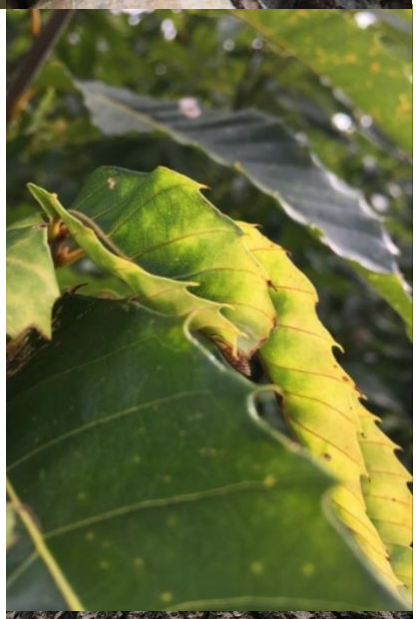
Biotechnology, the American Chestnut Tree, and Public Engagement
Workshop Report



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Acknowledgements

This report does not represent consensus among the participants in the workshop. Just as the workshop aimed at inclusivity and insight, so too does this report attempt to cover the diversity of perspectives without trying to wrestle with which ideas were best supported or most often expressed by participants. Nor should this report be interpreted as a success in representing the full breadth of perspectives that exist in the controversial debates surrounding biotechnology, restoration, and genetically engineered trees.

All workshop participants (listed in Appendix) were given the chance to review a complete draft of this report and provide feedback, but any errors, omissions, or misinterpretations are the responsibility of the research team, not the participants. We thank all workshop participants for their time, energy, and perspectives. As social scientists, we are keenly aware that it is only through the generosity of people who share their thoughts and experiences that we can do our work.

Finally, we are grateful to the National Science Foundation's Science, Technology, and Society Program (SES-1632670) and North Carolina State University's Genetic Engineering and Society Center for financially supporting this workshop. We also thank Christine Epps in the Research Administration Office of the College of Natural Resources for coordinating the travel of workshop participants.

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All images used in this report were taken by members of the research team.

Section 1: Introduction and Workshop Summary

As researchers at North Carolina State University, we convened a workshop entitled, "Biotechnology, the American Chestnut Tree, and Public Engagement" on April 25-26, 2018 on our campus in Raleigh, NC. The workshop was supported by a National Science Foundation grant from the Science, Technology, and Society program entitled, "Responsible Innovation with Genetically Modified American Chestnut Trees" (SES-1632670), with additional support from NC State's Genetic Engineering and Society Center.

The workshop aimed to foster dialogue among diverse stakeholders regarding strategies to engage broader publics in the governance of the genetically engineered (GE) American chestnut tree (GEAC). These trees were genetically engineered to tolerate the presence of a chestnut blight that entered the United States at the turn of the 20th century and drove the species to functional extinction within fifty years (Thompson, 2012). For some, the GEAC offers a promising possibility to save a much-beloved tree species. For others, the GEAC is viewed as a considerable risk to already stressed forests. Moreover, for some people, the GEAC represents a negative example of human intervention in nature, whereas for others it is an example of fixing damage that we caused to nature. Because these perceptions of the GEAC are already present in public debate, we argue that broad attention to public and stakeholder perspectives is warranted. The workshop explored options to broaden the mechanisms and content of future public engagement on the GEAC, and perhaps other emerging technologies.

Restoring the American Chestnut

(excerpted from Barnes, 2018)

Once abundant in forests from Maine to Georgia, American chestnut was rendered functionally extinct by an introduced fungal pathogen in the early 1900s (Freinkel, 2007). Likely imported along with Japanese chestnut trees through ports in New York and California, chestnut blight (*Cryphonectria parasitica*) colonizes and induces regional cell death in the vascular system of trees; the resulting perennial canker prevents the flow of water and nutrients throughout the tree and ultimately kills it above the point of infection (Jacobs et al., 2013). Due to the density of American chestnut in the landscape and the lack of native resistance to the pathogen, *C. parasitica* spread rapidly throughout the entire range of American chestnut in mere decades, transforming a population of over four billion large canopy trees (Gravatt, 1949) into a population of around 400 million understory sprouts (Dalgleish et al., 2015). American chestnut sprouts continue to regenerate from the root collars of old stumps, but they rarely flower and fruit before being killed by chestnut blight, which remains ubiquitous in the landscape (Paillet, 2002). While American chestnut is still relatively abundant and some portion of its gene pool still exists (Huang et al., 1998), its inferred ecological functions are believed to have stalled, and without sexual reproduction, it remains evolutionarily frozen in the early 1900s. As such, efforts to restore the species to its former dominance sit at a nexus between multiple forms of resurrection science, including ecological restoration, species reintroduction, facilitated adaptation, re-wilding, and de-extinction.

Current strategies to resurrect viable, evolving American chestnut populations include attempts at biological control using hypovirulent strains of the pathogen (Milgroom & Cortessi, 2004), as well as both intra- and interspecies breeding and trans- and cisgenic engineering of American chestnut trees (reviewed in Jacobs et al., 2013; Steiner et al., 2017). None of these approaches have yet resulted in trees ready for large-scale reintroduction, but "potentially blight-resistant" trees carrying resistance

genes from Chinese chestnut have been developed through backcross breeding by The American Chestnut Foundation (TACF) and are currently planted on almost 1,200 acres across 680 locations throughout the species' native range (TACF, 2018). Additionally, in cooperation with the New York Chapter of TACF, researchers at the State University of New York, College of Environmental Science and Forestry (SUNY-ESF) have used genetic engineering to transfer a gene from wheat into the American chestnut genome. This gene codes for an enzyme that neutralizes the destructive acid produced by *C. parasitica* and thus allows American chestnut trees carrying the gene to tolerate blight infection (Powell, 2014).



Background

From a U.S. federal regulatory perspective, the Coordinated Framework for the Regulation of Biotechnology governs the development and introduction of the GEAC. There are two important dimensions of the Coordinated Framework that are relevant to public engagement. First, U.S. policy regarding biotechnology focuses on the product of genetic engineering, rather than the process of development. This may bear relevance to where and when the public can offer input regarding the innovation and introduction of emerging biotechnologies - due to a focus on final products rather than how they were developed. And second, the regulation of biotechnology is wholly dependent on "verifiable scientific risk" (OSTP, 1986). As such, while public comment periods are part of the regulatory process, only input that is consistent with this particular definition of risk can be considered as part of the broader regulatory decision processes. In other words, the existing regulatory framework offers one particular mechanism for public engagement – public comment – that is delimited by predetermined notions of what is *verifiable*, what is *scientific*, and what is *risk*.

In part because of such wide-ranging perceptions, GEAC developers have long sought transparency and public input throughout the tree's development (Barnhill-Dilling, 2018). Made possible through a partnership between the New York Chapter of the American Chestnut Foundation and SUNY College of Environmental Science and Forestry, the development of the GEAC has always been situated in public institutions and is currently known as The American Chestnut Research and Restoration Project (https://www.esf.edu/chestnut/). The chestnut project has engaged in multiple successful crowdfunding campaigns, given numerous public talks, engaged public audiences on social media, and developed a TEDx talk – all to educate broad public audiences about chestnut heritage and efforts to bring it back to eastern forests. Importantly, the chestnut project has also used public input to inform molecular and experimental choices and their decision not to pursue a patent on the tree. Overall, the research and restoration teams have engaged public audiences in a variety of ways as they have sought to develop a publicly-acceptable genetically engineered American chestnut tree (Barnhill-Dilling, 2018).

Our aim as a social science team that is independent of the GEAC development partnership, however, was to create deliberative space to engage with broader bases for decision-making, and to cultivate public engagement processes that are not motivated by the goal of GEAC acceptance. From our perspective, thus far, GEAC public engagement organized by the chestnut project has been designed to garner and maintain public support - certainly a reasonable goal for the developers of an emerging

technology. Responding to calls for more democratic, participatory, and inclusive processes to inform decision making about emerging technologies (Stilgoe,Owen, & Macnaghten, 2013; Wilsdon & Willis, 2004), our research team drew upon decades of existing scholarship and practice in public engagement to design this workshop. We sought to create space for values and interests, socio-cultural perspectives, and broad conceptualizations of risk – to sit equally with scientific information and regulatory framings of risk. As such, for the purposes of the workshop, engagement was defined 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). To that end, the workshop operated under the premise that a diversity of stakeholders should guide decisions about how public engagement should proceed (see Appendix for a description of the recruitment process and list of workshop participants).

Workshop Overview

The workshop organized discussions around three *decision phases,* which we identified, that describe the lifecycle of an emerging technology:

1. Research and development
2. Regulatory review
3. Deployment, management, and monitoring

Within this decision phase framework, discussions focused on four primary objectives:

Objective 1: Understand and clarify the specific actions and events relevant to each of the decision phases with respect to GE chestnut restoration, and assess the state of public engagement thus far.

Objective 2: Identify and reflect upon the diverse interests and values at play across the decision phases, including those held by active stakeholders and affected publics.

Objective 3: Construct questions that are relevant to different decision phases, and understand how diverse forms of knowledge can contribute to the identification and exploration of these questions.

Objective 4: Imagine specific scenarios where public engagement could play an important role in decision making around GE chestnut restoration.

Outputs from discussion sections were recorded on poster paper and displayed for reference in future sessions. Through a mix of break-out groups and plenary discussions, participants worked to uncover and understand the diverse, entangled elements inherent to the development and possible deployment of the GE chestnut tree, as well as the role public engagement could play in these processes. (See Section 2 of the Workshop Report for the full agenda.)

Summary of Discussion Outcomes

While all discussions are described in detail in Sections 3-6 of the Workshop Report, key discussion outcomes identified by the research team are listed below. These outcomes were based on our analysis of notes and recordings of workshop discussions.

Deliberative public engagement has been limited. A number of participants suggested that decisions regarding the use of the GE American chestnut tree should involve many diverse stakeholders situated

beyond the halls of government regulatory agencies, such as the USDA or EPA. These organizations include other government agencies (e.g., the US Forest Service), NGOs/nonprofit organizations, funding agencies, indigenous populations, and university researchers. The "public" was identified as a key stakeholder in all decision phases for GE chestnut restoration, yet no good mechanism seems to exist for gathering and integrating public input at broad scale. Some workshop participants saw this last point as particularly problematic, as public attitudes can have an inhibitory effect on GE chestnut restoration, regardless of whether the tree fulfills regulatory approval requirements.

Interests and values are diverse and imply a mix of conflict and common ground. Participants reflected on their personal and professional stakes in chestnut restoration, as well as interests and values held by those not present at the workshop. The following interests and values were raised by participants through group discussion, and no effort was made to achieve consensus. (See Section 4 for a full list of interests and values.)

Key Interests

- Bringing stability to vulnerable forest ecosystems
- Ensuring equal representation in decision-making processes
- Agreeing upon explicit ecosystem restoration goals
- Understanding and responding to public perceptions of forest health
- Expanding adoption of biotechnology tools in conservation and restoration practices

Core Values

- Robust, inclusive, and pragmatic research
- The preservation and protection of forest ecosystems for future generations
- Cultural integrity and cultural restoration (including indigenous cultures)
- Efficient use of taxpayer funds
- Collaboration, transparency, and integrity across decision phases
- The ethical responsibility to right human wrongs

Public preferences can provide guidance for future investment in research and development. The current state of R&D for the GE chestnut is underway and well documented, so workshop participants focused on potential future R&D needs. Despite promising results from laboratory testing and early-stage field trials, many participants expressed the need for more research aimed at determining the efficacy and ethics of GE chestnut restoration. However, more research necessitates more research dollars, yielding a point of contention: Is GE chestnut restoration an important enough conservation objective to commit more funding (public or private)? In addition, there was intense focus on identifying future R&D questions that intersect with public engagement, particularly where ethics research is concerned. Engagement activities that foster public involvement and awareness around GE chestnut R&D were identified by some participants as important for determining future R&D pathways, especially for questions that are not answerable through laboratory-based explorations.

The narrow definition of safety in regulatory review discourages incorporation of diverse sources of knowledge and outcomes of public engagement. Many participants expressed frustration and dissatisfaction with the narrow definition of *safety* within regulatory processes and the methods that determine what the acceptable levels of uncertainty are in the context of implementing a technology like the GE chestnut. Discussions focused on imagining new, expanded criteria:

1. Comprehensive questions need to be asked about a technology to understand its complexity and determine *relative* levels of safety and uncertainty.
2. Diverse forms of knowledge and kinds of evidence are relevant for deciding if a technology is safe.
3. Engagement can play a role in determining the criteria for evaluating the safety of technology.

In addition, a number of participants recognized that deregulation of the GEAC would not inevitably lead to implementation if there were widespread public rejection of the GE chestnut. Involving and incorporating public preferences in discussions of safety and acceptable uncertainty are important goals, especially in setting precedent for other future biotech-based restoration efforts.

Strategies for deployment, management, and monitoring are unclear, with issues of responsibility and authority especially raising questions. Some participants consistently expressed concerns around how GE chestnut proliferation might be monitored across time and space, and what actors and institutions would be considered responsible for facilitating these activities. Designations of responsibility also extended to questions of reversibility, or irreversibility, of GE chestnut implementation in situations where harmful outcomes might occur. Similarly, this question of "who decides?" was explored in discussions around the process of determining "priority sites of implementation" and "sites of exclusion." Public engagement was seen as especially important here, with a number of participants placing a high value on the capacity of communities to determine if they want to be a part of implementation efforts.

Public engagement could play a role in guiding safety studies, prioritizing conservation needs, and determining priority areas for chestnut restoration. The final activity of the workshop encouraged break-out groups to generate a list of specific decisions that could benefit from engagement (see Table 6.1) and construct possible engagement scenarios around those decisions. One group further explored public engagement's possible role in informing environmental and human health safety studies. A second group examined the question of whether GE chestnut restoration should be pursued any further, given other pressing conservation needs. The third group constructed a scaffolding strategy for incorporating public engagement into determining priority areas for restoration and sites of exclusion.

Measuring Workshop Success

Reflecting on a comparison of stated goals with the contents of this workshop report, the workshop achieved Objectives 1-3 and partial success of Objective 4. Collectively, participants successfully considered engagement related to each decision phase, identified and reflected upon diverse interests and values, constructed questions, and recognized different knowledge bases for different question types.

Objective 4 – imagining specific engagement scenarios – was more challenging than we anticipated when planning the workshop. Breakout groups identified potential decisions that could be guided by public engagement but had difficulty in fleshing out the full list of design decisions necessary to construct an idealized engagement scenario. There may have been a number of reasons for this. For one thing, it is possible that stronger and more structured facilitation, or a greater level of expertise in engagement, is needed to make such design decisions. For another, some participants may have been unable to set aside their interests to envision engagement scenarios in which public values might emerge that are counter to their preferred position. Another possibility is that many stakeholders attending the workshop felt, insofar as they have been directly involved with GEAC so far, that they have already been engaging with the public and did not feel the need to rehash these activities in great detail.

All workshop participants completed questionnaires anonymously for organizers to gauge workshop impacts. Questionnaire data revealed a diversity of views about chestnut restoration prior to the workshop. These views did not change much over the course of the workshop, but when they did change, views became more moderated and somewhat less polarized. As a group, participants seemed to acknowledge and perhaps integrate the nuance from much of the small group discussions, which came through in the group-level data reported from the questionnaires (see Section 7 for full details). Based on information from group discussions and presentations, most of our workshop participants came to view both conventional and GE approaches to chestnut restoration in new ways.

