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Islands as Laboratories: Indigenous Knowledge and Gene Drives in the Pacific

Riley I. Taitingfong^{1*}

Western colonizers had long configured tropical islands into the contained spaces of a laboratory, which is to say a suppression of island history and indigenous presence.

—Elizabeth M. DeLoughrey, “The Myth of Isolates”

We are the sea, we are the ocean, we must wake up to this ancient truth and together use it to overturn all hegemonic views that aim ultimately to confine us again, physically and psychologically, in the tiny spaces which we have resisted accepting as our sole appointed place, and from which we have recently liberated ourselves.

—Epeli Hau’ofa, “Our Sea of Islands”

ABSTRACT

This article argues that the genetic engineering technology known as gene drive must be evaluated in the context of the historic and ongoing impacts of settler colonialism and military experimentation on indigenous lands and peoples. After defining gene drive and previewing some of the key ethical issues related to its use, the author compares the language used to justify Cold War-era nuclear testing in the Pacific with contemporary scholarship framing islands as ideal test sites for gene drive–modified organisms. In both cases, perceptions of islands as remote and isolated are mobilized to warrant their treatment as sites of experimentation for emerging technologies. Though gene drive may offer valuable interventions into issues affecting island communities (e.g., vector-borne disease and invasive species management), proposals to conduct the first open trials of gene drive on islands are complicit in a long history of injustice that has treated islands (and their residents) as dispensable to the risks and unintended consequences associated with experimentation. This article contends that ethical gene drive research cannot be achieved without the inclusion of indigenous peoples as key stakeholders and provides three recommendations to guide community engagement involving indigenous communities: centering indigenous self-determination, replacing the deficit model of engagement with a truly participatory model, and integrating indigenous knowledge and values in the research and decision-making processes related to gene drive.

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Gene Drives

A growing body of scholarship reflects ongoing deliberation over the technical, social, and ethical issues arising in pursuit of the first open field trials of gene drive—modified organisms. After defining gene drive and previewing the ethical considerations commonly addressed in discussions about its use beyond the laboratory, this article critically analyzes the tendency of this scholarship to frame islands as ideal test sites for gene drive. Proposals to use islands as testing grounds for gene drive contribute to a long history of injustice that has treated islands as sites of experimentation, with detrimental impacts to indigenous peoples and their ancestral lands. Researchers hoping to move gene drive to the field responsibly and ethically must commit to involving indigenous peoples as key stakeholders in gene drive research and governance. A set of three recommendations are provided to guide this engagement: centering indigenous self-determination, replacing the deficit model of engagement with a truly participatory model, and integrating indigenous knowledge and values in the research and decision-making processes related to gene drive.

Gene drives are systems of biased inheritance that enhance the transmission of a particular genetic element from parent to offspring (National Academies of Sciences, Engineering, and Medicine 2016). Whereas typical genetic inheritance incurs a 50% chance of an offspring inheriting some trait from its parents, gene drive systems elevate those odds through a variety of mechanisms (see Champer, Buchman, and Akbari 2016). With the advent of genome-editing tools such as CRISPR/Cas9 (clustered, regularly interspaced, short palindromic repeats—associated protein Cas9), gene drives can now be used to spread a targeted gene through nearly 100% of a given population of organisms (see Figure 1). CRISPR-based gene drives work by making precise cuts to the wild-type allele, then repairing it with an engineered version containing the drive, so that all or nearly all offspring will contain the drive allele. In this way, genetic modifications can be spread to entire populations of organisms more rapidly than ever before, which is considered both a major breakthrough and a cause for concern (Ledford 2015).

