Hurdles in responsive community engagement for the development of environmental biotechnologies

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Abstract
Recent calls for engaging communities in biotechnology development do not draw enough attention to the hurdles that must be overcome for engagement strategies to effectively feed back into research design and conduct. These hurdles call into question many standard ways of operating and assessing in traditional scientific disciplines. The first steps in addressing these hurdles can be the most difficult. In reflecting on our own experiences in the early-stage development of environmental biotechnologies, we provide a set of techniques to help scientists and their collaborators learn to become more responsive to the needs and attitudes of communities with which they are engaging.

Key words: gene drives; community and stakeholder engagement; responsive science; environmental biotechnologies

Graphical Abstract
Feedback Loops for Responsive Community Engagement

1. Introduction
Synthetic biology has fostered new conversations around environmental conservation, disease mitigation and ecosystem management (1). It has also called into question the ways that perspectives beyond those of the scientists are, and are not, incorporated into research design and conduct.

Recent advances in genome-editing technology, notably the ability to create synthetic gene drives using clustered regularly interspaced short palindromic repeats (CRISPR), have augmented the potential to deliberately shape the genetic portrait of shared ecosystems (2, 3). Gene drives that address mosquito-borne diseases have emerged as a well-funded area of synthetic biology...
in ecosystem management (4, 5). Given that these systems are likely to be tested through field trials in the near future (6), research groups are actively exploring ways to engage community stakeholders in the deployment process (7–10). Thus, the ongoing development and potential implementation of environmental biotechnologies is an opportunity to explore new engagement frameworks that steer the way research is conducted, particularly in (and by) communities where field trials are likely to occur (11).

1.1 How is engagement initiated?

While early and longitudinal engagement with potentially affected communities has been a part of efforts for planning gene drive field trials (12, 13), the specific hurdles that scientists and bioengineers come upon after initiating that engagement have so far not received sufficient attention. The scientist or bioengineer is often a primary mover within these methodologies, but they come into the work of engagement with little training on how to do it. Most scientific laboratories are not founded on a critical reflection of the relationship between science and society.

Several methodologies have emerged in an effort to create infrastructures that encourage scientists to engage with the ethical, political and social aspects of their work (14–19), but most bioengineers are not aware of this literature, even if they have had the exposure to it in some form through venues like the international Genetically Engineered Machines competition (20). There is a need, then, for the development of a connective tissue between the social science and the work in and outside the laboratory. Actual experiences of building this connective tissue often do not get covered in the literature about engagement, which instead tends to focus on formalized guidelines and principles.

Drawing on a broad range of experience with early-stage community engagement, including our own on the potential development of localized gene drive (daisy drive) systems (21) in the US Virgin Islands (USVI), we outline here several hurdles that we encountered in trying to be more responsive to communities at the beginning of the community-stakeholder engagement process. The first step toward becoming a more ‘responsive scientist’ (22) involves creating learning feedback loops that iteratively inform community engagement, collaboration with social scientists and experimentation in the laboratory.

2. Responsive Science Working Group and experiments in engagement

From 2016 to 2019, the Responsive Science Working Group, in conjunction with the Sculpting Evolution Group, at the MIT Media Lab conducted a set of initial engagement activities with communities in the USVI and New Zealand and continued engagement work with communities on Martha’s Vineyard and Nantucket, two islands off the state of Massachusetts (23). Each of these sites provided opportunities to experiment with very early-stage engagement around the potential development of engineered organisms with potentially affected communities. Below, we explore one of these sites, the island of St. John in the USVI, as an example of the types of hurdles researchers are likely to meet in developing learning feedback loops.

To address vector-borne diseases on the islands, our team sought to understand the potential development and deployment of daisy-chain gene drives, a kind of gene drive that separates CRISPR components into linked genetic elements and is designed to be self-limiting (21, 24, 25). At the time (and to this day), this technology had not yet been developed. Prior to experimental design or laboratory work, we wanted to first engage local residents and get feedback that could inform the experimental design (modeling daisy drive dynamics in Caenorhabditis elegans). With this goal in mind, we made several trips to the island to conduct semi-structured interviews with residents about the potential of implementing a daisy drive to address mosquito-borne illness.

