AN ABSTRACT OF THE DISSERTATION OF

Joshua D. Petit for the degree of Doctor of Philosophy in Forest Ecosystems and Society presented on June 7, 2019.

Title: Societal Responses to Using Genetic Engineering for Mitigating Chestnut Blight and Restoring American Chestnut Trees

Abstract approved:

____

Mark D. Needham

Forests face health threats from pests and diseases (e.g., mountain pine beetle, emerald ash borer, chestnut blight [CB], Swiss needle cast), and other issues such as climate change. Interventions such as genetic engineering (GE) have shown promise for mitigating some of these threats. CB, for example, has impacted most American chestnut (AC) forests in the eastern United States (US), but scientists have recently discovered a gene from bread wheat (oxalate oxidase [OxO]) that increases resistance to CB, and they are currently seeking regulatory approval for commercial release of this transgenic AC tree. This dissertation examined societal (i.e., public, forest interest groups [FIG]) perceptions of using GE for mitigating CB and restoring AC trees. Three standalone articles assessed: (a) cognitive and socio-demographic drivers of attitudes toward this use of GE (Chapter 2); (b) the extent that normative acceptance of this use of GE is related to perceptions of risks and benefits (toward humans and the environment), and trust in those charged with managing this application of GE (Chapter 3); and (c) whether these attitudes and norms are susceptible to change after being exposed to persuasive messages that utilize different wording or framing effects (Chapter 4). Chapter 2 involved multiple regression analyses of data from a mixed-mode (online, mail) survey of residents living in US counties that historically experienced CB, residents in all other contiguous US counties (i.e., those not known

to have been affected by chestnut blight), and FIGs (from academic institutions, government agencies, nongovernmental organizations, private forest companies) to examine cognitive and sociodemographic drivers of their attitudes toward this use of GE. Chapter 3 used these same samples and structural equation modeling to examine specific relationships among trust in managing agencies, perceptions of risks and benefits, and normative acceptance of this use of GE. Chapter 4 used data from two samples (the same samples of residents in Chapters 2 and 3 plus a separate online Qualtrics panel of other residents) coupled with an experimental design to assess the extent that six different wording and framing treatments influenced these attitudes and norms. Although each chapter discusses a variety of results, implications, and conclusions, the primary results across these three chapters taken together showed that: (a) there was majority support (i.e., positive attitudes, normative acceptance) for using GE to mitigate CB and restore AC trees, with slightly greater support among the FIGs; (b) perceived environmental benefits and risks were most strongly related to this support; and (c) although these cognitions were generally positive, they were extremely susceptible to negative messaging and wording effects aimed at persuading people to change their opinions. These results advance scientific understanding of societal responses to using GE in forests in general and forest conservation in particular. The findings can also assist scientists and managers, especially when communicating with people about this complex issue.

Societal Responses to Using Genetic Engineering for Mitigating Chestnut Blight and Restoring American Chestnut Trees

by
Joshua D. Petit

A DISSERTATION

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Doctor of Philosophy

Presented June 7, 2019
Commencement June 2019

Doctor of Philosophy dissertation of Joshua D. Petit presented on June 7, 2019

APPROVED:

Major Professor, representing Forest Ecosystems and Society

Head of the Department of Forest Ecosystems and Society

Dean of the Graduate School

I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

Joshua D. Petit, Author

ACKNOWLEDGEMENTS

First, I would like to express sincere appreciation to Dr. Mark Needham for all of his mentorship and support during each aspect of completing this dissertation. He has provided invaluable feedback throughout the research, statistical analyses, and writing stages. Not only has Mark supported me academically through his dedicated attention to detail and rigorous standards, but he has also supported me through some of the most difficult times of my personal life. I will be forever grateful for his unending support, and truly consider him my mentor and friend for life. Dr. Glenn Howe, the Co-PI of this research project, has also been instrumental during my time at Oregon State University. Dr. Howe played a key role in securing and designing this project, and provided essential research guidance in relation to genetics, my research proposal, and modern applications of genetic engineering for addressing forest stressors. I would also like to acknowledge and thank my other graduate committee members, Drs. Bryan Tilt, Bruce Schindler, and SueAnn Bottoms, for all of their invaluable input, support, and guidance. I would also like to acknowledge the funders of this project, the Forest Health Initiative, and the US Endowment for Forestry and Communities. Additionally, I want to express extreme gratitude to Oregon State University, the College of Forestry, and the Department of Forest Ecosystems and Society for scholarships, fellowships, teaching assistantships, and other additional sources of funding, without which this research would not have been possible. Finally, I greatly appreciate the OSU undergraduate and graduate students who assisted with survey administration, data entry, and related tasks.

CONTRIBUTION OF AUTHORS

Dr. Mark Needham and Dr. Glenn Howe in the Department of Forest Ecosystems and Society secured funding for this project, aided in research design, and provided invaluable guidance and direction during survey implementation, statistical analyses, writing, and presentations derived from this dissertation research. In particular, Dr. Needham's specialization in human dimensions of natural resources, paired with Dr. Howe's expertise in forest genetics, were instrumental for completing this project. Dr. Mark Needham also assisted with thorough editing of all chapters in this dissertation.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (Continued)

DEDICATION

I would like to dedicate this dissertation to Dale S. Petit for his unending love and support, and for instilling a sense of self-confidence, ethics, and determination throughout this journey. Additionally, I would like to dedicate this work to the memory of Mary Helen Petit (deceased) and Roberta L. Petit (deceased) for their maternal love and compassion, which cannot be measured in years, dollars earned, or publications derived from this work.

CHAPTER ONE

INTRODUCTION

Forests serve as key ecosystems for humans, wildlife, and other species (e.g., pollinators). In addition to providing natural resources (NR) and ecosystem services (e.g., carbon sequestration, erosion control, watersheds), forests are home to 80% of the world's biodiversity and 300 million humans, and provide livelihoods for 1.6 billion people worldwide (World Wildlife Fund, 2019). Given the value of forests, it is important to mitigate and monitor impacts of natural and human-caused stressors on these ecosystems. Natural threats to forests include outbreaks of native insects, drought, and naturally occurring wildfires (Woodall et al., 2011). Examples of anthropogenic stressors on forests include human induced climate change, deforestation, introduction of non-native species, and large-scale high intensity fires caused by humans (e.g., historic management practices emphasizing suppression of low intensity natural fires) (Kerns, Kim, Kline, & Day, 2016). These anthropogenic stressors can exacerbate or intensify natural forest health threats (e.g., climate change warming prevents pine beetle mortality during colder months, climate change related drought) (Abatzoglou & Williams, 2016).

Given these threats coupled with the importance of forests (e.g., cultural heritage, economic value, land ethic, outdoor recreation, ecosystem services), it is important that scientists and NR managers utilize available strategies and technologies for facilitating conservation initiatives (NASEM, 2019). Managers have historically employed silvicultural practices to mitigate some forest health threats; example practices include stand thinning, herbicide and insecticide applications, and nutrient inputs (Barrette et al., 2014). In addition to these traditional approaches, modern biotechnologies such as genetic engineering (GE) also have the potential to successfully address some forest health threats (NASEM, 2019; Strauss, Costanza, & Séguin, 2015). GE is the direct modification of a species' genetic material using laboratory methods where existing genes can be changed or genes from either sexually compatible (i.e., cisgenesis) or exogenous genes from sexually incompatible species are inserted into a host species' genome (i.e., transgenesis; Adams et al., 2007).

One species for which GE has shown some promise is the American chestnut (AC) (*Castanea dentata*). The AC was a keystone tree species in eastern US hardwood forests that historically provided abundant NRs to humans, in addition to habitat and a food source for wildlife (Wheeler & Sederoff, 2008). The AC was a valued timber species due to its massive size and abundance, rot-resistance and durability, and provision of edible chestnuts (Powell, 2016). Around the year 1900, however, the fungal pathogen *Cryphonectria parasitica* causing chestnut blight (CB) was unintentionally introduced from Asia and has decimated the species (95%+ adult mortality) in its historic range (Wheeler & Sederoff, 2008). CB infects trees by entering through bark wounds where it emits oxalic acid that girdles (i.e., blocks nutrient flow) and prevents the trees from reaching reproductive maturity. Remnant AC trees in the US now exist largely in a shrub state or are isolated geographically from infected stands (Wheeler & Sederoff, 2008).

In an attempt to resist CB and restore AC trees, scientists have employed a host of strategies ranging from traditional silvicultural approaches to using modern genetic technologies such as GE (Wheeler & Sederoff, 2008). Backcrossing AC trees with more blight-resistant Asian chestnut trees, for example, has been somewhat effective at enhancing CB resistance (Jacobs, 2007). The most promising approach to date, however, has been using GE to insert genes that confer resistance to CB (Zhang, Newhouse, McGuigan, Maynard, & Powell, 2011). Using transgenesis, scientists have inserted a gene from bread wheat (oxalate oxidase [OxO]) that breaks down oxalic acid into the AC genome, which has resulted in enhanced CB-resistance in field trials (Zhang et al., 2013). Based on these successes, researchers are currently seeking regulatory approval for commercial release of this transgenic AC tree (Powell, 2016; Steiner et al., 2017).

If these transgenic trees are released, it is important to understand what society thinks (i.e., attitudes, norms) about this issue and the potential correlates of these cognitions (e.g., risk and benefit perceptions, trust, demographic characteristics) (NASEM, 2019). Given the novelty of this application of GE, it is also important to understand the extent that these opinions might be susceptible to persuasion campaigns (e.g., positive versus negative message framing). Additionally, the utility and governance of NR management strategies and associated technologies in democratic societies is inherently influenced by societal opinions (Shindler & Cheek, 1999). These opinions, in turn, can be shaped by underlying cognitions and characteristics, such as attitudes in support or opposition, norms (e.g., should vs. should not be allowed), perceptions of risks and benefits, trust in decision makers and managers, value orientations (e.g., biocentric vs. anthropocentric), and demographics including age, sex (male, female), income, education, and race (see Frewer et al., 2013 for a review).

The limited research on public opinions about using biotechnology in forests (see NASEM, 2019 for a review) has generally shown that despite some perceived risks (e.g., concerns with gene flow, reduced genetic diversity, and humans manipulating, tampering, and interfering with nature), the majority of the public tends to be generally supportive of using some types of biotechnologies in select forest contexts, and that male, younger, higher income, and more educated individuals tend to be most supportive (Hajjar & Kozak, 2015; Jepson & Arakelyan, 2017a,b; Kazana et al., 2015; Kazana et al., 2016). Some research has suggested, however, that factors such as positive (i.e., emphasizing benefits) versus negative (i.e., emphasizing risks) framing might change these opinions, making them susceptible to persuasive messaging campaigns (Hajjar, McGuigan, Moshofsky, & Kozak, 2014).

Dissertation Purpose and Organization

This dissertation builds on this limited body of research by containing three standalone articles that assess societal perceptions of using GE to mitigate CB and restore AC trees. Three overarching research questions were investigated. First, what are the cognitive and demographic drivers of attitudes toward using GE for mitigating CB and restoring AC trees, and what is the relative strength of each of these drivers? Second, to what extent is normative acceptance of this use of GE related to perceptions of risks and benefits (toward humans and the environment) and trust in those charged with implementing this use of GE? Third, to what extent are these attitudes and norms susceptible to change after being exposed to persuasive messages that utilize different wording or framing effects (e.g., positive vs. negative terminology)? These articles are based on data from a survey of residents living in US counties that historically experienced chestnut blight, residents in all other contiguous US counties (i.e., counties not known to have been affected by chestnut blight), and forest interest groups (FIGs) from academic institutions, government agencies, nongovernmental organizations, and private forest companies.

The first article (Chapter 2) explored three research questions. First, what are the attitudes of people toward using GE for restoring AC trees? Second, what socio-demographic characteristics and other cognitions (e.g., risks, benefits, trust, value orientations, awareness) are related to these attitudes, and which are the most strongly associated? Third, to what extent do these cognitions, socio-demographic characteristics, and relationships differ between the US general public and FIGs.

The second article (Chapter 3) built on some of the most substantive results from the first article by examining in more depth the specific relationships among trust, perceived risks, perceived benefits, and normative acceptance within the context of using various GE approaches for mitigating CB and restoring AC trees. Five hypotheses were tested. First, perceived risks (to humans, to the environment) of using GE to mitigate CB and restore AC trees will be negatively related to normative acceptance of this use of GE. Second, perceived benefits (to humans, to the environment) of this use of GE will be positively related to normative acceptance. Third, trust in agencies (federal, nonfederal) will be negatively related to perceived risks (to humans, to the environment) of this use of GE. Fourth, trust in these agencies will be positively related to perceived benefits (to humans, to the environment) of this use of GE. Fifth, trust in these agencies will be positively related to normative acceptance of this use of GE. This article also examines whether: (a) these relationships among concepts differ between the general public and FIGs, and (b) perceived risks and benefits mediate any relationships between trust and normative acceptance of using GE in this context.

The third article (Chapter 4) then examined potential effects of message framing (e.g., positive vs. pejorative terminology, scientific information and consensus) on these attitudes and normative acceptance of using GE to restore AC trees. This article used data from two studies (including an experiment with multiple treatments) to examine two research questions. First, what are the current attitudes, norms, and intentions of people regarding the use of GE for mitigating CB and restoring AC trees? Second, to what extent are these cognitions susceptible to some message framing approaches (e.g., positive vs. pejorative wording, scientific information and consensus)?

Conclusions drawn from this dissertation will increase understanding of what people think about using modern technologies such as GE for addressing forest health threats. Specifically, this dissertation examines cognitive and demographic drivers of attitudes and norms toward using GE for mitigating CB and restoring AC trees, as well as the extent that these cognitions may be susceptible to persuasive messaging attempts. Results can provide insight to managers who wish to develop communication efforts informing the public about modern tools and technologies for addressing forest health threats.

References

Abatzoglou, J. T., & Williams, A. P. (2016). Impact of anthropogenic climate change on wildfire across western US forests. *Proceedings of the National Academy of Sciences*, *113*(42), 11770–11775.

Adams, W. T., Neale, D. B., Adams, W. T., Neale, D. B., Adams, W. T. (Wesley T., White, T. L., & White, T. L. (2007). *Forest Genetics*. Wallingford: Wallingford : CAB International.

Barrette, M., Leblanc, M., Thiffault, N., Paquette, A., Lavoie, L., Bélanger, L., ... & Tremblay, J. P. (2014). Issues and solutions for intensive plantation silviculture in a context of ecosystem management. *The Forestry Chronicle*, *90*(6), 748-762.

Frewer, L. J., van der Lans, I. A., Fischer, A. R. H., Reinders, M. J., Menozzi, D., Zhang, X., … Zimmermann, K. L. (2013). Public perceptions of agri-food applications of genetic modification: A systematic review and meta-analysis. *Trends in Food Science & Technology*, *30*(2), 142–152.

Hajjar, R., & Kozak, R. A. (2015). Exploring public perceptions of forest adaptation strategies in western Canada: Implications for policy-makers. *Forest Policy and Economics*, *61*, 59–69.

Hajjar, R., McGuigan, E., Moshofsky, M., & Kozak, R. A. (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. *Canadian Journal of Forest Research*, *44*(12), 1525–1533.

Jacobs, D. (2007). Toward development of silvicultural strategies for forest restoration of American chestnut (Castanea dentata) using blight-resistant hybrids. *Biological Conservation*, *137*(4), 497–506.