Section 2: Workshop Agenda

Biotechnology, the American Chestnut Tree, and Public Engagement

Deliberative Workshop

April 25-26, 2018
North Carolina State University
Talley Student Union

Wednesday, April 25th

8:30 Welcome and Introductions
Tom Gower, Department Head, Forestry and Environmental Resources
Participant Introductions
Discussion Guidelines

9:00 Presentation: "Restoring biotechnology's moral fiber? Genetically Modified American Chestnut Trees, Responsible Innovation, and Environmental Justice," NSF Grant 1632670 (Katie Barnhill-Dilling)

9:30 Review agenda

9:45 Decision Phases Introduction (Jayce Sudweeks)

10:00 Break

10:15 Discussion #1: Decision Phases
Breakout Groups
- Regulatory Review
- Deployment, Management, and Monitoring
- Research and Development
- Plenary Discussion

11:55 Qualtrics survey

12:00 Lunch

12:30 Presentation: Indigenous Perspectives on Chestnut Restoration and Biotechnology (Neil Patterson, SUNY-ESF Center for Native Peoples and the Environment, and Percy Abrams, Syracuse University, via web)

1:00 Discussion #2: Interests and Values

2:30 Break

2:45 Presentation: Social science of public engagement (Adam Kokotovich)

3:30 Presentation: "Public acceptance of using biotechnology to restore the American chestnut" (Mark Needham, Oregon State University, via web)

4:00 Discussion #3: Questions and Knowledges for Regulatory Review
Presentation: Typology of Knowledges (Dalton George)
Breakout Groups

5:25 Qualtrics survey

5:30 Adjourn to group dinner

Thursday, April 26th

8:30 Recap of day 1
Report-back from breakout groups (Katie, Adam, Andy)
8:55 Discussion #4: Questions and Knowledges for Deployment, Management and Monitoring
Breakout Groups
Report Back and Plenary
10:15 Break
10:30 Discussion #5: Questions and Knowledges for Research and Development
Breakout Groups
Report Back and Plenary
11:25 Qualtrics Survey
11:30 Ideal Engagement Scenarios
Orientation to activity
Brainstorm
Formation of small task groups
12:00 Working lunch (Ideal Engagement Scenarios)
1:15 Groups report back
1:45 Closing remarks
1:55 Qualtrics survey
2:00 Adjourn

Section 3: Decision Phases for Chestnut Restoration

Purpose and Goals

Public engagement activities can provide stakeholders and members of the broader public a forum to express their ideas, concerns and inputs about a policy problem (Stirling, 2012; Stilgoe, Lock, & Wilsdon, 2014). However, connecting engagement activity outputs to decision making proves difficult, as the ways in which engagement can influence decisions are not always well understood (Kuzma, Romanchek, & Kokotovich, 2008). Therefore, the goal of this discussion was to explore the decision-making terrain around GE chestnut restoration to identify points of possible influence. Ideally, feedback from engagement activities reaches decision makers, and in turn, influences governance decisions made at various stages in a technology's development cycle. This feedback could aid in the identification of risks and uncertainties and in the mitigation of unintended consequences. During this workshop session we identified three major decision phases governing chestnut restoration with a GE tree:

- research and development
- regulatory review of the GE tree
- potential deployment, management and monitoring

Discussion Structure

To introduce the discussion session, a facilitator gave a preamble presentation designed to prime discussion, and participants were then broken up into three discussion groups. Each group was tasked with exploring and clarifying actions and events associated with one of the decision phases: research and development, regulatory review, and deployment, management, and monitoring. To help guide and structure the discussions, each of the groups was asked to consider the following questions when addressing their assigned decision phase:

1. What decisions are being made?
2. Who is making the decision?
3. What informs the decision?
4. How is public and stakeholder input included? And whose voices are missing?

Facilitators verbally guided discussions and took notes, at times asking clarifying questions and keeping discussions on track. Facilitators were also responsible for reporting small group discussion results back to the full participant group, which took place immediately following the break-out sessions. Participants in other groups were given the chance to ask questions and offer input during the report backs, and any additional insights that resulted were added to the session outputs.

Session Outcomes

Below is a summary of the discussions of the three breakout groups. Captured here is not a consensus, but an accumulation of ideas and perspectives from notes taken during the small group discussions and plenary report-back. Some of these questions may already have answers, while others may be unexplored areas. We reiterate here that some participants had quite a bit of background knowledge on the American chestnut tree, while others had very little prior knowledge. These questions were suggested by participants as key areas of interest from their current perspective.

Research and Development (R&D) Decision Phase

1. *What decisions are being made?*
    a. What research questions are being addressed? For instance, why is the focus on blight when root rot is also an issue? Should the focus be on the tree or on the fungus?
    b. What types of technologies/research methods will be utilized to resolve the research questions. For instance, are genetic engineering technologies required? Where do non-GE technologies like backcrossing and biocontrol fit into the picture? How do recent technologies like CRISPR potentially resolve or create new issues?
2. *Who is making the decision?*
    a. US Regulatory agencies: EPA, USDA-APHIS, FDA
    b. Researchers
    c. Non-governmental organizations (NGOs) and nonprofit organizations
    d. US Forest Service
    e. Organizations that provide research funding
3. *What informs the decision?*
    a. Regulation
    b. Relationships between funders, regulators, and researchers
    c. Availability of funding
    d. Understanding and capability of available technology and research methods
    e. Public perception
4. *How is public and stakeholder input included?*
    a. Much of the public input comes from The American Chestnut Foundation and its membership
    b. Public and stakeholder perception of biosafety to make sure it is safe
5. *Whose voices are missing?*
    a. The public is not present so it cannot influence decision making during the R&D process
    b. Scientists critical of the research
    c. Broader biodiversity or conservation voices
    d. Groups and members of the public concerned with genetic engineering technology

Other Discussion Points

- With so many different trees being lost or under incredible pressure, how do we decide on research priorities? Who decides which trees are the most deserving of conservation attention?

Regulatory Review Decision Phase

1. *What decisions are being made?*
    a. Is the technology safe? How is safety assessed?
    b. Which regulatory agencies need to be involved in the assessment?
    c. Will an environmental assessment (EA) or environmental impact statement (EIS) be required by the National Environmental Policy Act (NEPA)?
    d. Each US regulatory agency looks at distinct safety aspects:
        i. USDA: Analysis attempts to determine to what extent does the new tree present a pest risk compared to traditional methods. USDA comes to a yes or no answer as to whether as to whether the new tree is pest risk. Those products that aren't seen as pest risk are deregulated.
        ii. EPA: Analysis attempts to determine if the pesticidal process is safe and what is the proper dose. EPA provides conditional approval (registration) and revisits this about every 5 years.
        iii. FDA: Analysis attempts to determine how safe is the tree for nutrition in humans and animals. This is a voluntary process that the researcher/developer initiates with the

FDA. FDA will work with the researcher to provide data until the FDA has no further questions. The FDA does not deregulate or provide certification.

2. *Who is making the decision?*
    a. US and potentially Canadian regulatory agencies
    b. US Forest Service and US Fish and Wildlife Services may act as collaborators with the regulatory agencies
    c. US states also have regulatory agencies. Most will follow the federal decisions, but some such as California and New York have independent review processes.
3. *What informs the decision?*
    a. Scientific data
    b. Public comments, where an agency is looking for scientific/technical questions that have not been considered yet.
    c. Results of environmental assessment or environmental impact statement
4. *How is public and stakeholder input included?*
    a. Potential government-sponsored meetings with stakeholders
    b. Public comment periods
5. *Whose voices are missing?*
    a. Indigenous populations
    b. No way for values-based concerns about the technology to be used in the evaluation
    c. A method to incorporate societal priorities into regulatory decisions

Other Discussion Points

- The public comment period is not a vote or popularity contest, but a way of raising scientific questions that have not been addressed yet. The public comment period is a terrible process, but the only way to engage the public.
- Do any of the regulatory agencies consider benefits, not just risks?
- How does the regulation of the GE chestnut fit within the coordinated framework? Due to the nature of the tree, should another regulatory framework be implemented?
- Researchers and developers feel frustrated with the current regulatory process. They feel that they meet the regulatory requirements, but that negative public perception and public comment can derail the entire process. It seems that facts don't matter. Some wonder how to communicate in a way that counteracts emotional reactions
- Indigenous people are not stakeholders nor members of the "public," but sovereign nations.

Deployment, Management and Monitoring Decision Phase

1. *What decisions are being made?*
    a. On what land should the tree be planted?
    b. Who will be responsible for raising and planting the trees?
    c. Who will be responsible for monitoring the planted trees?
    d. Who pays for each step of the process?
2. *Who is making the decision?*
    a. Federal and state agencies responsible for public land use in the historic chestnut range
    b. Private landowners in historic chestnut range
    c. Land trusts in historic chestnut range
    d. Chestnut growers
    e. The American Chestnut Foundation
3. *What informs the decision?*
    a. Motivations to plant the tree vary from restoration, to commercialization of nut and wood, to the ornamental beauty of the tree.
    b. Multiple reasons to oppose

4. *How is public and stakeholder input included?*
    a. Feedback from membership of the American Chestnut Foundation
    b. Feedback on public meetings, seminars and lectures conducted by developers
5. *Whose voices are missing?*
    a. Other users of forest lands including hunters, fishers and campers
    b. Very little racial or ethnic diversity represented in the workshop

Other Discussion Points

- Where to deploy is a strategic question when we think of the landscape more broadly. Need to determine where to deploy, *and not to deploy,* in the interest of preserving native genetic diversity and promoting adaptation
- Deployment and restoration could still occur even without regulatory approval.

Section 4: Interests and Values for Chestnut Restoration

Purpose and Goals

The plenary session was designed to be a space of open sharing, listening, and discussion rather than debate and contention. Consensus was not sought across ideologically conflicting interests and values, as potentially opposed stakeholders were asked instead to generate and hear a diversity of perspectives instead of arguing for or against what was shared. In doing so, we attempted to elicit recognition that working through the diverse interests and values *is extremely difficult* and requires broader engagement when the goal is inclusive decision making around chestnut restoration (Stirling, 2012).

Asking dedicated stakeholders to be explicit and honest about their interests and values is no easy task. There is always the chance that probing such things will encourage stakeholders to engage in arguments about which values are worthwhile, and which are not, potentially widening rifts between already ideologically opposed stakeholders. Nevertheless, articulating the diverse interests and values in the room, as well as understanding missing voices, was vital for preparing for the "questions and knowledges" discussions later in the workshop. Knowing this, our research team invoked a specific discussion structure and maintained a safe space for open sharing and listening.

Prior to the session on interests and values, participants heard a brief presentation by Dr. Percy Abrams of Syracuse University and Neil Patterson of SUNY-ESF Center for Native Peoples and the Environment. Their presentation focused on the perspectives of Native Americans—in particular the Haudenosaunee Confederacy—on both the chestnut and biotechnology.

Indigenous Perspectives on Chestnut Restoration and Biotechnology

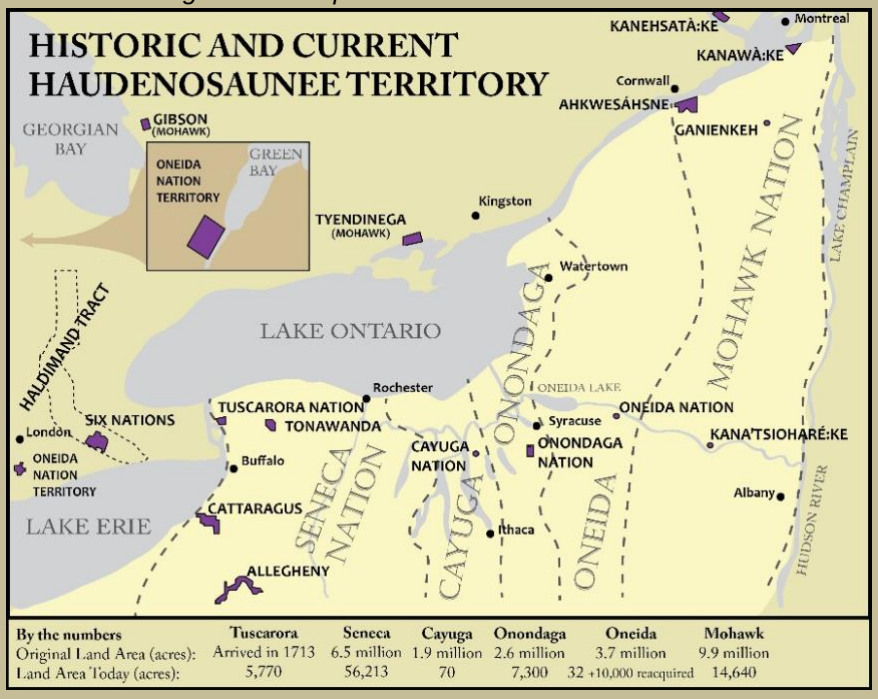
By Dr. Percy Abrams and Neil Patterson, Jr.

The primary sites of research for the GEAC, current field sites, and proposed release sites are situated in the heart of traditional and contemporary territory of the Six Nations of the Haudenosaunee Confederacy of Central and Upstate New York (see Figure below). Research on the Haudenosaunee perspective has focused primarily on how GEAC for restoration has created space for Haudenosaunee linguistic research. This presentation highlights several important points to consider for inclusive engagement around American chestnut restoration.

- Chestnut loss coincided with Haudenosaunee cultural loss – while the chestnut blight devastated the iconic tree, untold numbers of American Indian children were sent to boarding schools, forbidden to speak their languages or practice their customs. As a result of these two parallel historical processes, most of the traditional ecological knowledge about the American chestnut tree has been lost. To illustrate this point, several of the Haudenosaunee languages no longer have words for 'chestnut.'
- Abrams and Patterson have been meeting with elders across Haudenosaunee communities (see geographic expanse in Figure 4-1 below). Their aim has been to find old stories about the chestnut tree, with a particular focus on the old words that are used to tell these stories.

Haudenosaunee languages are deeply relational, which reflects a deeply relational worldview. In returning to the old stories, they aim to reconstruct how Haudenosaunee peoples once related to the chestnut.

Figure 4-1. Map of Haudenosaunee Territories.



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- Simultaneously, Abrams and Patterson have been talking to elders and native language speakers about how to communicate about a genetically engineered chestnut. While there are no old words for 'gene' or 'genetic engineering,' they hope to use GEAC as a vehicle for reconnecting with native language, worldview, and for building new phrases from old words to communicate about GEAC through the lens of Haudenosaunee worldviews.

Discussion Structure

For this session, discussion proceeded in a "Think, Pair, Share" format: Participants were asked to individually *think* about their interests and values, *pair* up to discuss these reflections with a partner, and then *share* with the group. The sharing portion was used to develop a master list of desired outcomes and normative commitments in a full plenary discussion. These thought/discussion exercises were prompted by questions designed to inspire reflection on personal and professional stakes held in chestnut restoration, as well as describing interests and values perceived to be missing at the workshop. The questions were:

1. *When you think about the potential restoration of the American chestnut tree, what are your interests? Your values? What do you care about? What are you concerned about?*

2. *As much as we attempted to recruit a diverse group, we were not perfect. Who is missing, and what might be their values and interests?*

Facilitators did not guide reflection or sharing sessions aside from answering clarifying questions and making sure that every participant had an opportunity to share during the plenary discussion. Values, interests, concerns, and missing voices communicated by participants were recorded as participants shared them.

Session Outcomes

Below is a summary of the various interests and core values communicated during this portion of the workshop, listed in no particular order. These results represent an aggregation and distillation of the interests and concerns expressed by the diverse stakeholder group, as well as a quote or two exemplifying how these interests and concerns were communicated. They are broken up into four themes that we identified when consolidating the master list: Economic, Scientific/Research, Political, and Social.

Economic Interests

1. Small-scale chestnut farming in the interest of supplying the culinary industry with chestnut-derived products and expanding this cycle of interest to more domains.
2. Concern about the economic interests of large biotech companies, and a lack of trust that the potential commercial applications of GE chestnut will be beneficial.

Scientific-Research Interests

1. Chestnut as an ecologically beneficial tree, bringing greater stability to damaged forest ecosystems.
2. Concerns about implications for future management practices:
    a. GE chestnut inspiring “heavy-handed” management
    b. Consequences of doing nothing with the tree, leading to full extinction of the American chestnut and further declines in forest health
    c. Opening the door to GE trees that might be more dangerous to forest ecosystems
3. Research interest in applying biotech tools to ecosystem management and species restoration.
4. Concerns about prioritizing some research agendas over others.

Political Interests

1. Reducing the scientific bias in decision making and recognizing that public viewpoints that reflect wider sets of restoration values and interests are not inherently invalid if they are technically unscientific.
2. Explicit definitions of what restoration means, and what the goals for chestnut restoration are.
3. Concerns with allocating resources to chestnut restoration, while more practical and effective forest restoration pathways may exist but go unfunded and unpursued.

Social Interests

1. Concerns that apathetic attitudes towards ecological restoration and/or public misconceptions around GMOs could negatively affect chestnut restoration and should be corrected to promote chestnut restoration and better connect interested publics to nature, especially youths.
2. Concerns about the negative effect chestnut restoration could have on the self-determination capacity for indigenous groups.
3. GE chestnut restoration has the potential to establish a positive legacy of American innovation and problem solving in the global domain of forest restoration, and also a positive individual legacy for those directly involved in its implementation that can be passed down through the generations.

