisms

On July 30th, 2015, the NASEM Committee on Gene Drive Research in Non-Human Organisms first convened in Washington, D.C. for a multi-day event kicking off the committee's year-long assessment of the state of the science and risks of deploying engineered gene drive bearing organisms. The NASEM Committee on Gene Drive Research in Non-Human Organisms was noteworthy in its composition in that it explicitly included scholars and experts in social science, ethics, and science and technology studies. The committee was co-chaired by James P. Collins, an evolutionary ecologist at Arizona State University, and Elizabeth Heitman, an associate professor of medical ethics at Vanderbilt University. Collins and Heitman were not newcomers to issues of emerging technologies and responsible science. For years, Collins had been a leading scientific contributor to establishing a subfield of "ecological ethics" to improve ethical decision-making regarding environmental conservation, development, and resource management (e.g., Minteer and Collins 2005). Furthermore, Collins was also an author alongside Esvelt and others on the 2014 *Science* article calling for regulatory review of gene drives (Oye et al. 2014) as well as expressing early support for the need for alternative, more “anticipatory governance” of the new gene drives (Langin 2014). Similarly, Heitman had previously been on the steering committee of the National Academies’ International Initiatives on Responsible Science in 2011 after she had already quite literally written the book on ethics and the biosciences (Bulger et al. 1993; 2002). The pairing of Collins and Heitman by the National Academies to co-chair the committee reflected their purposeful recognition of the importance of the normative implications of responsible development of gene drives as central to the technical evaluation and societal discussion of the technology.

Similarly, the multidisciplinary composition of the NASEM Committee on Gene Drive Research in Non-Human Organisms was not accidental, but deliberate, and indicated the degree to which public engagement and the broader societal implications of gene drives would be emphasized. In addition to several scientific experts in genetics, vector ecology, and molecular and cell biology, the committee also consisted of bioethicists, policy experts, and social scientists. Given the breadth of gene drive’s applications and implications in society, it stood to reason to assemble a similarly broad array of scholars and experts. Built into the structure of the committee was a diversity of disciplinary perspectives and stakeholders, consonant with prior calls from scientists like Esvelt for broadly inclusive discussion of gene drive research.

Several committee members, Gregory Kaebnick, a scholar of biotechnology and values at the Hastings Center, David Winickoff, an associate professor of the governance of biotechnology and law at the University of California Berkeley, and, in particular, Jason Delborne, a professor of science, policy, and society at North Carolina State

University, further directed the committee's attention toward public engagement. Delborne's research had focused on purpose, methods, and evaluation of public engagement decision-making about controversial technologies, specifically genetic technologies (Kleinmann et al. 2008; Delborne 2011; Delborne et al. 2011; Kleinmann et al. 2011; Powell, Delborne, and Colin 2011; Anderson et. al 2013). Not that Delborne alone was responsible for the committee's attention to public engagement with gene drive; rather, his selection for the committee indicated how public engagement was already recognized as an important part of the committee's task to develop responsible gene drive guidelines. For the NASEM committee, public engagement about gene drives, then, was framed as a matter which primarily concerned science and scientists as part of practicing responsible science, which further inscribed scientific experts, enhanced and supported in their expert status by a multidisciplinary committee, as epistemic and normative authorities for the research and use of gene drives.

However, the diversity of disciplines represented on the committee did not abdicate scientific communities' ownership of gene drive assessment and recommendations to others. Though the intent of the committee appeared to be to take a first step toward inviting other disciplinary experts to participate in discussions, in effect, the committee laid claim to greater responsibility for development of gene drives specifically for scientists. The framing of their task was to enable "responsible practices in gene drive research for the laboratory setting through to field releases for use by investigators, their institutions, the research funders, and regulators" (NASEM 2016, 16). Regardless of the number of social scientists, ethicists or other experts involved, the committee was nevertheless a creation of the NASEM at the behest of the NIH and

FNIH, who tasked the committee with providing guidance to and for scientific endeavors—in gene drive research practices, its governance, and the trustworthiness of science in society.

In the committee’s statement of task, the NIH and FNIH asked the NASEM committee to provide a comprehensive review of gene drives with several main objectives. First, as with most NASEM assessments, they asked NASEM to review the “state of the science” of gene drives and the relevant genetic engineering techniques with a focus on risk reduction strategies. Second, they asked NASEM to consider the ethical, legal, and social implications of potential gene drives for communities proximal to releases at specific trial or field sites. Third, they asked the committee to examine current regulatory mechanisms for likely applications of gene drives to assess the quality and adequacy of current regional and international regulatory and oversight mechanisms to ensure public and environmental health in the event of releases of gene drive organisms. Though the committee was not tasked with prescribing specific policy proposals, they were asked to identify and evaluate any perceived regulatory gaps. In each of these objectives, the Committee on Gene Drive Research in Non-Human Organisms was to provide principles to guide responsible gene drive research practices and how to use the technology for purposes outside the lab.

In addition to numerous internal meetings and workshops while developing their eventual report, the Committee on Gene Drive Research in Non-Human Organisms also held repeated public-facing events and webinars up through the publication of the report in June of 2016. These events featured perspectives for the committee regarding various aspects of gene drives including explanations of the state of current research progress and future direction, possible technological risks and how to assess and mitigate them, and the broader societal implications of gene drives across commercial, environmental, biosecurity, and public health sectors. Many of the events solicited public input and comment during explicitly designated comment periods and live question and answer sessions through both in-person and online forums. This more integrated approach to expert scientists and those outside the committee reflected their charge to take public engagement and societal implications of gene drives as central.

The NASEM committee's statement of task also did important work to intertwine notions of scientific responsibility and public engagement about gene drives with expert scientific authority. First, while "responsible practices" were identified as the committee's goal for gene drives, what constituted responsibility was largely taken for granted. In other words, responsible science was treated as an already known or codified value for the committee to pursue. However, what counted as responsible gene drive research and application was precisely the point at stake. The prior creation of gene drive organisms at UCSD and the resulting discussions as to what kinds of experiments, risks, or public discussion were appropriate or necessary at what stage of gene drive research were fundamentally a matter of divergent views of the imperatives of scientific responsibility. That demonstrated how what constituted responsibility was not a ready-made category of consensus among actors. Rather, it was a site of active negotiation where the values and practices of science that would be considered sufficiently responsible were worked out. As a result, the committee's aim to assess responsible practices for gene drives, though widely supported and rhetorically potent, left the criteria for evaluating that objective vague. That vagueness sidestepped the question of what responsible gene drives meant and further enabled an interpretive flexibility of the obligations and the stakes for responsible science on the part of the scientific experts conducting gene drive research themselves.

Public Engagement as Ethical Obligation: Gene Drives on the Horizon

The NASEM committee's work culminated in the release of their full report in June of 2016, titled *Gene Drives on the Horizon: Advancing Science, Navigating Uncertainty, and Aligning Research with Public Values*. As its title suggested, the report framed its analysis and evaluation of gene drives as a near-term but still future technology with emphasis on both the continued development of the science undergirding the technology's use as well as the broader implications of gene drives for publics' interests. In addition to routine discussion of the state of gene drive science, its possible applications and risks, and its governance implications, the report also devoted a full chapter to exploring public engagement. Unlike other invocations of public engagement as necessary and critical for decision-making of emerging technologies (e.g., NASEM 2017), the 2016 NASEM report on gene drives included an articulation of how the authoring committee understood public engagement well-grounded in scholarly literature from science and technology studies (STS) and the social sciences on publics and public engagement—what it entailed, who it implicated, why it was important, how it could be implemented, and the realities of the difficulties in pursuing that conceptualization of public engagement in-practice.

In their report, the committee defined "engagement" as "seeking and facilitating the sharing and exchange of knowledge, perspectives, and preferences between or among groups who often have differences in expertise, power, and values" (NASEM 2016, 131). Their rather broad characterization of engagement enabled the committee to draw upon a diversity of engagement styles, methods, and aims (Rowe and Frewer 2005) without staking more specific claims themselves. Instead, they noted that there was "generally little clarity about how public engagement should feed into governance" and that common practices of public comment periods were "inadequate" (NASEM 2016, 7). While on some level it was clear that the intent behind engagement reflected a "collective tacit understanding…that public engagement with science had to do with linking science to politics" (Nowotny 2014), it also highlighted how engagement entailed more than just soliciting public participation or a one-directional exchange of information. Engagement was conceived of as a way of ordering the relations between scientists and other societal actors primarily in terms of knowledge transfer. In doing so, the committee enabled "engagement" to remain an enterprise in which scientific experts could readily participate as epistemic authorities with specialized knowledge of a particular kind.

Importantly, the NASEM report presented public engagement in explicitly normative and prescriptive terms. It described public engagement as just as essential for governance of gene drives as understanding the technical aspects of the technology, saying that:

> "The question is not whether to engage communities, stakeholders, and publics in decisions about gene drive technologies, but how best to do so. The outcomes of engagement may be as crucial as the scientific outcomes to decisions about whether to release of [sic] a gene-drive modified organism into the environment. Thus, engagement cannot be an afterthought; it requires effort, attention, resources, and advanced planning. Those who organize and facilitate engagement about gene drive research need to explicitly consider who is to engage with whom, along with when, how, and for what purpose the engagement will occur. If

> engagement efforts are meant to have impact beyond mutual learning, it will be important those goals and plans are transparent to participants" (NASEM 2016, 141).

The report framed the stakes overtly in terms of scientists' "ethical obligation to engage public audiences" (NASEM 2016, 134), integrating engagement with sensibilities of the responsibilities and moral obligations of science to societies at-large for both the technical outcomes of any uses of gene drives as well as the social processes enabling and justifying that use. To do responsible research and development of gene drives also meant doing meaningful public engagement in a precautionary, inclusive, consent-seeking way. Thus, calls for public engagement about gene drives were also calls for scientific experts to assume a position of normative authority—in addition to a presumptive epistemic authority—to ensure ethical, just, responsible gene drives.

This was not to say that scientists were the final moral deciders in public engagement but that public engagement, as an ethically obligatory practice, was the responsibility of scientific experts to lead and perform. Likewise, the notion that scientists had responsibilities to society, including through engaging with broader audiences was not without precedent (Merton 1973; Krimsky 1982; Balogh 1991; Owen, Macnaghten, Stilgoe 2012). However, what distinguished the NASEM committee work from prior commitments to public-facing science, was a foregrounding of the role of publics' values, perspectives, and interests as being as important as the technical understandings of the science of gene drives. In doing so in such overt ways, the committee made explicit the longstanding implicit imperative for science to be socially responsible.

Thus, the need to pursue public engagement about gene drives was based on appeals to scientists' obligation to act responsibly. One aspect of this appeal was to gather publics' perspectives, understanding, and values relevant to gene drives. The committee noted that affected publics likely had "essential knowledge" for making decisions about gene drives that experts ought to include in any decision-making. Moreover, they argued that engagement provided an opportunity for mutual learning, reflective deliberation, and building trust between scientists and engaged publics, which were crucial in promoting the transparency and community consent they stated as necessary to ensure the just use of gene drives (NASEM 2016, 132).

While further, specialized knowledge was necessary, that knowledge was in service of something that was understood as not merely a knowledge problem. Rather, the committee placed "human values" (NASEM 2016, 5) as a core motivator for doing public engagement, saying that "the 'success' of gene drives will depend on the interaction of many parts of systems—social and technical" and, more specifically, that "technical expertise is insufficient for ensuring good governance" (NASEM 2016, 133). The upshot of their emphasis was that the report recognized gene drives as being emphatically sociotechnical in nature, not having neatly separable societal and technical components. Rather, the societal issues and technical considerations were an integrated whole. As a result, they claimed that "political decision-making is required" (NASEM 2016, 134). Therefore, public engagement, as a dually science and governance imperative, was a site of that sociotechnical negotiation and an arena in which scientific experts were to intervene.

However, doing so did not merely express the insufficiency of particular scientific expertise or knowledge alone to address questions of governance for gene drives. It also bolstered scientific experts' position as epistemic and normative authorities by demonstrating a kind of epistemic humility in seeking additional input and forms of expertise. Even if relevant knowledge about gene drive discourse were outside science, the acknowledgement of that limitation by scientific experts enables them to still claim access to those discussions by extending the boundary of the topics within the purview of responsible science to contain practices of including other expertise as relevant. At the same time, that drawing of boundaries both solidified scientific experts as trustworthy, ethical actors as well as diffused accountability for the outcomes of applications of gene drives across other fields of expertise beyond science alone. That diffusion insulated scientific experts from future criticism or backlash stemming from negative outcomes for gene drives by delimiting the scope of their responsibility.

Beyond being a matter of responsible science, public engagement also was constructed as an essential component of good, democratic governance. Scientists' obligation to do public engagement was rooted in a rationale "consonant with democratic visions of the governance of emerging technologies" (NASEM 2016, 134). Therefore, public engagement was a marker by which scientists could demonstrate their personal and collective moral character to advance gene drives. The ways that engagement with publics was pursued was understood as crucial for the forming of the appropriate publics needed for the good governance of gene drives—effective, inclusive, democratic, and just governance. The ethical imperative for scientists to do public engagement, therefore, was not limited to the morally-charged humanitarian aims of scientists like Esvelt. It also extended that imperative to envision, enable, and instantiate prescriptively democratic political commitments. As a result, the enshrinement of public engagement in the report also enshrined the position of scientists as epistemic and, implicitly, also as normative authorities in shaping the sociotechnical future visions of gene drives.

The committee further argued that "neglecting engagement also undermines the important connections among values, responsible scientific practices, risk assessments, and governance" (NASEM 2016, 131). Yet, responsible gene drives were framed in terms of the eventual development and deployment of the technology, aimed at "integrating precautionary measures into the research process…[which] can provide opportunities to gather further information and revisit decisions…but, at the same time, not hinder research progress" (NASEM 2016, 6). The framing of the committee's goal presupposed that moving forward with gene drive research was, or could be, consistent with notions of scientific responsibility. Similarly, in one of the report's official recommendations, it was its distinct, technical features that were to frame the societal appraisal of the technology (NASEM 2016, 10). Rather than being guided first by publics' values, scientific understandings of gene drives were, in effect, driving the conditions and terms of public engagement.

Given the framing of gene drive's promise of environmental and public health benefits, forward progress in developing the technology was characterized as being a requisite part of doing responsible science. The questions of moving forward with gene drive research and its applications were treated not as matters of whether the technology should be developed and used, but in what ways and under what conditions it would be done to ensure it was done responsibly. That emphasis also intertwined scientific responsibility and the advancement of gene drives. The rationale was that to appropriately advance gene drives, such an advance must be achieved responsibly. In other words, proper scientific advancement required also doing so responsibly**.**

While the apparent intent of such a framing was to assert an incontrovertible necessity of scientific responsibility in developing gene drives, it also did important boundary work to demarcate negative or harmful outcomes distinctly apart from areas of scientific accountability. The implication was that if legitimate science was, necessarily, responsible science, then any scientific practices or application of gene drives deemed to be irresponsible were therefore not proper, legitimate science at all. In so doing, the rhetoric of responsible science narrowed the avenues of critique that could be brought against development of gene drives. Gene drive research could be criticized as not sufficiently responsible (as the gene drive experiments at UCSD were by Esvelt), but the vocabulary and logic of that criticism was constrained to be in terms of other, more responsible ways of developing gene drives.

Flattening Local and Global Publics

The report also reflected an understanding of publics as plural, heterogenous groups with varied interests, values, and stakes in gene drives and their uses. The NASEM report specifically distinguished between “communities,” “stakeholders,” and “publics” as distinct groups to be engaged about gene drives. The primary lines of demarcation between those groups were geographic proximity and specificity of interests, conceptualized as “affected publics” (NASEM 2016, 6). They defined “communities” as those whose physical proximity to gene drives would be most immediate and whose interests are therefore acute (e.g., residents of a gene drive trial release site), "stakeholders" as those with specific interests implicated in release of engineered gene drive organisms, but lack physical proximity to the site of intervention (e.g., regulatory officials, public health professionals, environmental advocacy groups), and "publics" as those that lacked physical proximity and specific interests in interventions, but still had values, hopes, or concerns relevant for decision-making about gene drives (e.g., general populations) (NASEM 2016, 131).[23]

Moreover, publics were recognized as being the product of social construction, the features of which were not given in advance. Rather, publics were created through the specific practices of engagement, and that any delineations necessarily included some people while excluding others. The report stated that "publics do not just exist; they are constructed through procedures of engagement" (NASEM 2016, 136). Additionally, power dynamics at play in engagement with publics were noted as an important factor, especially in "low- and middle-income countries where power differentials may preclude such participation." (NASEM 2016, 6). Engagement, therefore, was to be tailored to be "dynamic and context-specific" such that there could not be a "standard approach that can or should be used across all scientific research and related applications" (NASEM 2016, 139).

As a result, the framings of public engagement about gene drives as contested and contingent on social context of a narrowly defined and affected groups, which delimited not only whom engagement was to target but also by whom and to what ends. By

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[23] Though the report uses these terms distinctly, my use of 'publics' and 'public engagement' is meant in reference to "communities," "stakeholders," and "publics" collectively and not only to the report's narrower use of "publics."

insisting that public engagement must be context-specific, the report also crafted the level of societal responsibility for interventions with gene drives to be fundamentally local in scope. Yet at the same time, the stakes which motivated the doing of public engagement in the first place were not only or discretely local stakes. Rather, as others have noted (Kofler et al. 2018), the ethical obligations for scientists to do public engagement were fundamentally global in scope, perturbing the boundary between ideas of the local and global publics, interests, and stakes implicated by gene drives.

The report stated that the governance of gene drives was a "global endeavor" with research and field trials that would likely span across countries in all parts of the world (NASEM 2016, 162). Moreover, the fact that features of an engineered gene drive organism allowed genetic traits to spread and persist in environments across the globe without regard for geopolitical borders meant that "gene drive research…[would] require international collaborations…and deliberate and participatory engagement in policy making by the people who will be impacted" (NASEM 2016, 163).

As a critical part of good governance, public engagement, then, was also a global endeavor, in at least two senses. In one sense, the NASEM report gestured generally toward a more globally imagined public, a community of humanity. The potential risks or benefits of gene drives concerned not only human health directly, but also the perceptions of people's relationship to the rest of their natural and social worlds (NASEM 2016, 65). In that way, public engagement globally was all-encompassing, potentially, of anyone and everyone, and therefore underwrote the responsibilities of science to and for society in an incredibly broad way. In another sense, public engagement was global in that while the publics that warranted engagement were many, localized, and specific, they were nevertheless distributed globally, if heterogeneously. Public engagement in-practice required that actual, discrete groups of people, narrowly, to be engaged.

The report did not make any sharp distinction between these senses of the global public implicated by gene drive research and potential use. As a result, the move for local public engagement in one place to be translated elsewhere goes to both senses of global simultaneously. It leveraged the stakes for a maximally conceived global public of humankind to underwrite the moral imperative for scientists to do public engagement while at the same time exporting the need for public engagement into globally distributed, localized publics. If public engagement about gene drives locally was essential and ethically obligatory in a context-specific way, then it was simultaneously also obligatory for global uses of gene drives and global publics to draw upon early, precedential cases that secured societal support and buy-in for future use. While the stakes of gene drives surely bore heavily on local, affected publics, the consideration and first implementations of gene drives and related public engagement efforts were not neatly separable from the stated intentions and hopes for gene drives as a humanitarian technology that scientists like Esvelt had repeatedly expressed (Braverman 2017b).

Global publics that either stood to benefit from gene drives or who were needed to endorse and legitimize their use, however, were not the sort of thing that could be engaged in a context-specific sense. Global publics, rather, were by necessity abstracted away from context so as to be as comprehensively inclusive of all applications of gene drives, community considerations, and ethical imperatives for engagement. As result, the commitment to context-specific public engagement also prescribed a commensuration of disparate local publics as similarly standing in for (or summing up to) an imagined global public of “humanity” in whose interest science had a responsibility to act.

Therefore, calls for and practices of public engagement as an ethical obligation of international scientific and governance communities, flattened gene drive discourse across disparate locales. By flattened, I mean that the ethical imperative to do public engagement reduced appearances of variation so as to minimize or ignore any dissimilarities among different public contexts. The requirement to do public engagement rendered disparate local publics commensurable to one another, homogenizing the kinds of features that publics might have. This process of making publics to be the same blurred the aligned local publics such that engagement in one part of the world about a specific application of genetic technology could be brought to bear on other discussions about other, distinct applications of gene drives and engagement in distinct cultural and spatial locales. Likewise, the weight of the global stakes and imperatives for gene drives fold back onto local manifestation of public engagement by blurring the lines between local and global stakes and stakeholders, particularly around who is empowered to speak on behalf of others, on what topics, and with what forms of representation and authority.

Importantly, the framing of the committee’s task regarding public engagement considerations was primarily bounded to local, affected publics “living in or near potential release sites” (NASEM 2016, 16). That delimitation stood in contrast to the scope of the committee’s evaluation of existing regulatory frameworks, which stretched to an international scope, including “institutional biosafety committee, national or local regulatory authorities, and international frameworks and instruments (NASEM 2016, 16). Similarly, the committee’s report further laid out the stakes for gene drive governance in global, international terms writing that “the unique qualities of gene-drive modified organisms to spread and persist in the environment will require any nation planning field tests or environmental releases to consider whether and how gene-drive modified organisms will cross national borders” (NASEM 2016, 163).

The publics imagined as salient to gene drive engagement were local, affected communities near prospective sites for deploying gene drives. Yet, the scale and scope of the committee’s assessment of regulatory oversight preparedness was global, attesting to the difficulty of controlling certain kinds of gene drives across geographical and political boundaries.[24] The result was a juxtaposition of global and local stakes and applications of gene drives in which the consideration of regulatory oversight was global in scope, but considerations of publics and their engagement was constrained to areas near laboratories where gene drive research occurred or field sites where they might be deployed.

