Forest Policy and Economics 125 (2021) 102385

Contents lists available at ScienceDirect

Forest Policy and Economics

journal homepage: www.elsevier.com/locate/forpol

Cognitive and demographic drivers of attitudes toward using genetic engineering to restore American chestnut trees

Joshua D. Petit, Mark D. Needham *, Glenn T. Howe

Department of Forest Ecosystems and Society, Oregon State University, Corvallis, OR, USA

ARTICLE INFO

Keywords:
Attitudes
Risks
Benefits
Value orientations
Trust
Genetic engineering

ABSTRACT

This article explored attitudes toward using genetic engineering (GE) for restoring American chestnut (AC) trees, and cognitive and socio-demographic factors related to these attitudes. Questionnaires were completed by a random representative sample of the US public (n = 278) and a purposive sample of forest interest groups (FIG) such as scientists and managers (n = 195). Results showed somewhat positive attitudes toward all three GE applications (change existing AC genes, add genes from distantly related organism to AC, add oxalate oxidase [OxO] gene from bread wheat to AC) for mitigating chestnut blight (CB) and restoring AC trees. FIGs were more aware of CB, had more favorable attitudes, and perceived greater benefits and lower risks of these GE uses. Perceived benefits and risks were among the strongest drivers of attitudes for both groups, with environmental benefits the most strongly related to attitudes toward all three GE uses for the public sample and two of the three uses for the FIGs. Benefits and risks to humans, general environmental value orientations, specific value orientations toward forests, trust in agencies, awareness about CB, and socio-demographic characteristics (e.g., age, income, education, political orientation, forestry involvement, residential proximity to forests) were not as strongly related to these attitudes. These findings can inform research on reactions to using GE for conservation, and enable organizations to effectively communicate about using emerging technologies (e.g., GE) for addressing natural resource challenges.

1. Introduction

The American chestnut (AC; *Castanea dentata*) was a keystone tree species in forests throughout the eastern United States (US) that provided timber and food (chestnuts) for humans, and habitat and food for wildlife. Chestnut blight (CB) is a tree disease caused by a fungal pathogen (*Cryphonectria parasitica*) that was accidentally introduced to the US from Asia around 1900 and has decimated this once-abundant tree species (up to 99% reduction in the AC native range). The fungus enters through bark wounds and emits oxalic acid that restricts nutrient flow and prevents trees from growing and reproducing (NASEM, 2019; Wheeler and Sederoff, 2009).

Traditional silvicultural strategies (e.g., hybridization, selective breeding with Asian chestnuts) have been somewhat effective for mitigating CB, but biotechnologies such as genetic engineering (GE) have been most efficacious (NASEM, 2019; Wheeler and Sederoff, 2009). These GE approaches involve inserting genes from sexually compatible species (cisgensis or cisgenics [within-species or genes from closely related organisms]) or from incompatible species (transgenesis or transgenics [between-species or genes from one organism into a different organism]) such as the oxalate oxidase (OxO) gene from bread wheat, which has yielded the highest resistance to CB (Zhang et al., 2013). Given the success of field trials, researchers are currently seeking regulatory approval for releasing these transgenic AC trees at a broader scale (Chang et al., 2018; Steiner et al., 2017). However, implementing technologies such as GE partially depends on support and favorability (i.e., attitudes) among the public and other groups (Sjoberg, 2004; Slovic, 2010). Given the important services provided by forests (e.g., habitat for wildlife; timber, air, recreation for humans), it is important to understand if people support technologies that can mitigate forest health threats such as diseases (e.g., CB).

Attitudes toward GE in different contexts (e.g., agriculture) have been shown to be related to socio-demographic characteristics and other cognitions such as perceived risks and benefits, trust, knowledge, and value orientations (De Groot et al., 2013; Siegrist, 2000). However, it is unclear if these factors are associated with attitudes toward using GE to conserve or restore forests in general or to address CB in particular. This article explored public and forest interest group (FIG) attitudes toward

* Corresponding author at: Department of Forest Ecosystems and Society, Oregon State University, Corvallis 97331, OR, USA.
E-mail address: mark.needham@oregonstate.edu (M.D. Needham).

https://doi.org/10.1016/j.forpol.2020.102385
Received 15 March 2020; Received in revised form 26 September 2020; Accepted 22 December 2020

using three applications of GE for enhancing resistance to CB and potentially restoring AC trees, as well as potential correlates of these attitudes. Investigating these issues informs understanding of opinions about GE in this context and communication efforts about benefits and risks of this use of GE.

2. Conceptual framework

2.1. Attitudes

Attitudes are evaluations of an object or issue with some degree of favor or disfavor where the entity being evaluated can be general (e.g., attitude toward all technologies) or specific (e.g., attitude toward a use of GE; Fishbein and Ajzen, 2010; Whittaker et al., 2006). Attitudes are often measured using semantic differential scales (e.g., "bad" to "good," "disfavor" to "favor;" Fishbein and Manfredo, 1992). Substantial variation exists in attitudes toward different genetic technologies, such as GE foods being generally viewed more negatively compared to other uses (e.g., medical biotechnologies; Frewer et al., 2013). For example, Condit (2010) found that genetic testing was more publically favorable than GE in food. In the context of the AC, it is important to recognize that its chestnuts are consumed by humans.

Little research has examined attitudes toward using GE in forest conservation in the US, although there is some analogous research from other countries (see NASEM, 2019 for a review). Kazana et al. (2015) found generally positive attitudes among students in mostly European countries regarding GE trees in plantations. Nonić et al. (2015) had similar methods and results. Hajjar and Kozak (2015) found that approximately 50% of residents in Western Canada accepted planting trees with traits introduced via biotechnology to address forest health threats from climate change. More recently, however, only 25% of the public in this same region supported reforestation with GE technologies to adapt to climate change (Peterson St-Laurent et al., 2018, 2019). Adding additional nuance, Jepson and Arakelyan (2017a, 2017b) found that cisgenic approaches were preferred among UK residents over transgenic applications for addressing ash dieback. Their respondents were also more supportive of planting cisgenic and transgenic ash trees in plantations compared to woodlands. Research has shown more support for GE that addresses specific forest health threats (e.g., pests, diseases) than more general issues that transcend forests (e.g., climate change; NASEM, 2019).

2.2. Trust

One potential correlate of attitudes toward GE is trust, which is the willingness to rely on entities responsible for making decisions or taking actions that affect public health, safety, and wellbeing (Siegrist et al., 2000). People often trust external sources (e.g., agencies, scientists) to assess technologies and natural resource (NR) issues, especially when personal experience with an issue is low (Needham and Vaske, 2008). Trust in sources charged with managing, researching, and providing information about technologies and NR issues is often positively related to favorable attitudes about these issues (Perry et al., 2017; Siegrist, 2000). This relationship has been examined in several contexts, including nuclear power (Siegrist et al., 2000) and gene technology (Connor and Siegrist, 2010). Less research has examined this relationship in the context of forestry, especially forest health issues. Although trust has been related to favorable attitudes toward using GE in plantation forestry, the bulk of this research has not addressed forest health issues (NASEM, 2019; Strauss et al., 2017). Hajjar and Kozak (2015), however, did find that among Western Canadian residents, trust in decision-makers was an important factor related to attitudes toward planting trees with traits introduced via biotechnology for addressing forest health threats from climate change. Trust in decision-makers in this same region, however, was low (less than 40%; Peterson St-Laurent et al., 2019). Researchers in the UK found that trust in forest managers was associated with favorable attitudes toward using GE for mitigating ash dieback (Jepson and Arakelyan, 2017a, 2017b).

2.3. Risks

Risk perceptions can also predict attitudes toward GE. Risk perceptions are subjective evaluations of threats posed by a hazard (e.g., CB, GE; Slovic, 2010). Unlike objective risk assessments based on actual probabilities and consequences of a hazard, perceived risks are intuitive judgments unique to each individual and informed partially by communication efforts (Needham et al., 2017). Risk perceptions can vary greatly between the public and other interest groups. Scientists, for example, often judge risks closer to actual probabilities, whereas members of the public often rate risks with more subjective and emotional responses (Wilson and Arvai, 2006). High perceived risks are often associated with negative attitudes toward GE (Frewer et al., 2013; Sjoberg, 2004). Strauss et al. (2017) and the NASEM (2019) reviewed the literature on potential drivers of attitudes toward GE in forestry and concluded that risk perceptions were likely to be negatively associated with favorable attitudes. Kazana et al. (2015, 2016) explored risk perceptions among mostly European students and found that concerns about gene escape (unintended gene flow into wild forests), disease susceptibility, and higher herbicide inputs were associated with GE trees in industrial forestry, and these risks predicted student attitudes toward this issue. Other studies have found similar concerns about using GE in forestry, such as loss of genetic diversity in wild forests (Nonić et al., 2015; Tsourgiannis et al., 2016). In addition, concerns over humans interfering or tampering with nature have been observed in studies of GE in forestry in Western Canada and the UK (Hajjar and Kozak, 2015; Jepson and Arakelyan, 2017b).

2.4. Benefits

In addition to these risks, perceived benefits are also related to attitudes toward technologies (Frewer et al., 2013). Perceived benefits are subjective evaluations that a particular action (e.g., using GE) will yield a positive outcome (e.g., mitigate CB, restore AC trees; De Groot et al., 2013). Studies on student perceptions of GE in plantation forestry have revealed perceived benefits such as reduced pesticide inputs and greater tree growth and productivity (Kazana et al., 2015; Nonić et al., 2015). Benefits are often positively associated with favorable attitudes toward GE in agriculture (De Groot et al., 2013; Siegrist, 2000), and Strauss et al. (2017) hypothesized the same relationship in forestry. However, studies examining this relationship in the context of forest restoration are limited, but they warrant attention given the potential utility of GE for addressing forest health threats. Research examining public responses to using GE for ash dieback in the UK found that people viewed this technology more favorably when used for addressing tangible issues (e.g., tree diseases, world hunger), suggesting that perceived benefits may correlate with favorable attitudes toward GE in forestry (Jepson and Arakelyan, 2017b).