To briefly contextualize this work, St. John is the smallest of the three main USVI, less than 20 square miles in size and home to 4170 residents (26). St. John is divided into two primary communities: Cruz Bay and Coral Bay, separated by the Virgin Islands National Park, which comprises 60% of the island overall (27). All of the official governance bodies and organizations we encountered and engaged with were USVI-, or US-wide, and not St. John specific. Two of the authors were graduate students pursuing Masters of Science during this time: Normandin in Media Arts and Sciences and Fitzgerald in Technology and Policy. As part of their training, both were members of the Sculpting Evolution Group, where they were developing genetic model systems for daisy-chain gene drive development. Yip was an anthropology postdoc with the Sculpting Evolution Group, and Evans was a Research Affiliate co-leading the Responsive Science Working Group with philosopher and ethicist Jeantine Lunshof. Normandin and Fitzgerald’s visits to St. John involved engaging with a range of actors—community leaders and organizations, business owners and employees, healthcare providers, national park representatives, retirees and vacationers—to better understand residents’ experiences with mosquito-borne illness and, more specifically, attitudes regarding genetics-enabled control of mosquitoes.

Below, we outline some lessons that we learned through our lived experiences of initiating community engagement, the specific hurdles we encountered and some basic tenets that others can apply in their own learning journeys.

3. Broaden the make-up of the team

Becoming responsive to local communities is difficult, and it can go against deeply ingrained scientific incentives and oversight systems. The capacity for research laboratories around the world to develop environmental biotechnologies is not necessarily matched by their ability to situate that development within issues of responsibility and ethics. To make a laboratory more engaged and reflective, processes of ‘learning-by-doing’ are required, and scientists would greatly benefit from connecting with disciplines that have a long history of studying engagement methodologies, such as science and technology studies (STS), anthropology and sociology.

Beyond engaging different kinds of disciplines, broadening the team to include different perspectives, types of expertise and diverse groups can help with problem identification, building relationships and trust (7). Yet it can be daunting to make these initial connections; almost all scientists operate outside of large, formalized and institutionalized networks that can generate frameworks like what Thizy et al. (11) describe, which included mixed social science expertise to inform each step of the process. While the structural change of the system of science might be what is needed for these types of networks to be commonplace, that change comes, in part, from many very low-level modifications to the way research is done. Graduate students are often the ones who have the most flexibility in making these connections to other disciplines and perspectives. Over time, the people they connect with can become peers, as well as mentors in these other areas of expertise (28).

In our particular experience, the Responsive Science Working Group actually formed after a chance meeting of Fitzgerald and Evans through another program both were part of.
Learning from experience: Missteps will be made during the engagement process, often of the sort scientists will not be used to making. Learning will be essential to developing responsive capacity. Our initial engagement design rested too heavily on the networks of socioeconomically advantaged groups on USVI, missing the cultural and ecological context of other communities on the island of St. John. Through partnering with anthropologists and STS researchers, we realized that our initial contacts not only affected how we came to understand communities and their dynamics but also how these communities viewed our engagement and research work.

For instance, an anthropologist who accompanied us on our first visit, Gabrielle Robbins, drew out the deep interplay in the local culture between disease, repair and community. It was not until we were reflecting on the first trip, however, that we had to grapple with what this deeper understanding of the relationship between disease and society meant for our own research trajectories. One benefit of incorporating an STS perspective through Evans’ mentorship of the team was an ability to realign our goals based on feedback from our first visit. Engagement efforts often rely, at least initially, on gaining access to, and the trust of, gatekeepers and power brokers within local communities. During our second visit, our engagement goals shifted to how we could better understand networks of communication and dissemination of information on St. John. We also aimed to discover who were the brokers of power on St. John; what governing bodies, if any, made key decisions about what happens both on St. John specifically and the USVI at large? To address these questions, we began to expand our network of contacts to include individuals who seemed to represent different communities and interests, ranging from business owners and developers, environmentalist organizations, religious groups and multi-generational resident communities and more recent transplants.