Scientific responsibility, then, became a means of navigating across local and global domains of gene drive discourse by empowering scientific experts considered to be responsible to act as legitimate ethical agents for gene drives in both global and local contexts. The global stakes for gene drives necessitated responsibility as being expedient and safe development of gene drives, which entailed avoiding and resolving any societal opposition to the uses of the technology. Such societal consent required opportunity and space for engagement with local and affected publics and avoiding perceptions of risk from local biosafety breaches because they damage the opportunity for public dialog.

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[24] Not every type of gene drive has the capacity for global scale and the design differences between gene drives intended for local and global spread is a topic of serious interest in the scientific literature (Akbari et al. 2013; Hammond et al. 2016; Noble et al. 2016; Esvelt and Gemmell 2017; Champer et al. 2020). Regarding the eradication of malaria-hosting mosquitoes, globally spreading gene drives have been considered (Esvelt et al. 2014a), though not necessarily as the only way to do so.

Thus, responsible science that would produce safe, expedient deployment of gene drives globally required locally responsible practices of public engagement prior to gene drive research to avoid societal controversy and any associated delay to its use.

Furthermore, the flattening also further enabled scientific experts to exert significant influence over both gene drive engagement and governance practices by virtue of their position as acting responsibly. In other words, because public engagement was itself an expression of scientific responsibility, those scientists that do so are empowered as epistemic as well as normative authorities. As a result, the emphasis on public engagement as a necessary precondition for gene drive field trials or use in effect reinforces a privileged position for scientific experts to preside over matters of gene drive governance while employing a rhetoric of public participation, scientific humility, and responsibility.

Through the activities of the NASEM committee and report, gene drives were formed into a technology of ethical consequence that required a vision of responsible science to guide. The notions of public engagement and responsible science expressed in 2014 by Esvelt et al. were consonant with the NASEM committee and their report, suggesting a stabilization of public engagement as part of responsible gene drive discourse and scientific repertoires. While Esvelt was not part of the NASEM committee (though his research group’s work and commentary about biosafety, regulation, and the need for broader societal discussion is cited throughout), similar patterns to his own framings of gene drives, responsible science, and public engagement were present. In particular, the NASEM report was consonant with Esvelt’s emphasis on scientists’ personal responsibility regarding gene drives and necessity of public engagement to do so. While the report highlighted that for gene drives “governance is a joint responsibility involving the collaboration of a broad range of publics” (NASEM 2016, 150), they also noted that responsibility for gene drives first “begins with the personal responsibility of the investigator” and that it was incumbent on scientists “to take responsibility for their science” (NASEM 2016, 169). In so doing, the NASEM report set the stage for uptake of public engagement as a personal and scientific responsibility in international gene drive discourse.

Additionally, the treatment of public engagement in the report showed a continuity of conceptual framing of public engagement that further solidified and reinforced the position of scientific experts as authorities for gene drive governance on both epistemic and normative grounds. In an epistemic sense, they had specialized subject-area knowledge salient to the assessment, development, and engagement of gene drives. In a normative sense, those scientific experts had an ethical obligation to do public engagement—and in so doing, public engagement by scientists did the prescriptive work of framing and forming publics, setting the stakes of gene drives, and defining the terms of engagement. As public engagement was part and parcel of being “responsible scientists,” that normative framing and vision-casting for the future of gene drives likewise became part of the authoritative remit of scientists qua scientists. Accordingly, the NASEM gene drive committee and report expanded the scope of scientific normative authority in gene drive discourse by reinforcing public engagement as an obligatory point of passage for responsible gene drives.

In the construction of a vision of responsible gene drives there was also a concurrent construction of a contrasting vision of irresponsible gene drives. That vision of irresponsible gene drives, when invoked, lent normative support to the specific ideations of gene drives constructed as being “responsible,” which centered public engagement as an ethically and properly socially attuned practice. Irresponsible gene drives were set up as the inevitable result of scientific inaction or business-as-usual. Responsible gene drives were constructed out of the need for exceptional scientific action and changes to the status quo relations of scientific experts in society. Avoiding public engagement—not having societal discussion led by scientists-- was definitionally irresponsible, which would invariably lead to bad outcomes, whether in the realization of avoidable risks or in the unnecessary delay of benefits. Thus, public engagement was not merely acting responsibly but also a heroic deed that embodied an imaginary of “science to the rescue” (Smallman 2018).

In framing gene drives in terms of a binary of more and less “responsible” and “irresponsible” science, the obligations of individuals and groups to act in consideration of the interests of others were foregrounded. Yet in the process, alternative approaches and evaluating gene drives that could have been chosen were instead screened off. For example, a discussion focused on whether use of gene drives was responsible or not was not also a discussion that was attendant to considerations of epistemic justice in who and whose knowledge is recognized as legitimate and authoritative, nor one that necessarily foregrounded the power dynamics of collective decision-making. The focus on gene drives as an issue of responsibility was a choice, conscious or not, to emphasize some considerations of the technology and not others. As a result, what had been a contested and constructed part of what it meant to do science responsibly (i.e., to do public engagement about gene drive) was naturalized as an innate demonstration of responsible character. Thus, this naturalization elided the ways that who constituted publics, what engagement entailed, and how gene drives would be developed were not given in advance of discussions about them but were built up through contestation among scientific and governance actors. The result was that public engagement became synonymous with responsible scientific practice, such that calling for and performing public engagement served as proof of the responsible character of science, which in turn reinforced scientists who prioritized public engagement as normative authorities regarding gene drives.

Uptake of Public Engagement

Ideas of the imperatives of public engagement were also expressed well-beyond the conclusions of the NASEM committee and report. Paying attention to the uptake of constructions of public engagement by other institutions and actors reveals the stability and endurance of particular patterns of public engagement over time and in different contexts across gene drive discourse.[25] To illustrate public engagement's uptake patterns, I briefly sketch four examples in which ideas of public engagement as an ethical imperative were taken up in other gene drive discussions across international governing bodies, NGOs, and scientific contexts. Each example illustrates a distinctive pattern of uptake of public engagement as a normative imperative in broader gene drive discourse,

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[25] The distinction between the construction and the uptake of conceptualizations of public engagement in the framing of my analysis is somewhat arbitrary. Public engagement is made and remade at every step and stage (Jasanoff 2005).For my purposes, I use 'construction' to refer to earlier formations of public engagement and as a cohesive conceptual unit. I use 'uptake' to refer to chronologically later assemblages of public engagement that resemble earlier formulations, though not necessarily causally linked with them.

which I have categorized as assimilation, modification, adoption, and implementation. These distinctions are not meant as generalizable categories of uptake, but simply as a way to distinguish between the ways that public engagement has been taken up into the particular logics and institutional habits. These examples are not exhaustive of all cases of public engagement around gene drive[26] or of analytical approaches (see Weiss-Evans et al. 2019). Rather, they demonstrate how, despite distinct differences in institutional, regional, and jurisdictional contexts, the uptake of stabilization of public engagement continues to reinscribe the authority of scientific experts in directing development of gene drives across local and global scales.

The Convention on Biological Diversity (CBD)—Assimilation

The Convention on Biological Diversity (CBD) is a multilateral treaty through the United Nations among nearly 200 nations that first adopted it in 1993. The CBD is governed by an internal body consisting of all signatories that oversees all aspects of the treaty's development and enforcement. The CBD convenes a general meeting every two years in which global issues related to biodiversity are discussed. The meeting has been one of the preeminent international venues for deliberations on the governance of international bioscience. Beginning in 2014, those deliberations also included debates about the regulation of synthetic biology (COP CBD 2014). However, it was not until the

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[26] Other possible sites for similar analysis of the uptake of public engagement about gene drives include discourse around the work of Jason Delborne and the American chestnut tree (e.g., Delborne et al 2018; Barnhill-Dilling and Delborne 2019), deliberations by the African Union (e.g., Glover et al. 2018; Hartley et al. 2019), rulings on gene drives by the European Court of Justice and an EU context (e.g., Bruetschy 2019) and surely others. Full analysis of these sites and comparison among them is beyond the scope of this chapter, but I mention them here to note that other constructions of public engagement may be distributed more broadly than presented here.

2016 meeting that gene drives became “arguably one of the major drivers of the present-day CBD debate [around synthetic biology]” (Keiper and Atanassova 2020). Central to that debate has been repeated calls for global moratoria on development and application of engineered gene drive organisms and regulation of the technology.

In those calls for a moratorium and the CBD’s response to the controversy, the CBD assimilated public engagement into their decision-making rationales as an attempt to resolve controversy without significant disruption to status quo handling of synthetic biology governance. By assimilation I mean that concepts of public engagement were incorporated into already existing institutional practices, structures, and rationales in the CBD. However, rather than simply an addendum to CBD approaches to gene drives, assimilation denotes how the uptake of public engagement took on qualities of the CBD and its operational norms. In other words, the CBD did more to shape the meaning of public engagement than vice versa.

In 2016, prior to the CBD biannual meeting set for December in Cancun, Mexico, a coalition of environmental groups initiated by Civil Society Working Group on Gene Drives and joined by more than 170 other organizations petitioned the CBD to adopt a global moratorium on gene drive research, citing the need to make better assessments of the risks that they posed to societal, cultural, and environmental interests (Civil Society Working Group on Gene Drives 2016). Similarly, the Europe-based International Union for the Conservation of Nature, passed a resolution in 2016 likewise calling for what was, in effect, a moratorium on gene drive research for conservation purposes (IUCN 2016, cited in Keiper and Atanassova 2020). The calls for a moratorium on gene drives focused on the uncertain, potentially wide-spread, and irreversible risks of the technology for the environment and human communities, citing the need for better understanding of gene drives before any consideration of field releases and that coordination among governments to prevent the release of gene drives was necessary.

Despite such impassioned calls, in the course of the meeting the CBD ultimately rejected calls for a moratorium on gene drives. The CBD largely refrained from making new decisions specific to gene drives, deferring instead to a previous decision made in 2014 regarding synthetic biology governance, which stated only that governments take a “precautionary approach” and “to carry out scientific assessments…with, where appropriate, the full **participation** of indigenous and local communities” (COP CBD 2014, emphasis added), and specified that the 2014 decision also could apply to “some living modified organisms containing gene drive” (COP CBD 2016). However, while a moratorium was not formally adopted for gene drives in particular, the 2016 CBD decision on synthetic biology did begin to provide cautious guidelines that reflected a growing notion of the importance of public engagement for development of gene drives.

Previously, in 2015, the CBD released a separate report on synthetic biology in which it specifically cited development of gene drives and affirmed calls for public engagement made by Esvelt and others regarding gene drives in light of possible environmental risks (Esvelt et al. 2014a; Oye et al. 2014; Secretariat of the CBD 2015). Though ideas about broader participation in decision-making were present in CBD decisions before gene drives were specifically referenced and even before Esvelt et al.’s initial work on gene drives was published (COP CBD 2012, 2014), it was only after that report that the CBD began to reference ideas of engagement rather than participation. That emphasis was reflected in 2016 as CBD added explicit calls for greater and broader engagement of different publics with the purpose “to promote and enable public and multi-stakeholder dialogues and awareness-raising activities on the potential benefits and potential adverse effects … involving all relevant stakeholders and with the full and effective **engagement** of indigenous peoples and local communities (COP CBD 2016, emphasis added).

Those explicit calls for engaging with broader publics were noteworthy. First, that they used “engagement” as a term, rather than the “participation” of the 2014 decisions, was a shift that suggested the penetrance of general ideas of public engagement into CBD discourse.[27] Also, they separated out the technical aspects of gene drives from the social and ethical, with the latter being the remit of public engagement, which further continued a pattern of delineating the kinds of responsibilities that scientific groups and lay publics have with regard to gene drives. More importantly, they continued to establish public engagement as a fundamentally local practice for local communities and stakeholders, while simultaneously affirming the prior notions of scientists and the CBD that the motivation for public engagement is the potential for gene drives to affect a “global commons” (Oye et al. 2014; Secretariat of the CBD 2015) and later articulated concerns about the global risks of potential, but yet unrealized, “transborder movement” and spread (CBD AHTEG on Synthetic Biology 2019).

Calls for a global moratorium on gene drives did not end with the CBD’s decision in 2016, however. Ahead of the COP meeting in November of 2018 held in Sharm El-

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[27] This is not to draw my own sharp, conceptual distinction between participation and engagement as ways of relating to different groups. Rather it is merely indicative of a shift in language that is both consistent with (though not necessarily caused by) calls by Esvelt and others for engaging with publics about gene drives and suggestive of a reconfiguration of CBD conceptions of engagement and what it entails.

Sheikh, Egypt, more than 200 concerned groups, such as the environmental watchdog ETC Group, again petitioned the CBD to support a moratorium on gene drives (ETC Group 2018). The 2018 CBD meeting featured gene drive discussions much more extensively than previous meetings, and also had more detailed explication of specific development of gene drives and guidelines which reflected growing pressures to address the controversial technology and associated calls for a moratorium.

The CBD noted that because of the potential risks of gene drive, "research and analysis are needed, and specific guidance may be useful, to support case-by-case risk assessment" (COP CBD 2018). Such a pronouncement was consistent with the precautionary approach that the CBD had set upon, but any mention of previous calls for engagement with local communities was conspicuously absent. Instead, the need for public engagement before implementing gene drives appears to have been replaced by a precondition of "'prior and informed consent', the 'free, prior and informed consent' or 'approval and involvement' of potentially affected indigenous peoples and local communities" (COP CBD 2018). Again, though, the CBD stopped short of supporting an outright moratorium and instead reaffirmed the precautionary approach with more thorough and regulatory recommendations for gene drives. However, in those recommendations, the emphasis on engagement with local publics about development of gene drives and governance began to be assimilated into already existing institutional frameworks.

The change in language indicated a shift in the rationale for public engagement, away from participation in a process and toward a model of development and governance that implicitly set gene drives on a path to eventual use to which those local communities must opt in but may not necessarily share in shaping. It also placed the inclusion of publics firmly within the already existing framework of the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) (UN General Assembly 2007). Such a framing did dual work of both contributing to the construction of affected publics as primarily Indigenous ones as well as framing the stakes of any such engagement, not in terms of scientific responsibility or ethical obligation, but in terms of globally constituted legal rights.

The point is not that the CBD got something wrong, misapplied ideas about public engagement, or abandoned them entirely. Rather, the notions of public engagement about gene drives akin to those initially proposed by Esvelt and the NASEM that were taken up by the CBD were soon assimilated into other routines, policies, and ideas about the kinds of people that ought to be involved in technoscientific decision-making and in what ways. In that way, the CBD absorbed public engagement into its own operating structures by rendering public engagement similar to other terms and concepts already endemic to the CBD’s approach to international governance.

This pattern of assimilation continued in the findings of an Ad Hoc Technical Expert Group on Synthetic Biology, which the CBD also commissioned at the 2018 meeting to review further the implications of rapidly emerging technologies like gene drives. The ad hoc group convened in June of 2019 in Montreal, Canada, and produced a decision which affirmed prior commitments to precaution with gene drives that “[took] into account human health, cultural and socioeconomic impacts, especially with regard to the value of biodiversity to indigenous peoples and local communities,” (CBD AHTEG on Synthetic Biology 2019). Specifically, they referred to “engagement” with local communities as “important for building the necessary understanding for informed consideration” (CBD AHTEG on Synthetic Biology 2019). However, engagement in this framing was instrumental to achieving, again, “free and prior consent” in the narrower sense of the UNDRIP, as not in the broader sense that CBD had referenced in 2015 and 2016. Instead, those ideas about engaging communities were assimilated into a formulation that already aligned with UN and CBD conceptual infrastructures.

As of the end of 2020, the question of whether to adopt a moratorium on gene drives was not yet fully resolved. Groups continue to express support for a moratorium on gene drives (European Parliament 2020). Requests for more information on gene drives (Biosafety Clearing House 2019, cited in Keiper and Atanassova 2020) also suggest that they remain poised to be contentious going into the CBD COP15 meeting, tentatively to be held in May of 2021 pending the public health and travel constraints of the COVID-19 pandemic, given that the CBD will adopt a Post-2020 Biodiversity Framework toward to 2050 vision of “living in harmony with nature” (COP CBD 2010).

CBD discussions and decisions calling for a moratorium on gene drives were moments in which the CBD faced discourse destabilizing controversies. In those moments, the CBD’s decisions reflected prior uptake of general principles of public engagement and also took up more explicit ones even further. However, that uptake of public engagement was quickly assimilated into other UN-legible procedures. In other words, public engagement was assimilated into already existing international governance structures and practice. Though public engagement with local communities as described by scientists like Esvelt was taken up, this happened in ways that did not disrupt or displace previous commitments and norms of the CBD, like making recommendations for countries and governments, and not scientists per se, and leaving science-oriented actions as being ultimately up to those scientific practitioners to determine.

The result was that public engagement gained a special urgency and international status through CBD uptake in the midst of a moratorium controversy in which public engagement about gene drive addendums were added to otherwise routine recommendations for further review, research, and guidance, which also stabilized the normative status of public engagement for gene drive governance. Public engagement-type responses were incorporated into answers to questions of what was to be done with gene drives vis a vis the kinds of concerns raised by environmental groups regarding a moratorium. The CBD, in effect, leveraged public engagement as a resolution to controversies around a moratorium on gene drives in a way that already align with their own internal logics, which largely maintained the status quo for gene drive research and development—leaving the authority to make decisions about gene drive research with scientists with the proviso that local engagement, particularly with Indigenous groups, was an important and necessary precondition of any implementation. In so incorporating it into their own globally-reaching institutional structures, the CBD assimilation of public engagement also rendered it a legitimate and necessary part of gene drive governance across local and global scales, and, as an item in science's purview, it also maintained scientific independence on such matters while also bolstering and extending the reach of scientific practitioners of public engagement.

Target Malaria—Modification

Target Malaria is a non-profit research consortium based at Imperial College London in the United Kingdom that was founded to develop genetic technologies for the purpose of reducing or preventing the spread of malaria. Though headquartered in Europe, Target Malaria's full operations, are international. When Target Malaria was founded in 2005, they were initially funded by the Bill and Melinda Gates Foundation to do work focused on the development of genetically modified mosquitos meant to be released into local environments. Over the next decade, Target Malaria's operations took place in several African nations with significant incidences of malaria, specifically Burkina Faso, Mali, Uganda, Ghana, and Kenya with modest research progress (Target Malaria n.d.). However, after the advent of gene drives, Target Malaria became a more prominent figure in discourse about gene drives as an anti-malaria technology.[28]

Like other advocates for the use of gene drives against malaria, Target Malaria has also framed their own pursuits of gene drives in normative terms of saving lives and preserving health. On the Target Malaria website, they cite the billions of people worldwide at risk for malaria infection, the hundreds of thousands of deaths that malaria causes each year, and how many children die each minute from malaria (Target Malaria

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[28] In 2016 the Gates Foundation invested an additional $35 million in Target Malaria, bringing their total investments to $75 million to support the consortium's gene drive and malaria research (Regalado 2016). Likewise, in 2017 the Open Philanthropy Project Fund awarded Target Malaria an additional $17.5 million in their mission "to help the project develop and prepare for the potential deployment of gene drives to help eliminate malaria in Sub-Saharan Africa" (Open Philanthropy 2017). In the years since these infusions of research support, Target Malaria has continued to publish significant research on gene drives in mosquitos (Kyrou et al. 2018; Collins et al. 2018; Burt et al. 2018 cited in Cisnetto and Barlow 2020).

n.d.). The strong moral valence of such accountings of the effects of malaria mirrors that of Esvelt and his measurement of the stakes for gene drives in human, and especially, children's lives. Also, like other advocates of gene drives, Target Malaria has situated engagement with local communities as one of the key pillars of Target Malaria's goals of "creating a path for responsible research and development of genetic technology" (Target Malaria n.d.). Moreover, the engagement that Target Malaria has prioritized bears some resemblance to prior formulations of public engagement in that they affirmed that gene drives ought not to be developed in isolation from potentially affected communities without their consent. Target Malaria says of their approach to gene drive engagement: "We see engagement as a two-way dialog and as a reinforcement of our commitment to co-development [of gene drive]" (Target Malaria n.d.).

However, the way that Target Malaria internalized others' calls for public engagement was a modification of the construction of public engagement that scientists like Esvelt and those on the NASEM committee had articulated. By modification I mean that Target Malaria directly altered the concept of public engagement of itself, independent of the process by which it comes to be part of another organization's identity or processes. In explicit contrast to "public engagement," Target Malaria referred to its strategy for engagement work as being "knowledge engagement" (Hartley et al. 2019). It framed engagement as being about knowledge exchange between experts and local communities about the features of gene drives itself, and less about the participation of communities in guiding research or governance priorities. For Target Malaria, engagement was "based on sharing knowledge and perspectives" though not as explicitly guidance or control of gene drive research priorities themselves. In that sense, modification of public engagement is a variant of the underlying conceptual constructions of what is entailed by both “public” and “engagement.” As a result, Target Malaria’s uptake of public engagement modified who precisely public engagement implicated as being a salient public as well as what practices constituted appropriate engagement.

Instead, Target Malaria’s approach of knowledge engagement located the site of meaningful engagement as being with local knowledges of communities rather than with the people in those local communities. In modifying and reframing engagement in that way, Target Malaria both displaced local communities qua communities as points of concern for development of gene drives and replaced them with a disembodied and abstracted notion of local knowledges which were more readily compatible with Target Malaria’s existing technical and scientific frameworks for pursuing gene drives. It also implicitly strengthened the influence and positional power of scientific experts with regard to gene drives by virtue of shifting the focus of engagement from a social domain of communities to a technical one of knowledge.

Whereas prior constructions of public engagement denoted “affected publics” as the appropriate targets of engagement, Target Malaria instead aimed engagement efforts at those “that might benefit from the technology and that are more **concerned** by the research activities” (Target Malaria n.d., emphasis added). So, the publics to be engaged were not just “affected” publics but an even narrower group of “concerned” publics. In setting up “concern” as a marker of engageable publics, Target Malaria pre-framed any actual engagement as an alleviation of concerns in which scientific experts were in the role of removing barriers to consent to gene drives, primarily through “explain[ing] the project and its phases, answering questions and addressing any concerns that may arise”

(Target Malaria n.d.). Moreover, Target Malaria’s construction of the relevant publics to be engaging in that way further delimited the possible points of objection to gene drives. Those that had concerns about gene drives were constrained to choose between an implicitly default position of opting into gene drives or to self-advocate through the engagement efforts by Target Malaria. As a result, Target Malaria’s construction of publics and of public engagement favored development of gene drives and use, which underpinned the need for technical expertise in facilitating the knowledge engagement necessary for responsible gene drives.