2.5. Value orientations

Value orientations can also be related to attitudes. Value orientations are patterns of beliefs that exist in general (e.g., environment) and more specific (e.g., forests) contexts (Vaske and Donnelly, 1999; Whittaker et al., 2006). A utilitarian or anthropocentric environmental value orientation is a human-centered conceptualization of the natural world, whereas a biocentric or protectionist value orientation suggests that the natural environment has inherent worth beyond human use. Value orientations have been investigated in relation to technologies such as GE. Pardo et al. (2002), for example, found that value orientations corresponded to attitudes toward technologies such as GE. Hajjar and Kozak (2015) found that more biocentric Western Canadians were less accepting of using biotechnologies for addressing impacts of climate change on forests compared to those with mixed or neutral value orientations. Another study in this same region showed that residents with anthropocentric orientations were most supportive of using biotechnology in reforestation efforts for responding to climate change (Peterson St-Laurent et al., 2018).

2.6. Awareness

Attitudes toward GE can also be related to awareness (Connor and Siegrist, 2010). When individuals are aware of forest health threats (e.g., CB), they are also likely to be aware of biotechnological interventions for addressing these threats (Kazana et al., 2016). Researchers have suggested that this increased awareness is likely to be associated with more favorable attitudes toward GE (Strauss et al., 2017). However, others have found that awareness about GE can elicit either negative or positive reactions depending on context (Kronberger et al., 2014) and a distinction should be made between awareness of a threat (e.g., CB) versus a technology (e.g., GE) for addressing the threat (NASEM, 2019).

2.7. Socio-demographic characteristics

Relationships between attitudes and socio-demographic characteristics have been studied in many contexts. These characteristics include age, race, income, education, interest group affiliation, industry involvement (e.g., forestry), political orientation, and residential location (e.g., rural, non-rural). Males, younger individuals, and Caucasians have viewed technologies such as GE more favorably than their counterparts (Hajjar and Kozak, 2015; Moerbeek and Casimir, 2005). Researchers in the UK, for example, found that younger people were more supportive of using GE to enhance ash tree resistance to dieback (Jepson and Arakelyan, 2017a, 2017b). Income can also be positively associated with favorable views toward using technologies to manage hazards (Dosman et al., 2001). Researchers have hypothesized that politically conservative individuals are likely to view GE in forestry most favorably (Strauss et al., 2017).

Research examining differences in attitudes between the public and other interest groups has shown that some groups (e.g., managing agencies, scientists) usually view GE more favorably compared to members of the general public (Jepson and Arakelyan, 2017b; Savadori et al., 2004). However, Hajjar et al. (2014) observed differences in support for using GE to mitigate effects of climate change on forests in Western Canada where residents showed greater support than did community leaders (e.g., mayors). Another study in Western Canada showed that nongovernmental organizations (NGOs) and indigenous groups viewed GE trees less favorably than did industry and government agencies (Nilausen et al., 2016).

Based on this literature, this article explored three research questions. First, what are the attitudes of people toward using various applications of GE for restoring AC trees? Second, what socio-demographic characteristics and cognitions (e.g., trust, risks, benefits, value orientations) are related to these attitudes, and which are most strongly associated? Third, to what extent do these cognitions, socio-demographic characteristics, and relationships differ between samples of the US public and FIGs?

3. Methods

3.1. Data collection

Data were from a mixed-mode survey of the US general public and FIGs (university scientists, government agency representatives, businesses, NGOs involved in forest issues) from January to June 2015. Sampling for the public was stratified by residents: (a) within the historic native range of the AC (chestnut counties), and (b) in the rest of the contiguous US (non-chestnut counties). Residents were sampled randomly and proportionally to county-level populations using zip codes. The FIGs consisted of a purposive sample selected based on expertise and involvement in forest issues. Six contacts were used for increasing response rates and sample sizes: (a) postcard mailing with an option to complete the questionnaire online, (b) full mailing (questionnaire, letter, postage-paid reply envelope), (c) postcard reminder with an option to complete the questionnaire online, (d) telephone call to encourage participation, (e) second full mailing, and (f) final full mailing. This number of contacts is high for survey research (three or four contacts are more common; Vaske, 2019) and funding limitations and constraints imposed by the university human subjects/institutional review board prohibited any additional contacts.

In total, 473 completed questionnaires were received (15% response rate). Completions for each stratum included: (a) 142 from the public in chestnut counties (12% response rate), (b) 136 from the public in non-chestnut counties (11% response rate), and (c) 195 from FIGs (33% response rate). A telephone non-response bias check of non-respondents from the public samples ($n = 107$) was conducted to determine if responses differed between respondents and non-respondents, but no substantive differences were found. To address sample representativeness, demographic characteristics of respondents from the public samples were compared to US census data to investigate any differences between the public samples and the larger population. There were slight differences in age (samples were slightly older) and education (samples were slightly more educated), so the data were weighted by these characteristics to improve public sample representativeness to the population. Few substantive differences were found between respondents from counties within the historic native range of the AC and those from the other counties, so responses from these two samples were aggregated into a single public sample.

Responses across the FIGs were also aggregated because they were not necessarily statistically representative of each of the four groups (scientists, agencies, businesses, NGOs) and the number of respondents in each group was small ($n = 35$–61 per group). In addition, there were no statistically significant or substantive differences among these four groups in their responses to each of the variables measuring attitudes toward each application of GE for restoring AC trees (attitude variables and GE applications are discussed in the section below; scientists: mean [M] = 3.40–4.07 on scales discussed below, standard deviation [SD] = 0.93–1.23; agencies: $M = 3.01$–3.57, $SD = 1.18$–1.46; businesses: $M = 3.15$–4.15, $SD = 0.85$–1.35; NGOs: $M = 3.25$–3.71, $SD = 1.23$–1.48; Kruskal–Wallis $H = 0.22$–3.15, $p = .369$–.974, eta [η] effect size = 0.07–0.23 [$M = 0.16$]).

3.2. Variables

Scenarios were embedded in the questionnaire to measure cognitions in response to three GE approaches for mitigating CB and restoring AC trees (Table 1). The scenarios were subjected to pretesting and expert feedback during focus groups. In all scenarios, respondents were presented with a factual description: “CB has killed more than 99% of adult AC trees within their native range. This disease is caused by a fungus that was accidentally introduced to North America around the year 1900.” The scenarios then described potential applications of GE to help trees resist CB and restore AC forests. The first scenario was “changing genes that are already present in AC trees,” the second was “adding genes from a distantly related organism to AC trees,” and the third was “adding a gene from wheat (e.g., bread wheat) to AC trees.”

Attitudes toward each scenario were measured on four separate 5-point semantic differential scales: “bad” to “good,” “foolish” to “wise,” “disagree” to “agree,” and “pessimistic/not hopeful” to “optimistic/hopeful,” with the lowest number (1) for the negative response and the highest (5) for the positive response. *Risk perceptions* were on 9-point scales from 0 “no risk” to 8 “high risk” in response to asking “to what extent do you think this scenario would pose a risk to each of the following:” (a) “trees/forests,” (b) “the broader environment,” (c) “yourself,” and (d) “other humans or society in general.” *Perceptions of*

Table 1
Verbatim wording for three GE scenarios including information about CB.

Scenario Number	GE scenario wording	Type of GE
1–3	*Chestnut blight* has killed more than 99% of adult American chestnut trees within their native range. This disease is caused by a fungus that was accidentally introduced to North America around the year 1900.	
1	*Changing genes that are already present in American chestnut trees* is being used to help trees resist chestnut blight and restore American chestnut forests. This involves using modern laboratory approaches to change genes that are already present in American chestnut trees. The genetically modified trees (also known as genetically engineered trees) contain thousands of genes from the original tree, plus one or a few genes that have been changed. Although this can add desirable traits to trees, there are concerns that the modified genes could unintentionally spread into nearby forests by seed, pollen, or other means.	Within species (Cisgenic)
2	*Adding genes from a distantly related organism to American chestnut trees* is being used to help trees resist chestnut blight and restore American chestnut forests. This involves using modern laboratory approaches to add new genes from some distantly related organisms, such as bacteria, to chestnut trees. The genetically modified trees (also known as genetically engineered trees) contain thousands of genes from the original tree, plus one or a few new genes that have been added. Although this can add desirable traits to trees, there are concerns that the added genes could unintentionally spread into nearby forests by seed, pollen, or other means.	Between species (Transgenic)
3	*Adding a gene from wheat* (e.g., *bread wheat) to American chestnut trees* is being used to help trees resist chestnut blight and restore American chestnut forests. This involves using modern laboratory approaches to add a new gene from wheat (e.g., bread wheat) to chestnut trees. This new gene breaks down a chemical produced by the chestnut blight fungus that damages the chestnut trees. The genetically modified trees (also known as genetically engineered trees) contain thousands of genes from the original tree, plus this one new gene from wheat. Although this can add a desirable trait to trees, there are concerns that the added gene could unintentionally spread into nearby forests by seed, pollen, or other means.	Between species (Transgenic)

benefits were measured by asking "to what extent do you think this scenario would benefit each of the following" (same four targets listed above) on 9-point scales from 0 "no benefit" to 8 "highly benefit."

There were additional concepts in the questionnaire that were not measured in direct response to these scenarios. *Trust* was measured by asking "how must trust do you have in each of the following to positively contribute to the management/stewardship of forests:" (a) "local government agencies (city, county, town);" (b) "state governmental agencies;" (c) "US Forest Service" (USFS); and (d) "US Bureau of Land Management" (BLM) on 9-point scales from 0 "no trust" to 8 "high trust." *Perceived risks to forests from tree diseases in general* were measured with two items (CB, other tree diseases such as blister rust and Dutch elm disease) on 9-point scales from 0 "no threat" to 8 "extreme threat." *General value orientations toward the environment* were measured with 13 belief statements from the widely used New Ecological Paradigm scale (e.g., "humans have the right to modify the natural environment to suit their needs," "when humans interfere with nature, it often produces disastrous consequences") on 5-point scales from 1 "strongly disagree" to 5 "strongly agree" (Dunlap, 2008). Consistent with previous research (Vaske and Donnelly, 1999), *specific value orientations toward forests* were measured with 10 belief statements (e.g., "the needs of humans are more important than forests," "forests should be protected for their own sake rather than to simply meet the needs of humans") on the same 5-point scale. *Awareness about CB* was assessed with a single dichotomous (yes/no) question asking if respondents had heard of CB.