Jepson, P., & Arakelyan, I. (2017a). Exploring public perceptions of solutions to tree diseases in the UK: Implications for policy-makers. *Environmental Science & Policy*, *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 and Economics*, *80*, 167–177.

Kazana, V., Tsourgiannis, L., Iakovoglou, V., Stamatiou, C., Alexandrov, A., Araújo, S., ... & Boutsimea, A. (2015). Public attitudes towards the use of transgenic forest trees: A cross-country pilot survey. *iForest-Biogeosciences and Forestry*, *9*(2), 344.

Kazana, V., Tsourgiannis, L., Iakovoglou, V., Stamatiou, C., Alexandrov, A., Araújo, S., ... & Boutsimea, A. (2016). Public knowledge and perceptions of safety issues towards the use of genetically modified forest trees: A cross-country pilot survey. In *Biosafety of Forest Transgenic Trees* (pp. 223-244). Springer, Dordrecht.

Kerns, B., Kim, J., Kline, J., & Day, M. (2016). US exposure to multiple landscape stressors and climate change. *Regional Environmental Change*, *16*(7), 2129–2140.

National Academies of Sciences, Engineering, and Medicine. (2019). *Forest health and biotechnology: Possibilities and considerations*. Washington, DC: The National Academies Press.

Powell, W. (2016). New genetically engineered American chestnut will help restore the decimated, iconic tree. *The conversation, Jan*, *19*, 2016.

Shindler, B., & Cheek, K. (1999). Integrating citizens in adaptive management: A propositional analysis. *Conservation Ecology*, *3*(1), 9.

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 Forests*, *48*(2), 317–336.

Strauss, S. H., Costanza, A., & Séguin, A. (2015). Genetically engineered trees: Paralysis from good intentions. *Science*, *349*(6250), 794–795.

Wheeler, N., & Sederoff, R. (2008). Role of genomics in the potential restoration of the American chestnut. *Tree Genetics & Genomes*, *5*(1), 181–187.

Woodall, C., Amacher, M., Bechtold, W., Coulston, J., Jovan, S., Perry, C., … Will-Wolf, S. (2011). Status and future of the forest health indicators program of the USA. *Environmental Monitoring and Assessment*, *177*(1), 419–436.

World Wildlife Fund. (2019). *Forests: Conserve the world's most important forests to sustain nature's diversity, benefit our climate, and support human well-being*. Retrieved from: https://www.worldwildlife.org/initiatives/forests

Zhang, B., Newhouse, A., McGuigan, L., Maynard, C., & Powell, W. (2011). Agrobacterium-mediated co-transformation of American chestnut (Castanea dentata) somatic embryos with a wheat oxalate oxidase gene. In *BMC proceedings* (Vol. 5, No. 7, p. 43). BioMed Central.

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 Research*, *22*(5), 973–982.

CHAPTER TWO

COGNITIVE AND DEMOGRAPHIC DRIVERS OF ATTITUDES TOWARD USING GENETIC ENGINEERING TO RESTORE AMERICAN CHESTNUT TREES

Introduction

The American chestnut (AC) (*Castanea dentata*) was a keystone tree species in forests throughout the eastern United States (US) that provided high quality timber (e.g., rot-resistant, durable) and food (i.e., chestnuts) for humans, and habitat and food for wildlife (Merkle, Andrade, Nairn, Powell, & Maynard, 2006). 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 (i.e., up to 99% reduction in the AC native range) (Wheeler & Sederoff, 2008). The CB fungus enters through bark wounds and emits oxalic acid that restricts nutrient flow and prevents young trees from growing and reproducing (Wheeler & Sederoff, 2008). 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 (Wheeler & Sederoff, 2008). These GE approaches involve either inserting genes from sexually compatible (i.e., cisgensis / cisgenics) or incompatible (i.e., transgenesis / transgenics) species 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 now seeking regulatory approval for releasing these transgenic AC trees at a broader scale (Chang et al., 2018; Steiner et al., 2017). However, implementing controversial technologies such as GE partially depends on support (i.e., attitudes) from the public and other interest groups (Sjoberg, 2004; Slovic, 2010). Given the important services provided by forests (e.g., timber, recreation, wildlife habitat, cultural heritage), it is important to understand if the public and other groups 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; Frewer et al., 2004a; Siegrist, 2000). However, it is unclear whether these factors are associated with attitudes toward using GE to conserve or restore forests in general or to address CB in particular. This article explores public and forest interest group (FIG) attitudes toward 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 will inform understanding of opinions about GE in this context and communication efforts about benefits and risks of this and related uses of GE.

Conceptual Foundation

Attitudes

Attitudes are evaluations of a particular 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 more specific (e.g., attitude toward GE) (Eagly & Chaiken, 1993; Whittaker, Vaske, & Manfredo, 2006). Attitudes can exist on a continuum from negative to positive, and are often measured using semantic differential scales (e.g., “bad” to “good”) (Eagly & Chaiken, 1993). 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) examined public perceptions of several gene technologies and concluded that genetic testing was viewed more favorably than GE in food.

Little research has examined attitudes toward using GE in forest conservation in the US, although some analogous research has examined these attitudes and related cognitions in other countries. For example, in a sample of students in mostly European countries, Kazana et al. (2015) found generally positive attitudes toward GE trees in plantations. Hajjar and Kozak (2015) found that approximately 50% of residents accepted planting trees with traits introduced via biotechnology to address forest health threats from climate change in Western Canada. Adding additional nuance, Jepson and Arakelyan (2017a,b) found that cisgenic approaches were preferred among UK residents over transgenic applications for addressing ash dieback. Their study also showed that residents were more supportive of planting cisgenic and transgenic ash trees in plantations compared to woodlands. Research has also shown more support for GE that addresses specific forest health threats (e.g., pests, diseases) rather than more general issues (e.g., climate change) (Nonić, Radojević, Milovanović, Perović, & Šijačić-Nikolić, 2015).

Social Trust

One potential correlate of these attitudes toward GE is social trust, which is defined as the willingness to rely on entities responsible for making decisions or taking actions that affect public health, safety, and wellbeing (Siegrist, Cvetkovich, & Roth, 2000). Individuals often trust external sources (e.g., agencies, scientists) to assess risks and benefits associated with technologies and natural resource (NR) management issues, especially when personal experience with an issue is low (Needham & Vaske, 2008). Trust in these sources charged with managing, researching, and providing information about NR issues and technologies is often positively related to favorable attitudes about these issues (Perry, Needham, & Cramer, 2017; Siegrist, 2000). This relationship has been examined in the context of managing technologies such as nuclear power (Siegrist et al., 2000) and NR issues such as wildlife (Needham & Vaske, 2008).

Less research has examined this relationship in the context of forestry, especially forest health issues. Although trust has been shown to be an important factor related to favorable attitudes toward using GE in plantation forestry, the bulk of this research has not addressed forest health (National Academies of Sciences, Engineering, and Medicine, 2019; Neumann, Krogman, & Thomas, 2007; 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. In addition, researchers in the UK found that trust in forest managers was associated with favorable attitudes toward using GE for mitigating ash dieback (Jepson & Arakelyan, 2017a,b).

Perceived Risks

Risk perceptions are another potential predictor of 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, perceived risks are intuitive judgments unique to each individual and informed partially by communication efforts (Needham, Vaske, & Petit, 2017). Risk perceptions can vary greatly between the general 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 emotional and subjective responses (Wilson & Arvai, 2006). Research on risk perceptions has shown that higher perceived risks are often associated with more negative attitudes toward GE (Frewer et al., 2013; Sjoberg, 2004). Strauss et al. (2017), for example, reviewed the literature on potential drivers of positive attitudes toward GE in plantation forestry and concluded that risk perceptions were likely to be negatively associated with these attitudes. Kazana et al. (2015, 2016) explored risk perceptions among students and found that gene escape (i.e., unintended gene flow into wild forests), disease susceptibility, and higher herbicide inputs were concerns 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, Kazana, & Iakovoglou, 2016). In addition, concerns over humans interfering or tampering with nature have been observed in studies of GE uses in forestry in both Western Canada and in the UK (Hajjar & Kozak, 2015; Jepson & Arakelyan, 2017b).

Perceived Benefits

In addition to these risks, perceived benefits are important cognitions 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 or restore AC trees) (De Groot et al., 2013). Studies on student perceptions of GE in plantation forestry have revealed benefits such as reduced pesticide inputs and greater tree growth and productivity (Kazana et al., 2015; Nonić et al., 2015). Perceived benefits are generally positively associated with favorable attitudes toward GE in agriculture (De Groot et al., 2013; Siegrist, 2000), and Strauss et al. (2017) hypothesized this same relationship in plantation forestry. However, studies empirically examining this relationship in the context of forest restoration are limited, but they warrant more attention given the potential utility of GE for addressing forest health threats. Recent research in the UK examining public responses to using GE for addressing ash dieback found that people viewed the technology more favorably when used for addressing tangible issues (e.g., tree diseases, world hunger), suggesting that perceived benefits may be correlates of favorable attitudes toward GE in forestry (Jepson & Arakelyan, 2017b).

Value Orientations

In addition to these perceptions of risks and benefits, value orientations might also be related to attitudes toward GE. Value orientations are patterns of basic beliefs that exist in both general (e.g., the environment) and more specific (e.g., forests) contexts (Fulton, Manfredo, & Lipscomb, 1996; Vaske, Donnelly, Williams, & Jonker, 2001). A domination (i.e., utilitarian, anthropocentric) environmental value orientation is a human-centered conceptualization of the natural world, whereas a mutualism orientation (i.e., social affiliation, caring, biocentric, protectionist) comprises beliefs that the natural environment has inherent worth beyond human utility. Vaske and Donnelly (1999) found that among Colorado residents, biocentric value orientations were predictive of favorable attitudes toward wildland preservation. Value orientations have also been investigated in relation to technologies such as GE. Both Boecker, Hartl, and Nocella (2008) and Pardo, Midden, and Miller (2002), for example, found that value orientations corresponded to attitudes toward biotechnologies such as GE. In the context of forest conservation, Hajjar and Kozak (2015) found that Western Canadians with more biocentric or mutualist value orientations were slightly less accepting of using biotechnologies for addressing impacts of climate change on forests compared to those with mixed or neutral value orientations.

Awareness

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

Socio-Demographic Characteristics

Relationships between attitudes and socio-demographic characteristics have been investigated in many contexts. These characteristics include age, sex (e.g., male, female), race, income, education, industry involvement (e.g., forestry), interest group affiliation, political orientation (e.g., conservative, liberal), and residential location (e.g., rural, non-rural). Males, younger individuals, and Caucasians have been shown to view technologies such as GE more favorably than their counterparts (Hajjar & Kozak, 2015; Moerbeek & Casimir, 2005; Rabino, 1998; Siegrist, 1998; Slovic, 1999). Researchers in the UK, for example, found that younger people were more supportive of using GE to enhance European ash tree resistance to dieback (Jepson & Arakelyan, 2017a,b). Others have shown that income can also be positively associated with favorable views toward using technologies for managing hazards (Dosman, Adamowicz, & Hrudey, 2001). Researchers have also hypothesized that politically conservative individuals are more likely than liberals to view GE in plantation forestry favorably (Strauss et al., 2017).

Research examining differences in attitudes between members of the public and other interest groups has shown that some groups (e.g., managing agencies, scientists) generally view GE more favorably (i.e., positive attitudes, less risky, more beneficial) than members of the general public (Jepson & Arakelyan, 2017; Savadori et al., 2004). However, Hajjar, McGuigan, Moshofsky, and Kozak (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 local 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 other groups such industry and government agencies (Nilausen et al., 2016).

Research Questions

Based on this literature, this article explored three research questions. First, what are the attitudes of people toward using GE for restoring AC trees? Second, what socio-demographic characteristics and other cognitions are related to these attitudes, and which are the most strongly associated? Third, to what extent do these cognitions, socio-demographic characteristics, and relationships differ between the US general public and FIGs?

Methods

Data Collection

Data were obtained from a mixed-mode survey of the US general public and other FIGs (university scientists, government agency representatives, businesses, and NGOs involved in forest issues) between January and June 2015. Sampling of the public was stratified by individuals living: (a) within the historic native range of the AC (i.e., chestnut counties), and (b) in the rest of the contiguous US (i.e., non-chestnut counties). The public was then sampled randomly and proportionally to county-level populations using US zip codes. The FIGs consisted of a purposive sample selected based on expertise and involvement in forest-related issues. Six contacts were used for increasing response rates: (a) postcard mailing with an option to complete the questionnaire online, (b) full mailing (i.e., questionnaire, letter, postage-paid reply envelope), (c) postcard reminder with an option to complete the questionnaire online, (d) personal telephone call to encourage participation, (e) second full mailing, and (f) final full mailing.

In total, 473 completed questionnaires were received (15% response rate). Completions for each stratum included: (a) 142 from the general 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 a random sample (*n* = 107) of nonrespondents from the public samples was conducted to determine if responses differed between respondents and nonrespondents, but no substantive differences were found. Demographic characteristics of respondents from the public samples were also compared to US Census data to investigate potential differences between the public samples and the population. There were slight differences in age (sample was slightly older) and education (sample was slightly more educated), which required weighting the data. No other substantive differences were detected. Few substantive differences were found between respondents from counties within the historic native range of the AC and those from other counties, so responses from these two samples were aggregated into a single public sample. Responses across each FIG (scientists, agencies, businesses, NGOs) were also aggregated because they were not necessarily statistically representative of each group and the number of respondents in each group was too small for rigorous statistical comparisons among groups (*n* = only 35-61 per group).

Analysis Variables

Scenarios were embedded within the questionnaire for measuring cognitions in response to three GE approaches for mitigating CB and restoring AC trees (see Table 1 for scenario wording). Based on expert feedback from initial focus group sessions and pretesting, these scenarios were worded as neutrally as possible to avoid potential framing effects. For all scenarios, respondents were presented with a brief description of CB: “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 scenario was: “Adding a gene from a distantly related organism to AC trees.” The third scenario was: “Adding a gene from wheat (e.g., bread wheat) to AC trees.” *Attitudes* toward each of these scenarios 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.” *Risk perceptions* were measured on 9-point scales from “no risk” to “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 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 “no benefit” to “highly benefit.”

There were additional concepts measured in the questionnaire that were not in direct response to these scenarios. *Trust* was measured by asking “How must trust do you have in each of the following individuals or groups to positively contribute to the management / stewardship of forests:” (a) “local government agencies (city, county, town);” (b) “state government agencies;” (c) “US Forest Service” (USFS); and (d) “US Bureau of Land Management” (BLM) on 9-point scales from “no trust” to “high trust.” *Perceived risks to forests from tree diseases in general* were examined with two items (CB, other tree diseases such as blister rust and Dutch elm disease) on 9-point scales from “no threat” to “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 “strongly disagree” to “strongly agree” (Dunlap, 2008).

Consistent with previous research (e.g., Vaske & 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 of CB* was assessed with a single dichotomous (yes / no) question asking respondents if they had ever heard of CB.