Core Values

- Successful restoration
- Positive ecosystem impacts
- Biodiversity
- Social equity
- Scientific credibility
- Natural evolution of forests
- Self-determinism
- Artistic expression
- Preserve forest ecosystems
- Restoration as cultural heritage
- Optimism
- Patience
- Integrity in collaboration
- Science-based decisions
- Transparency
- Cultural resurgence and recovery
- Ethical responsibility to right human wrongs

Sample Quotations from Participants: Interests and Core Values

Below we provide a few examples of comments made by discussion participants. These examples highlight the diversity of viewpoints put forth throughout the conversation on interests and values. The corresponding theme, identified by the research team during post-workshop review of notes and recordings, is indicated in brackets.

"I don't trust large biotech companies to do the right thing." [Economic]

"I value robust research, but I am concerned about our goals and what kind of things we are not researching, and how do we prioritize these things? Phytophthora [for example] has always been a big deal, but only recently has it been talked about consistently." [Scientific Research]

"Bringing back the chestnut because that's a tree that can be a benefit for restoration, a flagship for broader restoration. Not that biotechnology is a solution for everything, but [it] is a tool." [Scientific Research]

"From [a] heritage standpoint, I want to see restoration. On the other hand, I work for an org[anization] who works with publicly owned land where forests are 'out of whack,' where we have to weigh the money put on the ground to restore the forest, and I am not sure if the organization I work for will go for [chestnut] restoration from a financial expenditure standpoint." [Political]

"This is like the moonshot if we get it right, but it could also not work out." [Social]

"Humans made mistakes, humans should use our technology again to give the species a chance to survive." [Core Values]

"I'm thinking about all of these other environmental problems out there. Why does the chestnut get so much attention?" [Core Values]

Missing Voices

In addition to articulating their own values and interests, stakeholders were also asked to reflect on the stakeholders not present at the workshop, whose interests and values are important to discussions around chestnut restoration. (See Appendix for description of recruitment process and partial list of attendees.)

- Large forestry companies
- Large biotech companies
- Individual landowners
- Artists/poets/singers
- Chefs/restaurants
- Local NGOs
- Expert/advocates involved with wildlife populations
- Non-humans
- People with more immediate priorities, such as driving two-hour commutes to jobs just to put food on the table.
- Land managers
- Regulators
- Hunters, fishers, for both recreation and subsistence
- Urban dwellers
- African-American communities where chestnut was once a part of subsistence farming
- Cherokee nation

Following this large-group discussion on interests and values, participants heard a Skype/virtual presentation by Dr. Mark Needham of Oregon State University on his U.S. public opinion survey about American chestnut restoration.

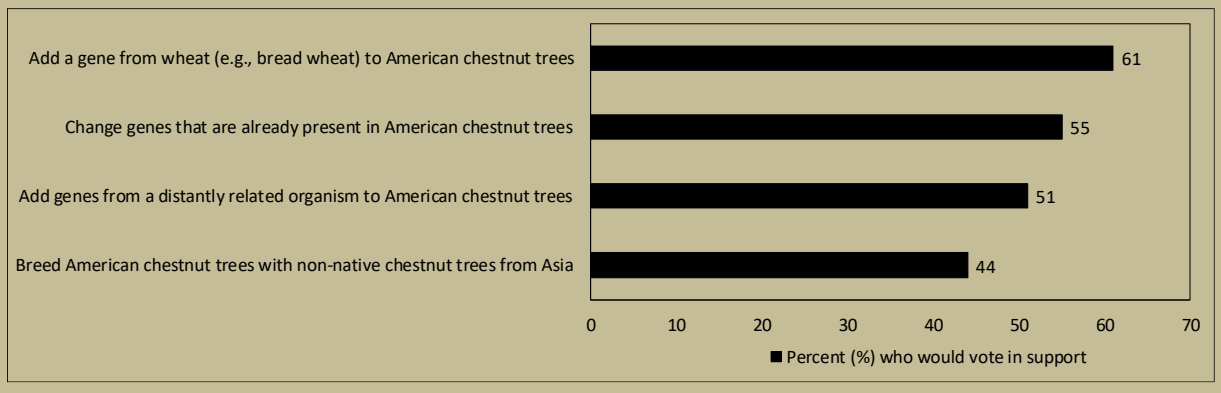
Public Perceptions of Chestnut Restoration

By Dr. Mark Needham

This project focused on understanding public responses to biotechnological and non-biotechnological interventions for addressing chestnut blight and restoring the American chestnut. Figure 4-2 (below) shows results from questionnaires answered by a representative nationwide random sample of US residents (*n* = 278, weighted by Census).

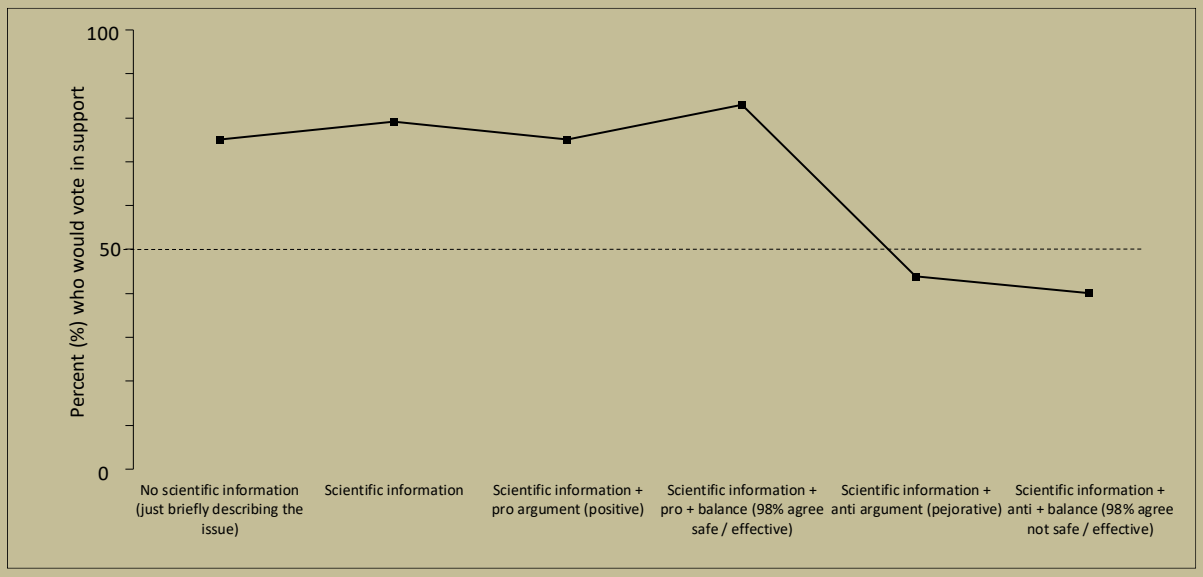
The largest proportion of these residents (61%) voted in support of adding the gene from wheat (i.e., bread wheat, OxO gene) to American chestnut trees to help these trees resist chestnut blight. The majority of these residents also voted in support of changing genes already present in these trees (55%) and adding genes from distantly related organisms (51%). Less than the majority, however, voted in support of breeding these trees with non-native chestnut trees from Asia to address chestnut blight (44%), even though this intervention would involve breeding and not genetic modification.

Figure 4-2. Percent of the US public from a nationwide survey who would vote in support of interventions to help American chestnut trees resist chestnut blight



However, this support for genetic modification of American chestnut trees to help them resist chestnut blight is extremely sensitive to informational messages and vulnerable to persuasion campaigns. Figure 4-3 shows results from a separate experimental survey with a panel of the public in nine eastern states (*n* = 528) and students from seven North American universities (*n* = 604). The majority of these respondents (75-83%) voted in support of this use of genetic modification irrespective of whether messages provided scientific information about this topic, positive / pro arguments, or statements that 98% of scientists agree this is safe and effective. However, this support dropped dramatically (down to 40-44%, less than the majority) as soon as messages provided any negative / anti arguments (i.e., pejorative language) about this topic and statements that 98% of scientists agree this is unsafe and ineffective.

Figure 4-3. Percent who would vote in support of genetic modification to help American chestnut trees resist chestnut blight



Section 5: Questions and Knowledges Across the Decision Phases

Purpose & Structure

Central to the workshop agenda was dialogue about three *decision phases* for the GEAC: (1) research and development (2) regulatory review, and (3) deployment, management, and monitoring (See Section 2). Each of the three decision phases served as the subject for small and large group conversations, which focused on the identification of important questions that would be important to consider for each decision phase, and what forms of knowledge – or "knowledges" (Ascher, Steelman, & Healy, 2010) – would be useful in addressing them.

The identification of relevant questions was not limited to any one domain of knowledge. Instead, participants were encouraged to think through how local knowledge and public preferences can supplement formal scientific expertise in the identification and exploration of relevant questions within each decision phase. The resulting outputs reflect the consideration of questions and forms of knowledge that go beyond the purely technical across all decision phases.

Each decision phase served as its own separate subject of discussion. Like the first discussion session, participants were divided into break-out groups with facilitators verbally guiding discussions and taking notes. Facilitators were also responsible for reporting small group discussion results back during the plenary discussion, which took place immediately following the break-out sessions. Participants in other groups were given the chance to ask questions and offer input during the report backs, and any additional insights that resulted were added to the session outputs. After the plenary conclusion, participants were shuffled around so that each discussion group was constituted of different participants.

5.1 Research & Development

Session Outcomes

Since most of the R&D for the GE chestnut is complete, we encouraged workshop participants to focus on future R&D needs for the restoration of the American chestnut. Below, we organize the wide range of questions related to future R&D needs for the restoration of the American chestnut into emergent categories:

1) Research agendas and resources
2) Commercial potential
3) Formal science
4) The role of engagement in R&D

Research agendas and resources

- Where does the money for future research come from (private, industry, government)?
- Why is the American chestnut an important "environmental crisis" deserving of additional R&D funding?
- Is GEAC the right restoration project?
- What else do we need to restore the chestnut?

- Given limited resources, and the issues faced by oak trees, why focus on something that has been missing from the landscape instead of something that is already present and at risk?
- What are the ethical considerations inherent to this form of species restoration? Which trees, if any, should be reintroduced? Where is the line we draw in restoration?
- How can we make sure we take the whole forest into consideration, and ensure that restoration plans are not just about the chestnut?
- Will newer technologies offer more effective ways of dealing with tree diseases?
- Who will map the genomes of the trees in development?

Commercial potential

- What is the best tree for consumer preferences? Best location? Best outcomes for growers?
- What form will the tree take (stem straightness, crown, growth, height, DBH)?
- What are the priorities of the wood industry?
- Can the GE American chestnut be grown on plantations?
- Can the tree exhibit consumer preferences: easy to peel, great taste, size?
- Are we producing junk trees? Specifically, will these trees be viable from a commercial and economic perspective?
- How much would a blight-tolerant chestnut play in food markets? Will there be breeding needed in an industry that relies mostly on hybrids?

Formal science

- Will the GEAC be resistant to root rot?
- Is there a way to develop hypo-viruses to combat the blight?
- How will diversity be fostered and maintained in the GEAC?
- What is the chemistry of the GEAC (tannins, other tree chemicals, etc.)?

The role of engagement in R&D

- Can engagement help determine the values that guide R&D?
- Who funds engagement? Public dollars, foundation dollars, private dollars, etc.? Is there a place for crowdfunding engagement activities?
- Could engagement lead to future funding for R&D?
- Could engagement help in the development of inclusive management policies for R&D?
- Can engagement inform ethical decision making?
- Could citizen science contribute to database creation and management?
- How can we design a study of public acceptance to involve a broad range of stakeholders and publics?
- Which agencies should be Involved in the development of long-term infrastructure for engagement (e.g., USFS)?
- How can we engage with other conservationists and scientists?
- How can we form international treaties on chestnut restoration, multinational efforts that go beyond US agencies?
- Would indigenous people be involved in GEAC dispersal? If so, treaties would be the way forward due to this being a land tenure question. There is a need for diplomacy that has not occurred in the past.
- How do we structure engagement led by a private foundation (e.g., TACF)? Can these efforts include citizen science?
- How do we define metrics of restoration success that include the input of multiple stakeholders?

5.2 Regulatory Review

Session Outcomes

The U.S. Coordinated Framework for the Regulation of Biotechnology draws on existing laws to evaluate the risks posed by biotechnology products to environmental and human health and safety. This session was thus guided by the overarching thematic question: Is the technology safe? Participant discussion focused on three sub-questions:

1) What questions need to be asked to decide if the technology is safe?
2) What forms of knowledge and types of evidence are relevant to answering questions posed during regulatory review?
3) What role can engagement play?

What questions need to be asked to decide if the technology is safe?

- What does "safe" mean?
    - What is the relevant timescale for determining safety?
    - What is the relevant biological scale? Should safety be evaluated at the level of the inserted oxalate oxidase gene or the entire modified tree?
    - What is the relevant geographical scale? How might safety decisions made under the Coordinated Framework intersect with other regional or national regulations, including those of sovereign indigenous groups, Canada, and the Great Lakes Compact?
    - For whom is it safe? What are the potential impacts on the forestry sector? On indigenous groups? On conventional chestnut growers?
    - How do we account for intergenerational differences in the perception or definition of safety?
- What is the nature of the modification that has been made (which methods and genes were used)?
- What is the impact of the modification on the biology of American chestnut over short and long timescales? For example, how might the growth rate and quality of the tree be impacted? What is the long-term impact of the marker gene on the biology of the tree?
- What are the impacts – both positive and negative – on non-target organisms and ecological processes? Specifically, what are the impacts on microbial communities? Consumers? Wildlife populations? Other plants?
- What are the risks posed by genetic engineering in relation to those posed by conventional breeding approaches?
- What are the "black swans"? What unpredictable and significant impacts might result from the modification or the wild release of transgenic trees?

What forms of knowledge and types of evidence are relevant to answering questions posed during regulatory review?

- Technical evaluation of the probability of risks
- Scenario-based and "possibilistic" thinking
- Modeling, particularly epidemiological and ecological modeling
- Incremental knowledge generated through adaptive management
- Experience with reintroductions by the Fish and Wildlife Service or Forest Service

What role can engagement play in deciding if the technology is safe?

- Including citizen scientists in monitoring experimental plantings of trees
- Creating a forum for discussing governance concerns beyond safety
- Including multi-disciplinary engagement to identify and answer critical safety questions
- Enhancing trust in the regulatory process and decisions made about safety
- Identifying and acknowledging values implicit in American chestnut restoration and a biotechnological approach

Other Discussion Points

- The Coordinated Framework was not designed to address broader questions about the desirability of the approach and has not historically considered safety over time and space, especially for a wild release.
- Need for "diplomats" to facilitate public engagement.
- The importance of American chestnut as a first regulatory case, setting precedent for other GE forest trees and other biotech-based restoration efforts.
- It is difficult to monitor impacts over the lifespan of the tree, but necessary to make a comprehensive determination about its safety. What uncertainties are acceptable for a long-lived tree?
- Questions about the potential for opting out, or for making regulatory decisions at levels other than the federal government, including by individual states, land managers like the Forest Service, and international bodies such as the Convention on Biological Diversity.
- If regulatory approval is granted through the Coordinated Framework, public acceptance is not guaranteed to follow.
- Questions about who conducts safety assessments and who pays for them.
- Considering recent clarification by the USDA that gene-edited products (e.g., using CRISPR) will not be regulated by the agency, participants raised concerns about the extent to which the definition of "safe" may vary by political administration and across agencies involved in future biotechnology regulation.

5.3 Deployment, Management, and Monitoring

Session Outcomes

The small groups and the plenary discussion generated a wide range of open questions and knowledge needs regarding the prospect of the deployment, management, and monitoring of a genetically engineered chestnut. We grouped discussion outputs into the following categories:

1) Risk
2) Monitoring and Management
3) Data
4) Temporality and Location
5) Responsibility and Red Flags
6) Dispersal and Phased Release
7) Engagement and Choice of Publics

Risk

- How do we consider risks that do not fall within the purview of the Coordinated Framework? What risks are being overlooked by the regulatory process?
- How is risk defined – if one looks at changes in genetic makeup as a measure of risk, then isn't the GEAC the least risky option?
- Why is the GEAC regulated so heavily (considered a risk) when hybrids and exotics are not?
- Is there a risk to not restoring at all?
- How can we think about risks both within the regulatory review process and beyond? Beyond the Coordinated Framework, how does one identify, measure, or evaluate risk? And who gets to make those decisions?
- What metrics will be used to assess risk? Again, who gets to make those decisions?
- Given the widely divergent views on risks about the GEAC, how do these different perceptions get addressed or possibly integrated into the same analyses?