The questionnaire included *socio-demographic* items measuring: age (years); sex (male/female); race (White/Caucasian, Black/African American, Hispanic/Spanish/Latino, Asian, American Indian or Alaska Native, Native Hawaiian or Other Pacific Islander, Other); annual income (below $50,000, above $50,000, unsure); political orientation (scale from 1 "very conservative" to 5 "very liberal"); education (less than high school, high school/GED, 2-year associates/trade school, 4-year college/bachelors, advanced degree beyond 4-year degree); forest industry involvement (no/yes); residential proximity to forests (within 1 mile, 1–5 miles, 6–10 miles, 11–20 miles, 21–50 miles, 51–100 miles, more than 100 miles); and residential community type (large city with 250,000 or more people, city with 100,000–249,999 people, small city with 25,000–99,999 people, town with 5000–24,999 people, small town/village with fewer than 5000 people, farm or rural area with few people).

3.3. Analytical approach

Items measuring attitudes, risks, benefits, trust, and value orientations (environment, forests) were combined into indices after testing for reliability using Cronbach's alpha (alphas were ≥ 0.71 and indices would not improve by removing any items; Tables 2, 3). Mean indices were created for both perceived risks and benefits for humans (yourself, other humans or society) and the environment (trees/forests, broader environment), and also risks to forests from tree diseases in general (CB, other tree diseases). Indices were also created for attitudes, trust in federal (USFS, BLM) and non-federal (local, state) agencies, general value orientations toward the environment, and specific value orientations toward forests. Independent-samples *t*-tests and point-biserial correlation (r_{pb}) effect sizes assessed if responses on these indices and other scales (e.g., age, political orientation) differed between the public and FIGs. Chi-square tests and phi (ϕ) effect sizes tested differences between these groups for the other variables. Dummy variables were created for categorical items (race [white, non-white], education [less than college degree vs. degree or more], community type [population less than 25,000 vs. 25,000 or more]).

Given that this study was exploratory, the analytical approach involved bivariate correlations and ordinary least squares multiple regression models to examine relationships between attitudes (dependent variable) and the other concepts. Partial models were run first to examine relationships between attitudes and: (a) scenario-specific cognitions (items measured specific to each scenario such as risks, benefits), (b) general cognitions (not specific to scenarios such as value orientations, trust, awareness), and (c) socio-demographic characteristics (e.g., education, age, political orientation, proximity to forests). Full models were then run to compare the relative strength of significant variables (standardized beta coefficients) while controlling for the others. These analyses were conducted for each group (public, FIGs) and scenario.

4. Results

4.1. Descriptive results

Compared to the US public sample, the FIG sample was significantly ($p < .05$; r_{pb} and $\phi = 0.10$–0.52) more likely to be older, male, white, more educated, involved in forestry, living closer to forests, and earning a higher income (Table 4). The FIGs also had significantly more trust in non-federal (local, state) agencies, had less biocentric (more anthropocentric) environmental and forest value orientations, and were more likely to have heard of CB (r_{pb} and $\phi = 0.10$–0.67).

Attitudes, risks, and benefits in response to all three scenarios (GE to change existing AC genes, GE to insert genes from distantly related organisms, GE to insert a gene from bread wheat [OxO gene]) also differed

Table 2
Scenario-specific scale reliabilities for the public (first value) and FIG samples (second value).

Indices and variables	Mean	Std. dev	Item total correlation	Alpha if item deleted	Cronbach alpha
Scenario 1 - Change existing AC genes					
Attitudes (Dependent Variable [DV])[a]					0.89, 0.96
Disagree: Agree	2.88, 3.72	1.15, 1.21	0.77, 0.85	0.86, 0.96	
Pessimistic/Not Hopeful: Optimistic/Hopeful	3.00, 3.63	1.15, 1.22	0.73, 0.87	0.88, 0.96	
Bad: Good	2.74, 3.85	1.26, 1.18	0.74, 0.94	0.87, 0.93	
Foolish: Wise	2.79, 3.75	1.18, 1.15	0.83, 0.94	0.84, 0.94	
Perceived risks to humans[b]					0.97, 0.97
Risk to yourself	3.03, 1.30	2.34, 1.84	0.94, 0.95	n/a	
Risk to other humans or society in general	3.00, 1.48	2.09, 1.92	0.94, 0.95	n/a	
Perceived environmental risks[b]					0.98, 0.98
Risk to trees/forests	4.26, 2.82	2.17, 2.20	0.97, 0.96	n/a	
Risks to the broader environment	4.32, 2.74	2.23, 2.30	0.97, 0.96	n/a	
Perceived benefits to humans[b]					0.98, 0.87
Benefits to yourself	2.33, 2.92	2.08, 2.41	0.96, 0.76	n/a	
Benefits to other humans or society in general	2.51, 3.71	2.13, 2.29	0.96, 0.76	n/a	
Perceived environmental benefits[b]					0.98, 0.95
Benefits to trees/forests	3.48, 4.83	2.46, 2.29	0.96, 0.90	n/a	
Benefits to the broader environment	3.32, 4.40	2.44, 2.33	0.96, 0.90	n/a	
Scenario 2 – Add genes from distant species to AC					
Attitudes (DV)[a]					0.94, 0.96
Disagree: Agree	2.53, 3.28	1.11, 1.26	0.81, 0.87	0.94, 0.96	
Pessimistic/Not Hopeful: Optimistic/Hopeful	2.63, 3.30	1.14, 1.22	0.81, 0.90	0.94, 0.95	
Bad: Good	2.53, 3.41	1.21, 1.29	0.90, 0.93	0.91, 0.94	
Foolish: Wise	2.60, 3.38	1.10, 1.19	0.93, 0.92	0.90, 0.94	
Perceived risks to humans[b]					0.98, 0.95
Risk to yourself	3.45, 1.64	2.37, 2.05	0.96, 0.90	n/a	
Risk to other humans or society in general	3.56, 1.99	2.35, 2.16	0.96, 0.90	n/a	
Perceived environmental risks[b]					0.98, 0.98
Risk to trees/forests	4.52, 3.50	2.21, 2.33	0.97, 0.97	n/a	
Risks to the broader environment	4.50, 3.41	2.39, 2.34	0.97, 0.97	n/a	
Perceived benefits to humans[b]					0.95, 0.91
Benefits to yourself	2.02, 2.41	1.92, 2.24	0.91, 0.84	n/a	
Benefits to other humans or society in general	2.20, 3.01	2.17, 2.24	0.91, 0.84	n/a	
Perceived environmental benefits[b]					0.99, 0.97
Benefits to trees/forests	3.13, 4.04	2.45, 2.37	0.98, 0.95	n/a	
Benefits to the broader environment	2.96, 3.78	2.50, 2.35	0.98, 0.95	n/a	
Scenario 3 – Add gene from bread wheat (OxO) to AC					
Attitudes (DV)[a]					0.95, 0.96
Disagree: Agree	2.85, 3.37	1.27, 1.31	0.87, 0.89	0.94, 0.96	
Pessimistic/Not Hopeful: Optimistic/Hopeful	2.78, 3.28	1.20, 1.21	0.85, 0.91	0.95, 0.95	
Bad: Good	2.74, 3.32	1.35, 1.30	0.87, 0.91	0.94, 0.95	
Foolish: Wise	2.73, 3.33	1.22, 1.25	0.95, 0.93	0.92, 0.95	
Perceived risks to humans[b]					0.98, 0.94
Risk to yourself	3.10, 1.79	2.36, 2.05	0.96, 0.89	n/a	
Risk to other humans or society in general	3.16, 2.19	2.31, 2.19	0.96, 0.89	n/a	
Perceived environmental risks[b]					0.99, 0.99
Risk to trees/forests	4.16, 3.47	2.17, 2.20	0.97, 0.97	n/a	
Risks to the broader environment	4.11, 3.50	2.24, 2.30	0.97, 0.97	n/a	
Perceived benefits to humans[b]					0.96, 0.89
Benefits to yourself	2.39, 2.40	2.04, 2.30	0.92, 0.80	n/a	
Benefits to other humans or society in general	2.72, 3.05	2.16, 2.38	0.92, 0.80	n/a	
Perceived environmental benefits[b]					0.97, 0.98
Benefits to trees/forests	3.54, 4.17	2.39, 2.41	0.93, 0.95	n/a	
Benefits to the broader environment	3.41, 3.85	2.34, 2.33	0.93, 0.95	n/a	

[a] Cell entries are means on 5-point semantic differential scales.
[b] Cell entries are means on 9-point scales from "no risk/benefit" to "high risk/benefit."

between the public and FIG samples. Compared to the public sample, the FIGs had more positive attitudes and perceived greater benefits (to humans, environment) across all three scenarios. The public sample perceived greater risks to humans and the environment for each scenario. In total, 13 of the 15 tests for these differences between groups were statistically significant at $p < .05$ ($r_{pb} = 0.14$–0.37). Public attitudes did not vary considerably among scenarios ($M = 2.75$–2.99), whereas the FIGs felt most positively about modifying existing AC genes ($M = 3.70$) followed by using GE to insert genes from distantly related organisms ($M = 3.34$) and using GE to insert a gene from bread wheat (OxO; $M = 3.32$).

4.2. Regression results

4.2.1. Scenario 1 (GE to change existing AC genes)

For the public sample, bivariate correlations between the independent variables and attitudes (dependent variable) showed that perceived benefits to both humans and the environment, both specific and general biocentric value orientations, trust in both federal and non-federal agencies, and age were positively related to favorable attitudes toward using GE to change genes in AC trees ($r = 0.20$–0.86, $p < .05$; Table 5). Involvement in the forest industry, higher income, awareness about CB, and risks to both humans and the environment were negatively related to these attitudes ($r = -0.21$ to -0.62, $p < .05$).

The scenario-specific cognitions partial model explained 84% of the variance in these public attitudes and there were significant positive

Table 3
Non scenario-specific (i.e., general) scale reliabilities for the public (first value) and FIG samples (second value).