Learning from experience: For our engagement on St. John, the scope of the project was largely defined by the length of the Master’s degrees of the students involved. While there was an intention to extend this work beyond the student engagement as appropriate, the details of how we would achieve that longevity were not defined at the time. Because our discussions with community members did not focus on creating these decision trees, after 2 years of engagement, we were uncertain how or when to end the project. It was challenging to make the timelines of scientific experiments match up with students’ degree programs, as well as the timelines of engaging communities.

At present, the future of this project is unclear. When we (Normandin and Fitzgerald) were completing our degrees, there were not obvious candidates within the Responsive Science or Sculpting Evolution groups to take over the pursuit of the work. More fundamentally, because we had not defined clear decision points or pathways, either within our groups or with the communities, the varied and significant skepticism we encountered in our engagements on the island left us unsure of whether we should proceed.

5. Resist the urge to educate rather than learn

Scientists are still regularly taught that there is a single body of knowledge about the world, and a single process, the ‘scientific method’, that we use to produce it. Recognizing that there are other valid knowledge systems (including traditional ecological knowledge), and that they are critical for guiding scientific work, is perhaps the biggest hurdle toward conducting research in a responsive way (29).

While communities might be unfamiliar with the specific biological intricacies of a given tool, scientists are likely to be unfamiliar with a community’s understanding of its own ecosystem and culture and how the scientific work may interact with it. Local expertise is invaluable, and responsive community engagement necessitates learning to work with local experts to help shape research trajectories (29). In the specific case of synthetic biology applications for the environment, learning about the ecosystem from permanent or long-term residents, and understanding firsthand possible effects of engineered changes, can be an excellent—and welcome—starting point for engagement and is a key element of success in project co-development (12, 30–32).

This process asks scientists and engineers to let their assumptions be challenged. It encourages them to stay open to new ideas that community members might present—ideas that reflect a unique personal and cultural history associated with a particular social context, environment and geography. It also requires critical self-reflection about how one’s own positioning, such as one’s institutional affiliations, funding sources, gender, race, etc., as well as the positioning of potential collaborators, will shape the engagement trajectory and its findings (33). Biases are not inherently bad, nor can they ever be fully eliminated. Instead, attending to biases allows scientists and engineers to critically think about research assumptions and goals.

4. Don’t build a bridge to nowhere

In academic settings, the high turnover rate and graduation of participating scientists make co-developed trajectories and exit strategies even more crucial to ensure that projects can outlast the length of a graduate degree. Scientists should be as deliberate in the handover of their engagement project as they are in handling over the scientific aspects of their work. Longitudinal engagement like that envisioned by the gene drive community will require dedicated staff to be the connective tissue between generations of students and researchers who will provide the bulk of empirical work. Long-term funding is the easiest way to facilitate this longevity, but even when this cannot be secured, deliberate planning from the outset and careful handover between scientists as project leads change can be highly impactful. Building flexibility into the development pipeline to account for both technical challenges observed in the laboratory and potential bureaucratic channels within communities is key. Biological research can be unpredictable, but mutually defined timelines for key deliverables not only grant communities leverage in a relationship but also provide a built-in mechanism for longitudinal engagement and accountability. In this scoping, it is useful to also co-develop exit strategies for community work from the inception of research (11). This includes strategies to ‘close’ or modify the research project or engagement work if the researchers encounter substantial skepticism from a majority of citizens in the earliest stage of the work. Mutually defining exit strategies with partner communities means going beyond generating awareness and instead letting the community steer what form appropriate closure takes.
Learning from experience: Initially, we sought to build an understanding of St. John’s ecosystems by seeking out the guidance of the National Park Service because Virgin Islands National Park comprises more than half of the island. In our team’s reflections meetings, though, we realized that such a partnership could only yield one type of thinking about ecology and the effects a gene drive or similar technology might have on the ecosystem. We were thinking of the island as a laboratory and not an environment integrated into society. We therefore actively sought out broader perspectives and started to ask both local environmental groups and individual community members how they came to learn about their environment and what knowledge they held regarding the role of mosquitoes in it. Our interactions with a diverse range of actors on St. John thereafter provided invaluable insights and personal accounts regarding the incidence of mosquito-borne illness, methods used to halt mosquito breeding, as well as potential ecological effects of mosquito removal based on rich individual experiences and deep local knowledge. By listening rather than seeking to educate, we were able to reshape our thinking around how and when potential drive systems could be released, what natural or mechanical methods could be combined with a genetics-based approach and ecosystemic effects of mosquito removal on the island. These discussions also highlighted to us which experimental data would be most critical to share with island residents in the early stages of the accompanying laboratory research. These on-the-ground experiences with residents rounded out a more holistic vision of St. John and provided local residents agency in the research process, as they were framed as having expertise that they could share with us as learners.