The equation of engagement with knowledge exchange between local communities and professionalized, technical and communications experts did important work to empower Target Malaria as a technical and normative leader in gene drive discourse. Even though Target Malaria framed engagement as emphatically a two-way dialog (see Rowe and Frewer 2005), the power to set the terms and stakes for that engagement was largely left with knowledge-domain experts. This is not to say that scientific experts alone benefitted from this framing, however. Target Malaria’s knowledge engagement explicitly includes traditional and cultural knowledges as part of what is prioritized. However, the point remains that by circumscribing engagement to knowledge domains, scientific expertise was also framed as a necessary component for staging and facilitating engagement and thus also for pursuing responsible development of gene drives.

It was not only public engagement as constructed by Esvelt or NASEM, but also the modified public engagement taken up in Target Malaria’s knowledge engagement that further solidified the epistemic and normative authority of scientific expertise to delineate the salient issues, stakes, and publics that they need to engage. By framing engagement as an act of communication and knowledge exchange, Target Malaria delimited publics as obstacles to development of gene drives to be overcome, disempowering the very local communities they alleged to be working for decision-making about gene drive research. As a result, public engagement was framed as a matter of communication aimed at securing community consent to applications of gene drives. Likewise, engagement came to be a similar site where scientific responsibility was performed in order to underwrite the eventual and inevitable use of gene drives against malaria.

The Genetic Biocontrol of Invasive Rodents (GBIRd)—Adoption

The Genetic Biocontrol of Invasive Rodents (GBIRd) is a collaborative, cross-sector, and interdisciplinary research and advocacy initiative to promote and realize conservation benefits through genetic technologies, and gene drives in particular. GBIRd officially formed in 2016 as the result of a partnership of seven international groups across governmental, academic, and advocacy sectors, headquartered in the United States, Australia, and Aotearoa New Zealand. Those in the partnership include environmental NGOs Island Conservation and New Zealand’s Biological Heritage, the United States Department of Agriculture (USDA), Australia’s Commonwealth Scientific and Industrial Research Organization (CSIRO), North Carolina State University (primarily the research group of NASEM gene drive committee member, Jason Delborne), University of Adelaide, and Texas A&M University. GBIRd also is a member of the Outreach Network for Gene Drive Research alongside Target Malaria and the Bill and Melinda Gates Foundation. Notably, though, GBIRd has not directly included key gene drive researchers like Kevin Esvelt or any of his affiliated universities or other projects.

GBIRd, like many of its composite members, is explicitly concerned with developing gene drives specifically, with the intent to use them for conservation efforts. In particular, GBIRd's focus is on invasive rodent populations on islands—one of the most commonly proposed targets for early trials of gene drives and uses apart from malaria and mosquitos. Although GBIRd is decidedly not aimed at malaria control, mosquitos, or even similar geographic regions to those in which malaria is endemic, the international partnership nevertheless has been discursively connected to broader development of gene drives and governance discussions by virtue of its international scope and its shared technological reliance on gene drives to enable its conservation aspirations. The goals of invasive rodent eradication have regularly been discussed in science journalism and popular media accounts of gene drives as part of a shared discussion space about the future of gene drives in which conservation goals for invasive species (and GBIRd by name) have been coupled with global health hopes for malaria control (Callaway 2018; The Economist 2018; Mitchell 2018; Watts 2018; Scudellari 2019; Kahn 2020). As a result, though GBIRd's explicit remit is limited to conservation, how GBIRd has taken up public engagement is not independent of broader gene drive discourse and the global stakes for development of gene drives and acceptance.

In GBIRd's framing of how they would pursue conservation goals regarding gene drives, they largely adopted public engagement into their internal structures, practices, and imaginations of technological futures of gene drives explicitly from the work of the

2016 NASEM report.[29] I use the term adoption to describe the way that, though expressed and conceived elsewhere, public engagement was institutionally hardened as part of GBIRd's missional aims in a largely unchanged form. In contrast to implementation, adoption shapes institutional structures and rationales rather than shaping in-practice engagement interventions. In other words, the uptake of public engagement by GBIRd was not as transformational for notions of public engagement as it was of GBIRd itself.

GBIRd has situated public engagement regarding gene drives front, center, and first in its own organizational mission. In a 2018 press announcement, GBIRd stated that their mission was: "The first guiding principle of the GBIRd partnership is early, sustained, and consistent engagement with stakeholders and communities" (GBIRd 2018). GBIRd's approach to promoting and enacting gene drives for invasive rodent control centered engagement in a way that stemmed directly from prior calls by NASEM and scientists like Esvelt. In describing their conception of and purpose for public engagement, GBIRd explicitly cites NASEM's 2016 gene drive report as its own "benchmark" for their conduct engaging with publics (GBIRd n.d.). Following the pattern of public engagement aims from that report, GBIRd has described that engagement as a necessary component of responsibly pursuing gene drives. They describe engagement as needing to be done "early and often" and focused on issues of "biosafety," "transparency," whether uses of gene drives were "societally acceptable," and "if, when, and how we should proceed with [gene drive]," reminiscent of Esvelt's reactions and

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[29] The conceptual continuity of public engagement, in part, may also be attributable to the overlap of personnel like Jason Delborne between the NASEM gene drive committee and GBIRd.

concerns after the controversy surrounding the work of Gantz and Bier at UCSD (GBIRd n.d.).

In the framing of questions of whether and how to proceed with gene drives, GBIRd has situated their considerations of gene drives as being highly context-dependent. The question that GBIRd has pointed to as important for engagement is not whether to use gene drives *at all,* or in *any case*, but rather in what specific contexts. For GBIRd, that has meant invasive rodent control primarily on islands. In doing so, however, they also framed gene drives in a techno-optimistic light which implicitly favors development of the technology and in which public engagement is enlisted to ascertain and promote the societal acceptability of gene drives. As a result, the publics to be engaged were localized to those in specific contexts, both geographically to islands and to conservation applications more narrowly.

Yet, at the same time, GBIRd also framed their aims for gene drives as being for human communities more broadly and in normatively positive terms. They describe their vision for gene drives to be developed in “the interests of society and nature” and to “save lives, support livelihoods, and preserve our natural world for generations to come” (GBIRd n.d.). GBIRd has also stated that their aims include also “to assess the potential of [gene drive] for advances in agriculture, food security, and human health” (Gene Drive Files 2017, cited in CSS, ENSSER, and VDW 2019). GBIRd’s commitments to public engagement about gene drives, likewise, were normatively intonated, echoing the comingling of engagement efforts with notions of societal responsibility laid out by scientists like Esvelt and the NASEM committee. Moreover, those normative imperatives to do public engagement were not anchored in the narrower contexts of local publics and uses of gene drive, but more generally to broad notions of society and posterity.

As in previous constructions, public engagement was adopted into GBIRd's response to an explicit question of "How can gene drive research be done safely and responsibly?" (GBIRd n.d.). Public engagement, then, continued to be in terms of responsibility to society, a responsibility that implicitly was on those scientific experts that were to do the work of engaging that was necessary to proceed. By appealing to public engagement as part of the responsible development of gene drives for the purpose of societal benefits and the saving of lives, GBIRd furthered the normative overtones of public engagement imperatives that Esvelt and the NASEM report laid out. In so doing, the public engagement about gene drives that was taken up and institutionally hardened by GBIRd reaffirmed the position of scientific experts as both the rightful engagers and moral stakes-setters for development of gene drives and use.

Mice Against Ticks—Implementation

Mice Against Ticks is a research initiative formally begun in 2016 by Kevin Esvelt, his research group, and colleagues based out of the Media Lab at the Massachusetts Institute of Technology (MIT). As Esvelt and colleagues describe, "Mice Against Ticks is a community-guided ecological engineering project that aims to prevent tick-borne disease by using CRISPR-based genome editing" (Bucthal et al. 2019). As part of being "community-guided," Mice Against Ticks was a project born out of Esvelt's own commitments to his Responsive Research paradigm in which public engagement, as well as notions of scientific responsibility, were strongly centered ("Responsive Science" 2018).

As one might expect, Mice Against Ticks, as an offshoot of Esvelt's research affiliates, was one of the earliest implementations of the ideas of public engagement that he and others had articulated in the years leading up to its founding in 2016. By implementation, I mean that Mice Against Ticks applied Esvelt et al.'s ideas of public engagement, essentially unchanged, to practical instances of interacting with targeted communities. Rather than pertaining to a particular organizational configuration, implementation is related more to public engagement praxis than to constituting public engagement in particular patterns of institutional formation. Therefore, Mice Against Tick's implementation of public engagement should be understood as a sustained expression of earlier constructions, stabilized around and through particular episodes of community interaction.

In December of 2015, shortly before the formal formation of Mice Against Ticks, Esvelt and his research colleagues convened a workshop at MIT to decide where or not to approach the Nantucket and Martha's Vineyard communities about any sort of gene drive or genetic technology intervention regarding the spread of tick-borne Lyme disease. The initial meeting included a wide array of technical, policy, and social science experts as well as representatives from government agencies, NGOs, and members of other island communities (but not from Nantucket or Martha's Vineyard themselves). Importantly, though their discussion was prompted by development of gene drives, the workshop itself was not necessarily focused on gene drives per se. Rather, the consideration of gene drives or other genetic interventions was ancillary to the core issue, the spread of Lyme disease by ticks and the rodents that carried them.

This early meeting accomplished two important things. First, public engagement was prioritized before and over development of gene drives and use itself. The probing workshop in 2015 at MIT also took place between the UCSD gene drive experiments and not yet published NASEM gene drive report. The timing of this workshop between these events suggests a continuity of the specific formation of public engagement and responsible science in and around Esvelt himself and his strong commitments to public engagement as a prerequisite for responsible development of gene drives.

Secondly, even in this setting up of public engagement as a priority, the decision-making regarding gene drives or not, and whether to approach the public or not in the first place, was concentrated initially among experts, especially scientists. The move to pause and consider the implications and best course of action to take was itself an act of discursive framing in which the terms, stakes, and aims of public engagement regarding gene drives were laid out before any actual implementation of public engagement itself. Moreover, that framing was done more or less implicitly on behalf of others who were not present—the communities of Nantucket and Martha's Vineyard who stood to potentially benefit from the discussed interventions. Even though publics were prioritized, the pre-steps of planning to do public engagement in the first place involved scientists and other experts assuming responsibility for initiating discussion as representatives of the interests of their imaginations of the island communities.

Esvelt and Mice Against Ticks followed through with their intentions several months later in 2016, meeting with local community members in Nantucket in June and

Martha's Vineyard in early July (Mice Against Ticks 2016; Bucthal et al. 2019). Notably, these occurred almost immediately after the release of the NASEM *Gene Drives on the Horizon* report at the beginning of June (NASEM 2016). Out of the tens of thousands of permanent residents on the islands (not including the many thousands more visitors the islands host during the summer months), about 30 community members attended the meeting on Nantucket, and about 100 people attended the meeting in Martha's Vineyard.[30] Also, the meetings, while open to the public, were with self-selecting community members that were not necessarily representative of the broader community of residents on the islands. Their commitments to do public engagement was carried through, though the scope of these early engagement forays was notably narrow in terms of who participated and on whose behalf.

In the meetings on Nantucket and Martha's Vineyard, Mice Against Ticks repeatedly emphasized that gene drives were unnecessary to address the problems of tick-borne illness on the islands. Mice Against Ticks explicitly advocated *against* the use of gene drives in their project on the islands. The use of gene drives on Nantucket and Martha's Vineyard at all was presented as an irresponsible path forward. Rather, different genetic interventions to alter island rodents was, in their assessment, a more responsible alternative. However, though gene drives were described as unneeded and inappropriate for Nantucket and Martha's Vineyard, the Mice Against Ticks project also cast public engagement on the islands as a key part of an aspirational vision for gene drive's use for similar, future efforts to control rodents elsewhere, including the Massachusetts mainland

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[30] These initial engagement meetings in 2016, were not the only such events planned or executed, but they set the precedent for the format and the purpose of future implementations of public engagement by Mice Against Ticks.

(Bucthal et al. 2019). Also, though the aims of Mice Against Ticks were neither specific nor exclusive to gene drives, the motivations and methods of public engagement they implemented were clear continuations of conceptions of public engagement as an ethical obligation of scientists to act on behalf of broader publics that Esvelt had laid out in the initial papers on gene drives and were articulated in the 2016 NASEM committee report.

By insisting on *not* using gene drives, Mice Against Ticks demonstrated their own responsibility through episodes of public engagement that served as both a performance stage and requisite proof of that responsible character. Moreover, even though the Mice Against Ticks project screened off the use of gene drives in the cases of Martha's Vineyard and Nantucket, the technology was still referenced in their public engagement in detail. While in one sense the meetings were emphatically *not* about using gene drives locally in New England, at the same time, Mice Against Ticks was distinctly situated as part of discourse about the development and use of gene drives globally. And in so doing, public engagement with local communities about *not* using gene drives on the islands as an act of responsible science somehow came to stand in for *affirming* the use of gene drives in other contexts as a likewise responsible act.

During the meetings with Nantucket and Martha's Vineyard communities, Esvelt and Mice Against Ticks pitched several discrete options for potential interventions of differing degrees, including an option of doing nothing (Mice Against Ticks 2016). Esvelt and Mice Against Ticks also asked residents of the islands about what options or combination of options they were interested in pursuing further, what criteria would need to be met before any field trials, and what independent oversight groups should monitor the project, as well as solicited further questions they had not addressed. Crucially, the public meetings emphasized that ultimate decision-making for any project on the islands belonged with the residents that lived there, saying “whatever their reasoning, it is their environment, and so the decision to alter the environment should also be theirs” (Bucthal et al. 2019) Esvelt and Mice Against Ticks repeatedly made the point that the proposed project “will only move forward if embraced by the community” (Mice Against Ticks 2016). By insisting on community decision-making as the ultimate determinant of the future of the project, Mice Against Ticks centered public engagement as a necessary part of any sort of intervention on the islands.

Moreover, though the option to do nothing was made clear as a viable decision for the island residents to make, the conditions for making those choices were not neutral. After all, the very existence of Mice Against Ticks was predicated on the assumption that there was a problem (i.e., Lyme disease) for which they had a solution (i.e., a genetic intervention in island mice). The practices of public engagement about gene driveswere intended to be community-guided and ultimately community-decided. Yet, the options that communities had to select from were provided by Mice Against Ticks themselves. In presenting several discrete options for moving forward (or not) with genetic interventions to prevent Lyme disease in the local island communities, Mice Against Ticks situated scientists as epistemic experts about the technical options of gene drives and other genetic control. At the same time, by screening out gene drive as unneeded and irresponsible in Nantucket and Martha’s Vineyard they also asserted scientists as normative authorities about the proper use of gene drives.

Later, in a 2019 interview with *VICE* about the project, Esvelt again made the point that community consent was an absolute prerequisite for any action by Mice

Against Ticks saying, “If it’s your environment, it’s your call. We don’t live there. We’re not going to be affected if you decide to do this” (Esvelt 2019). Wrapped up in the appeals to a community’s sovereign authority environment are also unclear and contestable notions of where one community’s environment ends, and another begins and who a particular genetic technology will affect or not, which draw upon understandings of locality, spatial relations, and prior judgements about what places “belong” to what people. Such matters cannot be separated from other longstanding discussions of the entanglements and continued harms of settler science, colonialism, empire, and the displacement of indigenous people from ancestral lands, especially around issues of genetics, the environment, and life itself (Reardon and Tallbear; 2012; Smith 2013; Povinelli 2016). By not acknowledging and engaging with these ideas, Esvelt and the Mice Against Ticks project perpetuate patterns of colonial science, epistemic injustice, indigenous erasure, and disenfranchisement from matters of governance.[31] At the same time, they also unironically leverage the rhetoric of a right to self-determination vis a vis the use of genetic technologies to change one’s lived environment as a warrant for the ethical imperative to engage with settler communities as part of what constitutes responsible and virtuous science.

Additionally, the sense that decisions about the environment in which a community lives do not affect those who do not live there is at odds with Esvelt’s and

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[31] Esvelt has engaged with indigenous communities about gene drives and the environment, namely in Aotearoa New Zealand regarding the use of the technology for invasive species control (Esvelt 2017a). However, this engagement has not been without controversy, moral missteps, or similar problematic patterns of colonial science (Esvelt 2017b). This topic is explored further in of this dissertation in Chapter 4, *Knowing and Controlling: Engineering Ideals and Gene Drive for Invasive Species Control in Aotearoa New Zealand.*

others' linkages of the stakes for engagement around gene drives and related technological, genetic interventions. In an earlier media interview, Esvelt put things quite explicitly saying, "If someone screws [gene drive] up with rodents…it would make it a lot harder for African nations to agree that they want to use it against malaria. And since malaria killed 429,000 people last year and infected over 200 million, that's not something that I really want on my shoulders" (Evans 2017). The different valences of how local engagement does or does not bear on the use of genetic technologies such as gene drives elsewhere, however, was more than a superficial contradiction.

The rhetorical maneuver both located rightful decision-making authority regarding genetic interventions as belonging to local, affected communities while also setting up a model of responsible, responsive science for global efforts to engage publics about gene drives. Esvelt simultaneously implicated a deeply entangled relationship between local public engagement, global stakes for gene drives, and notions of scientific responsibility. Despite the stark differences in affected publics and contexts, Esvelt's assertions depicted localized public engagement as precedent setting for the deployment of gene drives *elsewhere* for use against malaria. Likewise, the moral imperatives to use gene drives to eliminate malaria also underpinned motivations for engaging with other localized publics in the first place. And in each, it was his own, assumed responsibility, as a scientist, to make sure that gene drives were fully and responsibly deployed.

Commitments to public engagement as part of fulfilling scientists' ethical obligations to society enabled Mice Against Ticks to envelop their technical presentations of options for genetic control of island rodents and tick-borne Lyme in a rhetoric of responsible science, which also imparted an emphatic normative dimension to those technical presentations. In other words, scientists were authoritative vis a vis how gene drives ought to be used not merely because they had specialized technical knowledge about molecular biology or genetic engineering, but because they did public engagement in a way that publicly performed their responsibility. It was that demonstration of responsibility that then underpinned the legitimacy of the assertion of scientists like Esvelt that as scientists “we are morally responsible for all consequences of our work” (Esvelt 2014a). It was this assumption of public responsibility that public engagement enables to co-occur with technical expertise, which reinforces scientists’ position of authority in gene drive discourse—even when they are explicitly advocating to *not* use gene drives.

It is not that the public engagement done by Mice Against Ticks was a charade or that their goals of persuasion were necessarily coercion. Rather, the point is that their implementation of public engagement was necessarily and simultaneously both instrumental and performative of Esvelt’s and Mice Against Ticks’ own ethical, responsible qualities to local communities. Public engagement does work not only in its use but also in its display. It was the dual assertion of scientists’ epistemic and normative authority over gene drives that did the crucial work to reinforce the authoritative position of scientific experts in the discourses around genetic interventions on Nantucket and Martha’s Vineyard, as well as gene drives more broadly, because it grants an ethical stage upon which they can demonstrate their moral qualities. Yet, such normative performances are largely obscured by the fact that the stage is one and the same with the stage on which scientific experts also demonstrate their epistemic authority through presentations of specialized, technical knowledge.

The subtle power of public engagement to shape gene drive discourse—even when genuinely meant and implemented—is that public engagement does not require intentionality on the part of its practitioners to nevertheless be a performance of their own normative authority in a rhetorical bid to generate consensus support for some intervention option. Public engagement as an imperative for scientific experts, then, becomes a site where their dual authorities are collectively witnessed by the very publics whom scientists are meant to engage. In that collective witnessing, publics are ushered into a role of passive observation and legitimation of the active performances of scientific responsibility, rather than into being the final decision-makers about any technological intervention in their environments.

One might ask, since Mice Against Ticks was decidedly *not* a project oriented around developing or using gene drives per se, how Mice Against Ticks could be considered an instance of public engagement about gene drives in the same discourse as the other examples—their technical and ethical features—which are presented in this chapter. After all, Mice Against Ticks was not concerned with the eradication of malaria, nor mosquitoes generally, nor similar environments, geographies, or publics. As said before, Mice Against Ticks was not even advocating directly for gene drives itself.

Yet, while it was the case that Mice Against Ticks, unlike the UN CBD, Target Malaria, or GBIRd, was not concerned with implementing gene drives, the actions of Mice Against Ticks were nevertheless deeply connected to broader gene drive discourse. First, Esvelt was a central figure to both Mice Against Ticks in particular and to broader gene drive discussion generally, and the persistence of Esvelt as a figure across gene drive discourse as well as an architect constructing public engagement is an important analytical point to note in the coherency of public engagement itself. Moreover, despite all of these differences, Esvelt himself and the Mice Against Ticks project still distinctly situate themselves as being relevant to development of gene drives and use in other global geographies, particularly the issue of malaria eradication (Esvelt 2014a; "Responsive Science" 2018; Bucthal et al. 2019).

The dissonances in the Mice Against Ticks project with other cases associated with gene drives make the Mice Against Ticks case all the more worth paying attention to because, despite the apparent points of disjuncture—different purposes, different species, different tech variants, different locations, different publics, different engagement—a particular construction of public engagement nevertheless holds together at the center of these discussion. The continuity of these implementations of notions of public engagement across such disparate contexts of uptake suggests conceptual and institutional stability of the early framings of public engagement laid out years earlier (Esvelt el al. 2014).

In this way, public engagement not only canalized discussion around gene drives into narrow channels of normatively ethical scientific practices. It also connected disparate local and global contests by forcing responsible gene drives *anywhere* to travel through the restricted nodes of local public engagement instances. Those public engagement interventions, then, stand in for globally imagined publics and renders commensurable otherwise disparate, distinct local communities with one another. In so doing, the global, moral stakes of malaria eradication, also animate the practices of public engagement about gene drives locally. At the same time, local engagements with publics simultaneously fed back into global and international discourse around gene drives as a representative broader global publics.