Indices and variables	Mean	Std. dev	Item total correlation	Alpha if item deleted	Cronbach alpha
Forest value orientations (specific)[a]					0.80, 0.89
The needs of humans are more important than forests[d]	3.53, 3.13	1.29, 1.25	0.53, 0.59	0.78, 0.88	
The primary value of forests is to provide benefits for humans[d]	3.55, 3.22	1.54, 1.32	0.58, 0.71	0.78, 0.87	
Forests exist primarily to be used by humans[d]	4.20, 3.82	1.08, 1.27	0.61, 0.72	0.77, 0.87	
Forests are valuable only if they provide jobs or income for people[d]	4.60, 4.36	0.75, 0.98	0.41, 0.64	0.79, 0.87	
The value of forests exists only in the human mind. Without people, forests have no value[d]	4.60, 4.44	0.92, 1.05	0.33, 0.54	0.80, 0.88	
Humans should manage forests so that only humans benefit[d]	4.68, 4.64	0.84, 0.73	0.28, 0.46	0.80, 0.88	
Forests have as much right to exist as people	4.30, 3.58	1.02, 1.42	0.60, 0.70	0.77, 0.87	
Forests should be protected for their own sake rather than to simply meet the needs of humans	4.29, 3.64	1.08, 1.34	0.71, 0.65	0.76, 0.87	
Forests have value whether humans are present or not	4.79, 4.51	0.66, 0.92	0.24, 0.53	0.80, 0.88	
Forests should have rights similar to the rights of humans	3.33, 2.20	1.39, 1.21	0.51, 0.65	0.79, 0.87	
Environmental value orientations (general)[a]					0.87, 0.90
We are approaching the limit of the number of people the earth can support	3.43, 3.44	1.28, 1.43	0.56, 0.71	0.86, 0.89	
Humans have the right to modify the natural environment to suit their needs[d]	3.20, 2.61	1.34, 1.20	0.44, 0.40	0.87, 0.90	
When humans interfere with nature, it often produces disastrous consequences	3.72, 3.30	1.20, 1.24	0.51, 0.47	0.87, 0.90	
Human ingenuity will ensure that we do not make the earth unlivable[d]	3.04, 3.14	1.20, 1.25	0.41, 0.46	0.87, 0.90	
Humans are severely abusing the environment.	3.94, 3.48	1.24, 1.35	0.63, 0.67	0.86, 0.89	
The earth has plenty of natural resources if we just learn how to develop them[d]	2.47, 2.85	1.25, 1.35	0.40, 0.50	0.87, 0.90	
Plants and animals have as much right as humans to exist	3.98, 3.61	1.24, 1.27	0.55, 0.64	0.87, 0.89	
The balance of nature is strong enough to cope with the impacts of modern industrial nations[d]	3.64, 3.87	1.14, 1.15	0.57, 0.76	0.86, 0.88	
The so-called ecological crisis facing humankind has been greatly exaggerated[d]	3.35, 3.31	1.36, 1.49	0.72, 0.78	0.86, 0.88	
The earth is a closed system with very limited room and resources	3.43, 3.62	1.26, 1.31	0.55, 0.61	0.87, 0.89	
Humans were meant to rule over the rest of nature[d]	3.52, 3.71	1.39, 1.43	0.60, 0.57	0.86, 0.89	
The balance of nature is very delicate and easily upset	3.88, 3.14	1.08, 1.21	0.54, 0.50	0.87, 0.90	
If things continue on their present course, we will soon experience a major ecological catastrophe.	3.65, 3.18	1.26, 1.40	0.70, 0.75	0.86, 0.88	
Trust in federal government agencies[b]					0.85, 0.87
US Forest Service	5.41, 5.44	1.91, 2.01	0.74, 0.76	n/a	
US Bureau of Land Management	4.92, 4.56	2.00, 2.05	0.74, 0.76	n/a	
Trust in non-federal government agencies[b]					0.84, 0.79
Local governmental agencies (city, county, town)	3.35, 3.61	1.96, 1.93	0.73, 0.65	n/a	
State governmental agencies	3.13, 4.79	2.15, 1.84	0.73, 0.65	n/a	
Perceived risks to forests from tree diseases[c]					0.94, 0.71
Chestnut blight (a tree disease)	5.63, 4.90	2.05, 2.46	0.89, 0.58	n/a	
Other tree diseases (e.g., blister rust, Dutch elm)	5.65, 5.73	2.11, 1.76	0.89, 0.58	n/a	

[a] Cell entries are means on 5-point scale from “strongly disagree” to “strongly agree.”
[b] Cell entries are means on 9-point scale from “no trust” to “high trust.”
[c] Cell entries are means on 9-point scale from “no threat” to “extreme threat.”
[d] Item reverse coded for computed index.

relationships between favorable attitudes and benefits to both humans and the environment (standardized beta $\beta = 0.14$ and 0.64, $p < .05$). A negative relationship was observed between these attitudes and environmental risks ($\beta = -0.35$, $p < .001$). The general cognitions partial model explained 23% of the variance in attitudes with significant relationships between positive attitudes and both biocentric value orientations toward forests and trust in federal agencies ($\beta = 0.25$ and 0.30, $p < .05$). The socio-demographics partial model explained 25% of the variance in attitudes and showed a positive relationship between age and favorable attitudes ($\beta = 0.25$, $p < .05$), and negative associations between these attitudes and income, residential proximity to forests, and forestry involvement ($\beta = -0.23$ to -0.25, $p < .05$). The full model explained 85% of the variance in these attitudes. When controlling for variables, age and perceived human and environmental benefits were positively associated with favorable attitudes ($\beta = 0.10$–0.64, $p < .05$). Risks to the environment were negatively associated with these attitudes ($\beta = -0.23$, $p < .001$). Environmental benefits were most strongly related to favorable public attitudes toward using GE for modifying existing genes in AC trees ($\beta = 0.64$, $p < .001$).

For the FIGs, bivariate correlations showed perceived benefits to humans and the environment were positively related to favorable attitudes toward this use of GE ($r = 0.56$ and 0.77, $p < .001$). Being non-white and perceiving risks to both humans and the environment were negatively associated with these attitudes ($r = -0.23$ to -0.65, $p < .05$). The scenario-specific cognitions partial model accounted for 64% of the variance in attitudes with perceived benefits to the environment positively associated with favorable attitudes ($\beta = 0.68$, $p < .001$). Neither the general cognitions nor socio-demographics partial models yielded any statistically significant variables related to attitudes. The full model, which explained 59% of the variance in attitudes, showed that the perceived environmental benefits index was the only significant driver for this scenario when controlling for the other variables in the model, and these benefits were positively related to favorable attitudes among FIGs toward this use of GE ($\beta = 0.77$, $p < .001$).

4.2.2. Scenario 2 (GE to add genes from distantly related organisms)

For the public sample, bivariate correlations between the dependent (attitudes toward this scenario) and independent variables showed that favorable attitudes were positively related to perceived benefits for both humans and the environment, biocentric value orientations toward forests, trust in federal and non-federal agencies, and being female ($r = 0.22$–0.82, $p < .05$; Table 6). Favorable public attitudes toward this use of GE were negatively associated with environmental and human risks, awareness about CB, and living in close proximity to forests ($r = -0.19$

Table 4
Means and group differences for cognitive and socio-demographic items for three GE scenarios for restoring AC trees.

	Public	FIGs	t or χ^2 value	p-value	Effect size (r_{pb} or ϕ)
Scenario-specific Cognitions					
Scenario 1 - Change existing AC genes					
Attitudes[1]	2.99	3.70	4.29	< 0.001	0.29
Perceived risks to humans[2]	3.02	1.37	5.52	< 0.001	0.37
Perceived environmental risks[2]	4.25	2.78	4.58	< 0.001	0.31
Perceived benefits to humans[2]	2.42	3.31	2.87	0.005	0.20
Perceived environmental benefits[2]	3.37	4.62	3.61	< 0.001	0.25
Scenario 2 – Add genes from distant species to AC					
Attitudes[1]	2.75	3.34	3.45	0.001	0.24
Perceived risks to humans[2]	3.51	1.81	5.19	< 0.001	0.35
Perceived environmental risks[2]	4.51	3.46	3.14	0.002	0.22
Perceived benefits to humans[2]	2.11	2.71	1.99	0.048	0.14
Perceived environmental benefits[2]	3.05	3.91	2.45	0.015	0.17
Scenario 3 – Add gene from bread wheat (OxO) to AC					
Attitudes[1]	2.93	3.32	2.18	0.032	0.15
Perceived risks to humans[2]	3.13	1.99	3.49	0.001	0.25
Perceived environmental risks[2]	4.14	3.49	2.01	0.046	0.14
Perceived benefits to humans[2]	2.56	2.72	0.53	0.598	0.04
Perceived environmental benefits[2]	3.47	4.01	1.56	0.121	0.11
General Cognitions					
General environmental value orientations[3]	3.49	3.32	2.06	0.040	0.10
Specific forest value orientations[3]	4.16	3.77	5.26	< 0.001	0.25
Trust in non-federal government agencies[4]	3.29	4.20	3.57	< 0.001	0.24
Trust in federal government agencies[4]	5.18	5.00	0.72	0.471	0.05
Perceived risks to forests from tree diseases[5]	5.63	5.25	1.94	0.053	0.09
Heard of chestnut blight (awareness) [8]	30	96	225.79	< 0.001	0.67
Socio-demographic Characteristics					
Age (average number of years)	49	52	2.35	<0.001	0.11
Non-white[8]	11	6	3.90	0.048	0.10
Female[8]	53	19	50.01	< 0.001	0.34
Income greater than $50,000[8]	58	92	66.65	< 0.001	0.39
College education or more[8]	43	94	131.14	< 0.001	0.52
Live in town with population > 25,000 people[8]	46	45	0.06	0.808	0.01
Political orientation[6]	2.80	2.86	0.58	0.561	0.03
Proximity to a forest[7]	2.09	1.40	5.81	< 0.001	0.25
Involved with forestry[8]	15	58	83.71	< 0.001	0.45

[1] Cell entries are means on 5-point semantic differential scales.
[2] Cell entries are means on 9-point scales from "no risk/benefit" to "high risk/benefit."
[3] Cell entries are means on 5-point scale from "strongly disagree" to "strongly agree."
[4] Cell entries are means on 9-point scale from "no trust" to "high trust."
[5] Cell entries are means on 9-point scale from "no threat" to "extreme threat."
[6] Cell entries are means on 5-point scale from "very conservative" to "very liberal."
[7] Cell entries are means on 7-point scale from "within 1 mile" to "more than 100 miles."
[8] Proportion (%) of respondents in category.

to −0.64, $p < .05$).