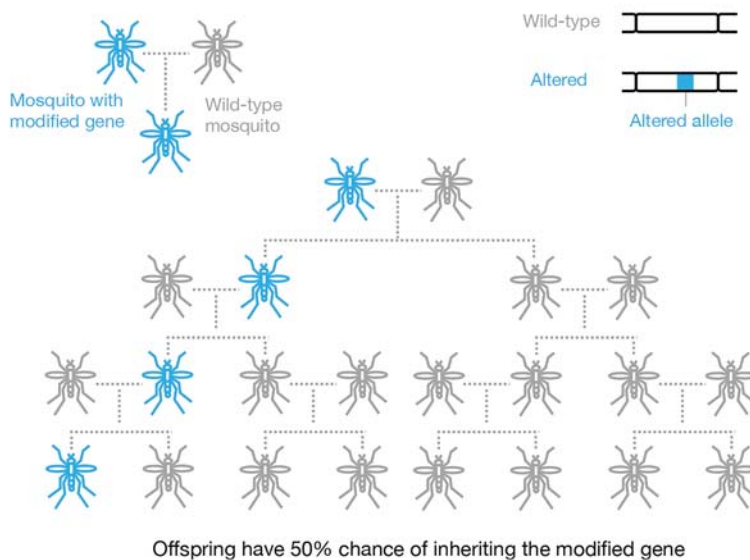
Advancements in gene drive have garnered

considerable attention for their potential to mitigate intractable issues across public health, agriculture, and conservation. Scientists and their funders are investing significant resources in the development of gene drives that may prevent the transmission of vector-borne diseases (e.g., malaria, Zika, and Lyme disease), suppress or eradicate populations of invasive species threatening ecological biodiversity, or manage pests carrying crop diseases (National Academies of Sciences, Engineering, and Medicine 2016). For instance, the Bill & Melinda Gates Foundation and the Tata Trusts of Mumbai have invested more than \$140 million combined in gene drive research for combating disease vectors and improving crop productivity (Courtier-Orgogozo et al. 2017). Gene drive may also offer a preferable alternative to extant methods of invasive species management and pest control (e.g., poisons or pesticides) that could expose humans and nontarget organisms to hazardous chemicals or lead to the development of resistance in target organisms.

While the potential benefits of gene drive are highly anticipated in scholarly and public discourse, there are also myriad concerns about its possible harms. A great deal of uncertainty surrounds the overall effects gene drive technologies will have once released outside laboratory settings, making informed risk assessment difficult to achieve. It remains to be seen how gene drive technologies will function in the environment, raising concerns about unintended deleterious effects on wild-type conspecifics, nontarget species, and overall ecosystem health (Caplan et al. 2015; Lunshof and Birnbaum 2017; Pugh 2016; Resnik 2014; National Academies of Sciences, Engineering, and Medicine 2016). Discussions of risks have also acknowledged the conceivable weaponization of gene drive, for instance, to spread infectious disease or coordinate attacks on crop plants.

These risks are intensified by the fact that some gene drives are designed to self-propagate indefinitely after the initial release of a modified organism, meaning gene drive systems could theoretically spread to every population of the target species on a global scale (Collins 2018; Esvelt and Gemmell 2017). Mathematical modeling has suggested that even the escape of a few organisms with self-propagating gene drive could rapidly alter wild populations of that organism (Noble et al.