Monitoring and Management

- With monitoring, there is a need to make sure we have robust tests (leaf assays) to keep track of tree dispersal.
- There needs to be development of better tools for research monitoring.
- There is a need for reliable, and verifiable large-scale database for monitoring.
- What lessons can be learned from other agencies that already have management plans for species release and dispersal (e.g., Fish & Wildlife Service)?
- Could other disciplines with a heavy modeling focus (e.g., epidemiology) offer insights?

Data

- Regarding monitoring, what data will be of interest?
- What will people want to know (and why)?
- Who will collect and maintain databases?
- Will all data be shared, or even public?
- How might citizen science be used as a method of data collection?
- Could participating in data collection be a condition of receiving a tree? (accountability, enforcement)
- In citizen science and more broadly, who will identify metrics, or what needs to be monitored?

Temporality and Location

- How can we make good decisions in the face of such uncertainty with a species that lives such a long time?
- How far out in time will the trees be monitored?
- How far out in time will there be a responsible party for potential long-term effects?
- How will location for plantings be decided upon?
- How do we balance suitable habitat and public acceptability?
- Could we find private landowners to be early adopters – like the proposed model for the 10,000 Chestnut Campaign?
- How might decisions be made on public lands?
- How will different agencies – possibly with conflicting missions and positions, and certainly with different jurisdictions and scales of governance – influence possible planting locations?

Responsibility and Red Flags

- With such a diffuse release, who is responsible for the different dimensions of deployment, managing, and monitoring?
- Who will pay for these phases?
- Who is ultimately responsible if something goes 'wrong?'
- What issues might be identified as red flags? Who will be responsible (or what kind of process) for identifying what the red flags would even be?
- Will there be a required 'kill switch' that – should deleterious effects be identified – allows for the removal of the trees?
- If negative effects are found in one location, will they be extrapolated out to all sites? In other words, if there is a problem in one ecosystem, will all of the trees in the project be destroyed?

Dispersal and phased release

- Could there be phased releases, in which a round of trees will be planted, and monitored carefully before the trees are released more widely? If so, decisions in this process may be contested.
- Research on how to structure tree survival over the next 100 years is required.
- Training protocols for restoration partners need to be developed.
- How do you plant the tree, where does it grow?
- How will selection pressure based on tree density affect how the tree spreads?
- What will the effects of climate change be on the dispersal of the tree.
- What are the more complex ecological impacts posed by the tree, such as water use?
- There is a need for complex ecological modeling of the trees impact on ecosystems.

Engagement and Choice of Publics

- What is the goal of engagement?
- There is a need for extensive social science on public acceptance and public perception of the issue.
- Is engagement explicitly interested in convincing people?
- Is citizen science an effective tool for public engagement, a data collection method, or both?
- How can engagement be scoped to include the broader chestnut restoration plan, not just the GE tree component?
- Can National Forest Management Plans offer suggestions?
- Can engagement be a useful tool to identify risks or risk perceptions that are beyond the purview of the Coordinated Framework?
- Should the broader public ("everyone") have a collective choice in the use of GEAC in restoration?
- Which public groups should have a say?
- Should some groups or publics have greater say than others?
- Could a neighbor have a say in whether a GEAC gets planted on adjacent land?
- In public lands, who would have the final 'veto' or decision-making power?
- If the GMAC is deregulated, does that mean individual choice – about where, if, how the tree exists in the landscape – is taken away?
- Who is going to grow and sell seedlings, and who will buy them? What is the relationship between the people who develop the technology and buyers and sellers?

Section 6: Generating Ideal Engagement Scenarios

Purpose & Structure

In this session, participants synthesized previous findings of the workshop to create ideal engagement scenarios. These scenarios identify decisions well suited to be informed by engagement and examples of what form this engagement could take. First, a large-group brainstorming exercise was conducted, where participants were asked to identify "specific decisions that would benefit from engaging communities, stakeholders, or publics." The goal was to create as robust a list as possible. Second, individual participants selected one or two decisions from this list that they were particularly interested in and formed small groups around commonly selected decisions. Finally, each small group was tasked to answer the following questions in regard to their specific decision:

1. What decision did you select and which decision phase is it in?
2. Who would be engaged?
3. What questions would be asked?
4. How are experts involved?
5. How are results communicated?
6. How are outputs connected to decision making?
7. Who sponsors the engagement?
8. Where do resources for the engagement come from?

Session Outcomes

One important outcome from this session is the list created by participants of decisions that would benefit from engaging communities, stakeholders, or publics. This list is presented in Table 6.1 below. Decisions identified by participants often had relevance in more than one decision phase, as indicated in the table.

Table 6-1. Decisions that would benefit from engagement. Decisions phases included: "R&D" = research & development; "RR" = regulatory review; and "DMM" = deployment, management & monitoring. Note: Decisions that were further explored in small group discussions are indicated with double asterisk (**).

	Decision Phase		
Decisions that would benefit from engagement	**R&D**	**RR**	**DMM**
**Should it [GEAC] be done at all? (ethical questions)	X	X	X
Is GE an acceptable strategy for pursuing restoration?	X	X	X
What research is next?	X		
How can R&D be structured as open sourced or otherwise? And does it matter?	X		
What are the best mechanisms to decide whether to use the GE tree?		X	X
Whose priorities take priority? Which priorities take priority?	X	X	X

Decisions that would benefit from engagement (continued)	**R&D**	**RR**	**DMM**
Who is responsible for the consequences (good and bad, over decades)?	X	X	X
How do you protect areas as hybrid or GE-free?		X	X
**Should “wilderness areas” be free from GE trees?		X	X
How might we modernize the legal and regulatory structures to include public engagement and acknowledge new knowledge?		X	
How do we identify people not currently engaged?	X	X	X
What expert practices might complement regulatory review, specific to restoration of threatened tree species?		X	
**What environmental and human health studies are sufficient to prove safety?		X	
How do we know when to stop asking questions?	X	X	X
How much science is enough to make a decision?	X	X	X
Who gets to make the final decision?	X	X	X
Assuming no ecological risk, should restoration occur?			X
How do we use GE chestnut to further sustainable forest health?			X
How do priorities inform management?			X
Where should the trees be restored?			X
Should there be (can there be) an opt-out strategy?		X	X
Can we recover and use chestnut medicines?			X
How could this tree be commercialized and should it?			X
What is the role of the scientists and developers in deployment and communication?			X
**Where and how does this tree get deployed?		X	X
How do we prioritize sites for restoration?			X
**What are check-boxes for successful deployment?		X	X

The three small group discussions varied in terms of how many of the guiding questions they covered and where their discussion led. Overall, participants seemed to have an easier time identifying decisions that needed to be answered than thinking through the specifics of engagement processes.

One group began with the decision topics: *(1) What are the check-boxes for successful deployment?* and *(2) What environmental and human health studies are sufficient to prove "safety"?* Their discussion explored whether and how engagement should be used within the assessments of environmental and human health safety. This discussion included debate over whether and how value judgements play a role in risk assessments and other safety assessments. This group also discussed the different engagement methods that would be appropriate to inform different types of value judgements, from a simple survey given out after public talks to more resource-intensive, deliberative workshops.

The second group began with the broad question of: *Should the GEAC be done at all?* In other words, given the host of conservation issues that currently exist, does it make sense to spend resources restoring the American chestnut, and is genetic engineering the right way to go about doing so? This group had a wide-ranging conversation involving a host of questions and issues that relate to this overarching question such as,

- Are we romanticizing the past and thinking about the future in science fiction?
- Is this a chance for restorative justice?
- Why not focus on other trees and conservation priorities?
- How do we define forest restoration? What does it look like, and how do we define what a forest is?
- Who is going to fund this restoration effort?
- Who has a relationship with the chestnut currently? How do you restore the relationship with the tree? Why not focus restoration on trees under peril where there is still a strong relationship?

The third and last small group advanced through all of the discussion prompts:

1. *What decision did you select and which decision space is it in?*
   - Should "wilderness areas" be free from genetically engineered trees?
   - How do we prioritize sites for restoration?
2. *Who would be engaged?*
   - Local communities; broader stakeholders such as conservationists and nut growers; those who have a specific interest in planting the tree
3. *What questions would be asked?*
   - Should we allow genetically engineered trees in wilderness areas? Which sites should we prioritize for planting? How do views differ between hybrid and GE trees? How do views differ between public and private land? Legally where can the tree be planted?
4. *How are experts involved?*
   - Answering and providing technical information; mapping and modeling (habitat suitability, pollination areas, public perceptions); chestnut genetics across tree types; studying public preferences.
5. *How are results communicated? How are outputs connected to decision making?*
   - Communicated to federal and state agencies; communicated via media and social media; ongoing dialogue on restoration and site prioritization; pooling of results of technical studies.
6. *Who sponsors the engagement?*
   - At first, organizations already involved such as SUNY, TACF, and USFS; then broader organizations and stakeholders
7. *Where do resources for the engagement come from?*
   - State, federal, and private sources; communities and individuals who are interested.

Overall, breakout groups identified potential decisions that could be guided by public engagement, but had difficulty in fleshing out the full list of design decisions necessary to imagine an idealized engagement

scenario. It is possible that stronger and more structured facilitation would have helped or that a greater level of expertise in engagement is needed to make such design decisions. Alternatively, some participants may have been unable to set aside their interests to envision engagement scenarios in which public values might emerge that are counter to their preferred position.

Section 7: Overview of Participant Questionnaire Results

In planning our workshop on public engagement surrounding the use of biotechnology in American chestnut restoration, we anticipated the need to measure participant experiences using more traditional quantitative social science methods. We aimed to use both qualitative and quantitative data to paint a richer, more detailed picture of the workshop experience. In this section, we report the main findings from quantitative survey measures using Likert-type response options.

We invited workshop participants to respond to a series of questionnaires before, during, and after the workshop. The questionnaires were all delivered electronically through the Qualtrics software platform. Responses were collected anonymously to encourage participants to be honest and open about their beliefs, values, and perceptions, and the questionnaires were approved by the NC State University Institutional Review Board (Protocol #12627). The questionnaires with complete question wording are available upon request from the research team.

In order to track changes over time within the group, we measured several concepts repeatedly. While we did not obtain a 100% response rate from every participant, all participants responded to most of the questionnaires and the questions within them. We report a selection of the quantitative data we gathered in this overview.

The following results are grouped according to several major concepts based on the literature about public engagement, deliberation, and the risks and benefits of technological hazards. First, we discuss the background characteristics of participants in terms of their values and their trust in different information sources. These results are compared to similar results from a survey of U.S. adults conducted by co-PI Binder (Berglund & Binder, 2013). Second, we discuss participant views on American chestnut restoration based on workshop discussions and information presented to participants.

Values and Worldviews

In the past 20 years, research in public opinion of science issues has moved toward accounting for how values and worldviews contribute to an individual's view of science and technology topics. We adapted two survey instruments to measure participants' views regarding (1) society's relationship to the environment and (2) citizens' relationships to society. The resulting measurement indicated that, even in our relatively small group of workshop participants, we had gathered people with heterogeneous views.

Participants had varied views with regard to the "new ecological paradigm" (Dunlap, Van Liere, Mertig, & Jones, 2000). This set of survey questions measures how much people value using natural resources for the aim of technological progress (e.g., "The earth has plenty of natural resources if we just learn how to develop them") compared to how much they view dangers inherent in the progress of technology (e.g., "If things continue on their present course, we will soon experience a major ecological catastrophe"). The four items were measured on a five-point scale (1 = "strongly disagree," 5 = "strongly agree") and averaged together. For the 21 participants who were invited to complete our pre-workshop questionnaire, we had a 100% completion rate on these items.

The scale is meant to indicate the extent to which a survey respondent is oriented more toward using natural resources to suit society's needs (a score of 1) or is more inclined to preserve nature even at the expense of benefits to society (a score of 5). The average overall score among our participants on the

new ecological paradigm scale was 3.381 (standard deviation of 0.692). The lowest score on this composite measure was 2.000, indicating that at least one participant expressed more of an overall preference for using natural resources, and the highest was 4.750, indicating at least one participant who very strongly felt compelled to preserve nature. In comparison with a representative sample (Berglund & Binder, 2013), there was no significant difference between our small workshop group and the adult population of the United States, $t(2804) = 0.728$, $p = .467$. We therefore have no evidence that our workshop participants – on average – expressed environmental views different from most people in the U.S.

Another concept that has received much attention recently in the literature addresses the extent to which individual citizens subscribe to both "group" and "grid" orientations in society. This cultural cognition approach (Kahan, 2012), as it known, builds upon work in sociology on how societies come to view technological risk (Douglas & Wildavsky, 1983). The approach measures two separate constructs. The *hierarchy-egalitarianism* construct represents how much a person feels a cultural imperative for an egalitarian society or one where established power hierarchies should be respected (e.g., "We have gone too far in pushing equal rights in this country"). The *individualism-solidarism* construct represents how much a person feels society should cater to individual needs or the needs of a solidary collective (e.g., "Government regulations are almost always a waste of everyone's time and money"). Two items were used to measure each of these constructs and coded such that 5 represented a full endorsement of one cultural approach (hierarchy or individualism) and 1 represented the other end of the spectrum (egalitarianism or solidarism).

Our workshop participants had varying views as measured by the cultural cognition constructs. The average score on the *hierarchism-egalitarianism* construct was 2.071 (standard deviation of 0.884), with a minimum value of 1.000 and a maximum of 3.500. The group average was significantly lower than the same construct measured in a 2013 survey of adults in the U.S. (Berglund & Binder, 2013), $t(2792) = 1.992$, $p = .046$, although the small size of our workshop participant group should give pause in over-interpreting this difference due to the likelihood of a false positive (Type II Error). The average score on the *individualism-solidarism* index was 2.071 (standard deviation of 0.912), with a minimum of 1.000 and a maximum of 4.000. The group average was also significantly lower than that of the general adult population, $t(2795) = 3.149$, $p = .002$. This result, with its lower p-value, is less likely to be a false positive. Overall, workshop participants indicated a stronger preference for egalitarianism and solidarism than the general adult population in the U.S.

We note here that the values and worldviews of our participants undoubtedly reflect their underlying interest in American chestnut restoration or environmental resources issues in general. (We also had a number of individuals employed at public universities, which likely plays a role as well.) Indeed, we included the measures reported above because they are often used in social science research to help explain the interests expressed on different science and technology topics. There was considerable variation even among this small group of 21 participants. This was not a group of people who universally shared a narrowly defined value system.