The scenario-specific cognitions partial model explained 79% of the variance in these public attitudes, which were positively related to perceived benefits to both humans and the environment (β = 0.15 and 0.53, $p < .05$), and negatively related to perceived environmental risks (β = −0.27, $p < .001$). The general cognitions partial model explained 26% of the variance in attitudes toward this use of GE with positive associations between favorable attitudes and both biocentric value orientations toward forests and trust in the federal government (β = 0.26 and 0.30, $p < .05$). The socio-demographics partial model explained 24% of the variance in these attitudes with positive relationships between favorable attitudes and both age and being female (β = 0.22 and 0.27, $p < .05$), and a negative association between these attitudes and living closer to forests (β = −0.39, $p < .01$). The full model accounted for 82% of the variance in public attitudes toward this use of GE with residential proximity to forests and environmental risks negatively related to favorable attitudes (β = −0.18 and − 0.42, $p < .01$), whereas environmental benefits were positively associated (β = 0.48, $p < .001$) and again, most strongly related to these attitudes.

For the FIGs, bivariate correlations showed positive associations between favorable attitudes toward this use of GE and perceived benefits to both humans and the environment (r = 0.60 and 0.81, $p < .001$), and negative relationships between these attitudes and both human and environmental risks (r = −0.50 and − 0.69, $p < .001$). No other variables were correlated with these attitudes for FIGs. The scenario-specific cognitions partial model explained 70% of the variance in these attitudes with perceived environmental benefits positively associated with favorable attitudes (β = 0.65, $p < .001$) and environmental risks negatively related (β = −0.32, $p < .01$). The general cognitions partial model explained 13% of the variance in these attitudes with only awareness about CB positively related to favorable attitudes (β = 0.26, $p < .05$). No variables from the socio-demographics partial model were statistically related to these attitudes. The full model explained 71% of the variance in attitudes toward this use of GE and showed that environmental benefits (β = 0.61, $p < .001$) and risks (β = −0.29, $p < .01$) were the only concepts related to these attitudes after controlling for the other variables, with environmental benefits most strongly associated.

4.2.3. Scenario 3 (GE to add a gene from bread wheat [OxO gene])

For the public sample, there were positive correlations between favorable attitudes toward using GE to add a gene from bread wheat and perceived benefits for both humans and the environment, biocentric value orientations toward forests, trust in federal and non-federal agencies, and being female (r = 0.26–0.86, $p < .01$; Table 7). These attitudes were negatively associated with risks to humans and the environment, awareness about CB, and forestry involvement (r = −0.33 to −0.58, $p < .001$).

The scenario-specific cognitions partial model explained 79% of the

Table 5
Partial and full model regressions predicting attitudes toward using GE to change existing genes in AC trees to mitigate CB (Scenario 1).

	Public			FIGs		
	Partial models[f]		Full model[g] (R^2 = 0.85)	Partial models[f]		Full model[g] (R^2 = 0.59)
	Zero-order correlations (r)	β	β	Zero-order correlations (r)	β	β
Scenario-specific Cognitions[a]		$R^2 = 0.84$			$R^2 = 0.64$	
Perceived risks to humans	−0.43***	0.10		−0.51***	−0.06	
Perceived environmental risks	−0.62***	−0.35***	−0.23***	−0.65***	−0.22	
Perceived benefits to humans	0.72***	0.14*	0.16*	0.56***	−0.09	
Perceived environmental benefits	0.86***	0.64***	0.64***	0.77***	0.68***	0.77***
General Cognitions		$R^2 = 0.23$			$R^2 = 0.09$	
General environmental value orientations[b]	0.21*	0.09		−0.21	−0.19	
Specific forest value orientations[b]	0.33***	0.25*	−0.05	−0.17	−0.01	
Trust in non-federal agencies[c]	0.20*	0.05		0.10	0.16	
Trust in federal agencies[c]	0.34***	0.30**	0.01	−0.04	−0.09	
Perceived risks to forests from tree diseases[d]	−0.05	−0.18		−0.12	−0.07	
Heard of chestnut blight (awareness)	−0.21*	−0.06		0.14	0.16	
Socio-Demographic Characteristics		$R^2 = 0.25$			$R^2 = 0.14$	
Age	0.26**	0.25*	0.10*	0.06	0.03	
Non-white	−0.02	0.01		−0.23*	−0.20	
Female	0.08	0.07		−0.07	−0.04	
Income greater than $50,000	−0.24*	−0.23*	−0.06	0.20	0.23	
College education or more	−0.08	−0.09		−0.04	−0.04	
Live in town with population > 25,000	0.11	0.19		−0.04	−0.11	
Political orientation	0.07	−0.08		0.02	0.03	
Proximity to a forest[e]	−0.10	−0.25*	0.07	0.01	−0.03	
Involved with forestry	−0.25**	−0.24*	−0.04	−0.14	−0.21	

[a] Cell entries are means on 9-point scales from "no risk/benefit" to "high risk/benefit."
[b] Cell entries are means on 5-point scale from "strongly disagree" to "strongly agree."
[c] Cell entries are means on 9-point scale from "no trust" to "high trust."
[d] Cell entries are means on 9-point scale from "no threat" to "extreme threat."
[e] Cell entries are means on 7-point scale from "within 1 mile" to "more than 100 miles."
[f] Independent variables were tested for multicollinearity, which was generally not present, as all but four correlations among the independent variables were $r < 0.70$ (Vaske, 2019). In addition, variance inflation factors (VIF) were all below 5.0 for the public sample, and all but one of the VIFs for the FIGs were also below 5.0 (environmental benefits VIF = 5.27), also suggesting minimal multicollinearity.
[g] All significant independent variables in the full models were tested for interaction effects. Public interaction effects significantly related to attitudes included environmental risks * human benefits (β = 0.49, $p < .001$) and environmental risks * environmental benefits (β = −0.35, $p = .01$). There were no interaction effects for the FIG sample.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

variance in public attitudes toward this use of GE with a positive association between favorable attitudes and perceived environmental benefits (β = 0.67, $p < .001$), and a negative association with perceived environmental risks (β = −0.27, $p < .001$). The general cognitions partial model accounted for 26% of the variance in these attitudes with favorable attitudes positively related to biocentric value orientations toward forests and trust in federal agencies (β = 0.25, $p < .05$), but negatively associated with awareness about CB (β = −0.24, $p < .05$). The socio-demographics partial model explained 24% of the variance in these attitudes with negative relationships between favorable attitudes and both forestry involvement and proximity to forests (β = −0.29 and − 0.31, $p < .05$). The full model explained 83% of the variance in these attitudes with positive relationships between favorable attitudes and perceived environmental benefits (β = 0.67, $p < .001$) and trust in federal agencies (β = 0.14, $p < .01$), and negative relationships between these attitudes and environmental risks, biocentric value orientations toward forests, and proximity to forests (β = −0.10 to −0.28, $p < .05$). Again, perceived environmental benefits were most strongly related to attitudes.

For the FIGs, bivariate correlations showed positive relationships between favorable attitudes toward this use of GE and income and perceived benefits to both humans and the environment (r = 0.24–0.70, $p < .05$). Human and environmental risks were negatively associated with these attitudes (r = −0.46 and − 0.69, $p < .001$). The scenario-specific cognitions partial model explained 64% of the variance in these attitudes with perceived environmental risks (β = −0.54, $p < .001$) and benefits (β = 0.46, $p < .001$) significantly related to these attitudes. The general cognitions partial model did not have any variables that were statistically related to attitudes toward this scenario. The socio-demographics partial model explained 16% of the variance in these attitudes with only income being positively related (β = 0.28, $p < .05$). The full model explained 63% of the variance in these attitudes, which were positively associated with environmental benefits and negatively related to environmental risks. Unlike the other models, however, environmental risks (β = −0.47, $p < .001$) were slightly more strongly related to attitudes compared to environmental benefits (β = 0.40, $p < .001$).

5. Discussion

5.1. The role of different groups

Compared to the public sample, the FIG sample had more favorable attitudes toward using GE for mitigating CB and restoring AC trees. The FIGs also perceived greater benefits and lower risks of these uses of GE to both humans and the environment. The FIGs were also more aware of CB. These findings are generally consistent with some existing research showing that certain interest groups or experts are more aware of GE and generally view it more favorably compared to the public (Jepson and

Table 6
Partial and full model regressions predicting attitudes toward using GE to add genes from a distantly related organism to AC trees to mitigate CB (Scenario 2).