Conclusions

The ideas of public engagement, while represented in and through both Esvelt and the NASEM committee and report, persisted further and in a more diverse way than those discursive contexts alone. In part, the continuity of a concept recognizable as public engagement demonstrates how public engagement has persisted as a responsible science and ethical imperative for gene drives to become stabilized as a recurring feature of global gene drive discourse. Additionally, though its formulation and uptake were not universally the same or without alteration in some cases, the framing of engagement with publics as important to the implementation of gene drives nevertheless retained earlier normative commitments that science ought to engage publics about gene drives because of science’s responsibility and remit to provide benefit to society. Furthermore, the upshot of public engagement as a recognizably similar concept to what Esvelt, NASEM, and others had established demonstrated the cohesiveness and durability of public engagement as a category in gene drive discourse and also, simultaneously, drew diverse locales into a shared technoscience discourse. Importantly, the joining of disparate and diverse publics in a shared discourse also reinforced the power of scientific experts, like Esvelt, to have greater epistemic and normative authority over gene drives because of the active rationales of scientific responsibility and ethical obligations of science to society.

Public engagement as it has been constructed and taken up in gene drive discourse has operated as an obligatory point of passage (Callon 1984) for responsible development of gene drives. As an obligatory point of passage, public engagement also “flattened” local and global publics and stakes to be commensurable with one another. The commensuration of those localities also enabled scientific authority to travel between global and local contexts through appeals to scientific responsibility and the ethical obligations implicit in the framings of public engagement, which also paved a way for engagement with specific local publics in one place to stand in for other specific publics elsewhere.

Discourse around gene drives set up its global and moral stakes such that developing the technology *must* be done responsibly, both to avoid risks and to avoid compromising or delaying potential benefits. To engineer gene drives responsibly, public engagement has been made an ethically obligatory prerequisite. Therefore, public engagement likewise *must* be done in order to realize gene drives fully. However, public engagement itself is localized to specific geographic and cultural communities around specific applications of gene drives. As a result, local public engagement comes to stand in for the public engagement needed to pursue gene drives for global goals, which does work to render local publics representative of globally imagined publics as well as disparate other local publics. Conversely, failure to do public engagement regarding gene drives in any locale would reverberate through other local and global contexts. Regardless, this construction of responsibility has rendered public engagement a stable feature of gene drive discourse further reinforced by its broad institutional uptake through which responsible science (and thus responsible gene drive) must pass.

In effect, the level of “global” discourse did work to create a metaphorical and discursive “gene drive” through which scientists could replicate and spread the ethically requisite engagements with publics not only in its own locality, but also in other localities—despite stark and salient differences in context. As a result, the uptake of public engagement also initiated an entangling of local applications of gene drives and considerations by and through international organizations, enabled by the continuity of shared understandings of public engagement taken up as ethically necessary for responsible scientific practice.

In gene drive discourse, public engagement has come to be equated with scientific responsibility, which reinforces (rather than check) scientific expert authority by giving scientific experts a key positional role in leading engagement efforts. The upshot of that position is that the visions of the future of gene drives are therefore heavily shaped by those scientists doing the work of engaging publics, which reproduces a social order of technoscientific decisions making that privileges scientific authority. However, perhaps more subtly, in doing so, that envisioning of gene drive decision-making comes to be hidden in a rhetoric of “inclusive,” “participatory,” and “community-guided” approaches, which only serves to reinforce a framework in which science retains an implicit epistemic and normative authority about gene drives.

This reinforcement of scientific experts’ authority reinscribes a status quo of science as the preeminent maker and validator of public knowledge for more democratic forms of decision-making about gene drives. In so doing, public engagement also reconfigures notions of democratic governance of science and technology vis a vis gene drives. Public engagement, though an ostensibly democratic practice, may actually reinforce scientific expertise to preside over decision-making, not only of gene drives, but over ideas of responsible science and democratic governance more broadly. This reconfiguration of democratic visions of science and technology is suggestive of not a democratization of science, but a scientizing of democracy in which democratic social order is underwritten by, upholding of, and co-produced with expert scientific knowledge (Ezrahi 1990*;* Laurent 2017). In the expansion of the normative and epistemic authority of scientific expertise over matters of political decision-making, the performance of scientific responsibility through public engagement becomes the authenticating mark of democratic legitimacy and accountability.

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CHAPTER 4

KNOWING AND CONTROLLING: ENGINEERING IDEALS AND GENE DRIVE FOR INVASIVE SPECIES CONTROL IN AOTEAROA NEW ZEALAND

Controlling life has long been a central aspiration of the biological sciences. In the early twentieth century, aspirations to greater control over life manifested in rigorous laboratory experimentation, attempts to engineer organisms to be more amenable to human purposes, and explanatory commitments to a mechanistic conception of life (Allen 1976; Pauly 1987).[32] Mechanistic approaches have been ubiquitous in biological practice aimed at bringing living things and their functions into the purview of human intention and volition by isolating, manipulating, and better understanding the function of its more fundamental parts.[33] The widespread mechanistic approaches in biology also helped create the conditions for the rise of genetics as the preeminent field in the biological sciences (Krimsky 1982).

In the decades following the close of World War II, experimental and molecular biology grew dramatically. Molecular biology increasingly displaced other fields of biology as a more physics-like science, a resemblance that lent a sense of hardness to biological theories and explanation (de Chadarevian 2002). The dominance of molecular

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[32] Such approaches to control in biology can be traced to early twentieth century biologist Jacques Loeb and his mechanistic conception of life, in which "control of natural phenomena as the essential problem of scientific research" (Pauly 1987, 114). Control required not just an apprehension of biological function in terms of the physico-chemical processes that underpinned them, but also "controlling at will the life phenomena…bringing about effects which cannot be expected in Nature" (Pauly 1987, 116).

[33] The terms "mechanism" or "mechanistic" have historically had variable meanings and uses, but epistemological distinctions among versions of mechanism are seldom used by biologists in-practice (Allen 2005; Casadevall & Fang 2009). As such, this chapter is not concerned with referring to a philosophically distinct account of natural phenomena but with a general pattern of explanatory practices in biology broadly construed as mechanistic. For scholarship exploring historical and contemporary conceptual formulations of mechanism see (Bechtel & Richardson 1992) (Machamer, Darden & Craver 2000), and (Nicholson 2012).

biology laid the foundation for epistemic status of genetics by providing a molecular articulation of fundamental processes of transcription and translation. Later, the development of recombinant DNA and similar biotechnologies further cemented genetics as the foremost scientific field for manipulating, changing, and controlling life for human uses (Bud 1994; Keller 2009). The experimental and commercial successes of genetic engineering and its products entrenched a narrative of biological control as one of having mechanistic understanding of the underlying genetic components, demonstrated through genetic isolation, replication, and rearrangement in versatile, predictable, and modular ways (Rasmussen 1992). By the close of the twentieth century, the genetic and mechanistic explanations of biology crescendoed in the promises of Human Genome Project to provide greater control of human health through a putatively comprehensive understanding of human genetics that would provide means of intervening in fundamental biological processes (Lee 1991). More than just an ideological commitment to particular scientific methodologies, life as mechanism was an animating metaphor for what it meant to both know and control living things (Keller 1995). To control life was to mechanistically understand its underlying phenomena, and genetics provided the kind of causal, molecular-level explanations that mechanistic biology prized.

In the twenty-first century, aspirations to control life through genetics finds new resonance in the technology of gene drive. Gene drive is a genetic engineering technology that embodies a mechanistic logic in which aspirations to control life are unified across biological scales, linking molecular genetic interventions with macroscale ecological outcomes. At its most basic level, gene drive enables the rapid spread of a desired genetic element through a species population by significantly increase its inheritance in subsequent generations. An engineered gene drive employs genome editing techniques and exploits innate cellular processes of genome repair to produce a self-propagating system of genetic modification such that, once introduced, the gene drive continues to spread across generations of a targeted population. The result is that the desired genetic element coupled to the gene drive is engineered into the genome of nearly every individual in a population over relatively few generations. The power and scalability of a gene drive to alter entire species populations has lent itself to many speculative ecological engineering projects ranging from the prevention of vector-borne disease to conservation efforts and invasive species control by inserting genetic elements that skew population sex ratios, cause sterility, introduce lethal mutations during development, or otherwise reduce the numbers of targeted species (Esvelt et al. 2014a).[34]

Control over life extends beyond harvesting or harnessing of nature. It suggests a broadening of the horizon of humanity's power to make and remake nature ever more in our own image. As such, what it means to control of life is necessarily intertwined also with the control of those mediating technologies and the particular visions of the material and social world that they authorize (Winner 1980; Joerges 1999). Scholars studying the biosciences in society have long argued that knowledge making of biological sciences are not independent of the from the social and cultural the worlds in which it takes place (Nelkin and Lindee 1995; Rabinow 1996; Goodman, Heath, and Lindee (ed.) 2003). Accounts of biological objects like genes, DNA, and cells are inseparable from and co-produced with normative visions social order and structures of power (Jasanoff 2004).

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[34] A genetic element driven by a gene drive can range in size from short nucleotide sequences to larger genetic cassettes comprised multiple different genes.

The entanglements of the biological and distinctive sociopolitical visions of the world become particularly evident in the ways that humans invest themselves, their aspirations, and their ideologies in the non-human animals that they make and are made by (Haraway 2003; Saraiva 2016). Divergent biological understandings of the world, then, are not merely the result of a singular nature refracted through the lens of many cultures (Latour 2004), but are disparate social, political, and cultural constructions of life itself (Rose 2001). Put another way, the social precedes and is embedded within every part of biological projects to engineer life (Franklin and Lock (ed.) 2003). Therefore, at stake in questions what it means to know and control life vis a vis gene drive are not only matters of technological precision, capacity, or predictability of technological outcomes but also of social order for the development and governance of science in society.

Scientific aspirations to engineer life also evoke questions about responsible science regarding a technology like gene drive. While the idea of scientific responsibility toward broader society is neither new nor is it unique to gene drive technology (Bernal 1939; Polanyi 1962; Brunner and Ascher 1992; Stilgoe, Owen, and Machnaghten 2013), what it means to do science responsibly does find distinctive resonance with notions of restraint, precaution, and deliberate action associated with metaphors of engineering life. Scientific responsibility has been understood in terms ranging from adherence to particular norms science of scientific practice (Merton 1973), individual “role responsibilities” of scientists as to avoid research misconduct (Chubin 1985), a “collective responsibility” of science as a knowledge-making profession (Braxton (ed.) 1994), or a “co-responsibility” between science and society (Mitcham 2003). However, others have problematized such accounts of responsibility in science as limited to the practices of scientists qua scientists (Douglas 2003). Because science and society are not so neatly separable from one another, the responsibilities of science and scientists are implicated at every turn with epistemic, social, political, and moral stakes (Jasanoff 2011; Glerup and Horst 2014). Those stakes are heightened all the more in projects of engineering and controlling life on potentially global scales. As such, notions of responsible science are inherently wrapped up with the mechanistic rationales that have dominated the life sciences for a century and underwrite scientific claims to controlling life. Questions of responsible science regarding gene drive, then, are also questions about how one knows and attempts to control life.

Gene drive promises greater control by contrasting the mechanistic precision of genetic engineering to impress human designs upon nature with an implicitly more disordered and out-of-control state of nature. In doing so, gene drive highlights how technologies of control are integral to the aims of biological engineering, and how such technologies render biological processes amenable to human intention and inescapably mediate human efforts to control life. As aspirations to bring nature under human control increasingly implicate a diversity of cultures and communities, mechanistic approaches common to Western biological engineering practice encounter alternative ways of understanding the natural world and what it means to control it.

This chapter examines discourse around the use of gene drive for invasive species control in Aotearoa New Zealand as an exploratory case of what it means to control life in the twenty-first century. It follows the research and community engagement activities of one the technology’s co-inventors and prominent advocates, MIT Media Lab scientist, Kevin Esvelt, to trace his articulations of the function, capabilities, and stakes of gene drive technology. Analysis of the notions of control embedded in descriptions of gene drive technology itself shows how mechanistic biological control becomes intertwined with ideas of responsible scientific practice and reveals limitations of mechanistic biology in navigating social words and distinct practices of meaning-making. It also prompts reflective examination of the visions of remaking nature that are animated by particular approaches to knowing and controlling life.

Aotearoa New Zealand and Invasive Species Control

Introduced predatory species have been a long-standing feature of the island environments of Aotearoa, also called New Zealand. The earliest introduced species to the islands was the kiore, also known as the Polynesian rat (*Rattus exulans)* that accompanied the arrival of Māori peoples in the late thirteenth century. Other predatory rodent species came later to the islands as stowaways on the ships of European colonizers or as intentional additions to the environment to attempt to control the population of other introduced species brought by European colonists during the nineteenth century (Wodzicki 1950; Atkinson 1973; Wilmshurst et al. 2008). Though the designation of introduced species as native or invasive is itself a thorny issue (Helmreich 2005), by the mid-twentieth century, most all introduced predator species on the islands came to be widely considered a major ecological concern.[35]

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[35] The designation of kiore as native or invasive in Aotearoa New Zealand has been disputed in part due to their earlier arrival to the islands, integration into local ecosystems prior to European colonization, and significance to Māori history and culture. However, similar contentions are not made concerning rodent species that accompanied European colonizers as being invasive to Aotearoa New Zealand (Best 1977; King 1984).

During the second half of the twentieth century, sustained action towards invasive species control grew, especially targeting rodents. Early efforts were relatively modest removals. In 1959, a handful of volunteers began one of the first rodent removal operations on Ruapuke Island, a two hectare islet off the eastern coast of Auckland in the Hauraki Gulf. The introduction of invasive rats in 1963 by commercial ships to Big South Cape Island, the largest island off the southern coast of New Zealand, galvanized national attention and resolve to eliminate the invasive species that had become increasingly out-of-control. Over the following decades, invasive species control in New Zealand grew as a national priority. Advances in toxin development in the late 1970s and 1980s led to increases in chemical control efforts that relied heavily on poison baiting of affected regions with poisons like Compound 1080 and brodifacoum. By the turn of the twenty-first century large-scale conservation efforts had become commonplace, with major projects declaring Campbell Island and Big South Cape Island cleared of invasive rodents in 2001 and 2006 (Thomas and Taylor 2002; Young 2004; McClelland et al. 2011; Russell and Broome 2016).

Though the control of invasive species had enjoyed decades of broad public buy-in, by the early 2000s, that support began to wane. The chemicals used to eradicate invasive species were chosen because of their high toxicity. However, those toxins were also indiscriminate in what organisms they affected which resulted in many cases of secondary poisoning of native and valued domesticated species. As a result, the chemical methods of invasive species control came under harsh criticism from environmental groups and communities that lived in areas where toxins and poison baiting were widely used. The dissonance the broad use of toxic, non-specific chemical controls for invasive species as part of environmental conservation became increasingly politically untenable.

One such group was the original Predator Free New Zealand (PFNZ), a grass roots movement founded by environmental activist Les Kelly in 2008. PFNZ had the ambitious aim of eliminating all invasive predatory species—including possums, stoats, feral cats, and rats—from all of New Zealand's more than 600 islands over the course of a couple decades. Importantly, the organization emphatically rejected the use of toxins and advocated for the consideration of alternative technologies to control invasive species (Kelly 2008). The goals of groups like PFNZ gained support among the general public as well as the New Zealand government. In July of 2016, New Zealand Prime Minister, John Key, announced the launch of Predator Free 2050, a government-supported initiative which put national resources and legitimacy behind the mission of eliminating invasive predator species from the island nation by 2050 (Department of Conservation, Te Papa Atawbai n.d.). The vision for invasive species control presented was one of a New Zealand entirely devoid of their existence. Control of invasive species entailed not just a modulation of their effects on native ecosystems, but their complete removal from them.

Predator Free 2050 retained many of the priorities and commitments of PFNZ, in particular an emphasis on pursuing a wide range of technologies for biological control, including renewed consideration of genetic engineering. Genetic engineering technology had been controversial in past decades, but more recently, public attitudes had become more accepting of genetic engineering technologies as a means of controlling living things, particularly in the service of environmental protection (Couchmang and Jensen 1990; Macer et al 1997; Cook et al 2004).

Gene Drive: A Technology of Control

In 2014, two years prior to the announcement of the Predator Free 2050, MIT scientist, Kevin Esvelt, and collaborators from Harvard Medical School and the Harvard School of Public Health published a pre-print manuscript detailing the design, function, and speculative applications of gene drive (Esvelt et al. 2014a). The landmark paper presented gene drive as a possible tool for large-scale environmental engineering. The paper included figure of a Venn diagram which summarized many possible applications of gene drive as ecological tools in human health, and conservation, specifically noting invasive species control. By driving a lethal or sterilizing genetic trait through an invasive population, the paper suggested that a gene drive could be used to effectively suppress and control their negative ecological impacts.

Though the paper did not specifically identify Aotearoa New Zealand as a good candidate region, it did explicitly state that gene drive might be used to “promote biodiversity by controlling or even eradicating invasive species from islands or possibly entire continents” (Esvelt et al. 2014a, 15). It did not take long for groups like Predator Free 2050 to connect the dots. Over the following years, gene drive grew to be one of the most high-profile technologies considered for invasive species control in Aotearoa New Zealand (Murphy et al. 2019).

Esvelt and his collaborators’ 2014 paper described gene drive as a technology for large-scale ecological engineering by causing a particular genetic element to be inherited in a sexually reproducing population at a much higher rate than that of typical probabilities of inheritance. Increasing the rate of inheritance results in the rapid propagation of that genetic element in a targeted population such that “over many generations, this self-sustaining process can theoretically allow a gene drive to spread from a small number of individuals until it is present in all members of a population” (Esvelt et al. 2014a). Though there are naturally occurring instances of gene drive (Trivers and Burt 2009), the 2014 proposal by Esvelt and colleagues relied on CRISPR-Cas 9 genome editing techniques to construct an engineered gene drive.

With CRISPR genome editing, new genetic elements are introduced by cutting the genome at a specific locus and providing an engineered DNA template which contains the desired genetic edits. First, an endonuclease protein is guided by custom-designed RNA molecules to specific, target locations in the genome. Once the endonuclease is guided to the target site, it cuts the DNA, introducing a double-stranded break into the genome. Upon detecting the double stranded break, the cell’s natural DNA repair processes attempt to repair the cut site, using the engineered DNA template as a guide. As a result, whatever desired genetic edits were included in the DNA template are copied and inserted into the genome.

To construct a gene drive, Esvelt and colleagues proposed inserting the genes for the CRISPR-Ca9 endonuclease, the guiding RNA molecules, as well as the genetic element to be driven into the genome. That way, any edited cells would also include the genes to produce more genome-editing CRISPR systems. Instead of a single genome editing event, a CRISPR-based gene drive and would continue to target, cut, and edit at the specified site in the genome indefinitely. For diploid species reproduction, that meant that if any offspring inherited an edited chromosome from one parent containing a gene drive, the analogous site in the chromosome inherited from the other parent would also be edited to contain the gene drive. As such, if an organism edited with gene drive were to reproduce, even with a wildtype organism, the genomes of all resulting offspring would contain the gene drive and the desired genetic edits, ensuring its continued self-propagation.[36]

The paper's description of gene drive function and invasive species control was heavily mechanistic. Esvelt and colleagues appealed to the molecular biology of CRISPR genome editing as part of the "mechanistic reasons" why gene drive was an effective means of controlling invasive species (Esvelt et al. 2014a, 2). Specifically, they argued that "if population-level engineering is to become a reality, all molecular factors relevant to [CRISPR genome editing] must be considered" (Esvelt et al. 2014a, 5). In doing so they employed a mechanistic notion of control in which biological engineering depended on sufficient knowledge of the underlying biochemical processes.

The paper also identified possible risks of gene drive use, namely the risk of a gene drive getting out-of-control. Esvelt and colleagues identified rare mating events and geographical leakiness of gene drive as some of main risks in which gene drive might spread to non-targeted species or regions. The strategies for mitigating those risks were to render gene drive more controllable through further acts of genetic engineering. Proposed solutions included introducing additional gene drive systems to counteract or outcompete the effects of a gene drive gone rampant, genetically engineering invasive species to have

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[36] For greater detail of CRISPR Cas9 function as it pertains to gene drive construction, refer to source Figures 3 and 4 (Esvelt et al. 2014a).

unique genomic sequences for more precise targeting by a future gene drive, and the introducing genetic sensitivities to less toxic molecular compounds for more traditional chemical control (Esvelt et al. 2014a, 13-17). In the risk management strategies posited, keeping gene drive under control was possible through the mechanistic control of genetic engineering, closely linking the manipulation of molecular-level processes to the control of populations and ecosystems.

Gene Drive and Responsive Science

Part of how gene drive became preeminent among biotechnologies for invasive species control was its use of CRISPR genome editing. In the years before the announcement of Predator Free 2050, the science and popular media was inundated with news of the "CRISPR revolution" in biology with rippling implications across global societies (Pennesi 2013; Barrangou 2014; Ledford 2016b). The synchronous development of New Zealand's Predator Free 2050 initiative with the scientific fervor around CRISPR genome editing brought significant attention to gene drive and its applications—including invasive species control, particularly of invasive rodents. The hype and molecular precision afforded by CRISPR genome editing promised that gene drive would enable greater control of invasive populations through greater precision of biological engineering, sidestepping the negative environmental impacts of traditional methods of invasive species control.

Gene drive also benefited from the high-profile actions of one of its inventors, Kevin Esvelt himself. Esvelt assumed a prominent and presumptive leading role in the unfolding discussions around the applications of gene drive. His influence on perceptions and consideration of gene drive and genetic engineering more broadly was significant. Not only was Esvelt a scientist at one of the world's most academically and socially elite research institutions, but he was also a charismatic media figure, sitting for numerous interviews and hosting public meetings to explain the science behind gene drive and to discuss the possible risks and benefits of its applications with a wide audience (Esvelt 2015a; Specter 2016; NOVA Wonders 2018).