A) Normal inheritance



B) Gene drive inheritance

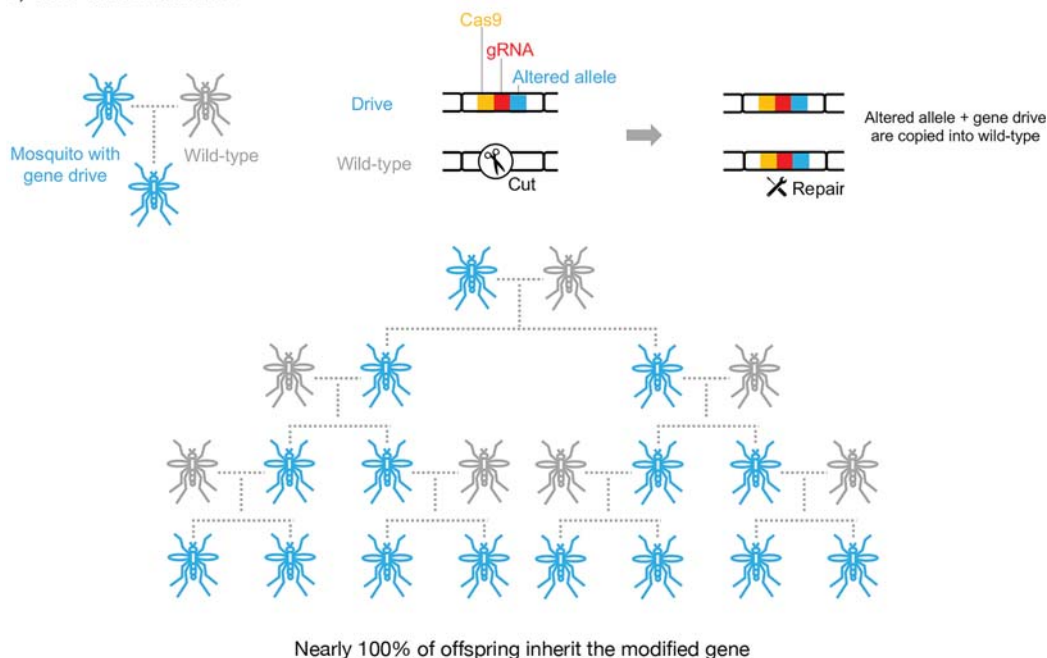


FIGURE 1. Normal inheritance versus gene drive inheritance.

2018). Though researchers are working on a range of strategies to limit or mitigate the effects of gene drive on the environment—the US-based Defense Advanced Research Projects Agency (DARPA) has contributed more than \$65 million to research on the containment and reversal of the effects of genome-editing technologies, including gene drive (Wegrzyn, n.d.; Callaway 2017)—questions of mitigation remain invariably complicated, as it is unknown whether the implementation of

additional gene drive systems, such as “reversal drives,” will introduce ecological issues of their own (National Academies of Sciences, Engineering, and Medicine 2016).

The risks and uncertainties outlined above have framed considerable discussion about the interconnected social and ethical issues of bringing gene drive technologies to the field. How should decisions be made about open releases of gene drive, given the conditions of uncertainty

surrounding their use outside the laboratory? Who should be included within those decision-making processes? How will transborder effects be negotiated, considering that after release into the environment, “a gene drive knows no political boundaries” (National Academies of Sciences, Engineering, and Medicine 2016)? As scientists, ethicists, and regulators continue to grapple with these questions, there is increasing interest in conducting early field trials of gene drive on islands in an effort to limit or circumvent the risk of unintentional global spread (Harvey-Samuel et al. 2017; WHO/TDR and FNIH 2014). While islands face myriad ecological and public health issues amenable to an intervention like gene drive, the framing of islands as test sites ought to raise an additional set of questions and considerations regarding the ethics of such proposals.

Gene Drives in Oceania

The potential benefits of gene drive have practical import in the Pacific Islands region (subsequently referred to as Oceania), particularly in the contexts of public health and conservation. For instance, strategies are needed to reduce the impact of vector-borne diseases throughout Oceania, such as lymphatic filariasis, dengue fever, chikungunya, Japanese encephalitis, and malaria (Reed 2018). These neglected tropical diseases disproportionately affect economically poorer regions throughout Oceania, which are less likely to have sufficient vector control programs and have limited health care infrastructure, and where socioeconomic conditions are compounded by environmental factors that facilitate the breeding of vectors like mosquitoes (Mavian et al. 2019). Moreover, due to the high rates of species endemism on Pacific Islands, scientists and conservationists are interested in gene drive for the preservation of endangered species. Biologists in Hawai‘i are developing gene drives to suppress populations of *Culex quinquefasciatus*, the mosquito that vectors avian malaria to endangered bird species, and Island Conservation’s Genetic Biocontrol of Invasive Rodents (GBIRD) program (<https://www.geneticbiocontrol.org/>) is investigating whether gene drive may be used to eradicate rodents that threaten island biodiversity (Harvey-Samuel et al. 2017).