	Public			FIGs		
	Partial models[f]		Full model[g] (R^2 = 0.82)	Partial models[f]		Full model[g] (R^2 = 0.71)
	Zero-order correlations (r)	β	β	Zero-order correlations (r)	β	β
Scenario-specific Cognitions[a]		$R^2 = 0.79$			$R^2 = 0.70$	
Perceived risks to humans	−0.58***	−0.13		−0.50***	0.05	
Perceived environmental risks	−0.64***	−0.27***	−0.42***	−0.69***	−0.32**	−0.29**
Perceived benefits to humans	0.69***	0.15*	0.10	0.60***	−0.02	
Perceived environmental benefits	0.82***	0.53***	0.48***	0.81***	0.65***	0.61***
General Cognitions		$R^2 = 0.26$			$R^2 = 0.13$	
General environmental value orientations[b]	0.11	−0.05		−0.23	−0.27	
Specific forest value orientations[b]	0.29**	0.26*	−0.03	−0.20	−0.01	
Trust in non-federal agencies[c]	0.30**	0.10		−0.01	−0.11	
Trust in federal agencies[c]	0.43***	0.30**	0.08	0.01	0.14	
Perceived risks to forests from tree diseases[d]	0.04	−0.04		−0.14	−0.08	
Heard of chestnut blight (awareness)	−0.26**	−0.17		0.22	0.26*	0.06
Socio-Demographic Characteristics		$R^2 = 0.24$			$R^2 = 0.15$	
Age	0.18	0.22*	0.05	0.13	0.09	
Non-white	−0.06	0.07		−0.22	−0.21	
Female	0.22*	0.27*	0.07	−0.17	−0.10	
Income greater than $50,000	−0.19	−0.19		0.20	0.23	
College education or more	−0.06	−0.06		0.09	0.10	
Live in town with population > 25,000	0.08	0.17		−0.01	−0.06	
Political orientation	0.05	0.01		0.02	−0.01	
Proximity to a forest[e]	−0.19*	−0.39**	−0.18**	0.02	−0.01	
Involved with forestry	−0.16	−0.07		−0.12	−0.14	

[a] Cell entries are means on 9-point scales from "no risk/benefit" to "high risk/benefit."
[b] Cell entries are means on 5-point scale from "strongly disagree" to "strongly agree."
[c] Cell entries are means on 9-point scale from "no trust" to "high trust."
[d] Cell entries are means on 9-point scale from "no threat" to "extreme threat."
[e] Cell entries are means on 7-point scale from "within 1 mile" to "more than 100 miles."
[f] Independent variables were tested for multicollinearity, which was generally not present, as all but five correlations among the independent variables were $r < 0.70$ (Vaske, 2019). In addition, the VIFs were all below 5.0 for the FIG sample, and all but two of the VIFs for the public sample were also below 5.0 (environmental benefits VIF = 6.61, human benefits VIF = 5.62), also suggesting minimal multicollinearity.
[g] All significant independent variables in the full models were tested for interaction effects. There were no significant interaction effects for the public sample. There was a significant interaction between environmental risk * environmental benefits for the FIG sample (β = 0.28, p = .003).
* $p < .05$.
** $p < .01$.
*** $p < .001$.

Arakelyan, 2017b; Savadori et al., 2004).

There were also differences between these groups in the number of variables that were significantly related to attitudes toward the GE scenarios. The final full models for the public sample contained three to five significant independent variables (e.g., risks, benefits, age, trust, proximity to forests, value orientations), whereas the FIG models had only one or two significant variables (risks, benefits). This difference suggests that public attitudes toward these uses of GE were related to more underlying cognitive (specific and general) and contextual (demographics) factors compared to FIGs who based their evaluations mainly on specific risks and benefits. This finding is consistent with research showing differences in how groups (e.g., public, experts) form risk judgments that shape related cognitions (Slovic, 2010; Wilson and Arvai, 2006).

The full models for the public sample also explained more variance in attitudes toward these GE uses (82–85%) compared to models for the FIGs (59–71%), suggesting the variables included were better for predicting public attitudes in this context. The additional unexplained variance (i.e., error) in predicting FIG attitudes toward these GE uses suggests that other factors not measured here are also related to their attitudes. Research is needed to understand other characteristics and cognitions that could serve as predictors for both the public and FIGs.

The public sample was randomly selected from addresses of American residents and the data were weighted by census information to improve representativeness to the population. The sample of FIGs was a broad cross-section of individuals and organizations with various interests and positions related to forestry (e.g., timber companies; genetics companies; scientists; local, state, and federal agency employees; environmental advocacy or anti-GE groups; woodland and forest owner associations; foundations; forestry and growers councils). Despite these efforts to achieve representative and diverse samples using established survey research methods, the sample sizes and response rates were relatively low, even after six contacts (Vaske, 2019). The samples were also not necessarily representative of smaller, targeted, and more homogeneous subgroups with specific interests (e.g., environmental advocacy or anti-GE groups). Although response rates have declined in survey research on natural resource issues (Stedman et al., 2019), studies with larger or different samples are needed to address these issues.

5.2. The role of scenario-specific cognitions

The FIGs viewed transgenic applications more negatively than they viewed within-species GE. This finding is supported by existing research showing that GE between sexually incompatible species (transgenesis) can be seen as manipulating nature and, therefore, is viewed more negatively than cisgenic approaches (Mielby et al., 2013). The public sample did not make this distinction, as they viewed all three GE scenarios somewhat equivalently. Although both the public and FIGs responded to modifying genes in the AC (scenario 1) most favorably,

Table 7
Partial and full model regressions predicting attitudes toward using GE to add a gene from bread wheat (OxO) to AC trees to mitigate CB (Scenario 3).

	Public			FIGs		
	Partial models[f]		Full model[g] ($R^2 = 0.83$)	Partial models[f]		Full model[g] ($R^2 = 0.63$)
	Zero-order correlations (r)	β	β	Zero-order correlations (r)	β	β
Scenario-specific Cognitions[a]		$R^2 = 0.79$			$R^2 = 0.64$	
Perceived risks to humans	−0.47***	0.06		−0.46***	0.13	
Perceived environmental risks	−0.58***	−0.27***	−0.28***	−0.69***	−0.54***	−0.47***
Perceived benefits to humans	0.73***	0.14		0.58***	0.01	
Perceived environmental benefits	0.86***	0.67***	0.67***	0.70***	0.46***	0.40***
General Cognitions		$R^2 = 0.26$			$R^2 = 0.08$	
General environmental value orientations[b]	0.12	−0.04		−0.19	−0.21	
Specific forest value orientations[b]	0.28**	0.25*	−0.10*	−0.18	−0.06	
Trust in non-federal agencies[c]	0.27**	0.09		0.07	−0.08	
Trust in federal agencies[c]	0.38***	0.25*	0.14**	0.11	0.22	
Perceived risks to forests from tree diseases[d]	−0.03	−0.07		−0.08	−0.02	
Heard of chestnut blight (awareness)	−0.33***	−0.24*	−0.09	0.09	0.10	
Socio-Demographic Characteristics		$R^2 = 0.24$			$R^2 = 0.16$	
Age	0.15	0.13		0.06	0.01	
Non-white	−0.09	0.01		−0.22	−0.21	
Female	0.26**	0.21		−0.15	−0.08	
Income greater than $50,000	−0.10	−0.12		0.24*	0.28*	0.05
College education or more	0.01	−0.05		0.09	0.09	
Live in town with population > 25,000	0.08	0.09		0.10	0.04	
Political orientation	0.13	−0.01		0.07	0.02	
Proximity to a forest[e]	−0.14	−0.31**	−0.13**	0.05	−0.05	
Involved with forestry	−0.34***	−0.29*	−0.07	−0.14	−0.13	

[a] Cell entries are means on 9-point scales from "no risk/benefit" to "high risk/benefit."
[b] Cell entries are means on 5-point scale from "strongly disagree" to "strongly agree."
[c] Cell entries are means on 9-point scale from "no trust" to "high trust."
[d] Cell entries are means on 9-point scale from "no threat" to "extreme threat."
[e] Cell entries are means on 7-point scale from "within 1 mile" to "more than 100 miles."
[f] Independent variables were tested for multicollinearity, which was generally not present, as all but five correlations among the independent variables were $r < 0.70$ (Vaske, 2019). In addition, the VIFs were all below 5.0 for the public sample, and all but one of the VIFs for the FIG sample were also below 5.0 (environmental risks VIF = 5.15), also suggesting minimal multicollinearity.
[g] All significant independent variables in the full models were tested for interaction effects. Public interaction effects significantly related to attitudes included environmental risks * forest proximity (β = 0.53, $p < .001$) and environmental benefits * forest proximity (β = 0.39, $p = .046$). For FIGs, a significant interaction effect was found for environmental benefits * environmental risks (β = 0.25, $p = .048$).
* $p < .05$.
** $p < .01$.
*** $p < .001$.

they viewed the transgenic scenarios (scenarios 2, 3) somewhat differently, as the public sample viewed adding genes from distantly related organisms (scenario 2) more negatively (less positive attitudes, higher risks, lower benefits) than inserting a gene from bread wheat (scenario 3). Conversely, the FIGs viewed inserting a gene from bread wheat as least acceptable. Other researchers have also found that some biotechnologies are viewed more positively than others. Jepson and Arakelyan (2017a), for example, examined UK resident perceptions toward using GE for addressing ash dieback and also found that cisgenic approaches were more preferable than transgenic methods. Although speculative, a distantly related organism, as worded in scenario 2, is somewhat general and may have primed consideration of other transgenic applications. In addition, perhaps the public sample viewed GE involving bread wheat (scenario 3) slightly more favorably because this is familiar, with both species (chestnuts, wheat) being consumed. Some researchers, however, have found that familiarity with GE can elicit either negative or positive reactions depending on the context (Kronberger et al., 2014). As a result, research is needed to examine if this phenomenon applies to attitudes toward other uses of GE in forestry.

Among the three scenarios, the public sample viewed inserting a gene from bread wheat (scenario 3) as most beneficial for both humans and the environment. This finding is somewhat surprising because GE applications that modify genes within species or transfer genes between closely related species (cisgenesis) have usually been viewed more positively than transgenic approaches (Jepson and Arakelyan, 2017a; Mielby et al., 2013). One potential explanation for this discrepancy could be that, compared to other GE foods that are consumed more frequently and may elicit more negative responses, the public might be less discerning among these recent GE applications in the context of forest conservation. It is also possible that some public respondents may have confused or not understood all of the differences among the three GE scenarios in the questionnaires (change existing AC genes, add genes from a distantly related organism, add a gene from bread wheat [a species of grass]). These possibilities deserve more research attention.

Compared to the general cognitions and socio-demographics partial models, the scenario-specific cognitions accounted for the most variance in attitudes toward all three GE scenarios for both the public (R^2 = 0.79–0.84) and FIG (R^2 = 0.64–0.70) samples. Consistent with previous research (Frewer et al., 2013), perceived benefits and risks were among the most strongly related to attitudes for both groups in the partial and full models across scenarios. Perceived environmental benefits were the strongest predictor of attitudes across all three scenarios for the public sample and two of the three scenarios for the FIGs (environmental risk was a slightly stronger predictor for scenario 3 among FIGs). Although much of the GE literature has focused on risks to humans, benefits appear to be more strongly related to attitudes in this context of forest conservation. Research in Europe also found that GE was viewed more favorably when used for providing specific or tangible benefits such as improving forest health (Jepson and Arakelyan, 2017b).