Trust in Information Sources

While one's worldview informs how a person makes judgments about science, technology, and risk, considerable research has also focused on the role of trust – and specifically the role of trust with regard to various sources of technical information. We measured participants' overall level of trust for a list of nine such information sources. (*Note*: The original measurement options ranging from 1 = "Trust not at all" to 5 = "Trust a lot" have been simplified to three categories of low [response of 1 or 2], medium [3],

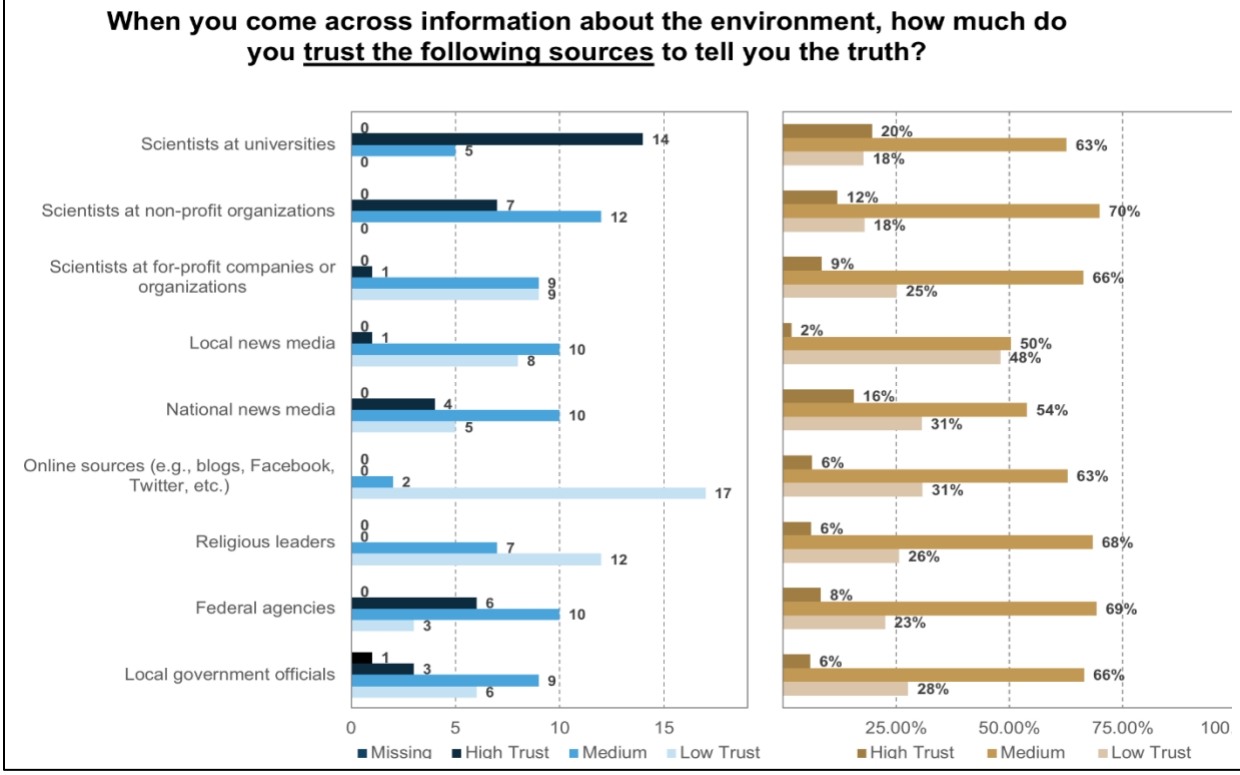
and high [4 or 5] trust.) As in the previous section, we also report how these levels of trust compare to the adult population in the U.S.

Looking at the frequency of "high trust" ratings, the three most trusted sources for information about the environment were scientists at universities (14 participants reporting high level of trust), scientists at non-profit organizations (7 participants), and federal agencies (6 participants). The three least trusted sources were online sources (17 participants), religious leaders (12 participants), and scientists at for-profit companies (9 participants). See full results in bar graph below (Figure 7-1).

Overall, for adults in the United States, the three most trusted sources for information about the environment were scientists at universities (20% reporting high trust), national news media (16%), and scientists at non-profit organizations (12%). The three least trusted sources were local news media (48% reporting low trust), online news sources (31%), and national news media (31%).

In comparison with the same survey question about trust in information sources from a nationally representative sample of U.S. adults, there are some notable similarities and differences. With the exception of scientists working at for-profit companies, whom our workshop participants trusted less than U.S. adults overall, we observed quite a bit of similarity in the frequency distribution of trust in these information sources. For example, the distribution of trust in local news media is quite similar. Our workshop participants differ in their nearly unanimous high trust in scientists at universities and low trust of online news sources.

Figure 7-1. Trust in information sources among workshop participants (left panel, N = 19) compared to the U.S. adult population (right panel, N = 2,800).

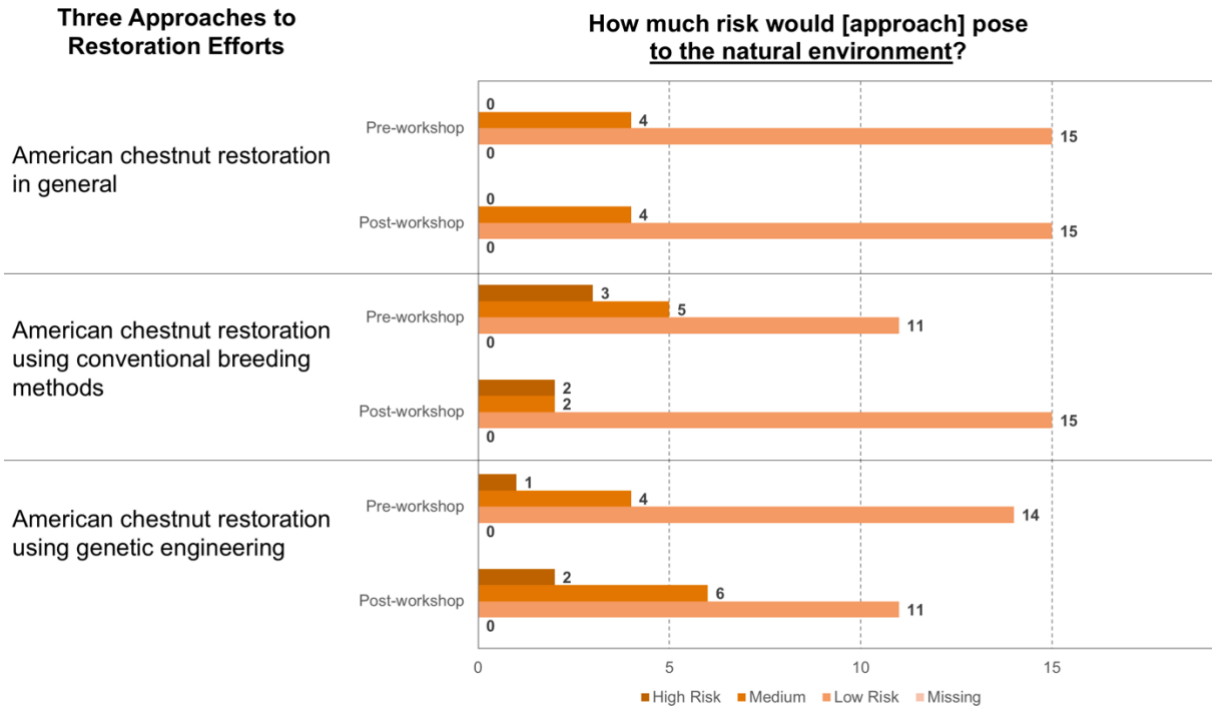


Perceptions of Risks and Benefits

We also investigated perceptions of risks and benefits, which have become fairly standard in academic work on new developments in science and technology. Since workshop participants initially had varying levels of familiarity with the genetically engineered chestnut tree, we chose to ask their perceptions of risks and benefits of each technique and their potential consequences in four different contexts. These were consequences for (1) the natural environment, (2) traditional cultural knowledge, (3) existing cultural practices, and (4) norms and values of broader society. In addition, we asked these series of questions both before and after the workshop in order to draw comparisons of how views may have changed following the various presentations and small-group discussion sessions.

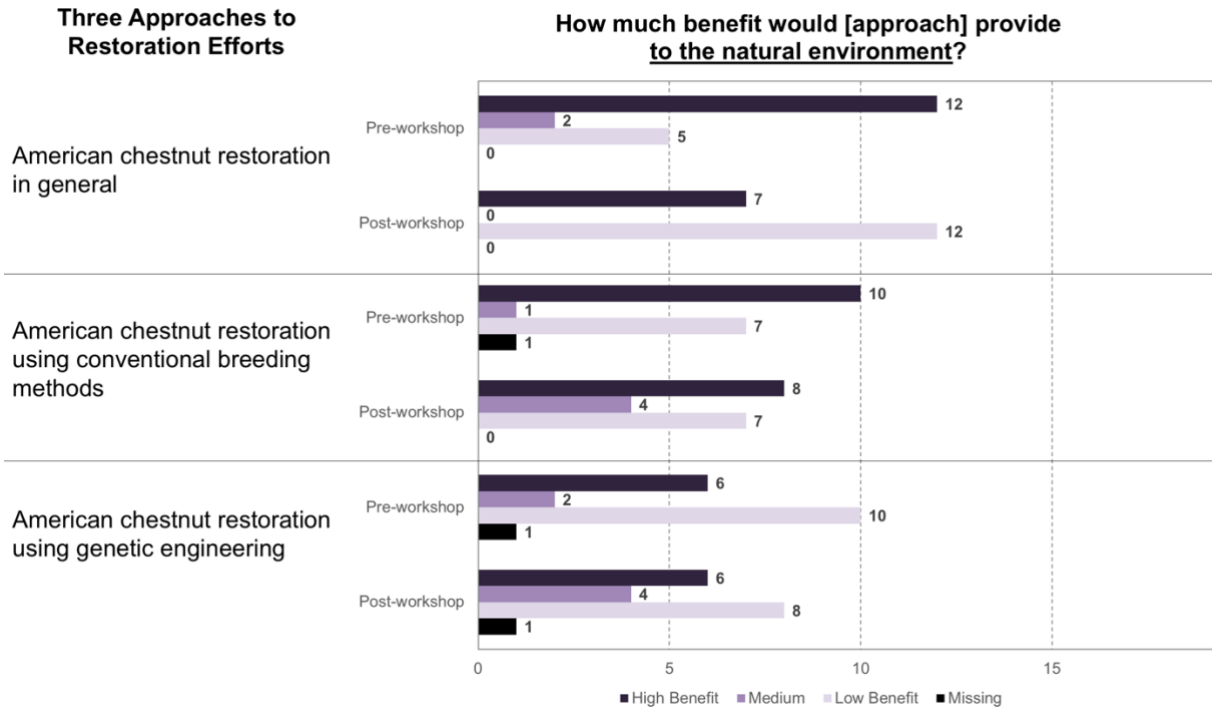
First, for *consequences to the natural environment*, workshop participants indicated few risks for American chestnut restoration in general but more risks if genetic engineering were used (Figure 7-2) in post-workshop measures. Notably, in the pre-workshop questionnaire, there were 8 participants indicating at least a medium perception of risk associated with conventional breeding but 5 indicating this perception of genetic engineering. After the workshop, 8 participants expressed at least a medium risk perception about the GE approach and 4 did so on conventional breeding.

Figure 7-2. Perceived risk to natural environment (N = 19).



Participant views were somewhat divided on benefits to the environment (Figure 7-3).

Figure 7-3. Perceived benefit to natural environment (N = 19).



Second, we asked about *consequences for traditional cultural knowledge* (Figures 7-4 and 7-5), mainly in reference to the indigenous peoples who live within the historic range of the American chestnut tree.

Figure 7-4. Perceived risk to traditional cultural knowledge (N = 19).

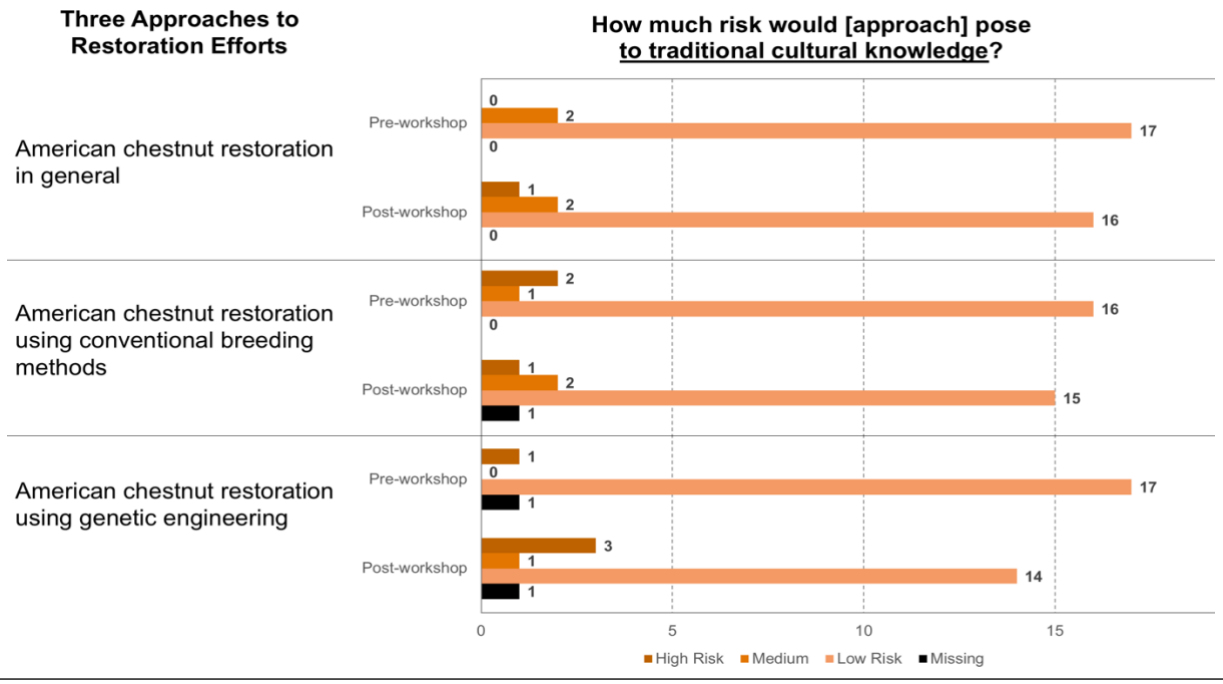
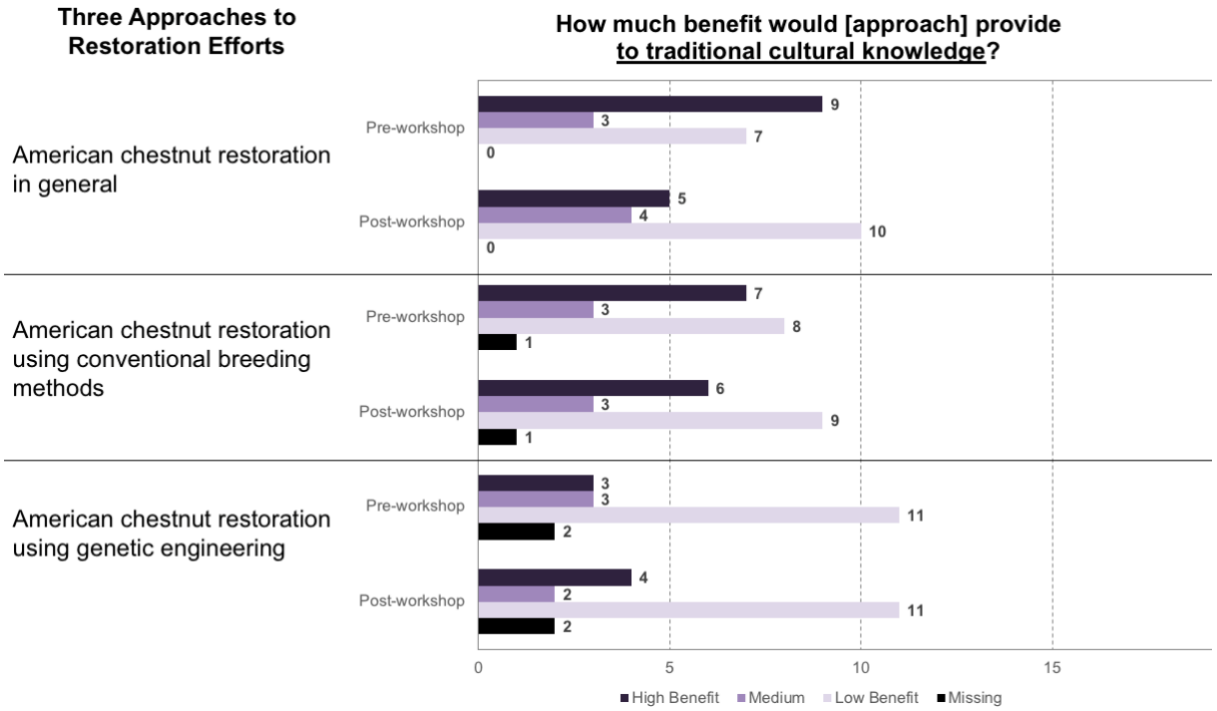


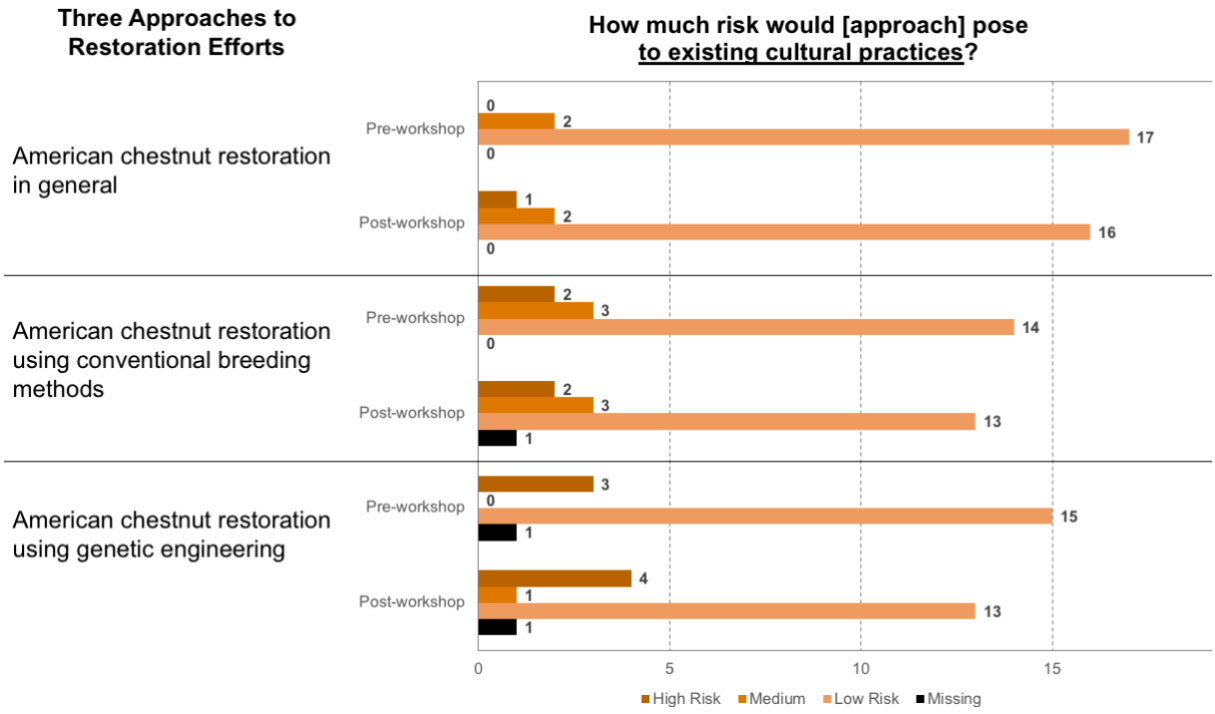
Figure 7-5. Perceived benefits to traditional cultural knowledge (N = 19).