Esvelt's emphasis on broader discussions about gene drive applications was not without principled cause, however. His participation in gene drive discourse, assuming a position as leading voice for the future of gene drive followed directly out of his commitments to a particular vision of responsible scientific research, which he termed "responsive science" (Responsive Science 2018). For Esvelt, responsive science was "a way of conducting research that invites openness and community involvement" from those that stood to be affected by the applications of technologies like gene drive and entailed that scientists are "morally responsible for all consequences" of their research (Esvelt 2015b). As such, Esvelt argued that scientists like himself are obliged to participate in and help inform discussions about the applications of his research on gene drive. Esvelt considered himself to have a personal, moral responsibility to ensure that if gene drive was to be developed at all, that it would be done so in a way that was sensitive to the interests and participation of the local communities where the technology would be used. In linking his sense of personal responsibility to the future uses and ultimate control of gene drive, Esvelt blended together notions of individual responsibility and scientific responsibility. As a result, Esvelt began to frame responsible development of gene drive in terms of a mechanistic conception of life and notion of control.

Problems with Controlling Gene Drive

Esvelt came to regret suggesting that controlling invasive species as a possible application of gene drive. Despite initial enthusiasm behind gene drive for controlling invasive species, as his research group continued to study gene drive, they became increasingly aware of what they identified to be a significant problem.

The problem with the standard gene drive system that Esvelt's research group had described in 2014 as a tool for invasive species control was precisely that—control.

The standard version of gene drive that had been proposed was a self-propagating, potentially globally-spreading system. If a standard gene drive were released into the environment, Esvelt and others argued that it would "likely to spread to every population of the target species throughout the world" as well as possibly to closely related species (Esvelt and Gemmell 2017). Given that one of the primary targets for gene drive control, invasive rodents, are also among some of the most globally distributed species, the possibility of unintentional gene drive spread was particularly alarming. Ironically, gene drive, the very technology designed and proposed to stem the spread of invasive entities and restore native, local environments, was itself an invasive threat to global ecosystems.

Even if the risk mitigation strategies they suggested were employed, it was increasingly clear to them that they could not ensure that a gene drive would remain localized geographically or to targeted invasive populations. Containment of gene drive to targeted invasive predator populations, even on the relatively isolated islands of Aotearoa New Zealand, was an unrealistic expectation given the realities of a highly interconnected global travel and trade systems. Unintended transmission of a standard gene drive could be facilitated by the same means by which rodents came to Aotearoa

New Zealand in the first place—as stowaways commercial shipping vessels. Standard gene drive spread to some non-invasive populations globally was likely, if not unavoidable.

Standard gene drive simply was too unwieldly for the localized control needed for addressing invasive species in a particular region. Esvelt later said of his initial suggestion that it was "profoundly wrong of me to even suggest it, because I badly misled many conservationists who are desperately in need of hope. It was an embarrassing mistake" (Esvelt 2017c). In Esvelt's view, standard gene drive was untenable for conservation because it was not sufficiently controllable. Despite the emphasis in the initial paper on the molecular controllability of gene drive, Esvelt later wrote of standard gene drive saying that it "lack[ed] control mechanisms and are consequently highly invasive" (Esvelt and Gemmell 2017). It did not allow for modulation of its effects once released, nor did it lend itself to biological containment measures. By early 2017, Esvelt had expressed significant skepticism as to how well a standard gene drive could be reliably contained. Ultimately, it was its own efficiency made standard gene drive difficult to control, given the self-perpetuating way in which it propagated (Science Media Centre 2017).

Notably, their conclusion that standard gene drive proved to be less than controllable relied on the mechanistic logic and notion of control that had become integral to modern biological practice. If life was brought under control by the understanding and manipulation of more fundamental components, then the lack of control was made evident by virtue of knowledge about the genetic and biochemical functionality of gene drive as insufficiently amenable to producing the kinds of phenomena desired. Even argued in the negative, it was the knowledge about the self-propagating features of standard gene drive on a molecular-level that was determinant in whether or not one had control over the entire function of the gene drive. Likewise, not only were invasive species populations to be controlled, but the technological means of that control also were a locus that required its own modes of control. The precise molecular manipulation which underwrote the claims to control of invasive species was also translatable to the control of gene drive itself. The various mitigating strategies presented indicated latent concerns about controlling the controls of life and further underscored the degree to which mechanistic approaches made controllability paramount. Standard gene drive was treated as a biological genie which, once released, could not be put back in the bottle.

Daisy Drive and Mechanistic Control

Beginning in 2016, Esvelt's research group published research on an alternative to standard gene drive, called daisy drive. Unlike standard gene drive, daisy drive promised greater innate controllability of invasive populations. Daisy drive was a variant of gene drive technology which Esvelt's group likened to a "daisy-chain" of serially linked gene drive systems. In a daisy drive, the molecular components of the gene drive were linked in "a linear series of genetic elements arranged such that each element drives the next in the chain," ultimately culminating in the driving of the desired genetic trait in the target population (Noble et al 2016).[37] No genetic element drove itself, so the spread of the

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[37] For a more comprehensive explanation of daisy drive design and function, see source Figure 1 (Noble et al 2016).

desired genetic trait was dependent of the successful driving of each of the prior, requisite parts. The daisy drive would function only if each of the necessary drive components were present.

Crucially, components earlier in the chain were designed to dissipate over a predictable number of generations. The result was that a daisy drive would have rapid initial spread in a targeted population but would eventually degrade and dampen in its effect and prevalence at a stable rate. The rate at which a drive might degrade could also be modified to be faster or slower, according to the amount of generational penetration and geographical spread desired for a particular application (Noble et al. 2016, 2).

The metaphor of a daisy-chain itself invoked a mechanistic accounting of complex biological function as the result of step-wise, causal relations between biological parts. Esvelt's research explicitly identified the manipulation of the molecular parts of daisy drive as the basis for the greater control saying, "By using **molecular constraints** to limit generational and geographic spread in a **tunable manner**, daisy drive approaches could expand the scope of ecological engineering by enabling local communities to make decisions concerning their own local environment (Noble et al. 2016, 11, emphasis added).

Esvelt's articulation of daisy drive invoked heavily mechanistic understandings of control. He analogized the function of molecular parts to control knobs altering population and ecosystem outcomes vis a vis invasive species. The mechanistic conceptions of control embedded in standard gene drive are only further reified in the notion of controlling life articulated in daisy drive. Daisy drive added more molecular and genetic parts, more mechanical relations between those parts, promising a greater degree and a finer resolution of control for both gene drive and invasive species. The metaphor of tunable control over daisy drive also suggested wider range of possible intensities or frequencies of particular applications. Linking greater technical control to local decision-making about gene drive implies there are more options on the table to choose from—not just whether to use gene drive, but how, to what extent, when, and by whom. It is worth noting, then, that in Esvelt's group's articulation of daisy drive, it was the increased controllability of daisy drive that was credited with the placing decision-making power in the hands of local communities. Esvelt's group explicitly linked together the mechanistic account of control afforded by daisy drive to the empowerment of local communities to make decisions about the use of gene drive. Local co-governance and decision-making about gene drive was enabled precisely because of the predictable control afforded by control of the molecular biology and genetics of gene drive, embedding a logic of mechanism in the articulation of the function of gene drive and the social ordering that they authorize.

In doing so, what it meant to do responsible science was linked with the mechanistic notions of control of daisy drive. Mechanistic control of gene drive was made out to be not only necessary for the technical challenges of conservation, but also a prerequisite for any practice of responsive science. The alignment of greater mechanistic control with values of Esvelt's paradigm of responsive science suggests that responsible scientific research also necessarily requires mechanistically controllable technologies. Mechanistic notions of controlling life, thus, become essentialized to responsible scientific practice. Such articulations of responsibility subtly reinforce mechanistic approaches to control as not only technologically practical, but also normatively necessary for biological engineering technologies like gene drive. More importantly, greater control of gene drive enabled the offloading of decision-making to local communities while still maintaining a position of moral responsibility over gene drive by virtue of the fact that the mechanistic tunability of gene drive control remained within the purview of scientists like Esvelt.

Community Engagement and the Limits of Mechanism

Convinced of the inherent uncontrollability of standard gene drive, Esvelt began a campaign to push for the adoption of the daisy drive variant in considerations for the use of gene drive for invasive species control in Aotearoa New Zealand. Esvelt's advocacy included personally traveling to the island nation, interviewing with local news media (Evans 2017; Esvelt 2017e), and a public meeting at the University of Otago in Dunedin in September of 2017, inviting interested community members, policy makers, and conservation organizations to participate in an open dialog about gene drive and invasive species control (Esvelt 2017b). The meeting provided Esvelt an opportunity to articulate his case for the control advantages offered by daisy drive if it were decided to move forward with the technology.

At the meeting, Esvelt met with individuals involved with the Predator Free 2050 initiative, the New Zealand government, and members of Māori-led organizations like Te Tira Whakamātaki (The Māori Biosecurity Network) with a record of representing Māori interests. Esvelt placed particular emphasis on including indigenous Māori groups in discussions about gene drive. In part, Esvelt was attempting to practice responsive science to include affected communities in discussions about the possible use of gene drive. Esvelt had stated, “ultimately, the decision of whether to guide the development of daisy drive is up to the people and government of New Zealand” (Esvelt 2017d). Not only was doing so consonant with Esvelt’s commitments to his “responsive science,” but it was also a politically important maneuver for the consideration of gene drive in Aotearoa New Zealand given the complex relationship between the Māori and the New Zealand government as a result of the colonial history that continue to be felt.[38]

The attempts by Esvelt to be attuned to the cultural and political realities for Māori communities was evidenced in the content and tone of what he presented at the Otago meeting. He identified Māori co-governance of gene drive as a fundamental and necessary prerequisite for himself and his involvement with any future use of gene drive on the island nation saying that “if Māori are not broadly supportive of a proposal [to use gene drive], our group will have no part of it” (Esvelt 2017d). Esvelt committed to partner with Māori communities in conjunction with New Zealand government and other organizations as part of broader discussion about the use of gene drive for invasive species control in attempts to ensure co-governance of the technology. Esvelt went as far as to incorporate Māori terms, language, and concepts into his descriptions of gene drive and the environment and acknowledged that Māori communities should have input about gene drive governance even if not put into scientific vocabulary (Esvelt 2017d).

Yet, the account of gene drive for invasive species control he presented at the meeting still mirrored the mechanistic notions of control that Esvelt and his colleagues

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[38] Under the 1991 Resource Management Act, the Māori gained some legal rights to co-governance of New Zealand’s natural and physical resources—including the management of invasive species. The relationship between Māori communities, the New Zealand government, and scientists, however, remains contentious, particularly around environmental, genetic, and biotechnological issues. (New Zealand Legislation, 1991).

had published previously. The function of gene drive and human control of it retained the heavily emphasis on mechanistic descriptions and explanations, especially regarding daisy drive. Risks were framed as pertaining to the geographic spread and biological effectiveness of gene drive to control invasive populations, and they were accordingly addressed by the control advantages of daisy drive (Esvelt 2017c). The focus remained on the molecular tools implemented, the genetic changes they caused, and the resultant impact on invasive populations.

However, despite his attempts to be culturally sensitive and inclusive of Māori communities in discussions about the use of gene drive, Esvelt nevertheless did not recognize and attend to an entangled history of science, indigenous peoples, and meaning (Helmreich 2005; Reardon and TallBear 2012; Kowal, Radin, and Reardon 2013). The reductive, mechanistic approaches to knowing and controlling life that he emphasized themselves were not neutral but were wrapped up in the alignment of science with projects of colonization, systemic displacement, and epistemic violence toward indigenous people and ways of knowing. Māori communities in particular had a long history with extractive, colonial science regarding biotechnologies like genetically modified organisms and approaches to environmental conservation (Robers 2005; Tipene-Matua 2006; Reynolds 2007; Waitangi Tribunal 2011). The longstanding and continued actions of scientific and colonizer actors had led to skepticism and suspicion of reductive, mechanistic bioscience and the ways that such technoscientific practices impact local environments and cultural values (Hutchings and Reynolds 2005).

Esvelt's lack of engagement with the complex, colonial relationships between science and Māori communities alongside his advocacy for the potential use of gene drive was yet another instance in a history of epistemic dispossession of indigenous people of lands, rights, and identities enabled and underwritten by scientific practice. By not attending to that history as part of his engagement with Māori communities, Esvelt demonstrated that he was not only unaware of the local politics and ecologies of the Aotearoa New Zealand but also of the historical context and stakes for engaging responsibly in the shadow of scientific colonization. As such, Esvelt's inattentiveness to histories of science and empire was not just a case of an individual scientist's missteps or irresponsibly but was symptomatic of the broader limitations of mechanistic conceptions of controlling life to consider the historical, social, political, and cultural aspects of implicated in aspirations to engineer life and practice responsible science.

Furthermore, by describing control for gene drive primarily as a matter of the interactions of mechanistic biological parts, Esvelt also reinscribed a particular vision of nature as being shared between himself and Māori communities. Esvelt's mechanistic approach brought with it commitments to reductive, materialistic explanations as sufficient for knowing organisms, that organisms themselves were reducible to more basic biochemical and genetic parts. Moreover, Esvelt's engagement with Māori communities about gene drive presumed that the issue was primarily one of culture and cultural difference, not epistemic or ontological difference. Taken for granted in that translation was an understanding that the features of gene drive and invasive species control in Aotearoa New Zealand were correspondent to the same entities, that there was a singular, shared nature that was perceived through different cultures (Latour 2004).

However, the constructions of what constitutes nature and what constitutes life were precisely what was at stake in those disjunctures in ways of knowing the world.

Distinctions such as what constitutes “living” and “non-living” entities and how one has particular kinds of knowledge or beliefs about the features and significance of organisms, their environments, and broader contexts of place relating to biodiversity and geography are not always shared between Western and indigenous approaches to knowledge (Povinelli 2016; TallBear 2017). Likewise, significant scholarship has demonstrated that sharp differentiations between epistemology and ontology in Western knowledge systems are also not necessarily shared by indigenous worldviews (Smith 2013; Watts 2013).

While Māori perspectives towards genetic technologies are not monolithic regarding gene drive or biotechnologies more broadly, Māori scholarship has demonstrated that Māori understandings of nature are not the same as those common to mechanistic biology, nor are the reducible to or necessarily incoherent them (Cram, Pihama, and Barbara 2000; Roberts 2005; Hudson et al 2019). Māori visions of the world situate humans within an ancestral lineage that draws and binds together human and non-human, animate and inanimate in a genealogical heritage of historically, culturally, and spiritually significant relations rather than as causally-linked, mechanical parts (Schwimmer 2004; Hudon et al 2019). Scientific conceptions of mechanistic biology and indigenous Māori knowledges were not merely culturally distinct ways of understanding a shared natural world, but fundamentally different ways of constructing of nature itself.

By not attending to the multiplicity of constructions of nature and how one knows it, Esvelt naturalized his own mechanistic approaches and presumptions about gene drive and control. Esvelt’s commitments to mechanistic explanations of the controllability of gene drive implicitly asserted Western, scientific constructions of nature as the normatively right way of understanding the world. As the epistemic basis of making gene drive predictable and controllable, mechanistic understandings of life were also how, for Esvelt, one would “responsibly” ensure Māori co-governance of the technology. In doing so, however, Esvelt pre-framed mechanistic approaches as the animating vision of engineering life in ways that would reflect the limits of biological mechanism and his inattention to the historical and political stakes for Māori communities.

Relational Missteps and Gene Drive Co-governance

The deficiencies in Esvelt’s mechanistic approaches to controlling gene drive were soon made manifest in the fallout surrounding his controversial publication of new gene drive research. In November of 2017, Esvelt and Neil Gemmell, a scientist colleague from New Zealand, published a scientific manuscript that described the deployment of daisy drive as a potentially preferable, more controllable solution for invasive species control (Esvelt and Gemmell 2017, 5). The paper built on the previous months of community engagement discussion about the use of gene drive in Aotearoa New Zealand for invasive species control, and though the paper did not overtly prescribe gene drive for addressing invasive species concerns, it did specifically identify New Zealand as a possible candidate location for it. Rather than gene drive being one of many possible pathways forward, some perceived the message of the paper to be that the daisy drive variant was a tailored fit for New Zealand’s invasive species problems (Biological Heritage National Science Challenge 2017).

The day after the publication of the manuscript, some of Esvelt’s Māori collaborators responded, wanting to understand why they had not been made aware of the forthcoming publication mentioning their home as a possible gene drive test site and why they had not been included in the process of reviewing the manuscript given the emphasis on community involvement that had been so prevalent during Esvelt's push for daisy drive over standard gene drive. One Māori scholar and the then Chief Executive of Te Tira Whakamātaki (The Māori Biosecurity Network), Melanie Mark Shadbolt criticized the paper saying it "unashamedly pushes for the use and consideration of their research" and failed to "build respectful relationships with indigenous peoples/communities"(Shadbolt 2017). Shadbolt further critiqued the paper saying that because of the exclusion of Māori partners from every step of the gene drive development process "it is now possible that Māori may never get co-governance in the discussion and/or development of gene-drive technologies" (Shadbolt 2017). Such critiques from Māori scholars like Shadbolt characterized the stakes of gene drive for Māori communities as involving not only their biological function but also how they would be developed and governed. By undermining Māori participation in the process of gene drive development, Esvelt and his research group—despite intention to the contrary—were seen to have potentially irreparably jeopardized Māori access to meaningful co-governance of gene drive for invasive species control.

Shortly after the critical reception of the paper, Esvelt published a public apology on his research group's website. He openly acknowledged his failure to include his Māori collaborators to participate in the publication of the manuscript as a mistake saying, "I singularly failed to uphold the ideals of Responsive Science" (Esvelt 2017b). Despite his overt attention and emphasis to do otherwise, Esvelt's failure to fully include his Māori partners further added to a history of harms and injustices against indigenous people under the banner of science. In addition to bringing into sharp relief the longstanding failures of science to shed its own institutionalized, colonial habits, it also highlighted the limitations of biological mechanism. Mechanistic approaches circumscribed the kinds of futures imagined in engineering aspirations to those that similarly characterize control of life in terms of stepwise, causal relations among biological components. Alternative conceptions of life, as well how one knows and controls it, were displaced by Esvelt's presumption of the epistemic supremacy of mechanistic science.

Esvelt accepted responsibility for his actions and their possible consequences for the Māori and the governance of gene drive, and he committed to a redoubling of efforts to restore trust and make amends. Amends-making would include meeting again with his Māori partners in Te Tira Whakamātaki (the Māori Biosecurity Network) and the Te Herenga Māori (the Māori National Network) early in the following year to continue discussing their interests, concerns, and ideas for the future of gene drive in Aotearoa New Zealand (Esvelt 2017b). In those meetings, Esvelt stated that he hoped to both improve his understanding of whether and how gene drive might be a help to local communities and ecosystems, as well as how he might "best fulfill [his] broader responsibilities to the world beyond" (Esvelt 2017b). However, how that process would unfold and with what impact for the future of gene drive and the role of the Māori in its governance remained unclear.

Conclusions

The controversy around Esvelt's manuscript publication without Māori input was not only a case of the continued relational missteps of scientific research amplified by Esvelt's own vigorous assertions to do otherwise. It also was suggestive of the disjunctures in what is salient to controlling life. The disconnect between in-depth discussion of the differences of standard gene drive versus daisy drive technologies and considerations of the relational realities for potentially affected communities reflected the emphasis of mechanistic approaches on reductive, technical explanations of controlling life. The oversight of not including his Māori partners was not only indicative of Esvelt's naiveté of the contested political situation of Aotearoa New Zealand but also of the limitations of mechanistic notions of control to consider alternatives.

The discussions and controversy around the use of gene drive for invasive species control in Aotearoa New Zealand show how a heterogeneity of notions of control, both of biological entities and the technologies employed to control them, simultaneously exist with aspirations to remake the natural world. However, such aspirations are not merely a technological expression of environmental engineering or design. Ascertaining what forms of life are sufficiently native or invasive, and therefore ought to be protected or eradicated, is inherently value-laden and normative, as are decisions about if and how gene drive might be used to do so. Questions of who is empowered to make such determinations are fundamentally social and political matters. Likewise, control of invasive species is also simultaneously an exertion of control over the kinds of cultural memory and narrative about the history of native and invasive species in that environment and humans' relationships with it (Foucault 1978; Boswell 2018). What it means to control life has implications not only for particular instances of biological engineering, but also for what, or whose, visions of nature remade are instantiated. In the making of particular epistemic visions of an engineered nature, so, too, are particular social formations of the world constructed (Jasanoff 2004). To repurpose the words of

Philip Pauly, the concepts of control employed are consequential for the kinds of "engineering ideals" they realize (Pauly 1987).

Implicitly, mechanistic approaches to understanding and controlling life embody an engineering ideal akin to that of Jacques Loeb in the early twentieth century. His engineering ideal entailed a privileging of biochemical explanations for more complex biological phenomena and embodied a notion of control as the repurposing of biological processes according to human volition. Control over the natural world was the chief purpose of scientific practice (Pauly 1987).[39] Contemporary biological approaches are more than reminiscent of Loeb's mechanistic conception of life. They are a direct continuation of a scientific tradition that locates control of life in the ability to understand and manipulate biological parts to produce intended phenomena. In so doing, they authorize a vision of the world in which non-biochemical dimensions of controlling life are systematically occluded. Such elisions of history and context are a serious lapse, especially so because the motivations for engineering nature are inextricably intertwined with human values and desires for a reimagined world. It is critical, then, in the undertaking of engineering life to reflect not only what it means to control life, but in so answering, to also recognize whose ultimate visions of nature and society remade are thereby privileged and made real.

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[39] See commentary at note 32.