Results here showed that perceived risks to humans were not significant drivers of attitudes across any scenario. This finding differs from most GE studies (e.g., other foods) that highlight human risk perceptions as principal drivers of attitudes toward GE (Frewer et al., 2013). However, this finding is logical, as human health concerns could be less likely to supersede environmental issues in the context of forestry. Although chestnuts are consumed by some people, more common uses of GE in agriculture (e.g., corn, potato, soy) can be perceived negatively due to possible human health concerns from frequently consuming these GE foods (Scott et al., 2016). Concerns over potential impacts from employing GE in forest conservation (e.g., gene escape, loss of biodiversity) could likely be seen as primarily impacting trees and forests more than risks from consuming some related GE products. Studies in Canada and Europe found that reduced genetic diversity and unintended gene flow into wild or native forests were environmental concerns from using GE in trees (Nilausen et al., 2016; Nonić et al., 2015; Tsourgiannis et al., 2016). Research on perceptions of GE in plantation forestry has also shown that biodiversity loss is a public concern (Kazana et al., 2015). These studies support results here showing that environmental benefits and risks were most strongly related to attitudes toward these GE uses.

The findings also support the principle of specificity and rule of correspondence, which both propose that social psychological concepts (e.g., attitudes, intentions, perceptions) measured at the same level of specificity (e.g., action, target, context, time) are more strongly related than those measured at different levels (Fishbein and Manfredo, 1992; Whittaker et al., 2006). Perceptions of environmental risks and benefits were likely most strongly related to attitudes (highest standardized betas and most variance explained) partly because these concepts were measured directly in relation to each of the three scenarios (scenario-specific cognitions). The general cognitions and socio-demographic variables were measured independently from these scenarios in the questionnaires, and these items explained less of the variance in attitudes.

5.3. The role of general cognitions

In comparison to the scenario-specific cognitions ($R^2 = 0.64$–0.84), the general cognitions ($R^2 = 0.08$–0.26) were less related to attitudes toward using GE to restore AC trees. In the partial models, general cognitions for the public sample contained several significant variables that explained two to three times the variance in attitudes toward these uses of GE ($R^2 = 0.23$–0.26) compared to models for the FIGs ($R^2 = 0.08$–0.13), which yielded few significant predictors. In particular, trust in non-federal agencies was not related to attitudes for either sample for any scenario, but trust in federal agencies (e.g., USFS, BLM) was associated with these attitudes in the partial models for the public sample. This might suggest that public respondents viewed federal agencies as responsible for managing these uses of GE more so than state and local agencies. It is also possible that agency trust may be less critical in understanding attitudes toward GE in forest conservation compared to other contexts such as acceptance of more common GE foods (e.g., corn, potato) where trust is often more strongly and positively related (Lang and Hallman, 2005; Siegrist, 2000).

The negative relationship in the bivariate analyses between public awareness about CB and attitudes toward these uses of GE was interesting. This might relate to the extent that the CB fungus is perceived as natural (tree diseases are inherent components of forests) and those who are more aware of CB might see it as natural and oppose any mitigation efforts. Another possibility is respondents who were aware of CB may not view GE as a viable or appropriate tool in these efforts. Awareness about CB, however, was not significant in any of the full models, likely due to the inclusion of higher order and more specific constructs (perceived risks, benefits) that accounted for the bulk of explained variance. Research has shown that awareness can sometimes lead to either negative or positive responses depending on contextual factors (Kronberger et al., 2014), so studies should clarify the context and role of awareness.

Biocentric value orientations toward forests were significantly and positively associated with favorable public attitudes in both the bivariate analyses and partial models. These results differ from some studies showing that people with anthropocentric orientations were more supportive of GE (Peterson St-Laurent et al., 2018, 2019) and those with biocentric orientations were less supportive (Hajjar and Kozak, 2015), but these studies examined using GE in forest adaptation to climate change. Other studies have shown that biocentric orientations can be associated with support for forest conservation efforts (Vaske and Donnelly, 1999). However, neither general environmental value orientations nor specific value orientations toward forests were strongly related to attitudes in the full models. These findings might be explained by the theoretical position of these constructs with regard to specificity. In most of the full models, value orientations were likely insignificant because the inclusion of higher order constructs (perceived risks, benefits) that were measured specific to each scenario and explained larger proportions of the variance in attitudes. This reasoning is supported by well-established social psychological theories, such as the cognitive hierarchy, which suggest that cognitions measured at similar levels of conceptual specificity and in proximal hierarchical order provide stronger measures of relationships among variables (Fishbein and Manfredo, 1992; Whittaker et al., 2006).

The application of these general and specific cognitions (e.g., value orientations, risks, attitudes) in this article followed established theoretical, conceptual, and analytical approaches that have been tested widely in social psychology, psychometrics, and natural resources (Dunlap, 2008; Fishbein and Ajzen, 2010; Fishbein and Manfredo, 1992; Slovic, 2010; Vaske, 2019; Whittaker et al., 2006). Some scholars, however, have suggested that humans do not always possess cognitions or behave in ways that are rational, consistent, predictable, or directly measurable (Ariely, 2008; Sloman and Fernbach, 2017). Instead, humans can be irrational and their behaviors and cognitions can be constructed, malleable over time, and dependent on experiences, issue framing, information availability, emotions, stereotypes, shared values, and other heuristics and contextual factors (Findlater et al., 2020; Kahneman and Tversky, 2013; Lichtenstein and Slovic, 2006). This study, for example, measured trust at one point in time using the unidimensional psychometric approach by directly asking respondents how much they trusted specific agencies (Needham and Vaske, 2008; Perry et al., 2017; Siegrist et al., 2000). Some researchers, however, have suggested that there are multiple types of trust (e.g., interpersonal, dispositional, procedural, social or shared values) and trust is contextual and consists of multiple dimensions (e.g., fairness, responsibility, integrity, competence, credibility, consistency, inclusiveness, caring, transparency; see Stern and Coleman, 2015 for a review). Research is needed to apply these different approaches, explore possible changes in cognitions over time, and examine other factors (e.g., framing, emotions, agendas, stereotypes) in the context of using GE to address CB and other forest health issues to build on this study and continue advancing this field of inquiry.

5.4. The role of socio-demographic characteristics

In the partial models, socio-demographic characteristics accounted for almost twice the variance in the public sample's attitudes toward these uses of GE ($R^2 = 0.24$–0.25) compared to those for the FIGs ($R^2 = 0.14$–0.16). Age was a significant predictor in the public full and partial models for changing AC genes (scenario 1), and the partial model for inserting a gene from a distantly related organism (scenario 2). Older individuals had more favorable attitudes. Hajjar and Kozak (2015) also found that older respondents were most accepting of using GE trees for climate-adapted forests. However, these findings are generally inconsistent with the GE literature in this and other contexts where younger people have more favorable attitudes. Jepson and Arakelyan (2017a), for example, found that younger UK residents viewed using GE for addressing ash dieback more favorably. Although speculative, findings here might relate to issue salience where older respondents may recall more healthy AC trees in the wild, so are more interested in restoration. Younger respondents may not prioritize restoring AC trees due to limited awareness or salience. Research needs to refute or confirm this possibility.

Involvement in forestry was negatively related to the public sample's attitudes for the first and third scenarios (those in forestry had less favorable attitudes), suggesting that people in forestry oppose these new or unknown technologies, perhaps due to concerns over potential economic impacts. This relationship, however, was not significant in the full models and forestry involvement was not associated with attitudes for the FIG sample for any scenario. Residential proximity to forests was also negatively associated with the public sample's attitudes (those closer to forests had less favorable attitudes). This finding might relate to the NIMBY ("not in my back yard") phenomenon where individuals, who may be advocates of conservation efforts elsewhere, oppose such efforts locally due to potential concerns such as aesthetics and property rights (Devine-Wright, 2005). This issue deserves research attention, especially now that transgenic AC trees are being sought for regulatory approval and commercial release (Chang et al., 2018).

5.5. Management implications

These findings have implications for those aiming to inform or change attitudes toward these uses of GE. To modify attitudes, practitioners could communicate with stakeholders before firm opinions are formed and tailor communications to specific target audiences based on issue familiarity and subject matter complexity. Given the low awareness about CB among the public sample (30%), messaging could focus on increasing awareness about forest health threats (e.g., CB). In addition, the results underscore the importance of focusing messaging on environmental benefits of using GE for mitigating this forest health threat (e.g., restore historic tree species, mitigate tree diseases and pests) given they were usually the strongest predictor of attitudes.

Certain GE uses (e.g., transgenic) can be perceived as riskier partially because they may be unknown, complex, or seen as changing nature (Mielby et al., 2013). Jepson and Arakelyan (2017a), for example, found that cisgenic methods were preferred by the public over transgenic approaches for addressing ash dieback. Similar results were found here where technologies perceived to be more natural or tampering less with nature, such as modifying existing AC genes (cisgenics, within-species), were viewed with less concern compared to other GE applications (transgenics, between-species). Thus, information and education campaigns aimed at enhancing favorability could consider using wording and other messaging approaches emphasizing techniques that are perceived as more natural or benefitting the environment in general.

6. Conclusion

To achieve conservation objectives, it is important to understand what drives attitudes toward issues such as using modern technologies (e.g., GE) to restore species and habitats. GE has been used for mitigating CB and restoring AC trees in laboratory and field trials, and researchers are now pursuing regulatory approval for commercial availability of transgenic AC trees, including approval from food agencies given that some people consume chestnuts (Powell, 2016; Steiner et al., 2017). If approval occurs, this issue could become contentious and, therefore, the results presented here will be salient.

In addition to these genetic approaches, there are other methods, such as breeding, for potentially addressing CB and restoring AC trees (see NASEM, 2019 for a review). Research has shown that breeding with native AC trees is quite strongly supported among the American public, whereas breeding with non-native Asian chestnut tree species is less acceptable and supported by fewer people compared to the transgenic approach of adding a gene from bread wheat (see NASEM, 2019 for a review). Regardless of approaches used, previous findings and those presented here may be applicable to other forest health threats such as diseases (e.g., sudden oak death), pests (e.g., emerald ash borer), and climate change. Future work should examine drivers of attitudes toward using GE and other approaches for addressing these threats.