Workshop participants saw relatively little risk regardless of the restoration approach. The highest level of perceived risk to traditional cultural knowledge appeared in conjunction with the genetic engineering approach, although these four individuals were overshadowed by 14 participants who saw little risk. In contrast, the benefits to traditional cultural knowledge were perceived to be less obvious. With regard to chestnut restoration in general, there was movement from higher benefit perception (pre-workshop) to lower benefit perception (post workshop); low benefit became a very slight majority position. There was no real observable change in reference to the GE approach, where a small majority (11 of 19) perceived little benefit both before and after the workshop. Participants after the workshop saw the most benefit with the conventional breeding approach, although this plurality of six participants was outweighed slightly by nine people perceiving low benefit.

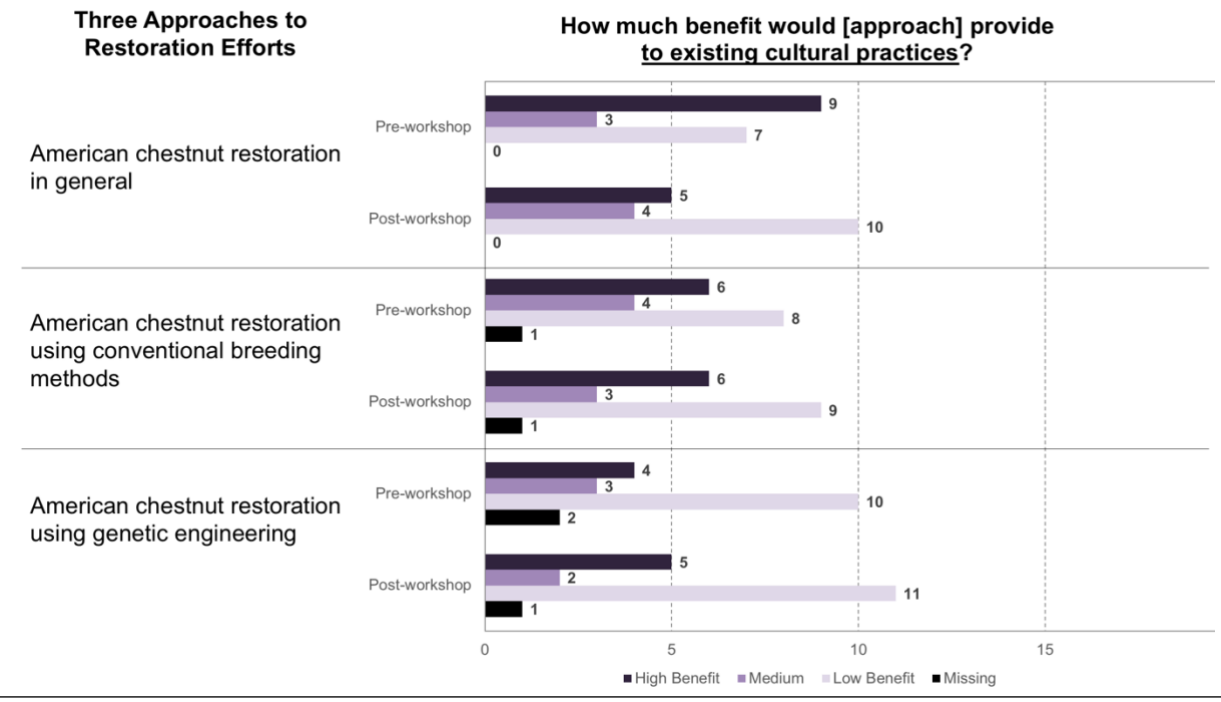
Third, we inquired about *consequences for existing cultural practices* (Figure 7-6 and 7-7). These practices were made in reference to indigenous groups as well as other groups of people residing in Appalachia since the chestnut blight arrived in North America.

Figure 7-6. Perceived risk to existing cultural practices (N = 19).



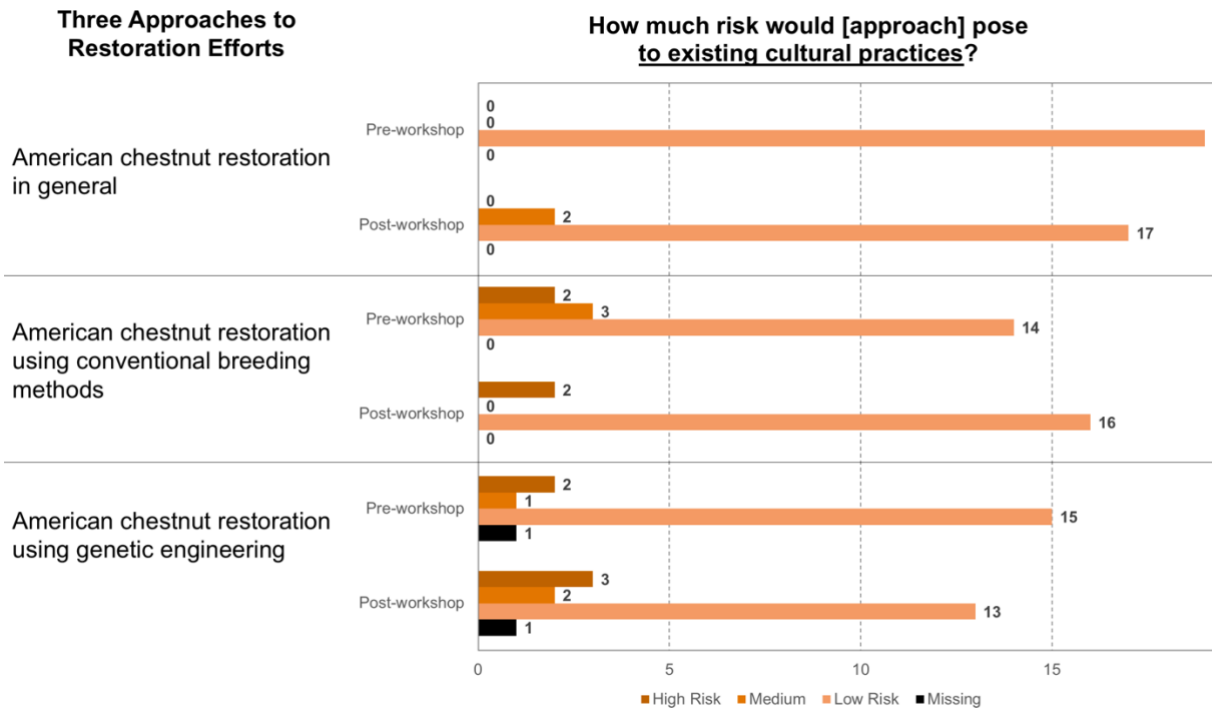
Participants saw very few risks to these cultural practices, and these perceptions did not shift much between pre- and post-workshop measures. The majority of participants were also unlikely to see much clear direct benefit to the people residing in this geographical area.

Figure 7-7. Perceived benefits to existing cultural practices (N = 19).



The fourth and final context for assessing risk and benefit was the *norms and values of broader society* (Figure 7-8 and 7-9).

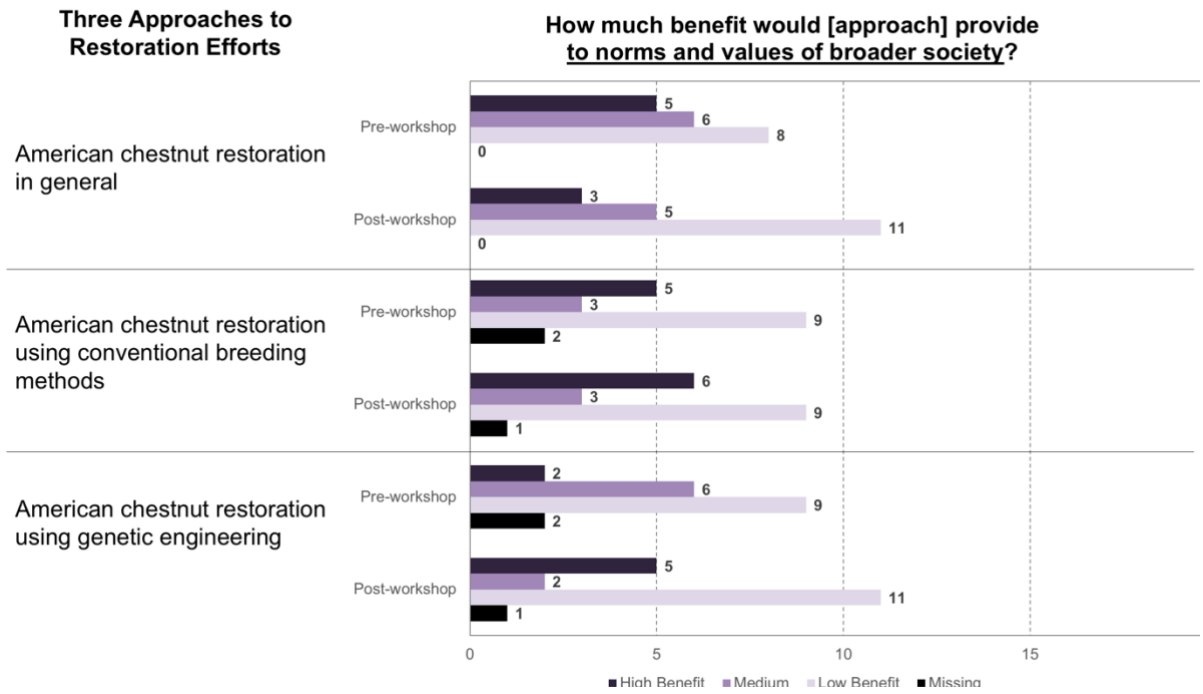
Figure 7-8. Perceived risk to norms and values of broader society (N = 19).



Perhaps more than in the other contexts, participants as a group saw very little risk to our society's norms and values. Where risk was perceived, it was more likely to appear prior to the workshop in conjunction with conventional breeding but after the workshop with the genetic engineering approach. Participants moved from unanimity on the idea of chestnut restoration in general being low risk (19 participants) before the workshop to slightly more equivocal (2 viewing a medium level of risk and 17 perceiving low risk). The pattern was similar for the GE approach, with the perception of risk slightly increasing. The shift for conventional breeding was in the opposite direction (more risk before and less risk after, although notably there were 2 people perceiving high risk both before and after).

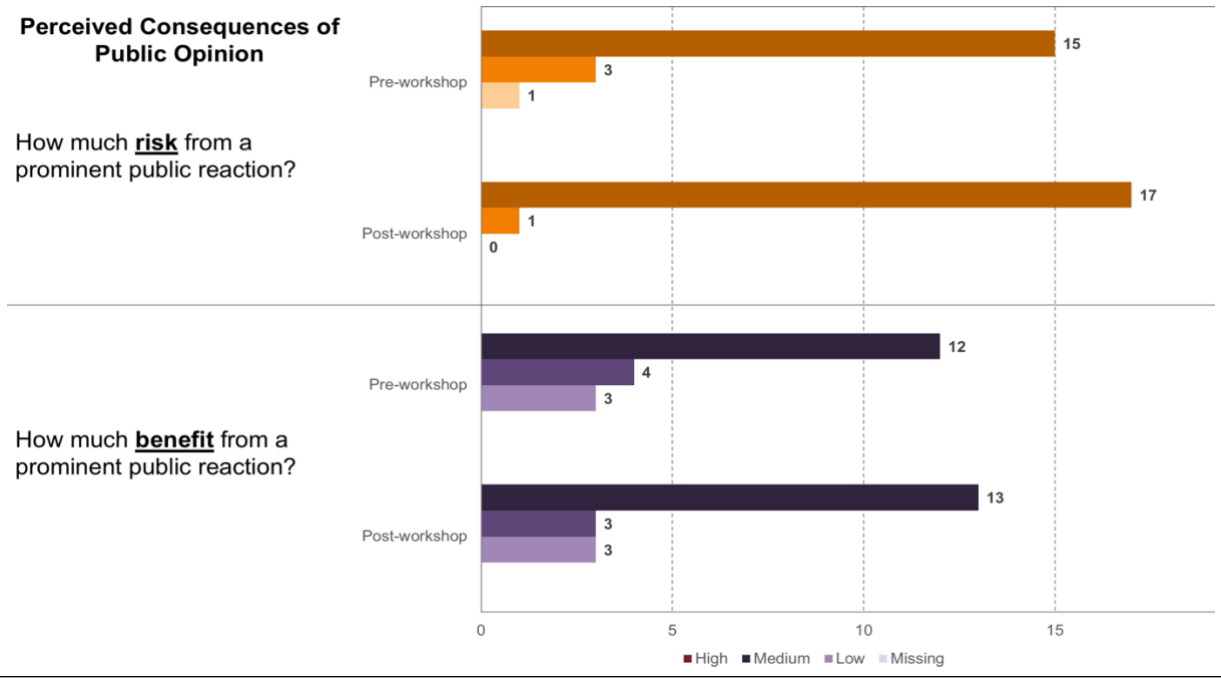
As with the other social and cultural contexts, there was less agreement on the benefits to norms and values of broader society among our workshop participants. Some viewed quite a bit of benefit regardless of approach, whereas a number of others expressed skepticism of such benefits. Following the workshop, the greatest benefit was perceived for conventional breeding (6 participants) and genetic engineering (5 participants), but these groups of participants were overshadowed by those seeing much less benefit (9 participants for conventional breeding and 11 for genetic engineering).

Figure 7-9. Perceived benefit to norms and values of broader society (N = 19).



The final question we asked about risks and benefits pertained to how much a prominent public reaction about chestnut restoration could help (provide benefit) or hurt (pose a risk to) restoration efforts overall. Participants expressed more certainty that a prominent negative reaction would most likely hurt the efforts. A prominent positive reaction was more likely to be viewed as beneficial, but less strongly than a negative response having the opposite effect.

Figure 7-10. Perceived consequences of public reactions (N = 19).