In addition to considerations of the specific ways gene drive may benefit islands, there is a broader discussion implying that islands may benefit the advancement of gene drive research overall. The World Health Organization has pointed to islands as “ideal” testing locations for genetically modified mosquitoes with gene drive, citing their geographic isolation as an important characteristic for minimizing biosafety risks (WHO/TDR and FNIH 2014). Similarly, the National Academies of Science, Engineering, and Medicine’s (2016) report on gene drives says that islands “constitute an ideal geographically isolated contained setting” to limit the physical dispersal of transgenic organisms with gene drive in field trials. This literature reflects a widely held sentiment that islands represent a natural or logical location for “confined” field trials of gene drive–modified organisms. Critical examinations of this claim, though lacking in scholarship focused on gene drive, are warranted when considering the fraught history of experimentation in Oceania and the ways the language of isolation has been mobilized to justify it.

First, it is important to note that the very framing of islands as isolated, small, and remote is incommensurate with indigenous Pacific Islanders’ views of their island homes. As the late Tongan and Fijian scholar Epeli Hau‘ofa argued, colonizers were the first to conceive of Pacific Islands as “tiny dots in a vast ocean,” basing their calculations of size on visible land surfaces alone (Hau‘ofa 1993). Indeed, settler colonialism is an inherently landcentric project: for colonizers hailing from continental geographies, the positioning of islands as “tiny” functioned to legitimize their claims to those already inhabited islands and the material wealth they found there. However, this narrow emphasis on land misses the centrality of the ocean to indigenous life and identity in Oceania. As a vital resource for survival and important avenue of transportation for Pacific Islanders, the ocean is as much a part of their world as the islands they inhabit. Kanaka Maoli (Native Hawaiian) scholar and surfer Karen Amimoto Ingersoll (2016) has observed this of Hawaiian relations to water, positing that “the ocean serves as an instrument of migration; as transportation; and as a source of food, medicine, and shelter.” When we recognize the significance of the ocean to indigenous communities of Oceania,

it becomes clear that their islands are not confined or isolated by the ocean but, rather, are sustained and connected by it.

As University of Hawai'i biologist Floyd Reed (2018) has noted, those harboring uncritical notions of islands as "external to daily life" and thus more disposable for experimentation likely do not live on (or have cultural ties to) islands in the Pacific. Such views reflect contemporary iterations of the settler-colonial logics described above: continents are centered as the metropole, while islands are marginalized to the periphery. This spatial configuration has been used to justify myriad harmful acts carried out in the Pacific by colonial and military powers, including the appropriation of indigenous lands for the establishment of military bases, training grounds, and nuclear experimentation. Throughout the Cold War era, the conception of islands as isolated was frequently used to rationalize the hundreds of nuclear tests conducted by France in Mururoa and Fangataufa Atolls, by the United Kingdom in Australia and Kiritmati Islands, and by the United States in Bikini, Enewetak, Johnston, and Kirimati (DeLoughrey 2012; Genz et al. 2018).

From 1946 to 1958, the United States conducted a total of 67 nuclear tests in the Marshall Islands. This included the most powerful nuclear weapon ever detonated by the United States: the Castle Bravo hydrogen test of 1954 at Bikini Atoll (Genz et al. 2018). Estimated to have been a thousand times more powerful than the bombs dropped on Hiroshima and Nagasaki, the Bravo test released radioactive debris into the atmosphere that fell over 7,000 square miles and affected the neighboring atolls of Rongelap, Utirik, and Ailinginae (DeLoughrey 2012; Cronkite et al. 1997). Direct radiation exposure, as well as fallout present in the soil and traditional food sources, has led to radiation exposure sickness in numerous communities throughout Oceania and continues to produce high rates of thyroid disease and cancer (Hakewill and Dallemagne 1995; Genz et al. 2018). Women in the Marshall Islands and Rongelap have also faced miscarriages, stillborn births, and children with birth defects as a result of exposure to radiation (DeLoughrey 2012).