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CHAPTER 5

HANDMAIDEN OF TECHNOCRACY: PUBLIC ENGAGEMENT AND EXPERTISE IN HERITABLE HUMAN GERMLINE EDITING GOVERNANCE

In recent years, the place of expertise in democratic decision-making has become increasingly contested. Science and technology are often fraught with technical, political, and ethical complexities and uncertainties, which many consider as requiring particular, specialized knowledge to navigate accurately and effectively. Yet, the status of expertise as an unquestioned source of authority remains hotly disputed in many areas of public discourse, calling into question who ought to have a say about science and technology, with what authority, and for what reasons. Such tensions about the right relations between experts and publics present acute challenges for effective and democratic technoscience decision-making.

One prominent response to such challenges has been commitment to public engagement with science and technology as essential components of democratic governance (Wynne 1993; Jasanoff 2003a; Giddens 1998; Leach, Scoones, and Wynne 2005; Callon, Lascoumes, and Barthe 2001; Stilgoe, Lock, and Wildson 2014; Chilvers and Kearnes 2020). The prevailing notion has been that "increased participation and interactive knowledge-making may improve accountability and lead to more credible assessments of science and technology" (Jasanoff 2003a, 243). Such calls for public engagement marshal democratic values of transparency, participation, and inclusion of diverse perspectives as ways to improve technoscience decision-making (Guston and Sarewitz, eds. 2006; Barben et al. 2008; Stirling 2005; Stilgoe, Lock, and Wilsdon 2014). Public engagement has come to be invoked as a remedy to ease tensions between expert authority and democratic representation in technoscience decision-making. However, despite the significant attention given to public engagement, precisely what public engagement entails and seeks to achieve vis a vis expertise and decision-making lacks unified consensus (Delgado, Lein Kjølberg, and Wickson 2011).

While understandings of the public have largely moved beyond the deficit portrayals of the public as merely ignorant, disinterested, or distrusting of science (Wynne 1991; Ziman 1991; Evans and Durant 1995), answering the question of who constitutes “the public” is a messy task. “The public” is not a singular, monolithic group but a plurality of multiply realizable publics with diverse interests, values, and attitudes towards technoscientific issues (Jasanoff 2012).

However, publics qua publics are not preexistent, natural entities out in the world but are the result of thoroughly social and generative activities. Frequently, publics form as the result of solicitation of particular “invited” publics by convening institutions and governments to create “mini publics” (Irwin 2001; Stilgoe 2009; Goodin and Dryzek 2008; Felt and Fochler 2010) as ostensibly representative units of democratic deliberation. Notions of “the public” are better understood, then, as collectives in shared social spaces formed around matters of mutual interests and decision-making, and less as a natural category of people with common interests existing “out there” in the world (Jasanoff 2014).

Similarly, what constitutes “engagement” with publics, however constructed, is not *a priori* obvious nor widely agreed upon. Review of the literature reveals a plethora of often contradictory definitions, models, and practices for engagement, ranging from one-directional, educational interventions to more bi-directional, participatory modes of governance (Wilsdon and Willis 2004; Rowe and Frewer 2005; Rowe et al. 2008; Barben et al. 2008; Burgess 2014). There has been some convergence around the notion that the goals of public engagement "had to do with linking science with politics" (Nowotny 2014), but much of public engagement work, in-practice, has centered instead on understanding the methods, mechanisms, and modes of designing, implementing, and evaluating public engagement interventions in-practice (e.g., Irwin 2006; Guston 2014a; Kleinman, Delborne, and Anderson 2011; Tomblin et al. 2017; Rowe et al. 2008; Carr et al 2014.; Neuhaus 2018).

However, further exploration of the reasons of whether, and under what conditions, engagement with science and technology is desirable have led to tensions regarding how publics and experts ought to be involved in democratic decision-making (e.g., Rip 2003; Bijker 2003; Collins, Weinel, and Evans 2010; Durant 2011). At times, the rationale for why public engagement is important for decision-making appears to be as straightforward as "the technical is political, the political should be democratic, and the democratic should be participatory" (Moore 2010). Accordingly, some scholars have strongly argued that some deference to technical experts on the basis of specialized knowledge are both justified and necessary for democratic societies (Collins and Evans 2002; 2008; 2017). That experts are fallible and susceptible to corruption and conflicts of interest is not sufficient reason to reject a privileged role of expertise in decision-making where said expertise is salient, as in matters of technoscience (Durant 2019). Moreover, they maintain that their skepticism of public engagement as a democratic panacea has been further validated in light of developing cultural narratives in which trust in experts is described by some as in decline in the wake of rising anti-science, anti-intellectual movements in democratic societies (Collins, Evans, and Weinel 2017).

Others, however, argue that reliance on experts to inform public decision-making as potentially dangerous for democratic societies if left unchecked and not kept within a narrow area of delegated authority to render expert judgements (Jasanoff 1990), or as definitely dangerous because the power of experts undermines the potential for extended discussion outside of technoscientific frameworks (Wynne 2016). Though expertise has been commonly used to differentiate "ordinary citizens" (Powell et al. 2011) from experts with specialized, technical knowledge and credentials, the bright lines between laypersons and experts often fade under scrutiny of how non-expert publics generate their own forms of expertise with distinct experiences and specialized knowledge that traditional experts lack (Wynne 1996).

Privileging the perspectives of technical experts is reflective of prior judgements about who ought to have standing in technoscientific decision-making and fails to recognize how appeals to expertise render expert judgments as naturalized, objective knowledge and not as subjective matters to which experts ought to be held accountable (Jasanoff 2003a, 2005; Wynne 2003, 2007). Public engagement with science and technology, then, serves as a democratic and epistemic check on technocratic power and authority in matters of public decision-making.

In this chapter, I examine how public engagement comes to be constructed such that it holds with imperatives for good governance of complex technoscientific issues as well as to maintain a normatively democratic relationship between science and the public. I do not intend to evaluate or participate in the disputes over the rightful places of expertise or publics in technoscientific decision-making as others have (Durant 2008; 2011; Sismondo 2017). Rather, I take the contestation of whether and how to do public engagement itself as a starting point to investigate the relationships among scientific expertise, publics, and technoscientific governance. More specifically, this chapter analyzes the forms of democracy "in the making" (Jasanoff 2004; Chilvers and Kearnes 2016; Laurent 2017) implicated by particular constructions of public engagement and the associated consequences for governance of science and technology (Irwin 2001; Jasanoff 2005; Chilvers 2008). To do so, I analyze scientific expert discourse about heritable human germline editing beginning from the 2015 International Summit on Human Genome Editing through the controversy surrounding the first CRISPR edited humans and renewed calls for a moratorium on germline editing, as a case study of such contestations. I argue that rather than expanding the range of stakeholders represented, public engagement, in fact, reinforces the position and perspectives of scientific experts in technoscientific decision-making. Specifically, I argue that expert discussions around heritable human germline editing frame public engagement primarily as a means of resolving public controversy and building societal consensus about heritable human germline editing and clearing a path forward for clinical germline editing. By calling for meaningful public engagement, experts thereby assert themselves as socially responsible actors, while at the same time stabilizing their positions of influence in decision-making as both epistemic and normative authorities.

Background

Since the development of CRISPR gene editing (Jinek et al. 2012) there has been much attention paid to the potential human applications of the technology. In recent years, numerous meetings and international summits have convened to discuss the scientific development and governance challenges of human genome editing (NASEM 2015, 2018; Nuffield Council on Bioethics 2018; WHO 2019; NAM, NAS, the Royal Society 2019; 2020). Human genome editing brings with it both the hype of unprecedented biological innovation as well as specters of societal catastrophe. Those tensions are compounded by the rapidity of the emergence of human genome editing and the potentially far-reaching societal implications of its use.

Applications of human genome editing tend to fall into two main categories: somatic editing and germline editing. Somatic editing targets fully-developed, human body cells, similar to gene therapy. The effects of any genetic edits are therefore localized to the areas of the body of the treated individual. Somatic editing applications are thought to be less controversial (Polcz and Lewis 2016) and broadly addressed by existing regulations (NASEM 2017) with clinical trials greenlit in the US (Sheriden 2018). Germline editing, however, has been much more contentious (e.g., Lanphier et al. 2015; NASEM 2017; Baylis 2019a; Andorno et al. 2020). Unlike somatic editing or gene therapy—heritable germline editing targets reproductive cells before fertilization or at the earliest stage embryos for genetic modification in order to correct a genetic mutation or disease before fully manifested in more developed individuals. Any germline genetic edits are, in principle, present in every cell throughout an individual’s body, including their reproductive cells. The result is that genetic edits of the germline can be inherited by future generations—in the same manner as any other genetic trait. Such potent technology to enable alteration, not only of current bodies, but also those of future humans has raised issues that have been scientifically complex, socially controversial, and ethically fraught.

The stakes surrounding heritable human germline editing have continued to heighten in the wake of the 2018 announcement of the birth of twin girls, the first gene edited humans, in China (Cyranoski and Ledford 2018; Marchione 2018; Regalado 2018). The ensuing flurry of condemnation by various scientists, governments, and international organizations (Wee 2018; Zhang et al. 2018; Organizing Committee 2018a) have characterized the event as the result of unethical actions of an alleged rogue scientist, He Jiankui. The news precipitated renewed calls for a moratorium on heritable germline editing research (Lander et al. 2019) and proposals for international oversight organizations (WHO 2019; NAM, NAS, the Royal Society 2019, Jasanoff and Hurlbut 2018). Yet more severely, in the final days of 2019, Chinese courts convicted and sentenced He Jiankui for the procedures which were found to be "illegal medical practices," carrying a three-year prison sentence and three million yuan fine (Normille 2019). Nevertheless, similar plans by another scientist in Russia to edit human egg cells continued with the goal of altering genes associated with deafness (Cyranoski 2019). The governance of heritable human germline editing remains as unsettled and high-stakes as they are complex.

With regard to heritable human germline editing, public engagement has been appealed to as way to grapple with its ethical, social, and legal implications in society by promoting diverse, inclusive participation in those deliberations. Although, in-practice, what public engagement around heritable germline editing entails has been or would intend to achieve has been less certain (Burall 2018; Nature Editors 2018; Bayliss 2019b). Some have criticized the particular framings of public engagement around heritable human germline editing as being perfunctory, one-off events that serve more as box-checking exercises than as democratic deliberations. They can also be exclusive of particular groups, requiring scientific values or technical proficiency about gene editing as prerequisites for participation. Such framings of public engagement, they argue, constrain the terms and agenda of public engagement in ways that innately privilege the knowledge and interests of scientists (Jasanoff, Hurlbut, and Saha 2015; 2019).

However, how public engagement has come to be constructed such that it conceptually and institutionally remains a recognizable aim and practice, while at the same time being heatedly disputed and contested, has not been attended to. Interrogations of the construction of public engagement in particular ways are fundamentally concerned with the purposes and interests that are thereby served. Closely examining the framings of public engagement provides opportunities to analyze how the stakes of heritable human germline editing, the epistemic authority of scientific experts, and the participation of publics come to be negotiated, disrupted, and reinforced. Scrutiny of public engagement, then, provides opportunity to study not only to whose voices are amplified or silenced in technoscientific decision-making, but also the forms of democratic order that are simultaneously underwritten.

Not for Science Alone

In the fall of 2015, the US National Academies of Science and Medicine, the Chinese Academy of Science, and the British Royal Society convened a joint summit in Washington, D.C. to discuss and address growing questions and concerns regarding advances in gene editing and its potential use in humans. The three-day summit brought experts from across the globe—from scientific and non-scientific backgrounds—for a series of thoughtful panel and round-table discussions focused on the “scientific, ethical, and governance issues associated with human gene editing research” (NASEM 2015).

In the lead up to the Summit, prominent summit organizers had published initial guidelines for decision-making about human gene editing, and germline editing in particular, to find a “prudent path forward” (Baltimore et al. 2015). A prudent path forward, they argued, centered first on discouraging attempts at heritable human germline editing until frameworks of open discourse to “consider the risks and rewards of using such powerful technologies…and the attendant ethical, social, and legal implications of genome modification” were developed (Baltimore et al. 2015). Deliberation and discussion in broader society were understood as necessary first steps to moving toward applications of heritable human germline editing.

However, the aim of creating opportunity for those discussions to take place was firmly to advance and “enable pathways to responsible uses of this technology” (Baltimore et al. 2015). The prevailing attitude was that human gene editing held enormous opportunity for societal benefit in its “promise of curing genetic disease, while in other organisms it provides methods to reshape the biosphere for the benefit of the environment and human societies” (Baltimore et al. 2015). On that framing, such advancing of human gene editing in a responsible manner was characterized as a virtuous pursuit of a public good. While the ethical, social, and legal ramifications of germline gene editing needed to be attended to, the technical development of germline gene editing was equated with the opportunity for societal progress. Deliberation about the societal implications and permissibility of germline gene editing became construed as being in service of movement along that prudent path forward.

The 2015 Summit began in a similar tone. Summit organizers argued that because the stakes were so high and far-reaching for dramatic human benefit or harm that “the range of stakeholders for human gene editing is very broad” and that “everyone has a stake in [human gene editing]” (NASEM 2015). Likewise, the president of the US National Academies of Science, Ralph J. Cicerone, noted that there was “critical need to engage the public on this rapidly advancing area of science” (Cicerone, Nat. Acad. Sci. 2015). Further still, the summit organizers asserted that “the decision as to whether to go ahead with any specific application or type of applications is not one for scientists to make alone” (Baltimore et al. 2015). The refrain of “not for science alone” would be reaffirmed through the close of the summit, when the chair of the organizing committee, Nobel laureate David Baltimore, identified “broad societal consensus” about heritable germline gene editing as a prerequisite for moving forward with the technology (2015).

In framing germline gene editing as not an issue for science alone, the Summit asserted the political and social position of publics, broadly construed, as having legitimate grounds to be included in decision-making for germline gene editing. In so doing, the Summit made the stakes of germline gene editing to be issues both of democratic governance and representation of wider publics in discussions and decision-making. If the shared stakes for germline gene editing collectively implicated society at-large, then, how would those decisions be made, by whom, and on whose behalf? Those stakes were made explicit by Baltimore during the closing panel of the Summit which referred to the Summit as “the way that decisions get made in a democracy. And we may not be representative of all…but it’s a beginning process” (2015).

That appeal to democracy, however, left questions of who exactly constituted the public only vaguely answered. The Summit constructed a public that was incredibly broad and non-specific. Summit organizers and panelists obliquely gestured toward “the public” or “society” without further detail. The public was used as a broad term for those non-experts who were not present at the meeting. Not that more specific groups were not recognized as populating that broader notion of “the public,” but such identifications were in long lists of various other stakeholders—scientists, ethicists, health care providers, patients, people with disabilities, policymakers, regulators, research funders, faith leaders, public interest advocates, industry representatives, and, as a final catch-all, members of the general public (NASEM 2015).The public was imagined both as an abstract, international citizen, without specific identifying features—to be universally generalizable and contextually flexible—as well as a distinct patient with features like genetic diseases or conditions needing alteration—to motivate morally valent action and with a recognizable stakeholder group. That construction of the public portrayed the public as a flexibly interpretable and versatile stakeholder which—as a relevant and necessary party to germline gene editing decision-making—also underwrote the decision-making discussion about germline gene editing as democratic and representative of broader society.

The Summit's framing of germline gene editing decision-making as "not for science alone" also set up the public as the source of societal and moral authorization for the development and application of germline gene editing. Summit discussions were fraught with ethical, social, and legal concerns about germline gene editing, including misgivings about violating human dignity, the specter of eugenic practices of editing genomes, the uncertainty of possible long-term, heritable effects across generations, and the inability of those affected future generations to consent to such alterations.

One summit speaker, George Q. Daley of Harvard Medical School expressed the need for public engagement about such controversial aspects of the technology saying, "There needs to be an attempt…to define when, if ever, there would be enough assurance of safety and efficacy and enough public consensus about the permissible medical application [of germline editing] that we would allow certain use" (2015). The identified prerequisite for moving forward with germline gene editing was a "broad societal consensus" on whether particular applications were ethically and socially acceptable or not (Baltimore 2015).

Alongside considerations of risk and benefits, societal controversy about its acceptable uses was among the barriers to clinical applications of heritable human germline editing. The resolution of societal controversy, moreover, was framed as an issue of permissibility in which public consensus authorized the development of heritable human germline editing applications. Implicit in the approaches to resolve societal controversy around germline gene editing was a notion that, like health and safety risks, societal controversy is a challenge for germline gene editing development to overcome. The ultimate development of germline gene editing applications, however, were nevertheless taken as the *de facto* end result. The eventual clinical application of germline gene editing was latent in the implied visions of the future, and the associated ethical and social concerns were merely speedbumps to be overcome along the way. Ethical and broader social concerns were not recognized reasons to abandon technological development altogether, but as guardrails to ensure a more prudent path forward. Public engagement, therefore, was constructed as a means of resolving societal controversy in a way that facilitated and authorized scientific experts to move forward with developing clinical applications of germline gene editing.

The Summit's focus on public engagement as a way to resolve societal uncertainty of germline gene editing circumscribed the public as an object of analysis that scientific experts were to consider as a source of legitimation for decisions about germline gene editing. Rather than promoting public participation in deciding whether to move forward or not, public engagement prepared the way for germline gene editing by smoothing out points of possible dissent or opposition. The framings of public engagement as tool for controversy resolution also stabilized a distinction and critical distance between scientific experts and the public. Setting up public consensus as an ostensible prerequisite to following a scientifically prudent path forward maintained a boundary that separated scientific experts as "outside" of the public. In so doing, the public, was characterized as an obstacle to be overcome along the prudent path forward for developing the technology and the associated promises of societal benefit. By contrast, scientific experts were elevated and reinforced as responsible actors working on behalf of the public good, demonstrated not only by their pursuit of the societal benefits of germline gene editing, but also through first eliciting "broad societal consensus."

Responsible and Rogue Scientists

In the years following the International Summit in Washington, D.C., heritable human germline editing's momentum continued. A US National Academies report on human genome editing was published in 2017, and incremental research advances in heritable human germline editing continued toward possible clinical uses (NASEM 2017; Liang et al 2015; Ma et al. 2017). Consideration of the potential applications and the broader implications of heritable human germline editing also remained prominent in international discourse (Reardon 2016; Ledford 2016b; Ormond et al. 2017).

In November of 2018, a Second International Summit on Human Genome Editing was set to convene in Hong Kong. The summit was set to be an opportunity to revisit the discussion from the first summit, taking into consideration the technical and societal developments around genome editing during the three years preceding. Days before the Second International Summit on Human Genome Editing was scheduled to begin, one scientist in China, He Jiankui, announced that he had successfully performed what he claimed to be the first germline gene editing of humans in a pair of twin girls, born in China a few months earlier, to modify genes in the twins associated with increased HIV resistance (Cyranoski and Ledford 2018).

He's actions were quickly and strongly condemned by international scientific communities including by those at the Hong Kong summit, as premature and labeled him as a "rogue scientist" (Zhang et al. 2018; Organizing Committee 2018a). [40] Those who

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[40] He Jiankui may not have himself thought that he was violating those principles (Baylis 2019a). Moreover, the narrative of He's motivations are more complicated than one of He merely as a rogue scientist in defiance of scientific norms (Hurlbut 2020), which calls attention toward the ways that norms of responsible science are (and are not) articulated, invoked, and enforced in-practice.

decried He cited numerous problematic and ethically troubling aspects of the genetic editing done, claiming that “the procedure was irresponsible and failed to conform with international norms” (Organizing Committee 2018b). In the first place, there was doubt as to if the intended edits were successful introduced to the individuals’ genomes. There were also objections that even if they had been successfully edited, it was not clear how one would be able make that determination without subsequent exposure to HIV to test edited individuals’ resistance. Moreover, if the editing of the particular HIV resistance-associated gene was successful, it may also have had other deleterious health effects. Namely, variations in the gene that He targeted have been associated with increased susceptibility to other more common infections with significant health risks, like West Nile Virus.

Those who remembered the recommendations of the prior international summit in Washington, D.C. and the subsequent US National Academies of Science report in 2017 also pointed out that the genetic edits that He made were precisely of the sort identified as inappropriate candidate targets for initial germline gene editing. That is, genetic editing to increase HIV-resistance was non-medically necessary procedure. The twins were not at significant risk of contracting HIV in the first place, not even from their HIV-positive father, and HIV prevention had other viable medical and non-medical alternatives already. Rather than addressing a medical need or providing a scientifically useful trial case, the genetic alteration was more likely motivated out of aversion to social stigma associated with HIV (Zhang et al. 2018). Instead of being a therapeutic when no viable alternatives were available, He’s editing enlisted a medicalized solution to a socially perceived problem.

Moreover, He carried out the editing work largely in secret from international and scientific communities. As a result, his announcement ahead of the Hong Kong summit was not only a surprise, but also evoked scientific outrage for violating a Mertonian-style scientific norm of openness about one's research (Merton 1973). Most prominently among the indictments of He's work were those that accused him of scant clinical ethical protocols used by He and his collaborators to ensure that a critical distance between researcher and subject was maintained. Ultimately, it was those breaches in medical and research ethics that were cited in He's conviction and sentencing by Chinese courts in 2019.

Setting aside the ethical concerns of doing the work in a concealed, less-than-forthcoming way, the problematic clinical and consent procedures used, and the dubious accuracy and effectiveness of the intended edits, He's experimental work was nevertheless a significant departure from the guidelines laid out at the first summit three years prior (Committee on Science, Technology… 2016). The first Summit had recommended international, public dialog and achieving a "broad societal consensus" about germline gene editing before attempts to move to clinical applications of heritable human germline editing would be acceptable. In light of He's actions, the Hong Kong summit in 2018 was an opportunity for scientists and the summit's organizers to reaffirm commitments to public engagement and societal consensus in the governance of germline gene editing. But that is not what happened. He was condemned for his ethically compromising consent process, for the amateurish and ineffective design of the actual edits, and for the secrecy with which he conducted the procedures. But failure to engage with publics or to develop broad societal consensus was not on the list of objectionable offenses that He had committed.