To feed our learning process back into our research design and ongoing engagement strategy, we wrote frequent reflections as a way of critically examining expectations of Responsive Science and the realities of our fieldwork, exploring questions in community-stakeholder engagement and reflecting on the contingencies with which our engagement began. These self-reflections combined with learning from local experts shifted the way we discussed which technologies, biological or otherwise, were suitable for mosquito eradication and ecosystemic effects of mosquito removal on the island. These discussions also highlighted to us which experimental data would be most critical to share with island residents in the early stages of the accompanying laboratory research. These on-the-ground experiences with residents rounded out a more holistic vision of St. John and provided local residents agency in the research process, as they were framed as having expertise that they could share with us as learners.

6. Do not underestimate social complexity as technical solutions are advanced

To get research funding, scientists and engineers need to tell a story about how their work matters to the larger society. These stories often offer idealized and simplified views of the relationship between the research and social objective. When conducting engagement, however, the story is much more complex and intertwined with other issues that local communities are grappling with. When working through this complexity, the scientist or engineer needs to decide how much each community’s voice should feed back into the ongoing research design, but this is neither a straightforward nor an objective decision. Societies have classes and experience the effects of particular technological interventions in radically different ways. As we show below, attending to the perspectives and concerns of those in more vulnerable sections of a society often means attending much more to the political dynamics of research trajectories.

Learning from experience: As we prepared to visit St. John, we expected to encounter highly varied perspectives on daisy-chain gene drives as a technology, especially as it may be applied to mosquitoes in USVI. However, we also assumed that the reduction of mosquito-borne illnesses in the region would be a top priority across groups. What we encountered was far more nuanced: while mosquito illnesses were certainly seen as problematic, many leaders and community members we met were also quick to point out that recovering from the damage inflicted by back-to-back hurricanes in 2017 on homes and other critical infrastructure across the island was far more pressing. This need was especially true of the more vulnerable and multi-generational residents we met, many of whom expected reconstruction to take many months or years and be prohibitively expensive.

Additionally, our conversations with community members illuminated a history of ecological interventions of which we had not been aware. In the 1800s, mongooses had been introduced to the island as a means of controlling rat populations on sugar plantations but caused significant damage to native species and agricultural systems. The legacy of those unintended consequences is pronounced in the region, and this history was top of mind for many of the community members we engaged as they considered our modern environmental biotechnology. Learning these histories engendered in us a humility about what we should expect any technical intervention to achieve.

7. Conclusion

The Responsive Science Working Group provides one example of how bioengineers can become more engaged with communities where potential environmental biotechnologies might be developed and deployed. By drawing out the hurdles we encountered, we have demonstrated that it is not a straightforward process to move from general statements about the need for stronger engagement with communities to the practice of actually doing that engagement (and having it feed back into research design). It is, however, worthwhile, particularly if the intention of the development is understood as addressing both ecological and social concerns.

There are things that we would do differently if we were starting this process again, but we share these missteps because of how likely other scientists are to repeat them. Bioengineers will inevitably mischaracterize the relationship between their technical goals (e.g. eradicating mosquitoes) and the social goals (e.g. improving ecosystem balance and social well-being) as uncomplicated and linear, when in fact the opposite is true.