The questionnaire also 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); income (below $50,000, above $50,000, unsure); political orientation (5-point scale from very conservative to 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 to 5 miles, 6 to 10 miles, 11 to 20 miles, 21 to 50 miles, 51 to 100 miles, more than 100 miles); and residential community type (large city with 250,000 or more people, city with 100,000 to 249,999 people, small city with 25,000 to 99,999 people, town with 5,000 to 24,999 people, small town / village with fewer than 5,000 people, farm or rural area with few people).

Data Analysis

Items measuring attitudes, perceived risks and benefits, trust, and value orientations (environment, forests) were combined into mean composite indices after testing for measurement reliability using Cronbach's alpha (i.e., all alphas were $\geq$ .71 and indices would not improve by removing any items; Tables 2 and 3). As a result, mean indices were created for both perceived risks and benefits for humans (yourself, other humans or society in general) and the environment (trees / forests, the broader environment), and 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 assessed whether responses on these indices and other scales (e.g., age, political orientation) differed between the public and FIGs. Chi-square tests examined differences between these groups for the other variables (e.g., awareness, sex). Dummy variables were created for the categorical items (race [white, non-white], education [less than college degree, college degree or more], community type [population less than 25,000, population 25,000 or more]).

Multiple regression analyses were conducted to examine relationships between attitudes (dependent variable) and the other variables. Partial models were run first to examine individual relationships between attitudes and scenario-specific cognitions (i.e., items measured specific to each scenario), general cognitions (i.e., not specific to each scenario), and socio-demographic characteristics. The partial models for the scenario-specific cognitions consisted of four independent variables (indices): perceived risks to humans, perceived environmental risks, perceived benefits to humans, and perceived environmental benefits. Partial models for the general cognitions consisted of six independent variables: general value orientations toward the environment, specific value orientations toward forests, trust in federal agencies, trust in non-federal agencies, awareness of CB, and perceived risks to forests from tree diseases in general. Partial models for socio-demographic characteristics contained nine independent variables: education, age, sex, political orientation, income, race, residential proximity to a forest, involvement in forestry, and community type. Full models were then run using all statistically significant variables from all of the partial models to compare their relative strength (i.e., standardized beta values) while controlling for the others. These analyses were conducted independently for each group (public, FIGs) and each scenario.

Results

Descriptive Results

Compared to the US public, the FIG sample was significantly ($p < .05$) more likely to be older, male, white, more educated, involved with forestry, to live closer to a forest, and to have a higher annual income (Table 4). The FIG sample also had significantly more trust in non-federal (local, state) government agencies, had less mutualist (i.e., more anthropocentric or domination oriented) environmental and forest value orientations, and were more likely to have heard of CB.

Attitudes, risks, and benefits in response to all three scenarios (i.e., using GE to change existing AC genes, using GE to insert genes from distant species, using GE to insert a gene from bread wheat [OxO gene]) also differed between the public and FIG samples. Compared to the public sample, the FIG sample had more positive attitudes and perceived greater benefits (to humans, to the 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 $p < .05$. Public attitudes did not vary considerably across the scenarios ($M = 2.75$ to 2.99), whereas the FIGs felt most positively about modifying existing AC genes ($M = 3.70$) followed by using GE to insert genes from distant species ($M = 3.34$) and using GE to insert a gene from bread wheat (OxO gene; $M = 3.32$).

Regression Results

Scenario 1 (using 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 value orientations, trust in both federal and non-federal agencies, and age were positively related to favorable attitudes toward using GE to change genes present in AC trees (r = .20 to .86, p < .05; Table 5). Involvement in the forest industry, higher income, awareness of CB, and risks to both humans and the environment were negatively related to these attitudes (r = -.21 to -.62, p < .05).

The scenario-specific cognitions partial model explained 84% of the variance in these public attitudes and there were significant positive relationships between favorable attitudes and benefits to both humans and the environment (β = .14 and .64, p < .05). A negative relationship was observed between these attitudes and environmental risks (β = -.35, p < .001). The general cognitions partial model explained 23% of the variance in attitudes with significant positive relationships between these attitudes and both mutualist value orientations toward forests and trust in federal agencies (β = .25 and .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 (β = .25, p < .05), and negative associations between these attitudes and income, residential proximity to a forest, and forestry involvement (β = -.23 to -.25, p < .05). The full model containing the significant variables from each partial model explained 85% of the variance in public attitudes. When controlling for variables, age and perceived human and environmental benefits were positively associated with favorable attitudes (β = .10 to .64, p < .05). Environmental risks were negatively associated with these attitudes (β = -.23, p < .001). Environmental benefits were the most strongly related to public attitudes toward using GE for modifying existing genes in AC trees (β = .64, p < .001).

For the FIGs, the bivariate correlations indicated that perceived benefits to humans and the environment were positively related to favorable attitudes toward this use of GE (r = .56 and .77, p < .001). Being non-white and perceiving risks to both humans and the environment were negatively associated with these attitudes (*r* = -.23 to -.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 these attitudes (β = .68, $p < .001$). Neither the general cognitions nor socio-demographics partial models yielded any statistically significant variables related to these 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 (β = .77, $p < .001$).

Scenario 2 (using GE to add genes from distantly related species). For the public sample, the bivariate correlations between the dependent (attitudes toward this scenario) and independent variables showed that these attitudes were positively related to perceived benefits for both humans and the environment, mutualist value orientations toward forests, trust in both federal and non-federal agencies, and being female (*r* = .22 to .82, $p < .05$; Table 6). Favorable public attitudes toward this use of GE were negatively associated with environmental and human risks, awareness of CB, and living within close proximity of a forest (*r* = -.19 to -.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 = .15 and .53, $p < .05$), and negatively related to perceived environmental risks (β = -.27, $p < .001$). The general cognitions partial model explained 26% of variance in attitudes toward this use of GE with positive associations between these attitudes and both mutualist value orientations toward forests and trust in the federal government (β = .26 and .30, $p < .05$). The socio-demographics partial model explained 24% of the variance in attitudes toward this use of GE with positive relationships between favorable attitudes and both age and being female (β

= .22 and .27, $p < .05$), and a negative association between these attitudes and living closer to a forest (β = -.39, $p < .01$). The full model accounted for 82% of the variance in public attitudes toward this use of GE with residential proximity to a forest and environmental risks negatively related to favorable attitudes (β = -.18 and -.42, $p < .01$), whereas environmental benefits were positively associated (β = .48, $p < .001$) and again, the most strongly related to these attitudes.

For the FIGs, the bivariate correlations showed positive associations between favorable attitudes toward this use of GE and perceived benefits to both humans and the environment (r = .60 and .81, $p < .001$), and negative relationships between these attitudes and both human and environmental risks (r = - .50 and -.69, $p < .001$). No other variables were correlated with these attitudes for the 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 = .65, $p < .001$), and environmental risks negatively related (β = -.32, $p < .01$). The general cognitions partial model explained 13% of the variance in these attitudes with only awareness of CB positively related to favorable attitudes (β = .26, $p < .05$). No variables from the socio-demographics partial model were statistically related to these attitudes. The full model containing the significant variables across each partial model explained 71% of the variance in attitudes toward this use of GE and showed that environmental benefits (β = .61, $p < .001$) and risks (β = -.29, $p < .01$) were the only concepts significantly related to these attitudes after controlling for the other variables, with environmental benefits most strongly associated.

Scenario 3 (using 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, value orientations toward forests, trust in federal and non-federal agencies, and being female (r = .26 to .86, p < .01; Table 7). These attitudes were negatively associated with perceived risks to humans and the environment, awareness of CB, and involvement in forestry (r = -.33 to -.58, p < .001).

The scenario-specific cognitions partial model explained 79% of the variance in attitudes toward this use of GE with a positive association between favorable attitudes and perceived environmental benefits (β = .67, p < .001), and a negative association with perceived environmental risks (β = -.27, p < .001). The general cognitions partial model accounted for 26% of the variance in attitudes toward this use of GE with these attitudes positively related to mutualist value orientations toward forests and trust in federal agencies (β = .25, p < .05), but negatively associated with awareness of CB (β = -.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 residential proximity to a forest (β = -.29 and -.31, p < .05). The full model explained 83% of the variance in public attitudes toward this use of GE with positive relationships between favorable attitudes and perceived environmental benefits (β = .67, p < .001) and trust in federal agencies (β = .14, p < .01), and negative relationships between these attitudes and environmental risks, value orientations toward forests, and proximity to a forest (β = -.10 to -.28, p < .05). Again, perceived environmental benefits were the most strongly related to public attitudes.

For the FIGs, the bivariate correlations indicated positive relationships between favorable attitudes toward this use of GE and income and perceived benefits to both humans and the environment (r = .24 to .70, p < .05). Human and environmental risks were both negatively associated with these attitudes (r = -.46 and -.69, p < .001). The scenario-specific cognitions partial model explained 64% of the variance in these attitudes with perceived environmental risks ($\beta = -.54$, $p < .001$) and benefits ($\beta = .46$, $p < .001$) significantly related to these attitudes. Neither the general cognitions nor the socio-demographics partial models had any variables that were statistically related to attitudes toward this scenario. The full model explained 63% of the variance in attitudes toward this use of GE, which were positively associated with perceived environmental benefits and negatively related to environmental risks. Unlike the other models, however, environmental risks ($\beta = -.47$, $p < .001$) were more strongly related to attitudes compared to environmental benefits ($\beta = .40$, $p < .001$).

Discussion

The Role of Different Interest 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 likely to be aware of CB. These findings are generally consistent with existing research showing that certain interest groups or experts are more aware and generally view GE more favorably in comparison to members of the general public (Jepson & Arakelyan, 2017; Savadori et al., 2004).

There were also notable differences between these groups in the number of variables that were significantly related to attitudes toward the GE scenarios measured in this study. The final full models for the public sample contained three to five significant independent variables (e.g., risks, benefits, age, proximity to forests, trust, value orientations), whereas the FIG models yielded only one or two significant variables (just risks and benefits). This difference suggests that public attitudes toward these uses of GE are related to more underlying cognitive (specific and general) and contextual (demographics) factors in comparison to FIGs who base their evaluations on more specific risk and benefit assessments. This finding is consistent with research that has found differences in how certain groups (e.g., public, experts) form risk judgements that shape related cognitions (Wilson & Arvai, 2006).

The full models for the public sample also explained more variance in attitudes toward GE (82-85%) in comparison to models for the FIGs (59-71%), suggesting that the variables included here were better for predicting public attitudes in this context. The additional unexplained variance (i.e., error) in predicting FIG attitudes toward these uses of GE suggests that other factors not measured here are also related to their attitudes. Although speculative, the variation in subgroups comprising the FIG sample (i.e., agencies, scientists, NGOs, businesses) might have contributed to this finding. Perhaps a more homogenous sample of FIGs would allow for a more powerful predictive model. This warrants future research to confirm this possibility.

The Role of Scenario-Specific Cognitions

Mean differences across scenarios showed that 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 (i.e., transgenesis) is more often seen as manipulating nature and, therefore, is viewed more negatively than cisgenic approaches (Mielby, Sandøe, & Lassen, 2013). The public, however, did not make this distinction, as they viewed all three GE scenarios somewhat equivalently. Although both samples responded to modifying genes already present in the AC (scenario 1) most favorably, they viewed the two transgenic scenarios (scenarios 2 and 3) somewhat differently, as the public viewed adding genes from distant species (scenario 2) more negatively (i.e., 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 Arakeylyan (2017a), for example, examined UK resident perceptions toward using GE for addressing ash dieback and found that cisgenic approaches were more preferable than transgenic approaches. A "distantly related organism," as worded in scenario 2, is somewhat general and may have primed consideration of certain transgenic applications negatively portrayed in the media (e.g., AquAdvantage salmon [Nature, 2015]). Although speculative, perhaps the public viewed GE using bread wheat (scenario 3) more favorably because this is more familiar, as both species are plants and wheat is commonly consumed. Some researchers, however, have found that familiarity with GE can elicit either negative or positive reactions depending on context (Kronberger et al., 2014). As a result, this warrants further research attention to examine whether this phenomenon applies to attitudes toward other uses of GE in forest conservation.

Among the three scenarios, the public viewed inserting a gene from bread wheat (scenario 3) as the 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 (i.e., cisgenesis) have been viewed more positively than transgenic approaches such as adding a gene from wheat (Jepson & Arakelyan, 2017a; Mielby et al., 2013). Although speculative, one explanation for this discrepancy could be that, compared to GE foods that are often consumed and can elicit a strong negative response, the public might be less discerning among various GE applications in the context of forest conservation. This line of research warrants attention to explore the role of any possible contextual differences.

Compared to the general cognitions and socio-demographics partial models, the scenario-specific cognitions partial models accounted for the most explained variance in attitudes toward all three GE scenarios for both the public (R^2 =.79-.84) and FIGs (R^2 = .64-.70). 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 toward GE across all three scenarios for the public and two of the three scenarios for the FIGs (environmental risk was a slightly stronger predictor for scenario 3 among the FIGs). Although much of the existing GE literature has focused on human health risks (in contexts such as food), perceived benefits appear to be more strongly related to attitudes in the context of forest conservation. Other research in Europe also found that GE was viewed more favorably when used for providing specific or tangible benefits such as improving forest health or global hunger (Jepson & Arakelyan, 2017b).

It appears from the results here that public risk perceptions might play a smaller role in understanding attitudes toward these GE applications when perceived benefits are also clearly present. Perceived risks to humans were not significant drivers of attitudes across any of the scenarios. This finding differs from the existing GE literature (e.g., food) that often highlights human risk perceptions as principal drivers of attitudes toward GE (Frewer et al., 2013). However, this finding is logical, as human health concerns (although not impossible) would be unlikely to supersede environmental issues in the context of forestry. GE used in agriculture (i.e., food), on the other hand, can be perceived negatively partly due human health concerns from consuming GE foods (Scott, Inbar, & Rozin, 2016). Concerns over potential impacts from employing GE in forest conservation efforts (e.g., gene escape, loss of biodiversity) would likely be seen as primarily impacting trees and forests in contrast to risks related to consuming GE products. Studies in Canada and Europe found that unintended gene flow into wild and native forests, and reductions in genetic diversity, were environmental concerns related to 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 primary public concern (Kazana et al., 2015). These studies support results here showing that environmental benefits and risks were most strongly related to attitudes toward GE across scenarios.

These findings also support the principle of specificity and rule of correspondence, which both propose that social psychology concepts (e.g., attitudes, intentions, perceptions) measured at the same level of specificity (i.e., action, target, context, time) are more strongly related than those measured at different levels (Fishbein & Ajzen, 2011; Fishbein & Manfredo, 1992). Perceptions of environmental risks and benefits were likely most strongly related to attitudes (i.e., highest betas and proportion of variance explained) partly because these concepts were all measured directly in relation to each of the three scenarios (i.e., 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.

The Role of General Cognitions

In comparison to scenario-specific cognitions (R^2 = .64-.84), the more general cognitions (R^2 = .08-.26) were less related to attitudes toward using GE to restore AC trees. General models for the public sample contained several statistically significant variables that collectively explained two to three times the variance (R^2 = .23-.26) in attitudes toward these uses of GE compared to the models for the FIGs (R^2 = .08-.13), which yielded few significant predictors. In particular, trust in non-federal agencies was not significantly related to attitudes for either sample for any of the scenarios, but trust in federal agencies (e.g., USFS, BLM) was significantly associated with these attitudes in the partial models for the public sample. This might suggest that public respondents view federal agencies as responsible for managing GE more so than state and local agencies. It is also possible that trust in agencies may be less critical in understanding attitudes toward GE used in forest conservation compared to other contexts such as acceptance of GE foods where trust is often positively related (Lang & Hallman, 2005; Siegrist, 2000).