The problem with what He did was not that there was not yet a broad societal consensus about whether or not attempt heritable human germline editing or how to best do so. That public engagement was not part of He's process was not his scientific sin, but that he had "failed to conform with international norms" of scientific communities (Organizing Committee 2018b). As one summit speaker later put it, "In effect, what [the summit organizers] said was that He did the right work the wrong way"(Hurlbut 2018). In doing so, the response at the summit and the ensuing narrative of He as a rogue scientist shifted the responsibility and authority for governing heritable human germline editing—whether to move forward at all, and, if so, how—belonged with the scientific community acting on behalf of the public interest. Importantly, though those decisions were for the interests of broader society, they were not ultimately for publics to regulate as responsible or not. The framing of He's actions as a violation of international, scientific norms, and not of a failure of public engagement and broad societal consensus about germline gene editing, effectively closed down the role of publics in germline gene editing governance. The undertone was that scientific experts, not the public, were the appropriate deciders for the application of heritable human germline editing. He was upheld in violation of and as accountable to the scientific community and not to society at-large. That configuration of relations of scientific responsibility were in apparent tension with prior insistence that decisions around human gene editing were "not one for scientists to make alone" (Baltimore 2015).

Instead of reasserting commitments to public engagement and open, inclusive dialog as prerequisites, the organizers closed the second summit discussing the need for a “rigorous, responsible translational pathway” (NAS et al. 2018) for germline editing to move from the experimental to clinical application. When asked explicitly about the departure from “broad societal consensus” previously articulated, organizers referred to the development of a “translational pathway” specific to various regional contexts as a sufficiently similar standard for moving forward with germline gene editing (NAS et al. 2018). The question of whether to proceed with germline gene editing or not was subtly, but definitively, taken off the table.

When public engagement was mentioned during the second summit, it was framed in ways that implicitly further reinforced scientific experts as the appropriate authorities for heritable human germline editing governance. During the one summit panel specifically on public engagement, social scientist Joy Zhang from the University of Kent suggested that “it is precisely the lack of public engagement that has turned scientific debates into highly political ones” (2018). Zhang identified that failure to engage publics has resulted in the conversion of issues that should have been scientific to move out of the purview of scientists and have become politically and socially disputed. Past public engagement efforts about germline gene editing were showcased as success stories in which lay publics were invited to participate in discussions with the caveat that they “stick to the empirical” and refrain from “value judgements,” effectively screening off any ethical or societal points of dissent or contestation (Zhang 2018). Public engagement, again, was presented as an important process by virtue of its ability to resolve the political and societal uncertainty around genome editing, and thereby enable decision-making about gene editing to remain in the remit of scientific experts. It was not the lack of meaningful, democratic participation, but the jeopardizing of the positional, decision-making authority of scientists that underpinned insistence on public engagement.

In the wake of the first genetically edited humans, clinical uses of germline editing were, in effect, treated as a foregone conclusion. The question of whether germline gene editing should move forward was displaced with the question of how, a shift that has since garnered sharp criticism from advocates for public engagement around heritable human germline editing. The move away from broad societal consensus in favor of developing translational pathways placed experts as self-appointed arbiters of the future of heritable human germline editing, as though their condemnation of He’s experimental work demonstrated their societal responsibility and thereby empowered and legitimized them to do so.

Scientizing Governance

In the aftermath of the He’s gene editing work, one might expect that such a censuring international response would dissuade similar kinds of heritable human germline editing research, at least for a time. But only a few months after the sweeping condemnation of He, another scientist in Russia, Denis Rebrikov announced his plan to pursue similar clinical, heritable human germline editing aspirations by implanting edited embryos in women with the intent to carry them to term (Cyranoski 2019). In response to scientists like He and Rebrikov, there has been a resurgence of calls from other prominent figures in science for a voluntary global moratorium on germline gene editing (Lander et al. 2019; Davies 2019).

The purpose of a moratorium would, in part, be to facilitate international public deliberation on if and how heritable human germline editing ought to proceed and with what sort of international standards and policies to guide it. The discussion of a moratorium, though, is not entirely dissimilar from that which occurred shortly after the advent of CRISPR gene editing (Bosley et al. 2015, Lanphier et al. 2015, Nature Editors 2019). Similar imperatives were given even prior to the first summit in 2015 and yet did not inspire such broad, international dialog of substantial scale ahead of He's germline editing work. However, it is unclear if being on the other side of a red line of genetically edited humans makes the renewed calls for public engagement in deliberation during a moratorium meaningfully different given the scientist' straying from commitments to broad societal consensus as a prerequisite.

The renewed attention for a moratorium on germline gene editing is also a call for scientists to assume tacit responsibility for and leadership of public engagement about the applications of the technology (Daley, Lovell-Badge, and Seffann 2019). In doing so, scientific experts—their perspectives, interests, and values—inherently shape the aims, means, and framings of decision-making about germline gene editing. Ultimately, such situating of the governance of germline gene editing as firmly within the purview scientists reinforces their position as the politically legitimate and normatively appropriate decision makers about germline gene editing, despite the purported purpose of public engagement to promote inclusive participation of diverse publics.

Reinforcing scientific experts not only constrained public engagement, but also inscribed the governance challenges of heritable human germline editing within explicitly scientific arenas. Shortly after the news of He's gene edited twins, the World Health Organization announced its formation of a multi-disciplinary advisory committee to develop guidelines for international governance of heritable human germline editing with heavy attention on the scientific, ethical, social, and legal challenges (WHO 2019). Likewise, in 2019 the US National Academies of Science and Medicine and the Royal Society of the United Kingdom established a new international commission that would hold multiple public meetings during the year to develop a report with more detailed and explicit frameworks for possible pathways for clinical germline editing (NAM, NAS, the Royal Society 2019). In each case, the questions the expert committees are tasked with answering are how to move forward with heritable human germline editing, not whether or not doing so has any sort of public consensus.

At the same time, those expert committees attempted to establish a disinterested, neutral position for experts in decision-making about heritable human germline editing. In particular, the 2020 report resulting from the collaboration between the US National Academies of Science and Medicine and the Royal Society focused their report on "responsible translational pathway toward potential clinical uses of heritable human genome editing" (NAM, NAS, and the Royal Society 2020, 145) in which "broad public engagement" was "as important as the clinical pathway components" (NAM, NAS, and the Royal Society 2020, 28). Questions of whether any particular use would be permissible were matters for engagement with specific relevant publics to decide, and the report noted that "questions of precisely how such discussions should proceed was beyond [their] charge" (NAM, NAS, and the Royal Society 2020, 146). However, in striving for an appearance of neutrality, though, the expert committee functionally offloaded ultimate responsibility for the development and use of heritable human germline editing to publics and broader society. It was the responsibility of society to deal with those questions, not the experts. Scientific experts were responsible to *practice* public engagement to cultivate societal consensus prior to applications of heritable human germline editing, but the responsibility for the ethical outcomes of its use laid with publics. In doing so the report set scientific experts up as trustworthy and moral actors who were therefore eligible to shape heritable human germline editing decision-making in significant ways. By committing to doing public engagement scientific experts were able to frame the stakes for the development of heritable human germline editing as a demonstration of their responsible character and normative authority while simultaneously framing public engagement in ways that deflected moral accountability for the outcomes of heritable human germline editing development and further stabilized their position of guiding influence over heritable human germline editing decision-making.

Despite the alarm from scientific communities following the news of He's work, considerations of moratoria, and subsequent expert reports addressing precisely the concerns raised, the actions taken to further discussion about heritable human germline editing were housed and facilitated by institutions of science. In doing so, science was further made into the sole appropriate arena for resolving the societal uncertainties and complexities of heritable human germline editing, as well as the technical ones. Yet, the treatment of the challenges and stakes of heritable human germline editing remained as fundamentally ones that belonged to the purview of science, while accountability for those stakes did not. Public engagement played a role in that process, but as a way to grease the wheels of germline gene editing development by resolving societal controversies around the technology, absolving scientists of accountability for the outcomes of the technology decision-making, and authorizing scientific experts' epistemic and normative authority in germline gene editing decision-making. Such positioning of scientific experts imparted a more cynical and instrumental undercurrent to claims that the decision about the future of germline gene editing is not one for scientists to make alone.

Conclusions

Public engagement—what it entails, who it implicates, empowers, and marginalizes—is fundamentally intertwined with how the issues of heritable human germline editing governance are themselves framed. In asking how to govern heritable human germline editing as a question of finding prudent or translation paths forward for applications, public engagement is shaped as a means of facilitating that procession via resolving societal controversy through collecting data on public attitudes. Likewise, constructing public engagement as an act of data collection simultaneously centers the discussion on having salient, sufficient knowledge, thereby reinforcing the ability of scientific experts as knowledge specialists to preside over the agenda setting and ultimate decision making for governing emerging technologies.

Despite the invocation of public engagement as an important part of navigating to find a prudent path forward for heritable human germline editing, the treatment of public engagement in those discussions functionally undermine meaningful participation in democratic deliberations. When public engagement is actually present in such discussions, it is framed as fundamentally about getting the right knowledge about publics in other to avoid, minimize, or resolve societal uncertainties. Doing so constrains public input as a form of data collection to supplement the assumed decision-making authority of experts if it is not quietly sidelined entirely.

Instead, public engagement can be leveraged to situate the broader societal implications of heritable human germline editing are appropriated as being fundamentally issues within the jurisdiction of science. Such re-categorizations of the stakes and nature of the challenges prompted by heritable human germline editing reinforce scientific experts as the primary wielders of adjudicative power and proper custodians of governance.

If we care about the rightful place of scientific expertise in society—and we have good reasons to care—then we also need to ask: for whom, then, is public engagement? Ostensibly, public engagement is for all of us, for some notion of a shared society and common good. But examining closely heritable human germline editing discourse, it is less than clear that is always the case. Publics as part of democratic deliberations around governance are undermined by knowledge framings and the presumption of pursuing a path forward. Though publics are not explicitly barred form discussions, they also are not included in the same capacity as experts, and the stratification of decision-making authority and inclusion, especially when it goes on unrecognized, is antithetical to fundamental democratic principles.

Insofar as public engagement continues, clears a translatable, prudent path forward for emerging technologies, it does not curb the influence of scientific experts. Rather, engagement further empowers them. The range of voices included in discussions is not grown, as much as the groups of people for whom experts are permitted to decide on behalf of is increased. Insistence on public engagement leverages the rhetoric of democracy and inclusion to authorize the expansion of oversight of public interests to scientific experts. Public engagement serves not as a check on governance by scientific experts, but as an enabling handmaiden of technocracy.

At stake in public engagement with science are fundamentally issues of who has influence and ought to be included in matters of democratic governance. Yet, the invocation of public engagement does less to expand the democratic participation of non-scientists than it does reinforce scientific experts as rightful epistemic and normative authorities in technoscience decision-making. Emphasizing public engagement without also making explicit who that includes, excludes, and whose interests are served by it muddies the waters of democratic governance. It is therefore imperative to ask earnestly, who does public engagement actually empower and to take seriously the questions of who gets to decide the future of science and technology.

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CHAPTER 6

CONCLUSIONS: PUBLIC ENGAGEMENT, RESPONSIBILITY, AND DEMOCRACY BY OTHER MEANS

In this dissertation, I set out to explain how public engagement around gene editing has been constructed in ways that it holds together with ideas of democratic governance and the configuration of the relationships between science and the public. Specifically, I sought to answer the questions:

1. How has public engagement been constructed in gene editing discourse?
2. What work do calls for public engagement do in visions of the right relationships among science, publics, and democratic governance of gene editing technologies?

By way of concluding, I take each of these questions in turn, synthesizing arguments that I have made over the previous chapters to answer these questions.

Public Engagement and Scientific (Ir)responsibility

First, how has public engagement come to be constructed in gene editing? In short, public engagement has been constructed as a fundamental expression of scientific responsibility. Though not in identical ways, across gene editing discourse calls for public engagement have been similarly constructed as a proof of scientific responsibility in opposition to a simultaneous, mirror construction of potential scientific irresponsibility. Public engagement furthered a vision of responsible science in which science was open, inclusive, and engaged in decision-making about gene editing with publics. In contrast, the implicit framing of irresponsible science was in terms of scientists acting in private, insularly, or unilaterally in making decisions about if and how to move forward with gene editing technologies. Scientific irresponsibility with gene editing was a kind of conceptual bogeyman, so to speak, that enabled scientific experts to set themselves apart as decidedly responsible actors.

The commitments by experts that public engagement was crucial for good decision-making about gene editing, then, served as a marker that denoted scientific experts as being responsible. As such, they had legitimate standing to influence and preside over questions of gene editing development, use, and ultimate governance. That marking was underwritten by the rhetorical move to call for the inclusion and participation of other, non-expert publics. In so doing, they create a site in which publics were beckoned to come "collectively witness" and therefore also help legitimize (Shapin and Schaffer 1985) the demonstrations of scientific experts as responsible, evidenced by their calls for public engagement. The very act of calling for public engagement—even prior to the accompanying practices of public engagement—about gene editing became tantamount to responsible gene editing itself. The framing of decision-making about gene editing technologies as something which necessitate publics' engagement was itself a proof of the responsibility of scientist experts as much as any actual engagement of publics in that decision-making.

However, the construction of public engagement as the marker of scientific responsibility occurred differently in different instances of gene editing discourse. In human germline gene editing discourse, as shown in Chapter 5, public engagement was set up as a way to avoid and resolve potential societal controversy. The organizers of the international summits on human germline gene editing set up publics' perceptions of potential problems, risks, and ethical objections about human germline gene editing as barriers that needed to be overcome and resolved in order to move further along a "prudent path forward" (Baltimore et al. 2015). Public engagement, then, was the means by which those societal controversies could be resolved, or, by engaging publics early enough, avoided altogether, clearing the way for human germline gene editing applications and use. Public engagement demonstrated scientists' responsibility through claims and commitments to value the inclusion and consideration of publics' interests and perspectives. Public engagement was what it meant for any decision about human germline gene editing to be "not one for scientists to make alone" (Baltimore 2015).

And yet, despite little to no "broad societal discussion" about whether and how to move forward with human germline gene editing, the lack of public engagement was not the primary indictment after the controversy surrounding the birth of the first gene edited humans in 2018. Rather, it was the *irresponsibility* of He Jiankui as a "rogue scientist" that was the breach of concern. It was not that science, or rather a particular scientist, made decisions about human germline gene editing alone, but that his acting outside of scientific and ethical norms might jeopardize the future of human germline gene editing technologies by casting doubt on the capacity of scientific experts, as an international community, to self-regulate and ensure responsible gene editing without the need for external intervention. The response to He Jiankui's actions was not primarily to do more public engagement,[41] but to censure, condemn, and disassociate from the "rogue

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[41] In the calls for a moratorium on human germline gene editing following the He Jiankui controversy, some did call for greater public engagement to take place in the pause on advancing gene editing research (e.g., Bayliss 2019a; 2019b). However, these were not the dominant reasons in the various calls for a moratorium, which emphasized more the need for developing scientific standards and ethical guidelines for

scientist” (Organizing Committee 2018a) whose actions were “irresponsible and failed to conform with international norms” (Organizing Committee 2018b).

Scientists showed how their notion of public engagement was less about public participation in decision-making itself and more about the preservation of scientific sovereignty. What was jeopardized was the perception of science as being responsible, and therefore not needing of external oversight or regulation. As such, scientific responsibility—both in public engagement and in condemnation of rogue scientists—was a collective endeavor within the scientific community. In the calls for a moratorium that followed, scientists cited the need for collectively agreed upon and international standards and ethical guidelines for future human germline gene editing research to prevent future irresponsible human germline gene editing controversies.

In doing so, they concentrated responsibility for human germline gene editing among communities of scientific expertise through a vision of responsible science in which scientists kept themselves in check by drawing boundaries between themselves and the likes of He Jiankui and by condemning future would-be rogue scientists. Public engagement was part of that vision of responsible science, but as a way of avoiding the sorts of societal controversies that led to crises of scientific responsibility. The purpose of public engagement, then, was constructed as creating the conditions for responsible human germline gene editing through the preservation of scientific sovereignty and self-regulation. As a result, public engagement, in enabling science to continue to be perceived as collectively responsible, also solidified the legitimacy and authority of

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continuing human germline gene editing research for the international scientific community without controversial incident.

scientific experts[42] to act on behalf of broader society regarding whether and how to move forward with human germline gene editing.

As argued in Chapter 3 (and implicitly in Chapter 4), public engagement was also deeply intertwined with notions of personal scientific responsibility and moral obligations regarding gene drives. Though public engagement was also constructed around avoiding public controversies that might stall or prevent the use of gene drives for humanitarian or environmental purposes, public engagement was framed in terms of avoiding irresponsible *uses* of gene drives rather than preventing irresponsible *scientists.*

From the earliest publications on engineered gene drives, the concerns of scientists such as Esvelt were consistently focused on the potential for accidental or premature releases of gene drive organisms (Esvelt et al. 2014a; Oye et al 2014). In contrast with human germline gene editing, Esvelt and others called for the regulation of gene drive technologies. Doing so was not a ceding of scientific autonomy or sovereignty, but as a display of responsibility in counter-position to a distinctly different imagination of what was at stake for irresponsible development of gene drives. Irresponsibility did not threaten the scientific community per se, but rather the future realization of gene drives' potential public health and environmental benefits.

Concerns about irresponsible gene drives were about unintentional gene drive releases, inadequate control of gene drives, and initial missteps spoiling the opportunity for future, potentially more important uses. Recall how the biosafety and containment

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[42] By scientific experts, I do not mean specifically natural scientists as distinct from social scientists (though to be sure, it has been the natural scientists that have dominated gene editing discourse). However, the pattern of the reinforcement of scientific expertise through public engagement applies also to social scientists in how publics, engagement, and stakes around gene editing have been framed.

concerns around the gene drive research at UCSD were rooted in wanting to avoid a "media circus" that would "set back by years" any future use of the technology (Ledford 2015c). The irresponsibility of scientists was to create an incident with gene drives that would lead to controversy. Scientists' trustworthiness was not based in keeping other scientists "in line," but in keeping gene drives from getting out of control. Scientists demonstrated responsibility through a self-regulation of personal restraint and caution in their experiments, not through a collective enforcement of ethical or research norms. That personal responsibility for gene drive development was underscored by Esvelt's claims that scientists were "morally responsible for all consequences of our work" (Esvelt 2014) and that the outcomes of early controversies would spoil the use of gene drives later elsewhere, whether for Lyme disease in the United States, invasive species control in Aotearoa New Zealand, or malaria eradication in sub-Saharan Africa.

Public engagement was constructed as part of how those irresponsible uses might be avoided by including potentially affected publics in the decision-making about gene drives, such that any uses that did occur would be rendered "responsible" by virtue of the engagement with publics that preceded it. As a result, responsibility for gene drives was also concentrated among scientific experts as those who would screen off and prevent those imagined "irresponsible" uses. Central to that envisioning of responsible science was public engagement, not only as a marker of scientific experts themselves as responsible actors but also as a way to establish early instances of gene drive early field trials and uses as nominally responsible ones. Public engagement in gene drive discourse, then, served to create the possible conditions for responsible gene drives by simultaneously creating conditions of impossibility for irresponsible gene drives in which irresponsibility was those events which might impede future development and use of gene drives.

In the specific examples of human germline gene editing and gene drive discourses analyzed in this dissertation, each located responsibility for gene editing technologies and outcomes in different ways—either in collectively preventing irresponsible *scientists* as in human gene line editing or in personally avoiding irresponsible *science* as in gene drives. Yet, both had similar centering effects on the place of scientific experts as the rightful custodians of the responsible development and governance of gene editing technologies. Public engagement, as a marker of that responsibility—and thus also legitimate decision-making authority—thereby further reinforced that centering of expertise within gene editing discourse. As a result, scientific experts were also empowered, even obligated, to drive decision-making about gene editing technologies on behalf of those publics whom they asserted needed to be engaged. Public engagement, then, did dual work to both reinforce scientific expert authority in gene editing discourse while also couching that reinscribing of expert authority as an act of societal responsibility and commitment to inclusive, participatory, and democratic forms of governance.

Turning to my second driving question: what work do calls for public engagement do in visions of the right relationships among science, publics, and democratic governance of gene editing technologies? Broadly speaking, calls for public engagement held together with broader visions of democratic governance of science and technology through the construction of public engagement as part of what it means for scientists to be responsible. As a result, calls for greater public engagement reinforced scientific expert authority to act on behalf of the interests of broader publics, which was itself also a structuring of democratic governance that reinforced the epistemic and normative authority of scientific experts.

An Imaginary of "Not for Science Alone"

The observation that the construction of public engagement around gene editing as authorizing support and reinforcement of scientific expert authority in decision-making resonates with what STS scholar Melanie Smallman has called a sociotechnical imaginary[43] of "science to the rescue" (2018). The "science to the rescue" imaginary separates out the social and ethical issues from technical considerations, particularly around gene editing, on the basis that such societal aspects have "nothing to do with the science" (Smallman 2020). As a result, the consideration of values or normative commitments which do not conform to technoscientific rationales are screened out or are out-competed by those perspectives that do adopt the appearance and sensibility of the "science to the rescue" imaginary. In so doing, the imaginary of "science to the rescue" pre-frames and precludes alternative visions of democratic decision-making by anchoring the standards of legitimacy, evidence, and grounds for dispute in the technoscientific arena. As such, Smallman challenges how, or if at all, public engagement might be equipped to resist the coercive power of such an imaginary that is so deeply entrenched.

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[43] Discussion of how I conceptually engage with sociotechnical imaginaries can be found in more detail in Chapter 1. As elsewhere, in this conclusion, I use "imaginary," "vision," and their variants to refer to the generative source of the rationales for how the world ought to be vis a vis science and technology (Jasanoff and Kim 2005).

My analysis in many ways echoes Smallman's, but I argue further that public engagement compounds with her notions of "science to the rescue" imaginary to generate a distinct imaginary which I term "not for science alone." This imaginary envisions scientific experts as technocratic guardians and guarantors of democratic governance on the basis of their demonstrations of responsibility through calls for public engagement, patterns that are particularly evident in gene editing discourse.