The question, then, is how we can recognize the limitations of our own perspectives early on and develop strategies to attend to them. While each group of bioengineers will encounter different challenges, there are similar steps that can be taken once those hurdles are recognized. Broadening the expertise in one’s team, attending to the lifecycle of the research project, learning to listen and value a wider set of expertise and not underestimating the social complexity of any technical intervention all move research in directions that make it more attentive of, and responsive to, the world in which any gene drive organism will exist.
The new perspectives and knowledge that we gained from these steps tangibly fed back into our engagement design and trajectory. The formation of the Responsive Science Working Group itself provided us with a reflective space to better understand our research within a broader context. Recognizing the temporal dynamics and priorities within our own laboratory made us temper the language we used for what such work might achieve with the local communities. By better understanding whose local perspectives we were attending to, we necessarily had to confront the political dynamics of the local community and how decisions we made about research trajectories would likely empower some members of that community over others. Moreover, by better understanding the history and relationships that the local communities had with their environment and with those who have come from the outside to ‘improve’ it in the past, we more deeply appreciated the complexity of ever understanding whether any intervention would provide a net benefit, and for whom.

Many researchers interested in developing environmental biotechnologies will likely start their project with a set of training and institutional priorities that do not include attention to or training in how to meaningfully engage with the broader aspect of one’s research. By approaching the hurdles of engaging local communities as opportunities to become more responsive to the broader contexts of our research, we have demonstrated ways that other bioengineers can move toward making meaningful progress in changing the way they research, and the content of that research.

Data Availability
Data from interviews conducted for this article are available upon request, and subject to the limitations of distribution required to maintain appropriate human subjects confidentiality under protocol #1901640965 of the Committee on the Use of Humans as Experimental Subjects (COUHES), Massachusetts Institute of Technology.

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A.M.N. and L.M.F performed the fieldwork; A.M.N., L.M.F., J.Y and S.W.E. wrote the manuscript. S.W.E. created and facilitated the Responsive Science Working Group.

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References
1 Alphey, L., Bennet, E., Delborne, J., Eggermont, H., Esvelt, K., King, L.A., Kokotovich, A., Koldziejczyk, B., Kuiken, T., Mead, A. et al. (2019) Genetic Frontiers for Conservation: An Assessment of Synthetic Biology and Biodiversity Conservation. International Union for Conservation of Nature, Gland, Switzerland.
2 National Academies of Sciences, Engineering, and Medicine. (2016) Gene Drives on the Horizon: Advancing Science, Navigating Uncertainty, and Aligning Research with Public Values. The National Academies Press, Washington, DC.
3 Esvelt, K.M., Smidler, A.L., Catteruccia, F. and Church, G.M. (2014) Emerging technology: concerning RNA-guided gene drives for the alteration of wild populations. Elife, 3, e03401.
4 Target Malaria (2021) Funding our research. https://targetmalaria.org/wp-content/uploads/2021/02/Funding_FS_EN_Funding-our-research_July21-1.pdf (31 October 2022, date last accessed).
5 Defense Advanced Research Projects Agency. 2017. Building the Safe Genes Toolkit. https://www.darpa.mil/news-events/2017-07-19 (31 October 2022, date last accessed).
6 Long, K.C., Luke Alphey, G.J., Annas, C.S., Bloss, K.J., Campbell, J.C., Gusmano, M.K., Kaebnick, G.E., Maschke, K.J., Neuhaus, C.P. and Esvelt, K.M., Smidler, A.L., Catteruccia, F. and Church, G.M. (2015) Framing responsible innovation within synthetic biology research and its broader contexts of our research. We have demonstrated ways that other bioengineers can move toward making meaningful progress in changing the way they research, and the content of that research.