Funding statement

Funding was from the Forest Health Initiative and US Endowment for Forestry and Communities, grant number 2013-015.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Ariely, D., 2008. Predictably Irrational: The Hidden Forces that Shape Our Decisions. Harper-Collins, New York, NY.
Chang, S., Mahon, E., MacKay, H., Rottmann, W., Strauss, S., Pijut, P., Jones, T., 2018. Genetic engineering of trees: progress and new horizons. In Vitro Cell. Develop. Biol. - Plant 54, 341–376.
Condit, C., 2010. Public attitudes and beliefs about genetics. Ann. Rev. Genom. Human Genet. 11, 339–359.
Connor, M., Siegrist, M., 2010. Factors influencing people's acceptance of gene technology: the role of knowledge, health expectations, naturalness, and social trust. Sci. Commun. 32, 514–538.
De Groot, J., Steg, L., Poortinga, W., 2013. Values, perceived risks and benefits, and acceptability of nuclear energy: acceptability of nuclear energy. Risk Anal. 33, 307–317.
Devine-Wright, P., 2005. Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy. Wind Energy 8, 125–139.
Dosman, D., Adamowicz, W., Hrudey, S., 2001. Socioeconomic determinants of health- and food safety-related risk perceptions. Risk Anal. 21, 307–318.
Dunlap, R., 2008. The new environmental paradigm scale: from marginality to worldwide use. J. Environ. Educ. 40, 3–18.
Findlater, K., Peterson St-Laurent, G., Hagerman, S., Kozak, R., 2020. Surprisingly malleable public preferences for climate adaptation in forests. Environ. Res. Lett. 15, 034045.
Fishbein, M., Ajzen, I., 2010. Predicting and Changing Behavior: The Reasoned Action Approach. Psychology Press, New York, NY.
Fishbein, M., Manfredo, M., 1992. A theory of behavior change. In: Manfredo, M. (Ed.), Influencing Human Behavior: Theory and Application in Recreation, Tourism, and Natural Resources Management. Sagamore, Champaign, IL, pp. 29–50.
Frewer, L., van der Lans, I., Fischer, A., Reinders, M., Menozzi, D., Zhang, X., Zimmermann, K., 2013. Public perceptions of agri-food applications of genetic modification: a systematic review and meta-analysis. Trends Food Sci. Technol. 30, 142–152.
Hajjar, R., Kozak, R., 2015. Exploring public perceptions of forest adaptation strategies in Western Canada: implications for policy-makers. Forest Policy Econ. 61, 59–69.
Hajjar, R., McGuigan, E., Moshofsky, M., Kozak, R., 2014. Opinions on strategies for forest adaptation to future climate conditions in Western Canada: surveys of the general public and leaders of forest-dependent communities. Can. J. For. Res. 44, 1525–1533.
Jepson, P., Arakelyan, I., 2017a. Exploring public perceptions of solutions to tree diseases in the UK: implications for policy-makers. Environ. Sci. Pol. 76, 70–77.
Jepson, P., Arakelyan, I., 2017b. Developing publicly acceptable tree health policy: public perceptions of tree-breeding solutions to ash dieback among interested publics in the UK. Forest Policy Econ. 80, 167–177.
Kahneman, D., Tversky, A., 2013. Choices, values, and frames. In: MacLean, L., Ziemba, W. (Eds.), Handbook of the Fundamentals of Financial Decision Making. World Scientific, London, UK, pp. 269–278.
Kazana, V., Tsourgiannis, L., Iakovoglou, V., Stamatiou, C., Alexandrov, A., Araújo, S., Vidal, N., 2015. Public attitudes towards the use of transgenic forest trees: a cross-country pilot survey. IForest - Biogeosci. Forest. 9, 344.
Kazana, V., Tsourgiannis, L., Iakovoglou, V., Stamatiou, C., Alexandrov, A., Araújo, S., Vidal, N., 2016. Public knowledge and perceptions of safety issues towards the use of genetically modified forest trees: A cross-country pilot survey. In: Vettori, C., Gallardo, F., Häggman, H., Kazana, V., Migliacci, F., Pilate, G., Fladung, M. (Eds.), Biosafety of Forest Transgenic Trees. Springer, Dordrecht, Netherlands, pp. 223–244.
Kronberger, N., Wagner, W., Nagata, M., 2014. How natural is "more natural"? The role of method, type of transfer, and familiarity for public perceptions of cisgenic and transgenic modification. Sci. Commun. 36, 106–130.
Lang, J., Hallman, W., 2005. Who does the public trust? The case of genetically modified food in the United States. Risk Anal. 25, 1241–1252.
Lichtenstein, S., Slovic, P., 2006. The Construction of Preference. Cambridge University Press, Cambridge, UK.

Mielby, H., Sandøe, P., Lassen, J., 2013. Multiple aspects of unnaturalness: are cisgenic crops perceived as being more natural and more acceptable than transgenic crops? Agric. Hum. Values 30, 471–480.
Moerbeek, H., Casimir, G., 2005. Gender differences in consumers' acceptance of genetically modified foods. Int. J. Consum. Stud. 29, 308–318.
National Academies of Sciences, Engineering, and Medicine (NASEM), 2019. Forest Health and Biotechnology: Possibilities and Considerations. National Academies Press, Washington, DC.
Needham, M., Vaske, J., 2008. Hunter perceptions of similarity and trust in wildlife agencies and personal risk associated with chronic wasting disease. Soc. Nat. Resour. 21, 197–214.
Needham, M., Vaske, J., Petit, J., 2017. Risk sensitivity and hunter perceptions of chronic wasting disease risk and other hunting, wildlife, and health risks. Hum. Dimens. Wildl. 22, 197–216.
Nilausen, C., Gélinas, N., Bull, G., 2016. Perceived acceptability of implementing marker-assisted selection in the forests of British Columbia. Forests 7, 286.
Nonić, M., Radojević, U., Milovanović, J., Perović, M., Šijačić-Nikolić, M., 2015. Comparative analysis of students' attitudes toward implementation of genetically modified trees in Serbia. IForest - Biogeosci. Forest. 8, 714–718.
Pardo, R., Midden, C., Miller, J., 2002. Attitudes toward biotechnology in the European Union. J. Biotechnol. 98, 9–24.
Perry, E., Needham, M., Cramer, L., 2017. Coastal resident trust, similarity, attitudes, and intentions regarding new marine reserves in Oregon. Soc. Nat. Resour. 30, 315–330.
Peterson St-Laurent, G., Hagerman, S., Kozak, R., 2018. What risks matter? Public views about assisted migration and other climate-adaptive reforestation strategies. Clim. Chang. 151, 573–587.
Peterson St-Laurent, G., Hagerman, S., Findlater, K., Kozak, R., 2019. Public trust and knowledge in the context of emerging climate-adaptive forestry policies. J. Environ. Manag. 242, 474–486.
Powell, W., 2016, January 19. New Genetically Engineered American Chestnut will Help Restore the Decimated, Iconic Tree. The Conversation.
Savadori, L., Savio, S., Nicotra, E., Rumiati, R., Finucane, M., Slovic, P., 2004. Expert and public perception of risk from biotechnology. Risk Anal. 24, 1289–1299.
Scott, S., Inbar, Y., Rozin, P., 2016. Evidence for absolute moral opposition to genetically modified food in the United States. Perspect. Psychol. Sci. 11, 315–324.
Siegrist, M., 2000. The influence of trust and perceptions of risks and benefits on the acceptance of gene technology. Risk Anal. 20, 195–204.
Siegrist, M., Cvetkovich, G., Roth, C., 2000. Salient value similarity, social trust, and risk/benefit perception. Risk Anal. 20, 353–362.
Sjoberg, L., 2004. Explaining individual risk perceptions: The case of nuclear waste. Risk Manage. 6, 51–64.
Sloman, S., Fernbach, P., 2017. The Knowledge Illusion: Why We Never Think Alone. Riverhead Books, New York, NY.
Slovic, P., 2010. The Feeling of Risk: New Perspectives on Risk Perception. Earthscan, New York, NY.
Stedman, R., Connelly, N., Heberlein, T., Decker, D., Allred, S., 2019. The end of the (research) world as we know it? Understanding and coping with declining response rates to mail surveys. Soc. Nat. Resour. 32, 1139–1154.
Steiner, K., Westbrook, J., Hebard, F., Georgi, L., Powell, W., Fitzsimmons, S., 2017. Rescue of American chestnut with extraspecific genes following its destruction by a naturalized pathogen. New For. 48, 317–336.
Stern, M., Coleman, K., 2015. The multidimensionality of trust: Applications in collaborative natural resource management. Soc. Nat. Resour. 28, 117–132.
Strauss, S., Jones, K., Lu, H., Petit, J., Klocko, A., Betts, M., Needham, M., 2017. Reproductive modification in forest plantations: Impacts on biodiversity and society. New Phytol. 213, 1000–1021.
Tsourgiannis, L., Kazana, V., Iakovoglou, V., 2016. A comparative analysis of consumers' potential purchasing behaviour towards transgenic-derived forest products: The Greek case. In: Vettori, C., Gallardo, F., Häggman, H., Kazana, V., Migliacci, F., Pilate, G., Fladung, M. (Eds.), Biosafety of Forest Transgenic Trees. Springer, Dordrecht, Netherlands, pp. 245–261.
Vaske, J., 2019. Survey Research and Analysis. Sagamore/Venture, Urbana, IL.
Vaske, J., Donnelly, M., 1999. A value-attitude-behavior model predicting wildland preservation voting intentions. Soc. Nat. Resour. 12, 523–537.
Wheeler, N., Sederoff, R., 2009. Role of genomics in the potential restoration of the American chestnut. Tree Genet. Genomes 5, 181–187.
Whittaker, D., Vaske, J., Manfredo, M., 2006. Specificity and the cognitive hierarchy: Value orientations and the acceptability of urban wildlife management actions. Soc. Nat. Resour. 19, 515–530.
Wilson, R., Arvai, J., 2006. When less is more: How affect influences preferences when comparing low and high-risk options. J. Risk Res. 9, 165–178.
Zhang, B., Oakes, A., Newhouse, A., Baier, K., Maynard, C., Powell, W., 2013. A threshold level of oxalate oxidase transgene expression reduces *Cryphonectria parasitica*-induced necrosis in a transgenic American chestnut (*Castanea dentata*) leaf bioassay. Transgenic Res. 22, 973–982.