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

Mutualist value orientations toward forests were significantly and positively associated with public attitudes in both the bivariate analyses and partial models. Other studies have also demonstrated that mutualist value orientations are generally associated with support for conservation efforts (Vaske & Donnelly, 1999). However, neither general environmental value orientations nor specific value orientations toward forests were strongly related to attitudes for either group in the full models. These findings might be explained by the position of these constructs with regard to specificity. In the full models, value orientations were likely insignificant because the inclusion of higher order constructs (i.e., perceived risks and benefits) that were measured specific to each scenario and explained large 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 & Ajzen, 2011; Fishbein & Manfredo, 1992; Whittaker et al., 2006).

The Role of Socio-Demographic Characteristics

Socio-demographic characteristics accounted for almost twice the amount of variance (R^2 = .24-.25) in public attitudes toward these uses of GE compared to those for the FIGs (R^2 = .14-.16). Age was a significant predictor in the public full and partial models for changing existing AC genes (scenario 1), and the partial model for inserting a gene from a distant species (scenario 2). Older individuals had more favorable attitudes. Hajjar and Kozak (2015) also found that older respondents were most accepting of GE tree seedlings engineered for climate-adapted forests. However, these findings are generally inconsistent with the literature on GE in this and other contexts where younger people sometimes 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 efforts. Younger respondents may not prioritize restoring AC trees due to a lack of awareness or salience. This issue needs further research to refute or confirm this possibility.

Involvement in forestry was negatively related to public attitudes (i.e., those more involved with forestry had less favorable attitudes toward these uses of GE) for the first and third scenarios, suggesting that individuals involved in forestry oppose new or unknown technologies, perhaps due to concerns over potential economic impacts. This relationship, however, was not statistically significant in the full models and forestry involvement was not associated with attitudes for the FIG sample for any scenario. Residential proximity to a forest was also negatively associated with public attitudes toward these uses of GE (i.e., those living 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 concerns such as aesthetics and property rights (Devine-Wright, 2005). This issue deserves empirical attention, especially given that transgenic AC trees are now being sought for regulatory approval and eventual commercial release (Chang et al., 2018).

Management Implications

These findings also have implications for those aiming to inform or change attitudes toward these uses of GE. To modify attitudes toward technologies such as GE, managers should communicate with stakeholders before firm opinions are formed (Eagly & Chaiken, 1993) and tailor communications to specific target audiences based on issue familiarity and subject matter complexity. Given the low public awareness of CB in this study (30%), messaging campaigns should focus on increasing awareness of forest health threats (e.g., CB). In addition, results underscore the importance of focusing messaging campaigns on potential environmental benefits of using GE for mitigating this forest health threat (e.g., restoring historic tree species, mitigating tree diseases and pests) given that these benefits were usually the strongest predictor of attitudes.

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

Conclusion

To achieve conservation objectives, it is important to understand what drives opinions toward contemporary issues such as using modern technologies (e.g., GE) to help restore species and their habitats. GE has been used effectively to mitigate CB and restore AC trees in controlled laboratory and field trials. Researchers are now pursuing regulatory approval for commercial availability of transgenic AC trees (Powell, 2016; Steiner et al., 2017). If approval occurs, this issue will likely become even more contentious and, therefore, the results here will be more salient. These findings may also be applicable to other global forest health threats such as other diseases (e.g., sudden oak death), pests (e.g., emerald ash borer), and also climate change. Future work should examine drivers of attitudes toward using GE for addressing these threats.

Table 1. Verbatim wording for three GE use scenarios including information about chestnut blight (CB wording identical for all scenarios).

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
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.	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.	Transgenic

Table 2. Scenario-specific reliabilities for US public (first value) and forest interest groups 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])[1]					.89, .96
Disagree : Agree	2.88, 3.72	1.15, 1.21	.77, .85	.86, .96	
Pessimistic / Not Hopeful : Optimistic / Hopeful	3.00, 3.63	1.15, 1.22	.73, .87	.88, .96	
Bad : Good	2.74, 3.85	1.26, 1.18	.74, .94	.87, .93	
Foolish : Wise	2.79, 3.75	1.18, 1.15	.83, .94	.84, .94	
Perceived risks to humans[2]					.97, .97
Risk to yourself	3.03, 1.30	2.34, 1.84	.94, .95	n/a	
Risk to other humans or society in general	3.00, 1.48	2.09, 1.92	.94, .95	n/a	
Perceived environmental risks[2]					.98, .98
Risk to trees / forests	4.26, 2.82	2.17, 2.20	.97, .96	n/a	
Risks to the broader environment	4.32, 2.74	2.23, 2.30	.97, .96	n/a	
Perceived benefits to humans[2]					.98, .87
Benefits to yourself	2.33, 2.92	2.08, 2.41	.96, .76	n/a	
Benefits to other humans or society in general	2.51, 3.71	2.13, 2.29	.96, .76	n/a	
Perceived environmental benefits[2]					.98, .95
Benefits to trees / forests	3.48, 4.83	2.46, 2.29	.96, .90	n/a	
Benefits to the broader environment	3.32, 4.40	2.44, 2.33	.96, .90	n/a	
Scenario 2 – Add genes from distant species to AC					
Attitudes (DV)[1]					.94, .96
Disagree : Agree	2.53, 3.28	1.11, 1.26	.81, .87	.94, .96	
Pessimistic / Not Hopeful : Optimistic / Hopeful	2.63, 3.30	1.14, 1.22	.81, .90	.94, .95	
Bad : Good	2.53, 3.41	1.21, 1.29	.90, .93	.91, .94	
Foolish : Wise	2.60, 3.38	1.10, 1.19	.93, .92	.90, .94	
Perceived risks to humans[2]					.98, .95
Risk to yourself	3.45, 1.64	2.37, 2.05	.96, .90	n/a	
Risk to other humans or society in general	3.56, 1.99	2.35, 2.16	.96, .90	n/a	
Perceived environmental risks[2]					.98, .98
Risk to trees / forests	4.52, 3.50	2.21, 2.33	.97, .97	n/a	
Risks to the broader environment	4.50, 3.41	2.39, 2.34	.97, .97	n/a	
Perceived benefits to humans[2]					.95, .91
Benefits to yourself	2.02, 2.41	1.92, 2.24	.91, .84	n/a	
Benefits to other humans or society in general	2.20, 3.01	2.17, 2.24	.91, .84	n/a	
Perceived environmental benefits[2]					.99, .97
Benefits to trees / forests	3.13, 4.04	2.45, 2.37	.98, .95	n/a	
Benefits to the broader environment	2.96, 3.78	2.50, 2.35	.98, .95	n/a	

Table 2. Continued

Indices and variables	Mean	Std. dev	Item total correlation	Alpha if item deleted	Cronbach alpha
Scenario 3 – Add gene from bread wheat (OxO) to AC					
Attitudes (DV)[1]					.95, .96
Disagree : Agree	2.85, 3.37	1.27, 1.31	.87, .89	.94, .96	
Pessimistic / Not Hopeful : Optimistic / Hopeful	2.78, 3.28	1.20, 1.21	.85, .91	.95, .95	
Bad : Good	2.74, 3.32	1.35, 1.30	.87, .91	.94, .95	
Foolish : Wise	2.73, 3.33	1.22, 1.25	.95, .93	.92, .95	
Perceived risks to humans[2]					.98, .94
Risk to yourself	3.10, 1.79	2.36, 2.05	.96, .89	n/a	
Risk to other humans or society in general	3.16, 2.19	2.31, 2.19	.96, .89	n/a	
Perceived environmental risks[2]					.99, .99
Risk to trees / forests	4.16, 3.47	2.17, 2.20	.97, .97	n/a	
Risks to the broader environment	4.11, 3.50	2.24, 2.30	.97, .97	n/a	
Perceived benefits to humans[2]					.96, .89
Benefits to yourself	2.39, 2.40	2.04, 2.30	.92, .80	n/a	
Benefits to other humans or society in general	2.72, 3.05	2.16, 2.38	.92, .80	n/a	
Perceived environmental benefits[2]					.97, .98
Benefits to trees / forests	3.54, 4.17	2.39, 2.41	.93, .95	n/a	
Benefits to the broader environment	3.41, 3.85	2.34, 2.33	.93, .95	n/a	

[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.”

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

Indices and variables	Mean	Std. dev	Item total correlation	Alpha if item deleted	Cronbach alpha
Forest value orientations (specific)[1]					.80, .89
The needs of humans are more important than forests.[4]	3.53, 3.13	1.29, 1.25	.53, .59	.78, .88	
The primary value of forests is to provide benefits for humans.[4]	3.55, 3.22	1.54, 1.32	.58, .71	.78, .87	
Forests exist primarily to be used by humans.[4]	4.20, 3.82	1.08, 1.27	.61, .72	.77, .87	
Forests are valuable only if they provide jobs or income for people.[4]	4.60, 4.36	.75, .98	.41, .64	.79, .87	
The value of forests exists only in the human mind. Without people, forests have no value.[4]	4.60, 4.44	.92, 1.05	.33, .54	.80, .88	
Humans should manage forests so that only humans benefit.[4]	4.68, 4.64	.84, .73	.28, .46	.80, .88	
Forests have as much right to exist as people.	4.30, 3.58	1.02, 1.42	.60, .70	.77, 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	.71, .65	.76, .87	
Forests have value whether humans are present or not.	4.79, 4.51	.66, .92	.24, .53	.80, .88	
Forests should have rights similar to the rights of humans.	3.33, 2.20	1.39, 1.21	.51, .65	.79, .87	
Environmental value orientations (general)[1]					.87, .90
We are approaching the limit of the number of people the earth can support.	3.43, 3.44	1.28, 1.43	.56, .71	.86, .89	
Humans have the right to modify the natural environment to suit their needs.[4]	3.20, 2.61	1.34, 1.20	.44, .40	.87, .90	
When humans interfere with nature, it often produces disastrous consequences.	3.72, 3.30	1.20, 1.24	.51, .47	.87, .90	
Human ingenuity will ensure that we do not make the earth unlivable.[4]	3.04, 3.14	1.20, 1.25	.41, .46	.87, .90	
Humans are severely abusing the environment.	3.94, 3.48	1.24, 1.35	.63, .67	.86, .89	
The earth has plenty of natural resources if we just learn how to develop them.[4]	2.47, 2.85	1.25, 1.35	.40, .50	.87, .90	
Plants and animals have as much right as humans to exist.	3.98, 3.61	1.24, 1.27	.55, .64	.87, .89	
The balance of nature is strong enough to cope with the impacts of modern industrial nations.[4]	3.64, 3.87	1.14, 1.15	.57, .76	.86, .88	
The so-called ecological crisis facing humankind has been greatly exaggerated.[4]	3.35, 3.31	1.36, 1.49	.72, .78	.86, .88	
The earth is a closed system with very limited room and resources.	3.43, 3.62	1.26, 1.31	.55, .61	.87, .89	
Humans were meant to rule over the rest of nature.[4]	3.52, 3.71	1.39, 1.43	.60, .57	.86, .89	
The balance of nature is very delicate and easily upset.	3.88, 3.14	1.08, 1.21	.54, .50	.87, .90	
If things continue on their present course, we will soon experience a major ecological catastrophe.	3.65, 3.18	1.26, 1.40	.70, .75	.86, .88	
Trust in federal government agencies[2]					.85, .87
US Forest Service	5.41, 5.44	1.91, 2.01	.74, .76	n/a	
US Bureau of Land Management	4.92, 4.56	2.00, 2.05	.74, .76	n/a	
Trust in non-federal government agencies[2]					.84, .79
Local governmental agencies (city, county, town)	3.35, 3.61	1.96, 1.93	.73, .65	n/a	
State governmental agencies	3.13, 4.79	2.15, 1.84	.73, .65	n/a	
Perceived risks to forests from tree diseases[3]					.94, .71
Chestnut blight (a tree disease)	5.63, 4.90	2.05, 2.46	.89, .58	n/a	
Other tree diseases (e.g., blister rust, Dutch elm)	5.65, 5.73	2.11, 1.76	.89,.58	n/a	

[1] Cell entries are means on 5-point scale from “strongly disagree” to “strongly agree.”
[2] Cell entries are means on 9-point scale from “no trust” to “high trust.”
[3] Cell entries are means on 9-point scale from “no threat” to “extreme threat.”
[4] Item reverse coded for index.

Table 4. Means and group differences for cognitive and 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	< .001	.29
Perceived risks to humans[2]	3.02	1.37	5.52	< .001	.37
Perceived environmental risks[2]	4.25	2.78	4.58	< .001	.31
Perceived benefits to humans[2]	2.42	3.31	2.87	.005	.20
Perceived environmental benefits[2]	3.37	4.62	3.61	< .001	.25
Scenario 2 – Add genes from distant species to AC					
Attitudes[1]	2.75	3.34	3.45	.001	.24
Perceived risks to humans[2]	3.51	1.81	5.19	< .001	.35
Perceived environmental risks[2]	4.51	3.46	3.14	.002	.22
Perceived benefits to humans[2]	2.11	2.71	1.99	.048	.14
Perceived environmental benefits[2]	3.05	3.91	2.45	.015	.17
Scenario 3 – Add gene from bread wheat (OxO) to AC					
Attitudes[1]	2.93	3.32	2.18	.032	.15
Perceived risks to humans[2]	3.13	1.99	3.49	.001	.25
Perceived environmental risks[2]	4.14	3.49	2.01	.046	.14
Perceived benefits to humans[2]	2.56	2.72	.53	.598	.04
Perceived environmental benefits[2]	3.47	4.01	1.56	.121	.11
General Cognitions					
General environmental value orientations[3]	3.49	3.32	2.06	.040	.10
Specific forest value orientations[3]	4.16	3.77	5.26	< .001	.25
Trust in non-federal government agencies[4]	3.29	4.20	3.57	< .001	.24
Trust in federal government agencies[4]	5.18	5.00	.72	.471	.05
Perceived risks to forests from tree diseases[5]	5.63	5.25	1.94	.053	.09
Heard of chestnut blight (awareness) [8]	30	96	225.79	< .001	.67
Socio-demographic Characteristics					
Age (average number of years)	49	52	2.35	<.001	.11
Non-white[8]	11	6	3.90[b]	.048	.10
Female[8]	53	19	50.01[b]	< .001	.34
Income greater than $50,000[8]	58	92	66.65[b]	< .001	.39
College education or more[8]	43	94	131.14[b]	< .001	.52
Live in town with population >25,000 people[8]	46	45	.06	.808	.01
Political orientation[6]	2.80	2.86	.58	.561	.03
Proximity to a forest[7]	2.09	1.40	5.81	< .001	.25
Involved with forestry[8]	15	58	83.71[b]	< .001	.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.

Table 5. Partial and full model regressions for attitudes toward using GE to change existing genes in American chestnut trees to mitigate chestnut blight (Scenario 1).