The nuclear legacy of America is not limited to Oceania, nor are Pacific Islands the only indigenous lands that have been appropriated for

the advancement of nuclear technologies. In the United States, the extractive practices associated with nuclear weapons development have disproportionately affected indigenous communities, with up to 90% of all uranium mining and milling occurring on or adjacent to Native American land (Grinde and Johansen 1995). Uranium mining and aboveground nuclear testing occurred for roughly 50 years on and around Navajo and Hopi reservations, leading to severe health effects in exposed communities. Due to mining on Navajo lands, at least 450 cancer deaths have been reported among Navajo mining employees (Endres 2009). For Pacific Islander and Native American communities alike, the environmental impacts and associated health effects of nuclear testing are transgenerational: decades later, there are still high rates of thyroid disease and cancers in Pacific Islander communities, and more than 500 abandoned uranium mines on Navajo nation continue to pollute water sources (US Environmental Protection Agency, n.d.).

Indigenous communities from Oceania to the US mainland have long been subject to (and actively resisted) the appropriation of their lands for nuclear testing and other forms of experimentation. The histories of nuclear testing as well as those of military buildups, failures in biocontrol, and other violations of indigenous self-determination represent a context from which ethical risk assessment of gene drive cannot be divorced. It is imperative that researchers cultivate an understanding of the historic and continued impacts of experimentation on indigenous communities in general, as well as in the particular regions where they are seeking to test their technologies. In the case of Oceania, there are many lessons to be learned from misconceptions about isolation, unanticipated consequences of experimentation, and failure to gain informed consent within the examples of colonialism and militarism previewed above. It is encouraging that consent and community engagement are frequently emphasized in the context of gene drive, but it remains to be seen how these discussions will translate to practice. As researchers work to organize community engagement for gene drive research and development, it is crucial not only that they involve indigenous peoples, but also that they do so in ways that incorporate the specific knowledge, values, and perspectives of those communities.

Table 1. Recommendations for the Ethical Engagement of Indigenous Communities in Gene Drive Research and Development

Recommendation	Implementation
Center indigenous self-determination	i. Conduct field trials and open releases of organisms with gene drive <i>only</i> when authorized by indigenous community partners. ii. Recognize that consent is not a guaranteed outcome of partnership (and pursue collaborative partnerships with local indigenous communities regardless).
Replace the deficit model of engagement with a participatory approach	i. Do not conflate unidirectional educational efforts (e.g., science communication) with participatory community engagement. ii. Pursue participatory approaches to community engagement (e.g., collaboration, mutual learning, community expertise). iii. Model participatory practices after other indigenous-led research.
Integrate indigenous knowledge and values	i. Identify culturally specific values and concepts relevant to gene drive research and risk assessment. ii. Draw on culturally specific values and knowledge to codesign questions in continued research and decision making related to gene drive.

Developing Indigenous Frameworks for Community Engagement

Community or public engagement is often underscored as a key aspect of gene drive research and development, and popular guidance documents have even made specific reference to the engagement of indigenous communities (Convention on Biological Diversity 2017; National Academies of Sciences, Engineering, and Medicine 2016; Kuzma et al. 2018). However, *engagement* remains ill-defined and is rarely operationalized in these discussions. Some of this scholarship emphasizes the hallmarks of participatory community-engaged research defined in the fields of education and the social sciences (Freire 1993; Adelman 1993), which calls on researchers to position communities as experts with valuable, situated knowledge and to use that knowledge to inform all stages of research and its use (Rowe and Frewer 2005; Thizy et al. 2019; Hartley et al. 2019; see also the Responsive Science website: <https://www.responsivescience.org/>). Still, researchers lacking experience in community-engaged research may (consciously or unconsciously) default to more instrumentalizing forms of engagement as a means to obtain consent rather than a genuine approach to an open-ended research inquiry. Further, the lack of attention paid specifically to indigenous communities in the gene drive literature leaves practitioners ill-equipped to take the necessary steps to build relations with indigenous communities they wish to engage.