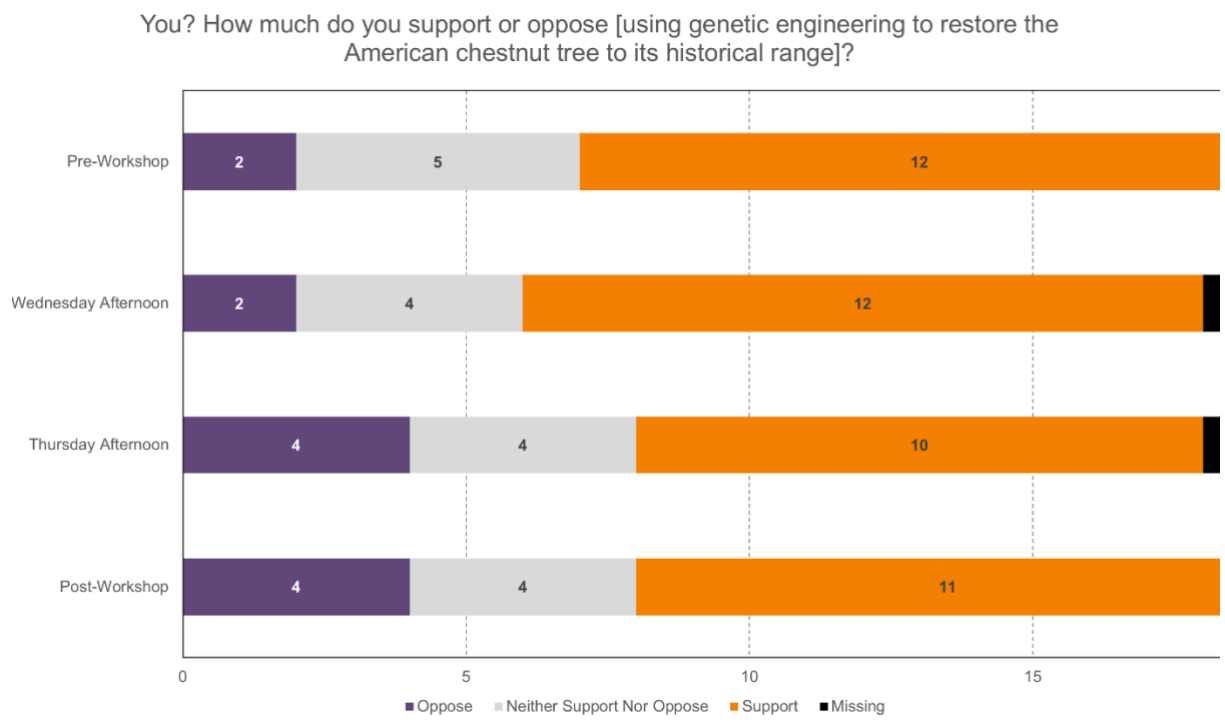


Genetic Engineering and Chestnut Conservation

We also measured participants' overall levels of support for the use of genetic engineering in chestnut restoration efforts. We asked these questions in two different ways. Before the workshop took place, we asked participants to indicate their overall level of support or opposition for GE techniques in chestnut restoration. This question was repeated twice during the workshop and again after the workshop. Because participants had not yet interacted with each other when completing the pre-workshop questionnaire, we complemented this question with another asking how they thought "the majority of people in the U.S." felt about it. During the workshop, we asked people after each day's sessions how they thought "other workshop participants" felt about GE in chestnut restoration.

With all of these measures put together, we had four measurements of participants' own attitudes toward GE in chestnut restoration (Figure 7-11). These responses were fairly uniform from pre-workshop through the end of the first day: 2 participants expressed opposition, 4 to 5 expressed neither support nor opposition, and 10 to 12 expressed support. A group shift occurred on the second day and after the workshop: the number of participants expressing opposition doubled (from 2 to 4), the share expressing a neutral viewpoint remained unchanged, and the number expressing support fell by 1-2 individuals. On the second day, this happened after the self-selecting small-group discussions on specific topic areas for developing engagement (see Section 6).

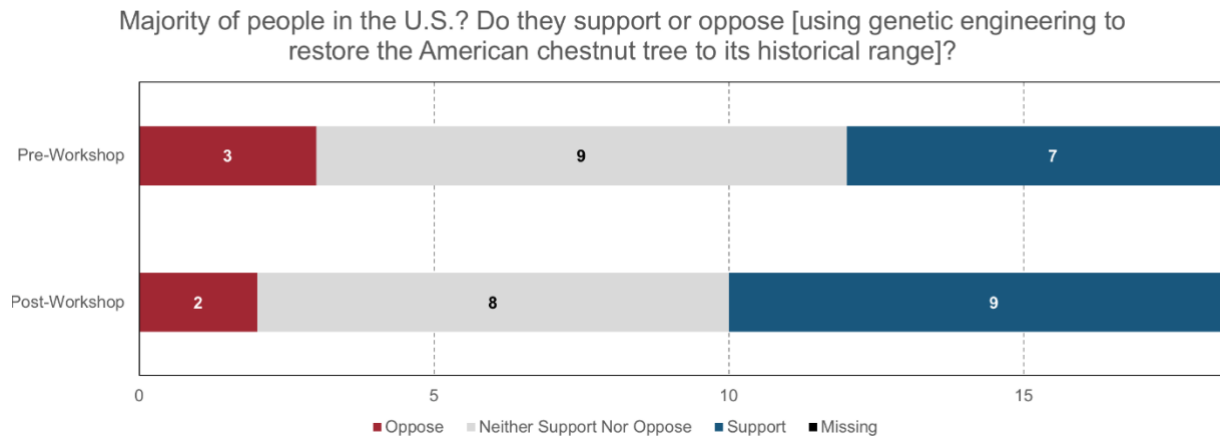
Figure 7-11. Workshop participants' views on GEAC over time (N = 19).



Regarding participants' estimates of public opinion in the United States generally (Figure 7-12), there was a slight difference between pre-workshop and post-workshop responses. Before the workshop, participants perceived a greater amount of opposition and neutrality. After the workshop, this shifted away from both opposition and neutrality; 9 participants felt, after participating in these group discussions over multiple days, that most people in the U.S. would be supportive of GE in chestnut restoration efforts,

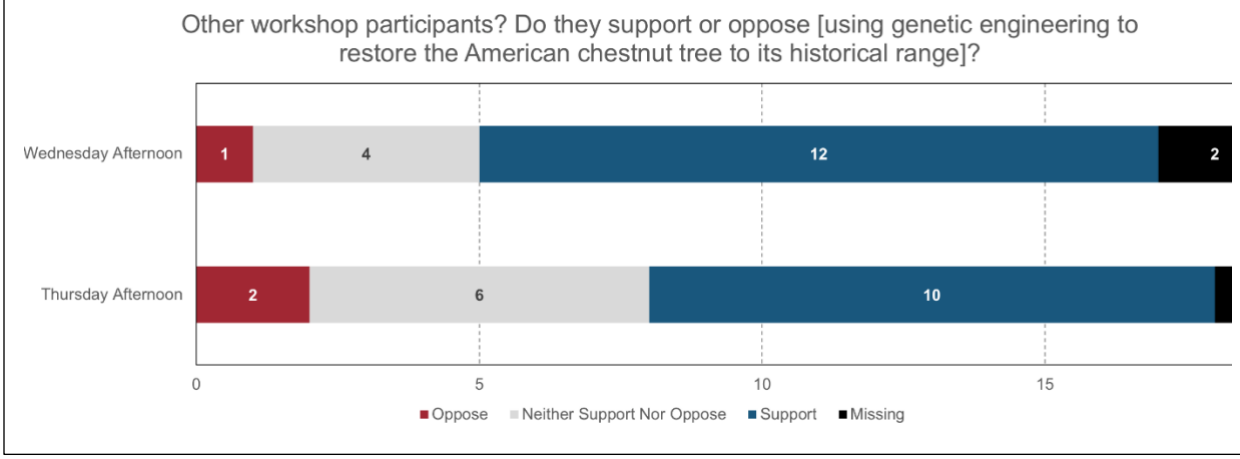
almost the same number of workshop attendees (8) felt public opinion would be neutral on the matter, and a couple of workshop participants (2) felt most people would oppose the use of GE for this purpose.

Figure 7-12. Participants' perception of majority opinion in US (N = 19).



Finally, when it came to workshop participants' perceptions of the viewpoints of their fellow participants, we saw the opposite shift take place. After the first day of the workshop, most participants (12) felt that other participants were supportive, some (4) detected a more neutral sentiment in the workshop, and 1 participant felt that most other participants were opposed. By the next day, the share of participants sensing support among most other participants dropped (10) while an increased number of participants sensed neutrality (6) and opposition (2). Notably, the perception of workshop opinion was fairly accurate both days. A majority of participants (12) accurately reported that the majority opinion was supportive on Wednesday and a slight majority of 10 individuals perceived the majority opinion to be supportive on Thursday as well. These results also suggest that workshop participants, as a group, were successfully able to acknowledge differences of opinion and position on the GEAC topic while also participating fully in small-group discussions. This result appears to contrast with the notion of polarization, where individuals may become more extreme as conversations unfold as a reaction to others' expressed viewpoints and arguments.

Figure 7-13. Participants' perception of majority opinion in workshop (N = 19).



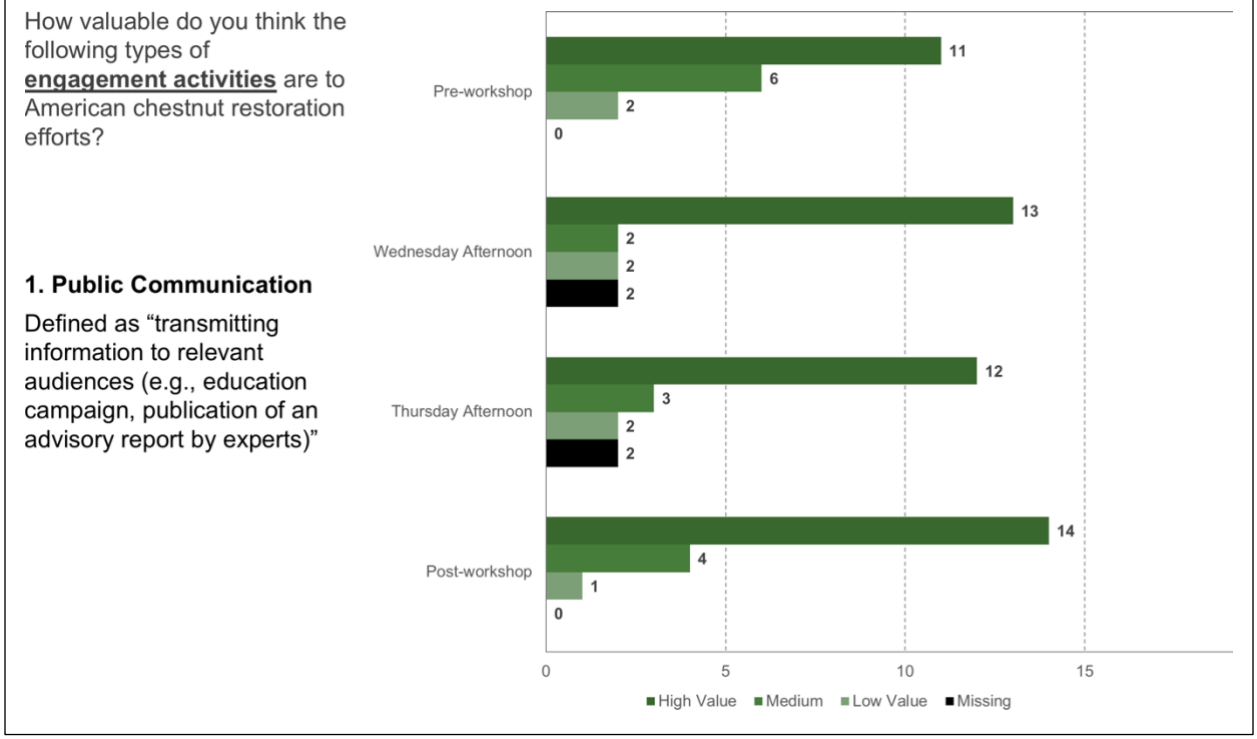
Public Engagement Mechanisms

The final concept we were interested in assessing among workshop participants concerned their evaluations of different forms of public engagement mechanisms. Specifically, we asked them about three forms of public engagement: public communication, public consultation, and public participation (Rowe & Frewer, 2005). These forms of public engagement have been identified due to their qualitatively different approaches in terms of sponsors and participants in engagement exercises.

We measured our workshop participants' evaluations of the value of these three forms of engagement activities at four different points in time. The first measurement was prior to the workshop and provides a baseline before any discussions on the topic of public engagement took place. The second and third measurements took place at the end of each day during the workshop. The final measurement was included in a post-workshop questionnaire. We note that the sessions included discussions of research on the value of public engagement, and we expected participants' views of value to increase.

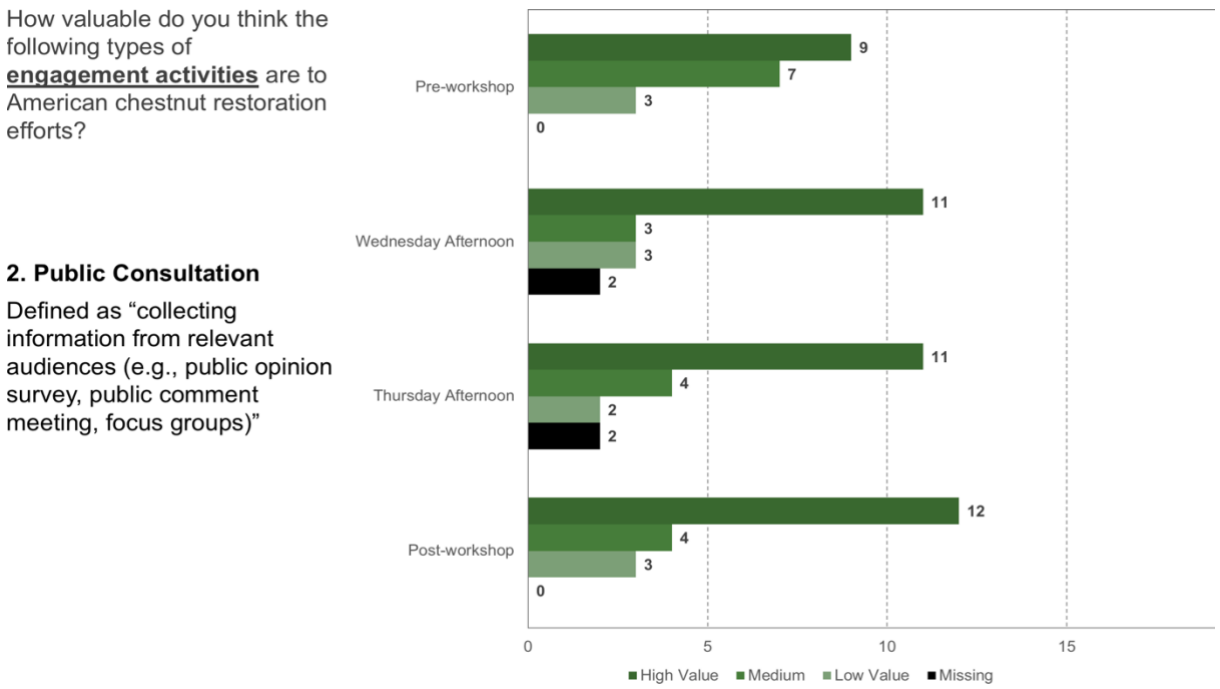
The first mechanism, **public communication**, involves transmitting information.

Figure 7-14. Participants' evaluation of public communication (N = 19).