	Public			FIGs		
	Partial models[6]		Full model[7] (R^2 = .85)	Partial models[6]		Full model[7] (R^2 = .59)
	Zero-order correlations (*r*)	β	β	Zero-order correlations (*r*)	β	β
Scenario-specific Cognitions[1]		R^2 = .84			R^2 = .64	
Perceived risks to humans	-.43***	.10		-.51***	-.06	
Perceived environmental risks	-.62***	-.35***	-.23***	-.65***	-.22	
Perceived benefits to humans	.72***	.14*	.16*	.56***	-.09	
Perceived environmental benefits	.86***	.64***	.64***	.77***	.68***	.77***
General Cognitions		R^2 = .23			R^2 = .09	
General env. value orientations[2]	.21*	.09		-.21	-.19	
Specific forest value orientations[2]	.33***	.25*	-.05	-.17	-.01	
Trust in non-federal agencies [3]	.20*	.05		.10	.16	
Trust in federal agencies [3]	.34***	.30**	.01	-.04	-.09	
Perceived risks to forests from tree diseases[4]	-.05	-.18		-.12	-.07	
Heard of chestnut blight (awareness)	-.21*	-.06		.14	.16	
Socio-Demographic Characteristics		R^2 = .25			R^2 = .14	
Age	.26**	.25*	.10*	.06	.03	
Non-white	-.02	< .001		-.23*	-.20	
Female	.08	.07		-.07	-.04	
Income greater than $50,000	-.24*	-.23*	-.06	.20	.23	
College education or more	-.08	-.09		-.04	-.04	
Live in town with population >25,000	.11	.19		-.04	-.11	
Political orientation	.07	-.08		.02	.03	
Proximity to a forest[5]	-.10	-.25*	.07	.01	-.03	
Involved with forestry	-.25**	-.24*	-.04	-.14	-.21	

[1] Cell entries are means on 9-point scales from “no risk/benefit” to “high risk/benefit.”
[2] Cell entries are means on 5-point scale from “strongly disagree” to “strongly agree.”
[3] Cell entries are means on 9-point scale from “no trust” to “high trust.”
[4] Cell entries are means on 9-point scale from “no threat” to “extreme threat.”
[5] Cell entries are means on 7-point scale from “within 1 mile” to “more than 100 miles.”
[6] Independent variables were tested for multicollinearity, which was generally not present, as all but four correlations among the independent variables were $r < .70$ (Vaske, 2008). 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.
[7] 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 ($\beta = .49$, $p < .001$) and environmental risks * environmental benefits ($\beta = -.35$, $p = .01$). There were no interaction effects for the FIG sample.
* = $p < .05$, ** $p < .01$, *** $p < .001$

Table 6. Partial and full model regressions for attitudes toward using GE to add genes from distant species to American chestnut trees to mitigate chestnut blight (Scenario 2).

	Public			FIGs		
	Partial models[6]		Full model[7] (R^2 = .82)	Partial models[6]		Full model[7] (R^2 = .71)
	Zero-order correlations (*r*)	β	β	Zero-order correlations (*r*)	β	β
Scenario-specific Cognitions[1]		R^2 = .79			R^2=.70	
Perceived risks to humans	-.58***	-.13		-.50***	.05	
Perceived environmental risks	-.64***	-.27***	-.42***	-.69***	-.32**	-.29**
Perceived benefits to humans	.69***	.15*	.10	.60***	-.02	
Perceived environmental benefits	.82***	.53***	.48***	.81***	.65***	.61***
General Cognitions		R^2 = .26			R^2 = .13	
General env. value orientations[2]	.11	-.05		-.23	-.27	
Specific forest value orientations[2]	.29**	.26*	-.03	-.20	-.01	
Trust in non-federal agencies [3]	.30**	.10		-.01	-.11	
Trust in federal agencies [3]	.43***	.30**	.08	.01	.14	
Perceived risks to forests from tree diseases[4]	.04	-.04		-.14	-.08	
Heard of chestnut blight (awareness)	-.26**	-.17		.22	.26*	.06
Socio-Demographic Characteristics		R^2 = .24			R^2 = .15	
Age	.18	.22*	.05	.13	.09	
Non-white	-.06	.07		-.22	-.21	
Female	.22*	.27*	.07	-.17	-.10	
Income greater than $50,000	-.19	-.19		.20	.23	
College education or more	-.06	-.06		.09	.10	
Live in town with population >25,000	.08	.17		-.01	-.06	
Political orientation	.05	< .01		.02	-.01	
Proximity to a forest[5]	-.19*	-.39**	-.18**	.02	< -.01	
Involved with forestry	-.16	-.07		-.12	-.14	

[1] Cell entries are means on 9-point scales from "no risk/benefit" to "high risk/benefit."
[2] Cell entries are means on 5-point scale from "strongly disagree" to "strongly agree."
[3] Cell entries are means on 9-point scale from "no trust" to "high trust."
[4] Cell entries are means on 9-point scale from "no threat" to "extreme threat."
[5] Cell entries are means on 7-point scale from "within 1 mile" to "more than 100 miles."
[6] Independent variables were tested for multicollinearity, which was generally not present, as all but five correlations among the independent variables were $r < .70$ (Vaske, 2008). 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.
[7] 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 = .28, p = .003).
* = $p < .05$, ** $p < .01$, *** $p < .001$

Table 7. Partial and full model regressions for attitudes toward using GE to add a gene from bread wheat (OxO) to American chestnut trees to mitigate chestnut blight (Scenario 3).

	Public			FIGs		
	Partial models[6]		Full model[7] (R^2 = .83)	Partial models[6]		Full model[7] (R^2 = .63)
	Zero-order correlations (*r*)	β	β	Zero-order correlations (*r*)	β	β
Scenario-specific Cognitions[1]		R^2 = .79			R^2 = .64	
Perceived risks to humans	-.47***	.06		-.46***	.13	
Perceived environmental risks	-.58***	-.27***	-.28***	-.69***	-.54***	-.47***
Perceived benefits to humans	.73***	.14		.58***	< .01	
Perceived environmental benefits	.86***	.67***	.67***	.70***	.46***	.40***
General Cognitions		R^2 = .26			R^2 = .08	
General env. value orientations[2]	.12	-.04		-.19	-.21	
Specific forest value orientations[2]	.28**	.25*	-.10*	-.18	-.06	
Trust in non-federal agencies [3]	.27**	.09		.07	-.08	
Trust in federal agencies [3]	.38***	.25*	.14**	.11	.22	
Perceived risks to forests from tree diseases[4]	-.03	-.07		-.08	-.02	
Heard of chestnut blight (awareness)	-.33***	-.24*	-.09	.09	.10	
Socio-Demographic Characteristics		R^2 = .24			R^2 = .16	
Age	.15	.13		.06	.01	
Non-white	-.09	.01		-.22	-.21	
Female	.26**	.21		-.15	-.08	
Income greater than $50,000	-.10	-.12		.24*	.28*	.05
College education or more	< .001	-.05		.09	.09	
Live in town with population >25,000	.08	.09		.10	.04	
Political orientation	.13	-.01		.07	.02	
Proximity to a forest[5]	-.14	-.31**	-.13**	.05	-.05	
Involved with forestry	-.34***	-.29*	-.07	-.14	-.13	

[1] Cell entries are means on 9-point scales from “no risk/benefit” to “high risk/benefit.”
[2] Cell entries are means on 5-point scale from “strongly disagree” to “strongly agree.”
[3] Cell entries are means on 9-point scale from “no trust” to “high trust.”
[4] Cell entries are means on 9-point scale from “no threat” to “extreme threat.”
[5] Cell entries are means on 7-point scale from “within 1 mile” to “more than 100 miles.”
[6] Independent variables were tested for multicollinearity, as all but five correlations among the independent variables were $r < .70$ (Vaske, 2008). 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.
[7] 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 = .53, $p < .001$) and environmental benefits * forest proximity (β = .39, $p = .046$). For FIGs, a significant interaction effect was found for environmental benefits * environmental risks (β = .25, $p = .048$).
* = $p < .05$, ** $p < .01$, *** $p < .001$

References

20 years of bio-lox. (2015). *Nature Biotechnology, 33*,(12), 1213.

Boecker, A., Hartl, J., & Nocella, G. (2008). How different are GM food accepters and rejecters really? A means-end chains application to yogurt in Germany. *Food Quality and Preference, 19*(4), 383–394.

Chang, S., Mahon, E. L., MacKay, H. A., Rottmann, W. H., Strauss, S. H., Pijut, P. M., … Jones, T. J. (2018). Genetic engineering of trees: progress and new horizons. *In Vitro Cellular & Developmental Biology - Plant, 54*(4), 341–376.

National Academies of Sciences, Engineering, and Medicine Committee on the Potential for Biotechnology to Address Forest Health, Board on Agriculture and Natural Resources, Division on Earth and Life Studies (NASEM). (2019). *Forest health and biotechnology: Possibilities and considerations*. Washington, D.C.: National Academies Press.

Condit, C. M. (2010). Public attitudes and beliefs about genetics. *Annual Review of Genomics and Human Genetics, 11*(1), 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. *Science Communication, 32*(4), 514–538.

De Groot, J. I. M., Steg, L., & Poortinga, W. (2013). Values, perceived risks and benefits, and acceptability of nuclear energy: Acceptability of nuclear energy. *Risk Analysis, 33*(2), 307–317.

Devine-Wright, P. (2005). Beyond NIMBYism: Towards an integrated framework for understanding public perceptions of wind energy. *Wind Energy, 8*(2), 125–139.

Dosman, D. M., Adamowicz, W. L., & Hrudey, S. E. (2001). Socioeconomic determinants of health-and food safety-related risk perceptions. *Risk Analysis, 21*(2), 307–318.

Dunlap, R. E. (2008). The new environmental paradigm scale: From marginality to worldwide use. *The Journal of Environmental Education, 40*(1), 3–18.

Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes* (Vol. xxii). Orlando, FL, US: Harcourt Brace Jovanovich College Publishers.

Fishbein, M., & Ajzen, I. (2011). *Predicting and changing behavior: The reasoned action approach*. New York, NY, Psychology Press, Taylor & Francis.

Fishbein, M., & Manfredo, M. J. (1992). A theory of behavior change. *Influencing Human Behavior, 24*(1), 29–50.

Frewer, L. J., Van der Lans, I. A., Fischer, A. R. H., Reinders, M. J., Menozzi, D., Zhang, X., … Zimmermann, K. L. (2013). Public perceptions of agri-food applications of genetic modification: A systematic review and meta-analysis. *Trends in Food Science & Technology, 30*(2), 142–152.

Frewer, L., Lassen, J., Kettlitz, B., Scholderer, J., Beekman, V., & Berdal, K. G. (2004). Societal aspects of genetically modified foods. *Food and Chemical Toxicology, 42*(7), 1181–1193.

Fulton, D. C., Manfredo, M. J., & Lipscomb, J. (1996). Wildlife value orientations: A conceptual and measurement approach. *Human Dimensions of Wildlife, 1*(2), 24–47.

Hajjar, R., & Kozak, R. A. (2015). Exploring public perceptions of forest adaptation strategies in Western Canada: Implications for policy-makers. *Forest Policy and Economics, 61,* 59–69.

Hajjar, R., McGuigan, E., Moshofsky, M., & Kozak, R. A. (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. *Canadian Journal of Forest Research, 44*(12), 1525–1533.

Jepson, P., & Arakelyan, I. (2017a). Exploring public perceptions of solutions to tree diseases in the UK: Implications for policy-makers. *Environmental Science & Policy, 76,* 70–77.

Jepson, P. R., & 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 and Economics, 80,* 167–177.

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 - Biogeosciences and Forestry*, 9(2), 344.

Kazana, Vassiliki, 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 C. Vettori, F. Gallardo, H. Häggman, V. Kazana, F. Migliacci, G. Pilate, & M. Fladung (Eds.), Biosafety of Forest Transgenic Trees (pp. 223–244). Springer Netherlands.

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. *Science Communication, 36*(1), 106–130.

Lang, J.T., & Hallman, W.K. (2005). Who does the public trust? The case of genetically modified food in the United States. *Risk Analysis, 25*(5), 1241–1252.

Merkle, S. A., Andrade, G. M., Nairn, C. J., Powell, W. A., & Maynard, C. A. (2006). Restoration of threatened species: A noble cause for transgenic trees. *Tree Genetics & Genomes*, *3*(2), 111–118.

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? *Agriculture and Human Values*, *30*(3), 471–480.

Moerbeek, H., & Casimir, G. (2005). Gender differences in consumers' acceptance of genetically modified foods. *International Journal of Consumer Studies*, *29*(4), 308–318.

Needham, M. D., & Vaske, J. J. (2008). Hunter perceptions of similarity and trust in wildlife agencies and personal risk associated with chronic wasting disease. *Society & Natural Resources*, *21*(3), 197–214.

Needham, M. D., Vaske, J. J., & Petit, J. D. (2017). Risk sensitivity and hunter perceptions of chronic wasting disease risk and other hunting, wildlife, and health risks. *Human Dimensions of Wildlife*, *22*(3), 197–216.

Neumann, P. D., Krogman, N. T., & Thomas, B. R. (2007). Public perceptions of hybrid poplar plantations: Trees as an alternative crop. *International Journal of Biotechnology*, *9*(5), 468–483.

Nilausen, C., Gélinas, N., Bull, G., Nilausen, C., Gélinas, N., & Bull, G. (2016). Perceived acceptability of implementing marker-assisted selection in the forests of British Columbia. *Forests*, *7*(11), 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 - Biogeosciences and Forestry*, *8*(5), 714–718.

Pardo, R., Midden, C., & Miller, J. D. (2002). Attitudes toward biotechnology in the European Union. *Journal of Biotechnology*, *98*(1), 9–24.

Perry, E. E., Needham, M. D., & Cramer, L. A. (2017). Coastal resident trust, similarity, attitudes, and intentions regarding new marine reserves in Oregon. *Society & Natural Resources*, *30*(3), 315–330.

Powell, W. (2016). New genetically engineered American chestnut will help restore the decimated, iconic tree. *The conversation*, *Jan*, *19*, 2016.

Rabino, I. (1998). Societal and commercial issues affecting the future of biotechnology in the United States: A survey of researchers' perceptions. *Naturwissenschaften*, *85*(3), 109–116.

Savadori, L., Savio, S., Nicotra, E., Rumiati, R., Finucane, M., & Slovic, P. (2004). Expert and public perception of risk from biotechnology. *Risk Analysis, 24*(5), 1289–1299.

Scott, S. E., Inbar, Y., & Rozin, P. (2016). Evidence for absolute moral opposition to genetically modified food in the United States. *Perspectives on Psychological Science, 11*(3), 315–324.

Siegrist, M. (1998). Belief in gene technology: The influence of environmental attitudes and gender. *Personality and Individual Differences, 24*(6), 861-866.

Siegrist, M. (2000). The influence of trust and perceptions of risks and benefits on the acceptance of gene technology. *Risk Analysis, 20*(2), 195–204.

Siegrist, M., Cvetkovich, G., & Roth, C. (2000). Salient value similarity, social trust, and risk/benefit perception. *Risk Analysis, 20(3),* 353–362.

Sjoberg, L. (2004). Explaining individual risk perceptions: The case of nuclear waste. *Risk Management, 6*(1), 51–64.

Slovic, P. (1999). Trust, emotion, sex, politics, and science: Surveying the risk-assessment battlefield. *Risk Analysis, 19*(4), 689–701.

Slovic, P. (2010). *The feeling of risk: New perspectives on risk perception*. Routledge.