Fortunately, a robust body of work has been produced by indigenous scholars and allies regarding the engagement of indigenous communities

in scientific research. These works emerge from several science and social science disciplines (e.g., genomics, biomedicine, indigenous studies, Pacific studies) and are an invaluable resource for those looking to engage indigenous communities in research and decision-making processes related to gene drive. The remainder of this article draws on some of this scholarship to offer a set of recommendations for engaging indigenous communities in gene drive research: (1) centering indigenous self-determination, (2) replacing the deficit model of engagement with a participatory model, and (3) integrating indigenous knowledge and values in the research and oversight of gene drive technologies. Table 1 summarizes these recommendations, which are discussed in depth below.

Center Indigenous Self-Determination

Indigenous self-determination has become increasingly centered in fields such as genomics, biomedicine, and data governance. In the context of gene drive research, respecting indigenous self-determination means understanding local indigenous authorization as a prerequisite for the release of organisms with gene drive. Like Claw et al.'s (2018) framework for ethical genomic research with indigenous communities, in which indigenous sovereignty and research regulations are positioned at the center, gene drive researchers must acknowledge the sovereignty and regulatory processes of all indigenous groups, regardless of federal or state recognition. Respecting indigenous self-determination also entails recognizing that partnership with indigenous communities does not necessarily guarantee authorization and pursuing

community-engaged partnerships regardless. This is crucial given the historical mistreatments of indigenous peoples in research and experimentation that did not seek their informed consent.

Replace the Deficit Model of Engagement with a Truly Participatory Model

While some gene drive scholarship encourages researchers to pursue participatory approaches to public or community engagement (i.e., building mutual relations with communities such that they are decision-making stakeholders), another emerging conception of engagement is informed by the more unidirectional practices of science communication and marketing, calling on scientists to educate lay audiences on the science of gene drives. Usually, these calls reflect a “deficit model” view, which focuses on a perceived lack of knowledge or literacy on the part of communities and assumes that this lack shapes skepticism toward a technology. For instance, researchers from North Carolina State University reported that some deficit-model views were expressed at the “Road Map to Gene Drives” workshop held in 2016, which convened an international group of experts from academia, business, government, and nonprofit organizations to discuss core governance issues and research needs for gene drive. Kuzma et al. (2018) reported that, when asked how to engage communities in geographic areas affected by gene drives, “some participants operated under the premise that the main goal [of public involvement] should be to educate the public, as they perceived a current lack of public knowledge about gene drives and, thus, were hesitant to include the public as full partners in decision-making for fear that this lack of understanding would lead to fear of anything that is genetically engineered” (p. S24).

A common presumption under the deficit model is that, with more education, publics will become more accepting of a given technology. While the goal of increasing public understanding of gene drive is important, research has shown that education does not entirely determine public support (National Academies of Sciences, Engineering, and Medicine 2016). Moreover, conflating education with engagement forecloses valuable opportunities afforded by participatory community engagement, namely, *mutual* learning and the leveraging of community expertise as a resource.

Integrate Indigenous Knowledge and Values

Though there is recognition of the value of multiple types of expertise in grappling with the complex ethical and social dimensions associated with gene drive, frameworks for regulatory decision making within this field still tend to privilege science-based knowledge and technical risk assessments over social and ethical considerations (Kofler et al. 2018; Brossard et al. 2019). Because concepts such as *risk* and *benefit* are contingent upon the communities or persons defining them, it is important that decisions surrounding gene drive do not rely solely on extant frameworks that will inevitably omit culturally specific considerations, including those of indigenous groups. The heterogeneity of indigenous communities is also important to note here. In the United States alone, there are more than 573 federally recognized tribes, hundreds more that are unrecognized by the government, and many other diverse indigenous Pacific Islander communities (Bureau of Indian Affairs 2019). Recognizing that indigenous knowledge and values will be as diverse and heterogeneous as the groups they come from, researchers should work collaboratively with specific communities to identify the most inclusive ways to approach gene drive research, risk assessment, and decision making about whether or not to pursue field trials in a particular region. Researchers can also draw upon the work of indigenous scholars who work to bridge Western and indigenous knowledge in scientific research. Two examples of this scholarship are briefly outlined below, to demonstrate the ways indigenous values may inform frameworks guiding gene drive research.