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References
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2 National Academies of Sciences, Engineering, and Medicine. (2016) Gene Drives on the Horizon: Advancing Science, Navigating Uncertainty, and Aligning Research with Public Values. The National Academies Press, Washington, DC.
3 Esvelt, K.M., Smidler, A.L., Catteruccia, F. and Church, G.M. (2014) Emerging technology: concerning RNA-guided gene drives for the alteration of wild populations. Elife, 3, e03401.
4 Target Malaria (2021) Funding our research. https://targetmalaria.org/wp-content/uploads/2021/02/Funding_FS_EN_Funding-our-research_July21-1.pdf (31 October 2022, date last accessed).
5 Defense Advanced Research Projects Agency. 2017. Building the Safe Genes Toolkit. https://www.darpa.mil/news-events/2017-07-19 (31 October 2022, date last accessed).
6 Long, K.C., Luke Alphey, G.J., Annas, C.S., Bloss, K.J., Campbell, J.C., Gusmano, M.K., Kaebnick, G.E., Maschke, K.J., Neuhaus, C.P. and Esvelt, K.M., Smidler, A.L., Catteruccia, F. and Church, G.M. (2015) Framing responsible innovation within synthetic biology research and its broader contexts of our research. We have demonstrated ways that other bioengineers can move toward making meaningful progress in changing the way they research, and the content of that research.
17. Rabinow, P. and Bennett, G. (2012) Designing Human Practices: An Experiment with Synthetic Biology. University of Chicago Press, Chicago.
18. Stirling, A. K., Hayes, R. and Delborne, J. (2018) Towards inclusive social appraisal: risk, participation and democracy in governance of synthetic biology. BMC Proc., 12, 43–51.
19. Torgersen, H. (2009) Synthetic biology in society: learning from past experience? Syst. Synth. Biol., 3, 9–17.
20. Human Practices Committee. What is Human Practices. international Genetically Engineered Machines Competition. https://responisbility.igem.org/human-practices/what-is-human-practices (31 October 2022, date last accessed).
21. Noble, C., Min, J., Olejarz, J., Buchthal, J., Chavez, A., Smidler, A. L., DeBenedictis, E. A., Church, G. M., Nowak, M. A. and Esvelt, K. M. (2019) Daisy-chain gene drives for the alteration of local populations. Proc. Natl. Acad. Sci., 116, 8275–8282.
22. Lunshof, J. (2020) Final Report—Part I Bioethics—a Mutually Responsive Approach to Developing Technologies That Alter Shared Ecosystems [internet]. ResearchGate. https://www.researchgate.net/publication/335404859_Final_Report_-_Part_I_Bioethics_-_A_Mutually_Responsive_Approach_to_Developing_Technologies_That_Alter_Shared_Ecosystems (31 October 2022, date last accessed).
23. Buchthal, J., Evans, S. W., Lunshof, J., Telford, S. R. and Esvelt, K. M. (2019) Mice against ticks: an experimental community-guided effort to prevent tick-borne disease by altering the shared environment. Philos. Trans. R. Soc. B Biol. Sci., 374, 20180105, pp. 1–10.
24. Min, J., Noble, C., Najjar, D. and Esvelt, K. M. (2017) Daisy quorum drives for the genetic restoration of wild populations. BioRxiv, 115618.
25. Min, J., Noble, C., Najjar, D. and Esvelt, K. M. (2017) Daisyfield gene drive systems harness repeated genomic elements as a generational clock to limit spread. BioRxiv, 104877.
26. Decennial Census of Island Areas, U.S. Virgin Islands Summary File. P1 | Total Population. https://data.census.gov/cedsci/table?g=0500000US78020&tid=DECENNIALVI2010.P1 (31 October 2022, date last accessed).
27. National Park Service. Saint John, VI: Virgin Islands National Park. https://www.nps.gov/articles/virginislands.htm (31 October 2022, date last accessed).
28. Balmer, A. S., Calvert, J., Marris, C., Molyneux-Hodgson, S., Frow, E. E., Kearnes, M., Bulpin, K., Schyfter, P., MacKenzie, A. and Martin, P. (2015) Taking roles in interdisciplinary collaborations: reflections on working in post-ELSI spaces in the UK synthetic biology community. Sci. Technol. Stud., 28, 3–25.
29. Ludwig, D. and Macnaghten, P. (2020) Traditional ecological knowledge in innovation governance: a framework for responsible and just innovation. J. Responsible Innov., 7, 26–44.
30. Taitingfong, R. I. (2020) Islands as laboratories: indigenous knowledge and gene drives in the Pacific. Hum. Biol., 91, 179–188.
31. Taitingfong, R. and Ullah, A. (2021) Empowering indigenous knowledge in deliberations on gene editing in the wild. Hastings Cent. Rep., 51, S74–S84.
32. Najjar, D. A., Normandin, A. M., Strait, E. A. and Esvelt, K. M. (2017) Driving towards ecotechnologies. Pathog. Glob. Health, 111, 448–458.
33. Lavery, J. V. (2018) Building an evidence base for stakeholder engagement. Science, 361, 554–556.