Steiner, K. C., Westbrook, J. W., Hebard, F. V., Georgi, L. L., Powell, W. A., & Fitzsimmons, S. F. (2017). Rescue of American chestnut with extraspecific genes following its destruction by a naturalized pathogen. *New Forests, 48*(2), 317–336.

Strauss, S. H., Jones, K. N., Lu, H., Petit, J. D., Klocko, A. L., Betts, M. G., … Needham, M. D. (2017). Reproductive modification in forest plantations: Impacts on biodiversity and society. *New Phytologist, 213*(3), 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 *Biosafety of Forest Transgenic Trees* (pp. 245–261). Springer, Dordrecht.

Vaske, J., & Donnelly, M. (1999). A value-attitude-behavior model predicting wildland preservation voting intentions. *Society & Natural Resources, 12*(6), 523–537.

Vaske, J., Donnelly, M., Williams, D., & Jonker, S. (2001). Demographic influences on environmental value orientations and normative beliefs about national forest management. *Society & Natural Resources, 14*(9), 761–776.

Vaske, J. J. (2008). *Survey research and analysis: Applications in parks, recreation and human dimensions*. Venture Publishing State College, PA.

Wheeler, N., & Sederoff, R. (2008). Role of genomics in the potential restoration of the American chestnut. *Tree Genetics & Genomes, 5*(1), 181–187.

Whittaker, D., Vaske, J. J., & Manfredo, M. J. (2006). Specificity and the cognitive hierarchy: Value orientations and the acceptability of urban wildlife management actions. *Society & Natural Resources, 19*(6), 515–530.

Wilson, R. S., & Arvai, J. L. (2006). When less is more: How affect influences preferences when comparing low and high- risk options. *Journal of Risk Research, 9*(2),165–178.

Zhang, B., Oakes, A. D., Newhouse, A. E., Baier, K. M., Maynard, C. A., & Powell, W. A. (2013). A threshold level of oxalate oxidase transgene expression reduces Cryphonectria parasitica-induced necrosis in a transgenic American chestnut (Castanea dentata) leaf bioassay. *Transgenic Research, 22*(5), 973–982.

CHAPTER THREE

SOCIAL TRUST, PERCEPTIONS OF RISKS AND BENEFITS, AND NORMATIVE ACCEPTANCE OF GENETIC ENGINEERING IN FOREST CONSERVATION

Introduction

As forests are inextricably linked to the history, land ethic, and public identity in the United States (US), conserving these natural resources (NRs) is thought to be a national priority (Nash, 2014). Threats to forests (e.g., diseases, pests, climate change), however, are common and have negative environmental, social, and economic ramifications. Given the value of forests (e.g., timber, recreation) in an increasingly developed landscape, it is important to consider all potential strategies and tools available to mitigate these threats. In addition to traditional forestry practices such as silviculture and conventional breeding, biotechnology (e.g., genetic engineering [GE]), might also be a useful tool in these efforts (e.g., to enhance pest or disease resistance). GE involves using laboratory approaches to modify existing genes within an organism or insert genes from either sexually compatible (i.e., cisgensis / cisgenics) or incompatible organisms (i.e., transgenesis / transgenics) (Burdon & Libby, 2006). A critical assessment of these technologies requires understanding their potential benefits and risks, and whether different groups (e.g., public, special interest groups) accept these technologies and trust government agencies to safely utilize and regulate them in the future.

One tree species that has received increasing attention in the field of biotechnology is the American chestnut (AC) (*Castanea dentata*), which was a keystone species in eastern US forests that provided sanctuary for wildlife and high quality timber (e.g., durable, rot-resistant) and food (i.e., chestnuts) for humans (Merkle, Andrade, Nairn, Powell, & Maynard, 2006). Around 1900, a fungus (*Cryphonectria parasitica*) that causes chestnut blight (CB) was accidentally introduced to the US from Asia and has since largely decimated this species (up to 99% mortality) (Wheeler & Sederoff, 2008). This pathogen enters through bark wounds and emits oxalic acid that destroys the cambium and kills the tree above the infection point (Zhang et al., 2013).

Scientists have attempted many strategies for increasing resistance to CB and restoring this tree species to its historic range (e.g., breeding, hybridization with CB-resistant Asian chestnut species, biotechnologies). For example, GE has been used for enhancing resistance to CB, and one successful approach involves inserting a gene from bread wheat that encodes the oxalate oxidase (OxO) enzyme that breaks down oxalic acid (Zhang et al., 2011, 2013). Given the success of field trials, researchers are now seeking regulatory approval for releasing these transgenic AC trees at a broader scale (Chang et al., 2018; Steiner et al., 2017).

The practical utility and efficacy of technologies such as GE partially depend on social acceptance (see Frewer et al., 2013 for review). Recent studies, especially in the United Kingdom (UK) and Canada, have assessed public acceptance of using GE for addressing forest health threats (see NASEM, 2019 for review). Hajjar and Kozak (2015), for example, found that using GE to enhance tree adaptability to climate change was more acceptable than doing nothing. Jepson and Arakelyan (2017a, b) found that cisgenic approaches were acceptable for addressing ash dieback in the UK. Given the various benefits that forests provide, it is important to understand acceptance of using GE as a tool in forest conservation, as well as other cognitive factors related to this acceptance. This article, therefore, examines relationships among social trust, perceived risks and benefits, and acceptance of three potential applications of GE for mitigating CB and restoring AC trees.

Conceptual Foundation

Norms

Acceptance of using GE for restoring AC trees is related to the concept of *norms*, which are defined as standards that individuals use for evaluating conditions, activities, or management actions as unacceptable or acceptable; norms clarify what people believe should or should not be allowed in a given context (Vaske & Whittaker, 2004). Personal norms can be aggregated to assess broader societal norms about an issue (Vaske & Whittaker, 2004; Zinn, Manfredo, Vaske, & Wittmann, 1998). Assessing group differences in normative acceptance of NR issues has been a prominent line of research (see Vaske & Whittaker, 2004 for review), especially between the general public and other interest groups (e.g., scientists, agencies). Research has shown, for example, that non-governmental organizations (NGOs), indigenous groups, and the general public are sometimes less accepting of biotechnologies such as using GE in forestry compared to other groups such as scientists and private industry personnel (Friedman & Foster, 1997; Hajjar, McGuigan, Moshofsky, & Kozak, 2014; Jepson & Arakelyan, 2017; Nilausen et al., 2016).

Normative acceptance of using various technologies in NR management has been investigated for issues such as nuclear energy (de Groot, Steg, & Poortinga, 2013; Visschers, Keller, & Siegrist, 2011), agriculture (Shew et al., 2015), forest insect disturbances (McFarlane & Witson, 2008), and intensive forestry (Williams, 2014). Compared to the literature on acceptance of using GE in agriculture (i.e., food), acceptance of using GE in forestry has received much less attention. A small number of studies have, however, focused on acceptance of biotechnologies such as using GE to: (a) improve the resilience of forests to climate change and disease, and (b) increase timber and biofuel production (Hajjar & Kozak, 2015; Hajjar et al., 2014; Jepson & Arakelyan, 2017; Jepson & Arakelyan, 2017; Kazana et al., 2016; Nonić, Radojević, Milovanović, Perović, & Šijačić-Nikolić, 2015; Tsourgiannis, Kazana, & Iakovoglou, 2016). Little research, however, has examined acceptance of using GE in tree species in the US such as the AC, and this warrants attention given that GE is being considered for mitigating CB and other forest threats (e.g., diseases, pests, climate change)(NASEM, 2019).

Perceived Risks

Perceived risks are often negatively associated with normative acceptance of technologies and NR management actions (Needham & Vaske, 2008; Siegrist, 2000). Compared to objective risk assessments (i.e., actual probabilities and consequences of hazards), perceived risks are subjective evaluations of hazards (Slovic, Fischhoff, Lichtenstein, & Roe, 1981). Risk targets can include risks to oneself (i.e., personal risk), society (i.e., general risk), or other entities (e.g., environment, forests). These distinctions are important, as individuals often rate personal risks lower than risks to other people or objects, which is known as a degree of risk denial (Sjöberg, 1998). Group differences in risk perceptions also exist where members of the public often tend to rate risks more subjectively than do more specific interest groups (e.g., scientists, agencies) who often form these perceptions based on more objective probabilities and consequences of hazards (Thompson & Dean, 1996). As a result, these interest groups often perceive technologies as less risky (i.e., safer) than do members of the general public (Savadori et al., 2004; Sjöberg, 1998).

Risk perceptions have been investigated in relation to NR issues such as wildlife diseases (Needham & Vaske, 2008; Needham, Vaske, & Petit, 2017), forest insect disturbances (McFarlane, Parkins, & Watson, 2012), and nuclear energy and waste (Visschers et al., 2011; Whitfield, Rosa, Dan, & Dietz, 2009). In the context of using GE in forestry, researchers in the UK investigated potential solutions for addressing ash dieback and found that although the public was generally supportive of some GE approaches, they were concerned about risks related to tampering with nature (Jepson & Arakelyan, 2017). Tsourgiannis, Kazana, and Iakovoglou (2016) found that concerns about human health and environmental impacts discouraged some people from supporting transgenic forest products in Greece. Kazana et al. (2015) examined perceived risks of using GE in plantation forestry and found that biodiversity impacts from potential unintended gene flow into wild forests were a concern for their respondents.

Perceived Benefits

Perceived benefits can also be related to normative acceptance of GE. Perceived benefits are subjective evaluations that a particular behavior, entity, or technology will yield positive outcomes (De Groot et al., 2013). Similar to risk perceptions, perceived benefits can be assessed in relation to different targets (e.g., self, society, environment). These benefits have been examined in many contexts including nuclear energy (Visschers et al., 2011), medicine (James, Campbell, & Hudson, 2002), tourism and recreation (Tew & Barbieri, 2012), and conservation (Bottrill, Mills, Pressey, Game, & Groves, 2012). Most research on perceived benefits of GE has focused on agriculture (i.e., food) where researchers have found positive relationships between perceived benefits and normative acceptance (Blaine, Kamaldeen, & Powell, 2002). In the context of forestry, acceptance of biotechnologies (e.g., GE) have been associated with perceived benefits such as improved consumer choice (Tsourgiannis et al., 2016), reduced pesticide and herbicide inputs, increased tree growth (Kazana et al., 2015, 2016), and reduced harvest pressure on wild forests (Nilausen et al., 2016). These perceptions of benefits are highly contextual and can vary according to factors such as forest ownership type and scale (e.g., large plantation vs. small private forests), and the intention for employing the technologies (e.g., timber production vs. forest restoration) (Strauss et al., 2017).

Social Trust

Social trust can be a related to benefits, risks, and normative acceptance of GE (Connor & Siegrist, 2010). Trust is defined as the willingness to rely on individuals or organizations responsible for making decisions or taking actions affecting public health, safety, and wellbeing (Siegrist, Cvetkovich, & Roth, 2000). The public may trust external sources (e.g., scientists, agencies) because of their expertise in assessing hazards associated with technologies (Siegrist, 2000). Trust has been examined in various NR contexts, including nuclear power, pesticides (Siegrist et al., 2000; Xiao, Liu, & Feldman, 2017), wildlife diseases (Needham & Vaske, 2008), and forestry issues such as insect outbreaks (McFarlane et al., 2012), wildfires (Shindler & Mallon, 2011), prescribed burning, and mechanical thinning (Vaske, Absher, & Bright, 2007).

Trust in officials charged with managing hazards has generally been associated with lower perceived risks, greater benefits, and more acceptance (Connor & Siegrist, 2010; Perry, Needham, & Cramer, 2017; Stern & Coleman, 2015; Vaske et al., 2007; Xiao et al., 2017). These relationships have also been examined in the context of forest conservation in general and the use of GE in forests in particular. Research conducted mostly in Europe and Canada has demonstrated that trust is often negatively associated with perceived risks of using GE in forestry, and positively associated with both perceived benefits and acceptance of these uses of GE (Connor & Siegrist, 2010; Hajjar & Kozak, 2015; Jepson & Arakelyan, 2017; Neumann, Krogman, & Thomas, 2007). Additional research on these relationships is warranted in the context of this study given the utility of GE for mitigating CB and the possible availability of transgenic AC trees in the future (Chang et al., 2018; Powell, 2016; Steiner et al., 2017).

Hypotheses

This article builds on this literature by examining relationships among social trust, perceived risks, perceived benefits, and normative acceptance within the context of using various GE approaches for mitigating CB and restoring AC trees. The model in Figure 1 shows the proposed relationships among these concepts based on the literature discussed above (e.g., Vaske et al., 2007; Visschers et al., 2011; Xiao et al., 2017). Five hypotheses are advanced:

H_1: Perceived risks (to humans, to the environment) of using GE to mitigate CB and restore AC trees will be negatively related to normative acceptance of this use of GE.

H_2: Perceived benefits (to humans, to the environment) of using GE to mitigate CB and restore AC trees will be positively related to normative acceptance of this use of GE.

H_3: Trust in agencies (federal, nonfederal) will be negatively related to perceived risks (to humans, to the environment) of using GE to mitigate CB and restore AC trees.

H_4: Trust in agencies (federal, nonfederal) will be positively related to perceived benefits (to humans, to the environment) of using GE to mitigate CB and restore AC trees.

H_5: Trust in agencies (federal, nonfederal) will be positively related to normative acceptance of using GE to mitigate CB and restore AC trees.

This article also examines whether these relationships among concepts differ between the general public and forest interest groups (FIGs [scientists, agencies, businesses, NGOs]). In addition, this article investigates whether perceived risks and benefits mediate any relationships between social trust and normative acceptance of using GE in this context. Mediation (partial, full) occurs when a given variable or concept accounts for any relationships between the predictor (i.e., trust) and criterion (i.e., normative acceptance) variables (Baron & Kenny, 1986).

Methods

Data Collection

Data were obtained from a mixed-mode survey of the US public and other FIGs (i.e., university scientists, government agency representatives, companies, and NGOs involved in forest issues) between January and June 2015. Sampling of the public was stratified by those living: (a) within the historic native range of the AC (i.e., chestnut counties), and (b) in the rest of the contiguous US (i.e., non-chestnut counties). The public was then sampled randomly and proportionally to county-level populations using US zip codes. The FIGs consisted of a purposive sample selected based on expertise and involvement in forest-related issues. Six contacts were used for increasing responses: (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) personal telephone call to encourage participation, (e) second full mailing, and (f) final full mailing.

In total, 473 completed questionnaires were received (15% response rate). Completions for each stratum included: (a) 142 from the general 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 a random sample (n = 107) of nonrespondents from the public samples was conducted to determine if responses differed between respondents and nonrespondents, but no substantive differences were found. Demographic characteristics of respondents from the public samples were also compared to US Census data to investigate potential differences between the public samples and the population. There were slight differences in age (sample was slightly older) and education (sample was slightly more educated), which required weighting the data. No other substantive differences were detected. Few substantive differences were found between respondents from counties within the historic native range of the AC and those from other counties, so responses from these two samples were aggregated into a single public sample. Responses across each FIG (scientists, agencies, businesses, NGOs) were also aggregated because they were not necessarily statistically representative of each group and the number of respondents in each group was too small for rigorous statistical comparisons among groups (n = only 35-61 per group).