Examples from Oceania: Kānaka Maoli and Māori Values in Research

Exemplary work on the importance of recentring indigenous knowledge in Western science comes out of Aotearoa New Zealand. Linda Tuhiwai Smith's (2012) seminal text *Decolonizing Methodologies* demonstrates how Western research furthers processes of colonization by defining what counts as “legitimate knowledge” and rendering indigenous knowledge outside of that which is considered valid, reliable, or rigorous. Smith discusses Kaupapa Māori research as an intervention

in the marginalization of Māori knowledge in research. The Kaupapa Māori approaches to research “are based on the assumption that research that involves Māori people, as individuals or as communities, should set out to make a positive difference for the researched.” In addition, “the research approach also has to address seriously the cultural ground rules of respect, of working with communities, of sharing processes and knowledge” (pp. 309–310). Taking a similar approach within the context of gene drive research means ensuring that indigenous communities agree with the perceptions of researchers on benefits of gene drive and that subsequent research honors indigenous processes for decision making, such as consulting particular leaders or subcommunities.

Hudson et al.’s (2019) recent pilot study on Māori perspectives on gene editing offers a valuable demonstration of Kaupapa approaches. After conducting a review of literature to identify Māori concepts and values that may be relevant to gene editing, coauthors engaged Māori participants in interviews and surveys to explore how those values may drive future research on the risks and benefits of gene editing in Aotearoa New Zealand. By grounding their discussions in Māori values such as *whakapapa* (genealogy), *mauri* (life essence), *mana* (power/authority), and *kaitiakitanga* (guardianship), the authors were able to pose valuable, community-guided questions, such as, “Do you think whakapapa is affected if you introduce DNA into one species from another?” and “Do you think gene editing can support kaitiaki responsibilities and under what circumstances?” (p. 4). Such inquiries offer a model for developing community-designed questions grounded in indigenous values and knowledge.

There is also a wealth of scholarship on the relevance of Hawaiian values for research. Kānaka ‘Ōiwi (Native Hawaiian) scholars have written about the importance of centering Hawaiian values in their research practice, such as *lāhui* (collective identity and self-definition), *ea* (sovereignty and leadership), *kuleana* (positionality and obligations), and *pono* (harmonious relationships, justice, and healing) (Goodyear-Ka’ōpua 2016). In reflecting on findings from her own community-engaged scholarship, Noelani Goodyear-Ka’ōpua (2013) has written about *‘āina* (land; literally translated as “that which feeds us”) as the embodiment

of Hawaiian ancestors, positing that for Kānaka ‘Ōiwi, *‘āina* “is not *something* but *someone*.” What is at stake in developing a technology that could irreversibly affect the environment when land is ancestor and when the well-being of that land directly reflects the well-being of the community it sustains? Researchers should anticipate these types of questions when working with communities that maintain deep connections to their ancestral lands. The establishment of respectful research partnerships will depend on researchers’ capacity to recognize and support community values, including the obligation to steward and protect indigenous lands.

Conclusion

There are important opportunities for the cultivation of ethical partnerships between researchers and indigenous communities in the context of gene drive research. However, as evidenced with the example of nuclear testing in Oceania, new forms of experimentation on indigenous lands are inevitably implicated within the structures of settler colonialism and militarism that continue to shape inequalities among indigenous communities. To pursue more ethical research practices, researchers must contend with these histories and the position of their scientific practices within them, and work to engage indigenous peoples in research and decision-making processes related to gene drive. The recommendations for engagement outlined in this article offer a preliminary set of tools for researchers hoping to collaborate with indigenous peoples in gene drive research. By respecting indigenous self-determination and moving beyond unidirectional forms of engagement to incorporate indigenous knowledge and values in their research, researchers will be positioned to enter into reciprocal and generative partnerships with the communities their research impacts.

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