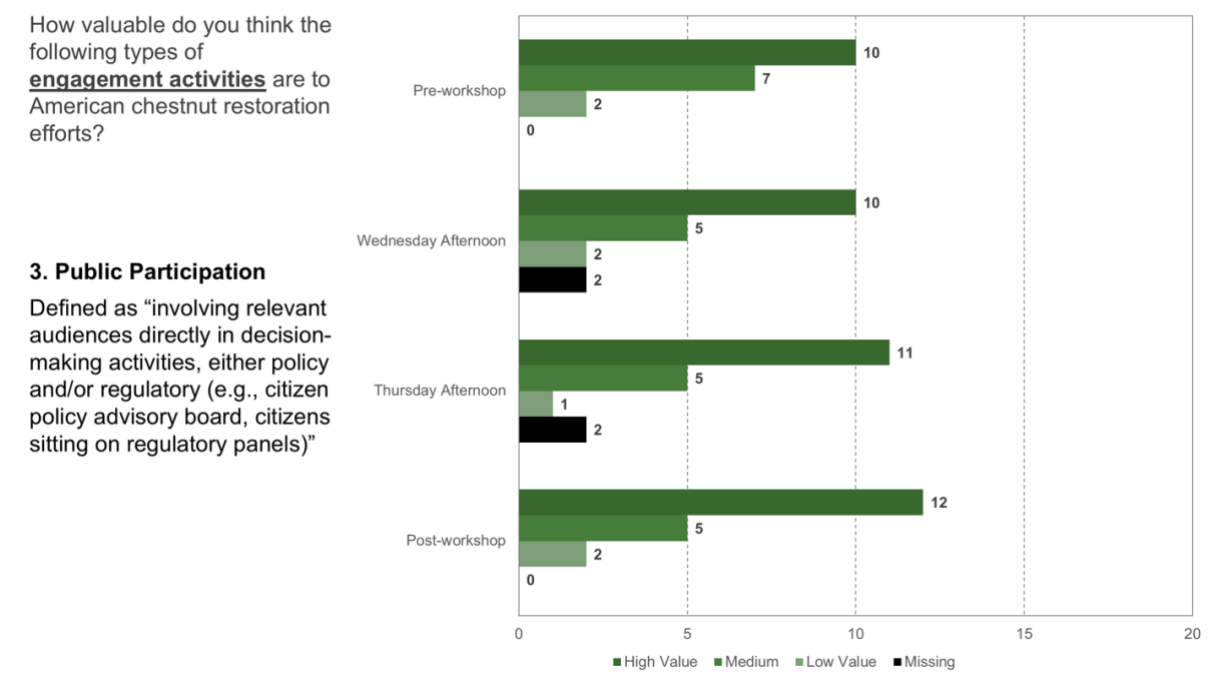
Second, **public consultation** involves the gathering of public preferences.

Figure 7-15. Participants' evaluation of public consultation (N = 19).



Third, **public participation** identifies an engagement exercise in which public audiences have a direct voice in outcomes on the issue being decided.

Figure 7-16. Participants' evaluation of public participation (N = 19).



There were some shifts in the distribution of responses over these four points in time, but the results were fairly consistent across the three different types of engagement mechanisms. The shifts we saw were all in the same direction, with participants changing from lower levels of value to higher levels. For all three forms of public engagement, a slim to small majority of participants saw high value before, during, and after the workshop (the exception was 9 individuals who did not see high value in public consultation prior to the workshop). Public communication enjoyed the highest reported value over the four time points. The biggest shift occurred for public consultation: 9 participants saw this as highly valuable before the workshop compared to 12 afterwards. Even so, a consistent minority of workshop participants rated each form of engagement as not very valuable at every time point (ranging from 1 to 3). The highest amount of skepticism was for public consultation, with 2 to 3 participants rating it as low value at each data collection point.

Conclusions from Participant Questionnaires

The main purpose of this section of our workshop report was to provide a descriptive overview of the anonymous questionnaire data we gathered on various workshop topics. These data highlight a number of broader, albeit tentative, conclusions.

First, as mentioned above, our workshop invitations managed to bring together a group of people with relatively heterogeneous sets of values and worldviews. As participants pointed out during group discussions as part of the workshop, they were aware of the types of people—based on professional affiliation, physical appearance, or geographical origin—absent from the workshop. Nonetheless, in terms of the characteristics that might remain hidden, such as one's beliefs, values, and perceptions, there was more variation within the group than might have been evident to participants at the time. We feel this speaks to a minor success of our efforts at recruiting diverse participants.

Second, these data have brought into focus some of the contours of the potential wider public debate over restoration of the American chestnut tree—whether using genetic engineering or not. In particular, participants' evaluations of the risks and benefits of chestnut restoration suggest that these two aspects of restoration efforts are considered in very different ways. Risk often appears as an explicit consideration in this and similar debates over novel uses of science and technology. But the absence of a high level of risk perception does not necessarily translate into an endorsement of the potential benefits of such efforts. The small group discussions during the workshop sometimes reflected this dynamic. Some participants highlighted the perceived absence of risk as justification enough for technology deployment and for the marketplace to determine whether or not it is beneficial. Others were skeptical of the purported benefits and used that as a basis for a less supportive viewpoint overall. These two examples suggest very different ways of thinking through the value of the genetically engineered American chestnut tree. The specific ways in which stakeholders and others think about these aspects of restoration therefore deserve much more attention.

Section 8: Discussion and Recommendations

While the previous sections primarily represent our research team's best understanding of what was voiced and experienced by participants in the workshop, the following represents our interpretation and analysis of those discussions. We acknowledge that not all of the participants of the workshop would agree with our analysis or endorse our recommendations – indeed, the diversity of participants would likely preclude this possibility.

What is Engagement? Why does it matter?

According to The National Academies of Sciences, Engineering, and Medicine (2016) engagement is "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" (p.131). Our research team shares the view that engagement is important for the introduction of new technologies or processes that are fundamentally novel, boundary crossing, and values-laden. The potential introduction of the genetically engineered American chestnut tree (GEAC) into the wild satisfies these criteria. The tree would be the first GE tree to be purposely deployed to spread in natural ecosystems. The governance issues surrounding the tree have the potential to cross multiple boundaries: physical (the tree is designed to spread across the landscape), disciplinary (multiple disciplines are required to examine the full impact of the tree's release) and political (the tree may cross different political boundaries, including into sovereign territories of Native American nations). The introduction of the GEAC is driven by a diverse set of motivations, such as fixing human-caused ecological problems and restoring a tree species that used to be socially and economically important.

Considering the potentially contentious nature of the GEAC and related decision making, we believe there is a need for engagement with a diverse set of stakeholders. Allowing for substantive input (which often means a concrete role in decision making processes) and discussion from a range of stakeholders can help to build trust between these disparate groups and foster an atmosphere of mutual learning. At a more fundamental level engagement helps to fulfill the democratic norms of transparency and justice.

An Inadequate Framework for Engagement

The existing regulatory framework within the United States offers little opportunity for, and was not designed to sustain, broad, substantive engagement around GEAC governance questions. Some workshop participants made clear that decision making around the GEAC is complex and involves many types of uncertainty. The science, the deployment, and the research and development associated with the tree all feature different types of both scientific uncertainty (e.g., epistemic uncertainty, or things that are theoretically knowable but difficult to know in practice) and social uncertainty (e.g., whether the GEAC is wanted and under what conditions). Much of this nuance has been ignored by the narrow focus of the existing US regulatory framework on a deceptively simple dichotomous choice: whether GEAC is *approved* (or not) from a regulatory perspective. Deregulation of the tree by U.S. regulators would be incredibly significant; however, the centrality of this process to discussions about GEAC has narrowed the scope of engagement about the tree. The U.S. regulatory system does not provide an adequate forum for addressing the scientific and social complexities inherent to the GEAC, a point that echoes a recent National Academies report, *Preparing for Future Products of Biotechnology* (NASEM, 2017).

For example, the American chestnut historically played a role in the lives of Native American tribes within its range. The introduction of GEAC to the wild is not without controversy amongst some tribal communities (Antoine, 2014; Francis, 2015; IEN, n.d.). How would the GEAC match the traditional

indigenous role of the American chestnut? How will decisions about whether to use the GEAC on tribal lands be made? What effects will the GEAC have on habitats on tribal lands? These are just a few of the pressing questions about the introduction of the GEAC that the current regulatory process provides few opportunities to address. Furthermore, there is a need for the exploration of how treaties between Native American nations and the U.S. are relevant to potential GEAC introduction, since many of these tribal nations are legally sovereign entities. These treaties will require diplomacy and coordinated engagement with relevant tribes. Existing consultation processes within the current U.S. regulatory system have proven inadequate for meaningfully addressing this needed engagement (Barnhill-Dilling, 2018).

This is only one example of the shortcomings involved with structuring engagement on the GEAC using only the existing U.S. regulatory system. This report identifies many important discussions and decisions that are not adequately addressed by the current regulatory process. There is a need to develop a paradigm of engagement that can foster a more holistic conversation about the GEAC.

Risks and Benefits

According to the findings from this workshop, an engagement process for the GEAC should explore potential risks, potential benefits, and uncertainties associated with the tree from a diversity of viewpoints. Workshop participants thought about risk in two broad categories: (1) potential adverse effects to the environment from the GEAC, such as those examined within the regulatory process, and (2) other concerns relating to the potential use of the GEAC, such as whether the GEAC will take attention away from more pressing conservation needs. We acknowledge that these categories reflect a departure from the narrower view of technical risk that is addressed in regulatory approval. For example, several participants held different views concerning which potential adverse effects should be assessed as part of the regulatory review, which scientific studies should be conducted to assess those potential adverse effects, and whether the existing regulatory process was sufficient. Echoing broader philosophical debates around conservation, participants also held differing views concerning whether the American chestnut should be prioritized for restoration given the vast number of other conservation challenges that currently exist. There was a recognition of the need for productive deliberations around these important topics.

It also became clear during the course of the workshop that there is a need to engage broadly on the potential benefits of the GEAC. A focus on the regulatory review process emphasizes environmental risk; however, many discussions during the workshop were driven by the potential benefits that the tree offers and conflicts among different groups about the perception of these potential benefits. For example, on one hand, proponents of the GEAC tout the re-introduction of the nut to the American diet. On the other hand, some commercial growers question this potential benefit due to a concern that the general public may react negatively to a GE nut as opposed to a nut that comes from a tree developed through traditional backcrossing techniques. The questionnaire results (see Section 7) indicated that risks and benefits were perceived in very different ways, with a plurality or majority of participants perceiving low potential for risk but less consensus on benefits. Indeed, reviewing these questionnaire data in conjunction with notes and transcripts suggested that, at times, there were two parallel conversations happening within group discussions, one concerning the risks in different contexts and the other addressing benefits. A broader discussion of the GEAC's potential risks and benefits would also contribute to the identification of discrete governance decisions.

Challenges and Recommendations

Designing potential engagement processes for the GEAC is an important, yet daunting, task; numerous challenges emerged from this workshop:

- The complexity of the science involved in the development of the GEAC;
- The value-laden nature of the GEAC and its introduction to natural ecosystems;
- The controversies that have attended other genetically engineered products;
- Multiple stakeholder groups with competing objectives, values, and worldviews;
- The limited engagement opportunities within existing regulatory processes;
- The need to adequately assess and consider both the risks and benefits of the GEAC, while acknowledging that one's values and worldview will impact how we should define, "adequately";
- The complex web of decision points that operate both in parallel and in sequence;
- The difficulties in recruiting ethnically and culturally diverse participants for engagement and facilitating an inclusive process.

In light of these challenges it is not feasible to suggest a one-size-fits-all engagement process for the GEAC. However, based on formal and informal conversations among workshop participants and the research team, we offer the following four recommendations:

1. *Ask the right question to the right audience:* The GEAC impacts a diverse set of audiences. It is neither feasible nor productive to involve every audience in every governance decision, but it is critical that the appropriate audience is engaged for each decision point. For example, determining the chemical profile of the GEAC (such as tannins) is probably best suited for a select audience of scientists. However, determining the potential benefits and risks of this chemical profile requires engagement of a wider set of stakeholders, from timber industry representatives to tribal members concerned about medicinal uses.

2. *Expertise is necessary but not sufficient:* The GEAC is the result of complex science and will require scientific expertise for further study. It is critical that scientists with this expertise are involved in engagement. However, the GEAC is also a value-laden proposition, which requires deliberation with a broader set of stakeholders and broader publics at all decision phases (research and development; regulatory review; and deployment, management, and monitoring).

3. *Uncertainties need to be acknowledged:* There is a significant amount of uncertainty surrounding the science and governance of the GEAC that needs to be acknowledged in engagement processes. In fact, this uncertainty can often help set the stage for meaningful deliberation. For example, the potential impacts of the tree on forest ecosystems that have changed significantly over the past 100 years are uncertain, which represents an opportunity both for further study (to reduce uncertainty) and for deliberation concerning how to navigate this uncertainty in decision making.

4. *A multi-disciplinary team is needed:* Multiple fields of expertise need to be involved in designing and conducting engagement for the GEAC. There is clearly the need for biological scientists that understand the genetic manipulation of the tree, as well as for natural scientists to study ecosystem impacts and the potential range of the tree. Social scientists need to be involved as well, and they can assist with addressing governance issues, understanding public opinion, and helping design and conduct engagement exercises. A diverse mix of experts can support the design and delivery of meaningful engagement process that incorporate high-quality information and diverse perspectives to address decisions during research and development, regulatory review, and deployment, management, and monitoring.

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Appendix: Workshop Participants

Participants were recruited attending to multiple aspects of diversity with the goal of fostering inclusive and insightful dialogue. The research team identified and invited representatives from the U.S. Forest Service, non-governmental organizations, academia, Native American tribes, and the private sector. While budgetary limitations and calendar conflicts made it impossible to have all interests perfectly represented, the research team made great efforts to create some balance among proponents, critics, and those with less defined positions on the GE American chestnut tree. While the NC State University human subjects research protocol (#12627) does not allow us to make public the complete list of stakeholders who received invitations or who attended the workshop (which would provide complete transparency regarding recruitment efforts), the following table lists **all workshop participants who gave their express permission to be listed as attendees** (along with their professional sector, organizational affiliation, and their title at the time the workshop took place).

LIST OF WORKSHOP ATTENDEES (who gave permission to be listed)

Name	Sector	Organization	Title / Additional Information
RESEARCH TEAM			
Barnes, Jessica	Academia	NC State	Ph.D. student, Forestry & Environmental Resources (FER), Genetic Engineering and Society (GES)
Barnhill-Dilling, Katie	Academia	NC State	Ph.D. student, FER, GES
Binder, Andrew	Academia	NC State	Co-Principal Investigator, Faculty, Communication, GES
Delborne, Jason	Academia	NC State	Principal Investigator, Faculty, FER, GES
George, Dalton	Academia	NC State	Ph.D. student, FER, GES
Kokotovich, Adam	Academia	NC State	Postdoctoral Researcher, FER, GES
Rivers, Louie	Academia	NC State	Co-Principal Investigator, Faculty, FER
Sudweeks, Jayce	Academia	NC State	Ph.D. student, Public Administration, GES
INVITED PARTICIPANTS			
Abrams, Percy	Academia / Tribal	Syracuse University	Faculty, Linguistics, Onondaga Nation (virtual participation)
Barilovits, Steve	NGO	American Chestnut Foundation	Board Treasurer
Crane, Debbie	NGO	The Nature Conservancy	Communications Director
Costantini, Danielle	Academia	NC State	Undergraduate student, Science, Technology, and Society

Gillis, Doug	NGO	American Chestnut Foundation	President, Carolinas Chapter
Goodwin, Jean	Academia	NC State	Faculty, Communication, Director of Leadership in Public Science program
Gould, Fred	Academia	NC State	Faculty, Entomology, Co-Director of Genetic Engineering and Society Center
Haenn, Nora	Academia	NC State	Faculty, Anthropology, GES
Kirk, Jack	Private	Chestnut Growers of America	Landowner and chestnut grower
Kuiken, Todd	Academia	NC State	Senior Research Scholar, GES
McCord, Susan	NGO	Institute for Forest Biosciences	Executive Director
Megalos, Mark	Academia	NC State	Extension Faculty, FER
Needham, Mark	Academia	Oregon State University	Faculty, Department of Forest Ecosystems and Society (virtual participation)
Newhouse, Andy	Academia	SUNY-ESF	Ph.D. student, Environmental and Forest Biology
Patterson, Neil	Academia / Tribal	Center for Native Peoples and the Environment	Haudenosaunee Environmental Task Force, Tuscarora Nation
Powell, Bill	Academia	SUNY-ESF	Professor, Environmental & Forest Biology
Petermann, Anne	NGO	Global Justice Ecology Project	Executive Director
Quinn, Cathy	Private	Arborgen	Director, Communications and Marketing
Summerville, Kenneth (K.O.)	NGO	American Chestnut Foundation	Former president, Carolinas Chapter
Wang, Jack	Academia	NC State	Faculty, FER, forest biotechnology group