Analysis Variables

Scenarios were embedded within the questionnaire for measuring cognitions in response to three GE approaches for mitigating CB and restoring AC trees (see Table 8 for scenario wording). Based on expert feedback from initial focus group sessions and pretesting, these scenarios were worded as neutrally as possible to avoid potential framing effects. For all scenarios, respondents were presented with a brief description of CB: "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 scenario was: "Adding a gene from a distantly related organism to AC trees." The third scenario was: "Adding a gene from wheat (e.g., bread wheat) to AC trees."

Normative acceptance of each scenario was measured using two separate 5-point semantic differential scales ("unacceptable" to "acceptable" and "should not allow" to "should allow"). These scales are consistent with previous research measuring norms (e.g., Ceurvorst & Needham, 2012; Vaske & Whittaker, 2004). *Perceived risks* were measured by asking "To what extent do you think this scenario would pose a risk to each of the following?" with four risk targets: "trees / forests," "the broader environment," "yourself," and "other humans or society in general." These were measured on 9-point scales from "no risk" to "high risk." *Perceived benefits* associated with these same four targets were measured by asking "To what extent do you think this scenario would benefit each of the following?" with responses on 9-point scales from "no benefit" to "highly benefit."

Trust was not measured in direct response to these scenarios. Respondents were asked "How must trust do you have in each of the following individuals or groups to positively contribute to the management / stewardship of forests:" (a) "local government agencies (city, county, town);" (b) "state government agencies;" (c) "US Forest Service" (USFS); and (d) "US Bureau of Land Management" (BLM) on 9-point scales from "no trust" to "high trust."

Data Analyses

Descriptive analyses (e.g., percentages, means) were conducted for both the public and FIG samples. Cronbach's alpha was used for testing measurement reliability of the multiple questionnaire items measuring each concept to justify computing mean composite indices (trust in federal agencies [USFS, BLM]; trust in nonfederal agencies [local, state]; risks to humans [yourself, other humans or society in general]; environmental risks [trees / forests, the broader environment]; benefits for humans [yourself, other humans or society in general]; environmental benefits [trees / forests, the broader environment]; acceptance of each GE approach [should not allow / should allow, unacceptable / acceptable]). Independent-samples *t*-tests and point-biserial correlation (r_{pb}) effect sizes tested for any differences between the public and FIGs in these scale indices measuring each concept. SPSS version 24 software was used for these analyses.

Confirmatory factor analysis (CFA) tested the construct validity of these scales measuring each concept and then structural equation modeling (SEM) tested the predictive validity of the hypotheses listed above and shown in Figure 1. SEM also assessed whether perceived risks and benefits mediated (either fully or partially) any relationships between trust in the agencies and acceptance of each GE approach. EQS version 6.3 software with the Robust estimation procedure (to account for multivariate nonnormality) was used for these analyses. Fit indices included the comparative fit index (CFI), root mean squared error of approximation (RMSEA), nonnormed fit index (NNFI), and χ^2/df to ensure acceptable model fit (CFI and NNFI $\geq$ .90, RMSEA $\leq$ .08, χ^2/df $\leq$ 2:1 to 5:1) based on guidelines from Byrne (2006).

Results

Cronbach alpha reliabilities for each scenario for the public and FIG samples ranged from .95 to .99 for perceived environmental benefits, .87 to .98 for perceived benefits for humans, .98 to .99 for perceived environmental risks, .94 to .98 for perceived risks to humans, and .96 to .98 for normative acceptance of these GE applications (Table 9). Alpha reliabilities for the public and FIG samples were also .85 and .87 for trust in federal agencies, and .84 and .79 for trust in nonfederal agencies, respectively. Deletion of any variable from its respective concept would not have improved reliability. All of these alpha reliability coefficients exceeded the standard of $\geq$ .65 suggested by Vaske (2008), indicating high internal consistency among the variables measuring each concept and justifying computing mean composite indices for each concept.

For all three scenarios, the public sample was significantly less accepting (M = 2.77 to 2.93) of these uses of GE than were the FIGs (M = 3.42 to 4.00), t = 2.45 to 6.13, $p \leq$ .015 (Table 10). Using guidelines from Vaske (2008) for interpreting effect sizes, the point-biserial correlation effect sizes were “substantial” (r_{pb} = .40) for scenario 1, “typical” for scenario 2 (r_{pb} = .26), and between “minimal” and “typical” for scenario 3 (r_{pb} = .17). The public sample also viewed all three GE applications as riskier to both the environment (M = 4.14 to 4.51) and humans (M = 3.02 to 3.51) than did the FIGs (environment: M = 2.78 to 3.55; humans: M = 1.37 to 1.99; t = 2.01 to 5.69; $p \leq$ .046). The effect sizes ranged from r_{pb} = .14 to .37 (“minimal” to "substantial"). The FIGs viewed all three scenarios as more beneficial to both the environment (*M* = 3.91 to 4.61) and humans (*M* = 2.71 to 3.31) than did the public sample (environment: *M* = 3.05 to 3.47; humans: *M* = 2.11 to 2.56) and these differences were significant (t = 1.99 to 3.61, $p \leq .048$) with "minimal" to "typical" effect sizes (r_{pb} = .14 to .25) for changing existing AC genes (scenario 1) and adding genes from distant species to the AC (scenario 2), but not for adding a gene from bread wheat to AC trees (scenario 3) (t = .53 to 1.56, p = .121 to .598). Comparing across scenarios, the public sample considered adding genes from distant species to the AC to be the riskiest, least beneficial, and most unacceptable, whereas the FIGs generally viewed adding a gene from bread wheat (OxO gene) to the AC in this manner. The public sample (*M* = 3.29) trusted nonfederal government agencies charged with managing forests significantly less than did the FIGs (*M* = 4.20), t = 3.57, $p < .001$. The strength of this difference (r_{pb} = .24) was "typical." Conversely, trust in federal agencies was slightly higher among the public sample (*M* = 5.17) than the FIGs (*M* = 5.00), but this difference was not significant, t = 0.66, p = .511.

The data fit the models for both samples, with CFIs ranging from .95 to .99 across the three scenarios for the public and .98 to .99 for the FIGs. The NNFIs ranged from .92 to .99 for the public and .96 to .98 for the FIGs. The RMSEAs were .04 to .11 for the public and .02 to .07 for the FIGs. The χ^2/df ranged from 1.15 to 2.16 for the public and 1.02 to 1.40 for the FIGs. The CFA factor loadings for each variable measuring its respective concept all exceeded .71 (Table 9), which is well above the typical guideline of approximately $\geq$ .40 (Byrne, 2006).[1]

Figures 2 through 4 show the final SEM results and associated statistics (i.e., β, R^2) for each scenario. As hypothesized, perceived environmental risks were significantly ($p < .05$) and negatively related to normative acceptance of all three GE scenarios for both the public (β = -.26 to -.39) and FIGs (β = -.32 to -.63). In other words, those who perceived that using these GE approaches for helping AC trees resist CB was risky to the environment were less likely to accept using these approaches. Perceived risks to humans, however, were only significantly and negatively associated with acceptance for the public sample for adding genes from distant species to the AC (scenario 2; $\beta = -.19$); there were no other significant relationships between human risks and acceptance of GE. As also hypothesized, perceived environmental benefits were significantly and positively associated with acceptance of all three GE scenarios for both the public ($\beta = .40$ to $.64$) and FIGs ($\beta = .53$ to $.83$). Those who perceived environmental benefits of these GE approaches for helping AC trees resist CB were more likely to accept using these approaches. Perceived benefits toward humans, however, were not related to acceptance of any scenario for either group. The overall variance explained in normative acceptance of these uses of GE ranged from 66% to 76% for the public and 68% to 75% for the FIGs, with acceptance largely related to perceived environmental risks and benefits for both groups.

As hypothesized, public trust in federal agencies was negatively associated with environmental risks for changing existing AC genes and adding genes from distant species to the AC (scenarios 1 and 2; $\beta = -.22$ to $-.28$), but not for adding a gene from bread wheat to the AC (scenario 3). Conversely, a positive relationship was found between these concepts, but only for the first scenario for the FIGs ($\beta = .29$). Trust in federal agencies was also positively associated with risks to humans for this scenario for the FIGs ($\beta = .39$), but not for the other two scenarios or for the public across all three scenarios. Trust in nonfederal agencies was not significantly associated with environmental or human risks for any of the three scenarios for both the public and FIGs. For these few relationships between trust and risks, only 2% to 9% of the variance in environmental risks and 3% to 18% of the variance in human risks were explained by trust.

Relationships between trust and benefits varied across the three scenarios. As hypothesized, FIG trust in nonfederal agencies was significantly and positively associated with environmental benefits of changing existing AC genes (scenario 1; $\beta = .27$), but this relationship was insignificant for the other two scenarios and for the public across all three scenarios. This same positive association was also found between FIG trust in nonfederal agencies and perceived benefits to humans for scenario 1 ($\beta = .27$), but not for the other two scenarios or for the public across any scenario. As also hypothesized, trust in federal agencies was positively associated with environmental benefits of all three scenarios for the public sample ($\beta = .27$ to .40), but this relationship was insignificant for the FIGs across all scenarios. Trust in federal agencies was also positively associated with perceived benefits to humans, but only for the public for scenario 1 (changing existing AC genes; $\beta = .23$). Taken together, only 1% to 18% of the variance in environmental benefits and 0% to 9% of the variance in human benefits were explained by trust.

The potential role of perceived environmental and human risks and benefits mediating any relationships between trust in federal and nonfederal agencies (predictors) and normative acceptance (criterion) was examined for both samples for each scenario. For scenario 1, there was no mediation for the FIGs given that all initial direct paths between the predictors and the criterion were not significant ($p > .05$). In the direct effects model for the public, however, there was a significant relationship between trust in federal agencies and normative acceptance for this scenario. In the partial mediation models, the path coefficients between this trust and both environmental risks and benefits were significant, and the paths between these risks and benefits and normative acceptance were also significant. The initial direct relationship between this trust and normative acceptance, however, was no longer statistically significant, indicating full mediation in these two instances (i.e., mediation by both environmental risks and benefits).

Further support for these full mediation models was evident from the change in chi-square statistics (i.e., chi-square difference tests). The full mediation models had significantly better fits than did the direct effects models in these two instances, but were statistically equivalent to the partial mediation models ($\Delta\chi^2 = 2.02\text{-}2.41$, $p = .121\text{-}.155$). These same patterns and similar statistics indicating full mediation were also observed for these two instances for public responses to scenario 2. For public responses to scenario 3, mediation was observed for only one of these instances where environmental benefits fully mediated the relationship between trust in federal agencies and normative acceptance. There was no mediation observed for any of the three scenarios for the FIGs.

Discussion

These findings contribute to the small body of research on acceptance of GE in the context of forest conservation, and have important implications for managing GE as a response to forest health threats. Compared to the public sample, the FIGs viewed all three GE approaches for mitigating CB and restoring the AC as more acceptable, less risky, and more beneficial. This finding is consistent with research in other contexts. Savadori et al. (2004), for example, found that experts in their study (i.e., professors or Ph.D. students in biology at an Italian university) viewed food and medical biotechnologies as less risky and more useful than did the public. Similar patterns have also been found in the context of forestry (Hajjar, McGuigan, Moshofsky, & Kozak, 2014; Nilausen et al., 2016). Nilausen et al. (2016), for example, found that representatives of government agencies and the forest industry were more supportive of using forest biotechnologies than were citizen organizations (i.e., NGOs) and indigenous populations. These differences may occur because special interest groups (e.g., scientists, agencies) tend to judge risks more objectively and accurately (i.e., estimates closer to actual probabilities), whereas the public often perceives risk more subjectively (Thompson & Dean,1996).

Results also showed that perceived environmental benefits were positively related to normative acceptance of all three GE approaches, and were the strongest predictor of public acceptance for all three scenarios and FIG acceptance for two scenarios. This finding is contrary to many studies that have shown perceived environmental or human risks to be primary determinants of acceptance of genetic technologies (Frewer et al., 2004; Siegrist, 2000; Strauss et al., 2017). This finding might relate to the most obvious beneficiaries of GE in this context. Forest conservation efforts, such as mitigating CB and restoring AC trees, might be seen as benefitting trees and forests (i.e., the environment) more so than eliciting perceptions of risks to humans or otherwise. In fact, a few studies have shown that perceived benefits are more strongly related to GE acceptance than are perceived risks (Connor & Siegrist, 2010). Gaskell et al. (2004), for example, examined public perceptions of GE foods and concluded that the absence of perceived benefits was a stronger predictor of opposition to GE than was the presence of perceived risks. Visschers et al. (2011) found that perceived benefits of a secure energy supply were stronger predictors of acceptance of nuclear energy than were perceived risks. These findings suggest that the relative importance of perceived risks and benefits in relation to acceptance of GE can vary by context (e.g., forest conservation, food, energy).

In addition to environmental benefits, perceived environmental risks were also related to public and FIG acceptance across all three scenarios, with higher perceived risks associated with lower acceptance of each GE approach. Perceived risks to humans were also significantly related to public acceptance, but only for inserting a gene from a distant species (scenario 2). These findings are consistent with research in other GE contexts showing that risks are often inversely related to acceptance (see Gupta, Fischer, & Frewer, 2011, for review). Although studies examining relationships between risks and acceptance of using GE in the context of forest conservation are rare, Strauss et al. (2017) hypothesized that acceptance of using biotechnologies in plantation forestry is likely to be negatively related to perceived risks and positively related to perceived benefits. Results presented here confirm these relationships in a forestry context.

These findings also showed differences in risk and benefit perceptions across targets (i.e., to humans vs. the environment). Perceptions of environmental benefits and risks were most strongly related to normative acceptance of using GE to mitigate CB and restore AC trees. Perceived benefits and risks to humans, however, were not strongly related to acceptance. In fact, only one of 12 potential relationships between acceptance and human risks and benefits was statistically significant. This finding is inconsistent with most studies on perceived risks and benefits of GE, which have generally focused on risks and benefits to humans in relation to acceptance of GE. Studies on using GE in food, in particular, have emphasized perceived human health concerns from consuming GE foods as a primary driver of acceptance (see Frewer et al., 2013, for review). In this study, however, both the public and FIG samples viewed the topic of using GE to mitigate CB and restore AC trees as having more environmental implications than consequences for humans. Although somewhat novel, this finding is logical given that the context of this study involves forest conservation and restoration. Future research should examine various risk and benefit targets in other forest conservation contexts (e.g., climate change, other pests and diseases) to see if results found here generalize to these other contexts.

Findings also suggest that trust played a role in predicting risks, benefits, and acceptance of using GE in this context of forest conservation, but this was not a substantial role because trust explained only 18% or less of the variance in these cognitions. As hypothesized and consistent with past research, public trust in federal agencies was positively associated with environmental benefits across all three scenarios, and negatively associated with environmental risks across two of these scenarios (Siegrist, 2000). This suggests that increasing public trust in federal agencies responsible for managing forests may reduce perceptions of environmental risks and increase perceptions of environmental benefits associated with using GE for forest restoration purposes.