Visions of gene editing governance as matters of "not for science alone" construct public engagement not as a check on the continued development of gene editing technologies per se but acts as societal guard rails by resolving possible objection and challenge to them. In so doing, the moral responsibility of scientific experts is fulfilled in the appeal to and inclusion of public engagement as needed in the process of decision-making. The epistemic and normative authority of scientific experts, then, is reinforced through their demonstrative performance of responsibility vis a vis calls for public engagement to resolve societal controversy and by that measure, not be the sole deciders in science and technology governance.

Furthermore, the imaginary of "not for science alone" enlists a notion that advances in science and technology are fundamentally a normative, collective, good for society. The imaginary of "not for science alone" mobilizes a cultural understanding in which technoscientific innovations are equated with societal goods (Hilgartner 2015). Deviations from that framework in which science and technology lead to bad outcomes are not a feature of the science and technology per se, but some feature of the social world, namely scientific irresponsibility. In so doing, the "not for science alone imaginary" separated the manifestation of the risks of gene editing as scientific irresponsibility, while the potential benefits are scientists' positive responsibility to realize. Science, and scientific experts in particular, are set up as responsible to save us from the imagined irresponsibility of science apart from efforts of public engagement.

It is not that the imaginary of "not for science alone" or related constructions of public engagement are a failure or rupture in democracy, rather they are sites in which both public and expert are mutually constituted and configured (Jasanoff 2011). In scientific experts' calls for greater public engagement, public engagement did work to enable scientific experts to represent publics in technoscientific decision-making. The imaginary of "not for science alone" rendered the public engagement of gene editing governance discourse to be not only "what democracy looks like" (Baltimore 2015) or as "consonant with democratic visions of the governance of emerging technologies" (NASEM 2016, 134), but also further reinforced an imagination of scientific experts as responsible by virtue of their commitments to broader public engagement and inclusion of a more diverse range of voices. In that envisioning of science, science and scientific expertise were integral parts of democracy. In so doing, science is positioned to create the conditions for good, democratic governance of science and technology by promoting public inclusion, participation, and representation in decision-making. In other words, scientific experts' authority is reinforced not merely as custodians of science and technology but also of democracy through public engagement.

Importantly, though, the construction of scientific experts as public representatives is not itself a *less* democratic mode of governance pe se due to presence of representation. Representation is not "an ersatz of direct democracy," but its cornerstone (Callon, Lascoumes, and Barthe 2001, 116). At stake in the construction of public engagement was a reconfiguring of democratic imaginaries as much as ones of the right relations between science and publics. The representation of publics by experts that was enabled through constructions of public engagement is constitutive of visions of democracy as depending upon and being coproduced with scientific expert judgements (Jasanoff 2009). Moreover, that democratic stakes are interwoven with notions of scientific expertise is not itself cause for concern. However, what makes the case of public engagement in gene editing discourse significant and at the same time precarious is that the move of representation of publics by experts, goes unrecognized as such.

By asserting their responsibility for the development and eventual use of gene editing technologies, scientific experts also asserted responsibility to act on behalf of those publics. Calls for greater public engagement, then, underwrote a discursive move in which the reinscribing of scientific authority in gene editing discourse were democratically legitimate. As an expression of scientific responsibility, public engagement simultaneously also situated scientific experts as representatives of publics and their interests as part of their remit as scientists. Failing to recognize how “the technical is political” is consequential for how who comes to be recognized as having legitimate standing in decision-making and who is understood as being responsible for what kinds of technical or political judgements (Thorpe 2007). Those judgements about what issues fall within or without of boundaries of “science,” “public concern,” or “needing public engagement” also depend on the enforcement of boundaries of publics for whom scientific experts imagine themselves to be responsible.

Engaging Everywhere at Once

Public engagement in gene editing discourse has also reinforced scientific expert authority by universalizing their claims to responsibility through localized instances of engagement. In both human germline gene editing and gene drive discourses, the reach of scientific expertise, authority, and responsibility extend to be simultaneously both localized to particular publics, places, and gene editing applications and yet also, so to speak, everywhere at once (Shapin 1995). Though the particularizes of different contexts, stakes, and different affected publics may vary from locale to locale, from individual case to case, the salience of public engagement as part of scientific experts' responsibilities in each of these instances remains unchanged. What public engagement is thought to accomplish in developing responsible, clinical paths forward for human germline gene editing is also that which is imagined as needed for responsibly developing gene drives for invasive species control in Aotearoa New Zealand. Ditto for eradicating mosquito-borne malaria globally. Regardless of context, public engagement is constructed as essential to ensuring responsible science and responsible gene editing, wherever or however it might be pursued. In that way, public engagement has a universalizing effect on how the stakes for gene editing and for whom are framed and understood, namely that issues of gene editing governance are sufficiently similar across every case—irrespective of the features of specific publics or specific gene editing uses—that greater public engagement is the appropriate move to ensure that gene editing is developed and governed responsibly.

Yet, it is precisely because public engagement is constructed as working through localized instances of engagement with specific publics about specific technological interventions that public engagement comes to also be universally salient and applicable. As a result, public engagement likewise extends the responsibility and authority of scientific expertise for gene editing decision-making elsewhere. More strongly stated, this universalizing logic enables local instances of public engagement as demonstrations of scientific responsibility to underwrite further claims of experts' responsibility, thus also legitimacy and authority, in any number of other "elsewheres."

To be sure, the uptake of particular constructions of public engagement is not universally homogenous, as I demonstrate in the latter parts of Chapter 3 in the variable uptake of public engagement across international organizations about gene drive governance. But though the specific formulations of public engagement may vary, the everywhere-ness of its performances of scientific responsibility renders all publics, places, and purposes of gene editing commensurable and comparable with one another. In so doing, public engagement also makes salient the same sorts of questions about gene editing governance to be asked in every case, and by extension, for the same sort of questions to go systematically unasked. Questions such as: What constitutes acceptable levels of risk to realize potential benefits? Among whom are those risks and benefits distributed and how? What does it mean to have control (or not) over gene editing technologies, and who has control? In the event that gene editing "goes wrong," who is liable for any harms done?

Not Merely a Matter of Intent

Importantly, I do not mean to suggest or claim that the ways that public engagement has reinforced scientific expert authority were the result of experts acting in nefarious or Machiavellian grabs for power.[44] The point is not that scientific experts were false or acting in bad faith in calling for public engagement or that their earnestness to meaningfully engage with publics was an elaborate charade to achieve some undisclosed agenda. On the contrary, by all accounts they were and are likely every ounce as sincere as they made themselves out to be. The disconcerting point is that such reinforcement of scientific expert authority did *not* require any ill intent or selfish ambition on the part of experts to nevertheless occur. Rather, it was a feature of the constructions of public engagement as an expression of responsible science that created the conditions for that reinforcement to occur. Moreover, it is precisely because of the sincere desire and potential to both do good in gene editing discourse that makes it all the more important to recognize how commitments to public engagement subtly reinforced scientific expertise. Rather than centering political representation, public accountability, or clear ideation of public values, the framing of public engagement as an imperative for science quietly centered scientific expertise as normative authorities as well as epistemic ones.

The case study in Chapter 4 of Kevin Esvelt's engagement with Māori communities about the use of gene drives for invasive species control illustrates how scientists' intentions need not be malicious to nevertheless reinforce their own authority and that of scientific knowledge. In that chapter, I argued that scientific framings of mechanistic biology dominated the terms of engagement with Māori communities about potential use of gene drives for invasive species control. Moreover, I showed how the

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[44] Intentionally attempts to shore up power of some sort or another are surely omnipresent in any sort of decision-making, and gene editing discourse is no exception. There likely are various actors in gene editing discourse who actively and intentionally seek greater influence. What I mean is that the moves to call for greater public engagement were not patently some attempt to gain overtly political or decision-making power over others.

presumptive mechanistic approaches to the control of gene drives contributed to serious and detrimental social and political consequences for Māori co-governance of the technologies in Aotearoa New Zealand. As a result of the limitations of mechanistic biological approaches, the imagined possible futures for gene drives in Aotearoa New Zealand, their governance, and their impacts for local communities were likewise constrained. In the particular example, it was the practices and efforts to do public engagement that enabled those mechanistic approaches to dominate the imaginations of gene drive governance precisely because public engagement was constructed as Esvelt taking responsibility for the effects of his research and upholding his ideas and commitments to "responsive science."

Public engagement was a site in which both knowledge about gene drives control and the social ordering of the co-governance of gene drives for Māori communities were co-produced. Social and technical control over gene drives were intertwined with one another. As a result, scientific perspectives came to be privileged and entrenched as the suitable ones through practices of engagement even though they were meant to be responsible, inclusive, non-science centering. Despite intentions to do the opposite, engagement, in fact, did work to reinscribe the visions of scientific experts as authoritative.

The point is that the ways that public engagement reinforces scientific expert authority in gene editing discourse is not a matter of doing public engagement the "wrong" way or doing so with "wrong" motivations. Rather, it shows how commitments to public engagement as demonstrations of responsibility in science implicitly and subtly structures the conditions of engagement and technoscientific governance such that scientific expertise is reasserted as the responsible way of making decisions. Public engagement, then, simultaneously configured notions of the right forms of knowledge and the right social relations as being those that aligned with, upheld, and bolstered scientific expert epistemic and normative authority.

That public engagement tended to reinforce scientific expert authority, though, ought not be totally surprising. Constructions of public engagement in ways that ultimately and fundamentally uphold, reinforce, and strengthen scientific sovereignty, authority, and expertise in technoscientific decision-making is entirely consistent with how public engagement has developed conceptually and genealogically. As I show in Chapter 2, the conceptual origins of public engagement as an important part of science and technology decision-making are directly and tightly linked with decades of aspirational and concerted efforts to improve public understanding of science. I further show how the equating of public understanding of science with public appreciation of science for its value to society in advancing scientific knowledge, technological innovation, and expert policy advice is also carried through in contemporary constructions of public engagement.

Animating the moves to promote public understanding of science (and thus public appreciation of science) were explicitly social and political aims—visions of the right kind of science and the right kind of society. Those vision were decidedly pro-science and pro-democracy for the dual reasoning that the right science was that which enabled and upheld democracy and the right sort of democracy was one that supported the scientific enterprise. Public understanding of science was always a project foremost about social ordering of science and democracy in tandem with its epistemic aims for public apprehension of science.

Like public understanding of science before it, public engagement is not merely or even primarily an epistemic project of right public knowledge but a social and political project. Public engagement takes the emphatic aims from public understanding of science to establish and maintain the place of science in society and transmutes them into democratic aspirations through a rhetoric of public participation in science and technology decision-making. Yet, it does so in ways that also specifically and explicitly intend to reinforce the scientific expert authority by framing democratic and collective decision-making as also matters of scientific responsibly. Public engagement redraws the boundaries of scientific responsibly to include not only epistemic expertise, but also governance expertise as belonging to the purview of science. As a result, public engagement is fundamentally aligned with governance that concentrates decision-making influence and authority with scientific expertise, despite any earnest intention for public engagement to do otherwise.

The Limits of Public Engagement

This dissertation set out to answer questions of how public engagement conceptually hold together with visions of sociotechnical systems and democratic governance in gene editing discourse. Alongside those questions, another relatively straightforward question has lingered in the background of this dissertation: Should we do public engagement about gene editing or not? In this dissertation’s introductory chapter, I laid out a “normative gap” as discussed in the scholarly literature about the role of scientific expertise and publics in democratic decision-making about science and technology. In short, the normative gap prompts the question of whether public engagement is a desirable part of technoscientific decision-making as claims that it is are underdetermined by scholars' observations and arguments by scholars about the relationships between experts and publics (Collins and Evans 2008).

Over the course of this dissertation, I have argued that public engagement, despite intentions to the contrary, ultimately has reinforced the authority of scientific experts in gene editing discourse. While the findings of this dissertation may not fully extend to every manifestation of public engagement with science and technology, they do complicate and prompt further scrutiny of strong, a priori commitments to public engagement as a democratic enhancement of science and technology governance or as a reliable check on technocratic power. But the observation alone that public engagement is socially and politically fraught in various way, admittedly, does not quite answer the spirit of the question of whether or not we should do public engagement around gene editing or science and technology generally. I hesitate to answer that question directly, in part, because I think the answers to that question are themselves not particularly enlightening relative to the reasons why one would ask it in the first place.

It is certainly possible that one might make a number of arguments for or against specific instances of engagement or with specific publics as being worthwhile based on a number of reasons that appeal to deliberative, participatory, or otherwise democratic commitments (Irwin 2001; Wilsdon and Willis 2004; Barben et al. 2008; Moore 2010). Or one might argue for particular infusions of public engagement into science and technology discourse in an attempt to redirect the flow or framing of discussion (Goven

2003; Stirling 2008; Nisbet 2009), or as a counter-weight to expert driven decision-making (Jasanoff 2009; Wynne 1992a; 2016). But the scope of such answers would necessarily be limited to those particular instances of public engagement on an ad hoc basis. They would say little about whether we should pursue public engagement, generally, in science and technology governance. The contested, in-the-making nature of public engagement itself and its varied permutations and styles in-practice (Rowe and Frewer 2005) that this dissertation explores at length further problematizes the asking of the question.

Instead, this dissertation carves out a conceptual and discursive space to ask better questions about the normative relationships between publics and expertise, technoscientific governance and democracy, and how notions of public engagement figures in those considerations. Indeed, a key conclusion of this dissertation is a recognition of how the question of whether or not we should engage publics about decision-making about science and technology (especially emerging science and technology) is actually considerably more difficult to answer than one might assume at first blush. What may seem a simple question of inclusion or participation, further scrutiny reveals to be an entangled knot of contested and conflicting visions of the relationships between scientific expertise and publics, who even constitutes the right or relevant publics, and the rightful place of science in society.

The very asking of the question, “Should we do public engagement as part of science and technology governance?” already has a slew of other questions and presumptive answers that stand behind it—questions that are far more about *who* ought to and how ought they have a say about the governance of science and technology than about the particular features or uses of science and technology themselves. Who ought to represent or act on behalf of whom? Who ought to be responsible for what kinds of decisions and responsible to whom? Such questions concern not only our technical capacities to alter the natural world but also, more crucially, our collective visions for the kinds of social worlds we want to inhabit. Only after answering those questions, does asking whether or if we should pursue public engagement to realize those ends then start to take on more meaning.

Attentive readers will note that I have, yet again, danced around directly answering the question of whether or not public engagement around science and technology is worth doing. And, I have done so in classic academic style by dismissing the question as being poorly asked and instead posed numerous other, ostensibly better questions to ask instead.[45] In an attempt to answer more directly: If the aims of public engagement around gene editing are to decenter or to check against scientific expert authority in discourse on technoscientific decision-making in the name of greater democratic governance, then public engagement, as constructed in gene editing discourse, seems an unsuitable remedy.

At best, public engagement has a deeply fraught relationship with how it enables particular visions of technocratic versus democratic governance and likewise with regard to who public engagement actually empowers or disempowers to participate in science and technology decision-making. Alternatively, public engagement may be entirely ineffectual toward those democratic ends. I do not suggest that public engagement is ineffectual in the sense that it does nothing, but that it does not accomplish what its

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[45] Although those better questions are also left conspicuously without any direct or clear answer.

advocates hope or mean for it to do. Clearly, public engagement *does* avail something—in fact, a specific and potent imaginary that reinscribes scientific expert authority, sovereignty, and responsibility as a democratic necessity. Whether or not that is a desirable outcome or not is another question, but it is one that normative commitments to public engagement answer by co-locating ideas of good science and democratic governance as mutually reinforcing (Ezrahi 1990; Thorpe 2007; Jasanoff 2011).

It may be that doing public engagement exacerbates the challenges of democratic governance. If public engagement offers no real improvement in democratic participation presenting as a solution that confounds more than it clarifies, who is it that really makes decisions about science and technology and who ought to. The appearance of responsibility is not the same as the genuine article, nor is the language of responsibility the same as the doing of responsible action.[46]

Or perhaps the problem lies less with the constructions of public engagement itself and more with how it is understood as improving governance of science and technology. Perhaps we ask too much of public engagement to simply solve longstanding political problems in democracy of how to navigate and resolve competing individual and communal interests (Dewey 1927). The challenges of democratic governance of science and technology may be too substantial, the relationships between experts and publics too complex for public engagement to resolve alone. Public engagement may be a necessary

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[46] As legal scholar Jedidiah Purdy has put it excellently, "The language of responsibility-taking easily becomes merely high-minded and sermonizing. It can mistake serious thinking, the earnest naming of problems, and heroic intentions for a high form of action in themselves. The appeal of the language of responsibility is often a delusion: the instinct that talking that way, all by itself, will help to call into being the agent of responsibility—a person or community that can *do something*." (2015, 4, emphasis in original).

but insufficient part of democratic visions of science and technology. At the least, prompting scientific experts to be more reflexive through more inclusive, collective deliberations that better represent a diversity of values may, in and of itself, be a worthwhile pursuit for building greater capacity for technoscience governance (Guston 2014b). In any case, however, this dissertation shows how, in discourse on the governance of gene editing technologies, public engagement does not appear to accomplish what it was intended to do or what many appear to believe that it does.

Alternative Paths Forward for Public Engagement

If, indeed, public engagement as scientific responsibility in gene editing discourse does not do what it is intended to do, then a reasonable next question is: What should we do instead? I propose that one productive direction for gene editing governance is to shift discourse to engage more directly with ideas of accountability for gene editing technologies. Largely missing thus far from the gene editing discourse, has been an explicit grappling with fundamental issues of representation and democratic governance implicated therein. Taking responsibility to serve public interests is simultaneously also asserting the right to act on behalf of others. What publics science serves, how, and with what expectations for accountability is profoundly consequential for the ultimate governance of gene editing—however they end up being (or not being) used. In addition to considering scientific experts as being responsible *for* gene editing, we also must consider *to whom* they are to be responsible, not only to realize benefits but also who is liable in the event of harms. Thus, some questions about public engagement with gene editing technologies that are not being asked are quite fundamental, political ones: Who ought to act on whose behalf and why?

One possible path of inquiry for beginning to answer that question is for engagement to prioritize not only public inclusion, participation, and consent prior to developing or implementing gene editing technologies, but also to establish clear guidelines and polices for public restitution for potential harms. Centering restitution for potential harms in public engagement around gene editing builds upon the prior proposals for scientists to pursue gene editing responsibly (Esvelt et al. 2014a; Oye et al. 2014; Doudna 2015; Baltimore et al. 2015), for networks of scholars and organizations to create opportunities for cross-national discussion of gene editing (Jasanoff and Hurlbut 2018); Kofler et al. 2018), and for the creation of partnerships with local and regional governing authorities and communities (Daley et al. 2019; Long et al. 2020).

More pointedly, such efforts could be reoriented to not only focus on public inclusion and consent, but also the creation of concrete consequences and understandings of liabilities for outcomes or harms that have the force of law and formalized regulatory policy. Such discussions of liability and appropriate restitution are part and parcel of what meaningful, effective public engagement must entail and are essential to the development of publicly accountable gene editing technologies. They are necessary not merely in preparation for what happens if something should go wrong with gene editing technologies in terms of recompense, but also in terms of making systemic, institutional changes so that harms do not happen again. In other words, consideration of accountability and liability are essential to identifying how conditions for democratic decision-making about gene editing might be altered such that they do not merely reproduce the same patterns of scientific expert authority and decision-making power.

Importantly, the focus on restitution also requires a willingness on the part of both governing authorities and interested publics to want to do the work of holding gene editing developers accountable, which also requires that the relations among scientific experts, policy makers, and publics be reconfigured more tightly and in mutually integrative ways, not more independently. This is particularly the case for scientists for whom imaginaries of science as autonomous and sovereign are strong, socially durable, and often go unrecognized as contingent social orders that could be arranged otherwise (Jasanoff 2004; Jasanoff and Kim 2015; Smallman 2018).

In summary, public engagement with science is itself never a neutral activity—it actively reinforces the position of scientific experts by imbuing them with a character of responsibility. By committing to public engagement as part of responsible science, the site decision-making about the social, ethical, and political stakes for gene editing was established as a scientific one. Questions of whether and how to proceed with gene editing in accordance with public interests, then, fell to science as the imminent authority. Though scientists may insist that ultimate decision-making authority resides (or ought to reside) with publics, their governments, and their communities, and not with science alone, constructions of public engagement around gene editing as part of scientific responsibility show how public engagement with science and technology is itself democracy by other means.

The trouble is not that such constructions of public engagement as scientific responsibility are prima facie undesirable or inherently degenerative for democracy, but that they render unnecessary further probing and problematizing of the social dimensions and political mechanisms of governance and accountability. The problem is that representative expansion of for whom scientific experts act goes unstated, upheld by imaginaries of responsible scientists working on behalf of the public interests. However, the construction of public engagement as part of scientific experts' responsibilities as scientists occludes how gene editing decision-making is a product of expert judgements. Such constructions narrow the frame of the kinds of questions that are salient to gene editing governance to be those which public engagement itself purports to answer.

Public engagement both marked scientific experts as responsible and itself did the work of responsible science by including broader publics. As a result, there was not a need to interrogate those other questions of who is accountable to whom or obligated to act in what sorts of ways and with what kinds of oversight, because public engagement already does that work as *the* marker of responsible gene editing development and governance. Thus, public engagement obviated the need to ask those questions by aggregating societal and ethical concerns about gene editing such that public engagement responds to and resolves them, imparting a seal of societal approval and license for gene editing to proceed unabated and be recognized as being done responsibly.

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APPENDIX A

PUBLISHABLE WORKS

At the time of submitting this dissertation, portions of Chapter 4, “Knowing and Controlling: Engineering Ideals and Gene Drive for Invasive Species Control in Aotearoa New Zealand” are *in press* to appear in the following publication:

Ross, Christian H. 2021 (*in press)*. “Knowing and Controlling: Engineering Ideals and Gene Drive for Invasive Species Control in Aotearoa New Zealand.” In *Nature Remade*, edited by Luis A. Campos, Michael R. Dietrich, Tiago Saraiva, and Christian C. Young, 5-23. University of Chicago Press.

At the time of submitting this dissertation, portions of Chapter 5, “Handmaiden of Technocracy: Public Engagement and Expertise in Heritable Human Germline Editing Governance” *in review* for the following publication:

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