For the FIGs, trust in federal agencies was also related to perceived environmental and human risks, but only for changing existing AC genes (scenario 1) and these relationships were positive, not negative. This finding is incongruent with the hypotheses and most of the existing literature that has shown an inverse relationship between trust and perceived risks. Needham and Vaske (2008), for example, found that hunters who trusted agencies to manage chronic wasting disease in deer and elk reported slightly lower risk perceptions associated with the disease compared to those with less trust. Likewise, Xiao et al. (2017) found that trust led to lower risk perceptions and greater acceptance of nuclear power plants in China. Other research, however, has sometimes found a positive relationship between trust and perceived risks, although this is comparatively uncommon. McFarlane et al. (2012), for example, reported a positive relationship between trust in managers and perceived risks from mountain pine beetle (*Dendroctonus ponderosae*) outbreaks in Canada. The authors suggested that this finding likely related to communication efforts at the time that emphasized risks from the outbreaks rather than minimizing public concerns. As the Canadian public trusted these managers and their messaging, perceived risks increased. In the context of using GE to mitigate CB and restore AC trees, one possible explanation for the results found here is that FIGs, on average, moderately trust federal agencies (M = 5.00 on 9-point scale), but may still perceive potential risks associated with these uses of GE because they remain largely unknown, inevitable, or outside of federal agency control. Research has shown, for example, that technologies such as GE can be viewed with concern due to unforeseen or unintended consequences, which can be difficult to anticipate and manage irrespective of the competence or trustworthiness of those responsible for managing the technologies (Sjöberg, 2004). This line of research warrants more investigation and might provide insight into the complexity of understanding and communicating potential risks of GE.

Trust in nonfederal government agencies was significantly and positively related to FIG perceptions of environmental and human benefits, but only for changing existing AC genes (scenario 1). There were also no relationships between trust in nonfederal agencies and both risks and benefits for the public sample. These results might suggest that FIGs view local agencies as on-the-ground facilitators of benefits from applications of GE such as cisgensis (e.g., modifying existing genes), which may be more acceptable partially because they are perceived as more natural and involve less manipulation of nature compared to transgenic approaches (Tenbült, de Vries, Dreezens, & Martijn, 2005). Conversely, federal agencies might be ascribed as more responsible for mitigating risks and facilitating benefits of GE uses that are potentially perceived as more manipulative of nature (e.g., transgenesis between sexually incompatible organisms). These suggestions, however, are speculative and require more research to confirm or refute.

In comparing results across the three applications of GE for both samples, there were more statistically significant relationships and paths among concepts for modifying existing AC genes (scenario 1; 11 significant relationships) than there were for adding genes from distant species in general (scenario 2; 7 significant) and from bread wheat in particular (scenario 3; 5 significant). The amount of variance in normative acceptance explained by the other concepts in the models was also highest for the first scenario (74-76%) and lowest for the third scenario (66-68%). Taken together, these results suggest that there are more concepts that are more strongly related to risks, benefits, and acceptance of cisgenic (i.e., within-species) applications than there are for transgenic approaches (i.e., between-species). Additional research in forestry and other contexts is needed to confirm or refute this finding.

On average, the FIGs viewed modifying existing AC genes (i.e., cisgenic; scenario 1) most positively (i.e., highest acceptance, lowest risk, most beneficial) and adding a gene from bread wheat (i.e., transgenic; scenario 3) least positively. For the public sample, there were minimal differences in responses among the three scenarios, but this sample did view adding a gene from bread wheat most positively. Other research has shown similar variation in responses to different GE applications with some studies reporting results contrary to those found here. Kronberger, Wagner, and Nagata (2014), for example, found that the public was most concerned about transgenic applications that crossed interspecies boundaries. Jepson and Arakelyan (2017) also found more public support for cisgenic than transgenic methods for addressing ash dieback.

Interestingly, the two transgenic scenarios here were viewed somewhat differently between samples. The public sample generally viewed adding genes from distant species to the AC (scenario 2) least positively, whereas the FIGs viewed adding a gene from bread wheat to the AC (scenario 3) this way. It is possible that the two groups may have interpreted the scenario wording differently, even though these scenarios are both examples of transgenesis (i.e., GE between sexually incompatible species). The public might have interpreted “adding genes from a distantly related organism” (scenario 2) as an application that manipulates or tampers with nature more so than “adding a gene from wheat (e.g., bread wheat)” (scenario 3), perhaps due to the perceived naturalness or familiarity of bread and wheat, and common silvicultural approaches (e.g., selective breeding, crossing, hybridization) involving two plant species. Previous research has found that perceived familiarity and naturalness of some GE applications can be positively associated with acceptance (Slovic, 2000, 2010; Tenbült et al., 2005). Conversely, FIGs should arguably be more familiar with GE applications in forestry and may have perceived “distantly related organism” as including species more closely related to the AC than bread wheat. This warrants further research into scenario wording effects on responses from various groups.

Given the results showed that environmental benefits were most strongly related to acceptance of each GE approach, communication efforts aimed at increasing acceptance of using GE for forest conservation should focus primarily on environmental factors, with an emphasis on potential environmental benefits that might result from using this technology in these efforts. In addition to communicating these benefits, discussion about any potential risks of using GE in this context is also warranted given that they were also related to acceptance. Including any known risks in communication efforts will help to maintain transparency and provide a sense of accountability and balance in messaging. In addition, social psychology research has shown that communication campaigns are often most effective when messaging uses a type of “inoculation effect” by including some potential concerns (e.g., risks) alongside favorable information (e.g., benefits) (Banas & Rains, 2010; Eagly & Chaiken, 1993).

Findings also showed that although both the public and FIG samples had moderate trust in federal government agencies, they only had slight trust in state and local agencies. These nonfederal agencies serve as day-to-day managers of many public lands and often cooperate with federal agencies to manage forests at broader regional scales. Many of these nonfederal agencies may also be charged with regulating and monitoring GE (e.g., transgenic) trees if regulatory approval is obtained, as well as informing the public about these efforts (Chang et al., 2018). Research suggests that trust-building efforts should: (a) focus on facilitating transparent dialogue between agency personnel and the public, (b) involve the public in some agency planning efforts,

(c) emphasize the local benefits of management strategies, (d) minimize turnover in agency personnel who regularly interact with the public, and (e) assess local contextual factors that shape or constrain these efforts (Shindler, Brunson, & Stankey, 2002; Shindler & Mallon, 2011).

In closing, this article showed several relationships among concepts related to acceptance of using GE for mitigating CB and restoring AC trees. The results also yielded implications related to using GE for addressing this forest health issue. These results and implications, however, are limited to only a few potential GE interventions for addressing a single forest health threat (i.e., CB) in a single tree species (AC). The applicability and generalizability of these findings to other contexts remain topics for further empirical investigation.

Notes

1. A single exploratory factor analysis (EFA) of all variables in this article without rotation and with the number of factors fixed to one showed that this factor explained less than 50% of the variance. This approach coupled with the CFA findings (i.e., high factor loadings and model fit indices) represent Harman single factor tests (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003) and suggest that common method variance or bias was generally absent.

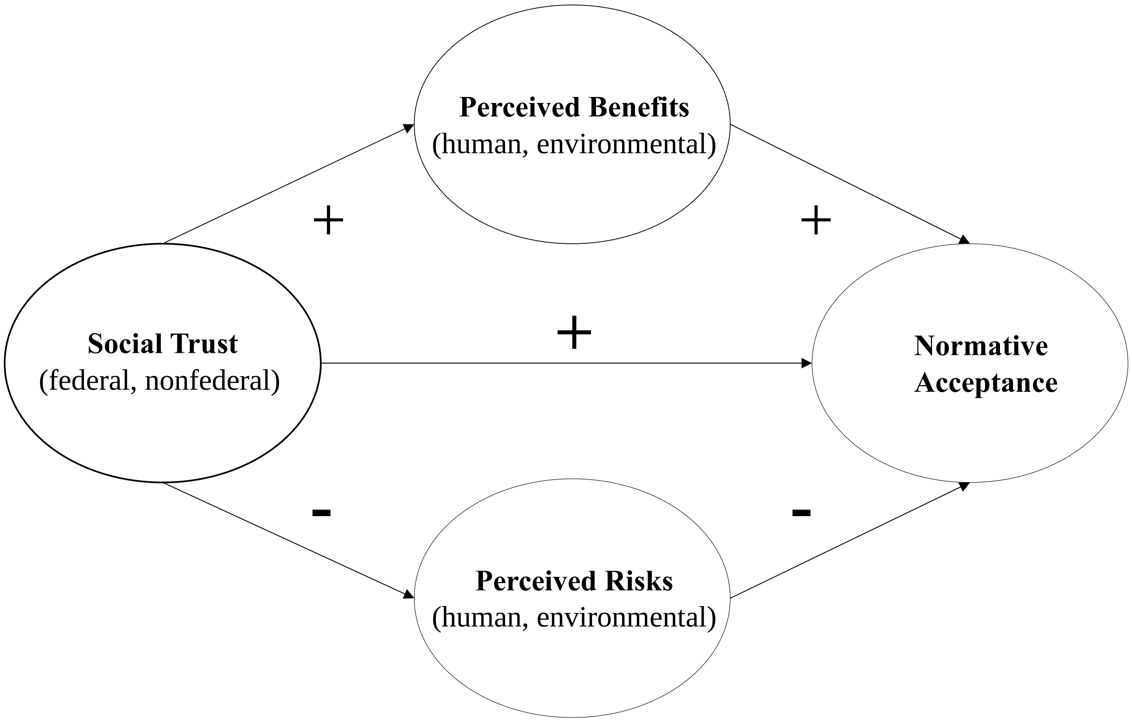

Figure 1. Conceptual model representing the hypothesized relationships among trust in agencies, perceived risks, perceived benefits, and normative acceptance of using GE to restore AC trees ("+" denotes a positive relationship among concepts and "-" denotes a negative or inverse relationship).

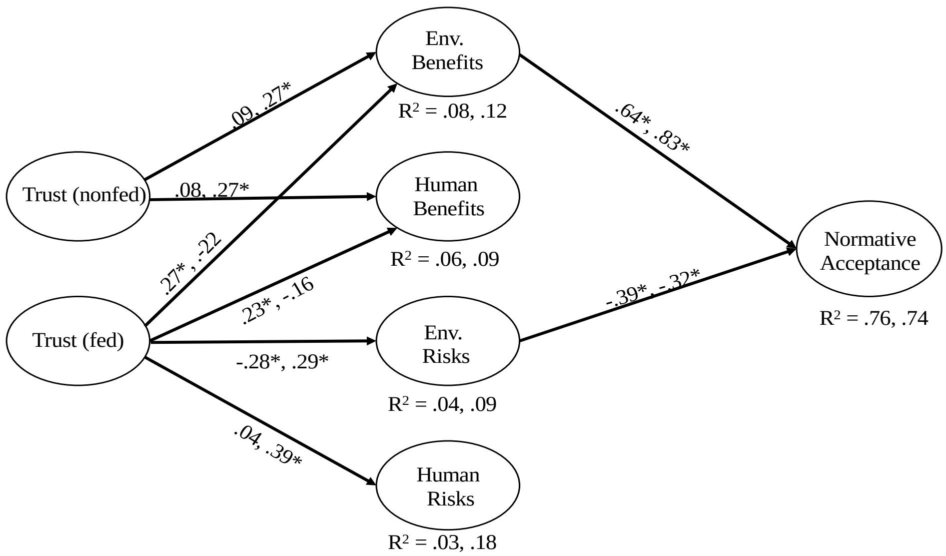

Figure 2. Path model predicting acceptance of using GE to change genes already present in the AC (scenario 1) for the public (first value) and FIGs (second value). Only paths where there was a significant relationship are shown. Insignificant paths are not shown. Significant ($p < .05$) paths are indicated by an asterisk (*).

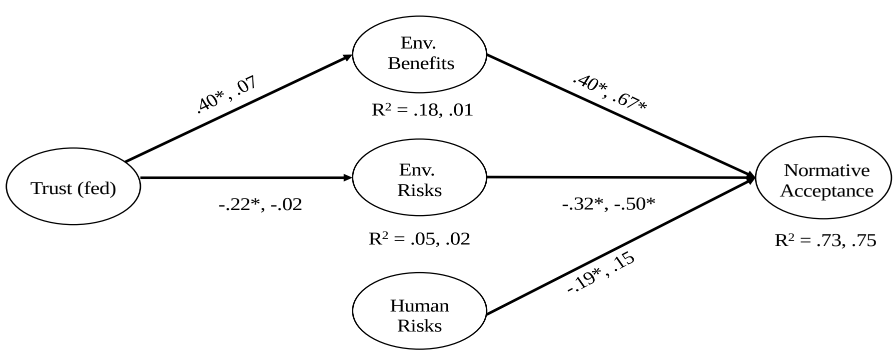

Figure 3. Path model predicting acceptance of using GE to add genes from distantly related species to the AC (scenario 2) for the public (first value) and FIGs (second value). Only paths where there was a significant relationship are shown. Insignificant paths are not shown. Significant ($p < .05$) paths are indicated by an asterisk (*).

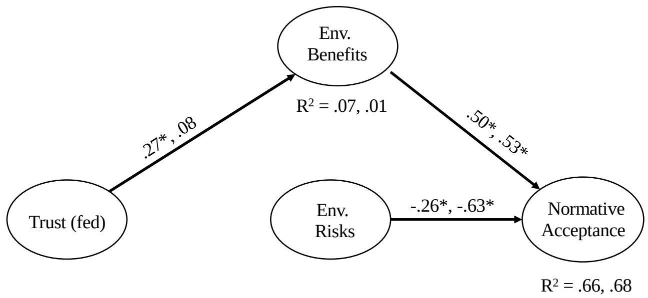

Figure 4. Path model predicting acceptance of using GE to add a gene from bread wheat (OxO) to the AC (scenario 3) for the public (first value) and FIGs (second value). Only paths where there was a significant relationship are shown. Insignificant paths are not shown. Significant ($p < .05$) paths are indicated by an asterisk (*).

Table 8. Verbatim wording for three GE use scenarios including information about chestnut blight (CB wording identical for all scenarios).

Scenario Number	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.	n/a
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
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.	Transgenesis
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.	Transgenesis

Table 9. Cronbach's alpha reliability statistics and CFA factor loadings for the public and FIGs for each of the three GE scenarios.

	Cronbach's Alpha[5]		CFA Factor Loadings[5]	
	Public	FIGs	Public	FIGs
Scenario 1 - Change existing AC genes				
Normative acceptance[1]	.96	.98		
should not allow/should allow			.97	.95
unacceptable/acceptable			.96	.99
Human risks[2]	.97	.97		
yourself			.99	.95
other humans or society in general			.95	.99
Environmental risks[2]	.98	.98		
trees/forests			.96	.97
the broader environment			.99	.99
Human benefits[3]	.98	.87		
yourself			.97	.81
other humans or society in general			.96	.97
Environmental benefits[3]	.98	.95		
trees/forests			.95	.95
the broader environment			.97	.95
Scenario 2 - Add genes from distant species to AC				
Normative acceptance[1]	.96	.97		
should not allow/should allow			.96	.95
unacceptable/acceptable			.97	.99
Human risks[2]	.98	.95		
yourself			.95	.90
other humans or society in general			.99	.99
Environmental risks[2]	.98	.98		
trees/forests			.99	.97
the broader environment			.96	.99
Human benefits[3]	.95	.91		
yourself			.87	.84
other humans or society in general			.98	.99
Environmental benefits[3]	.99	.97		
trees/forests			.96	.96
the broader environment			.99	.98

Table 9. Continued

	Cronbach's Alpha[5]		CFA Factor Loadings[5]	
	Public	FIGs	Public	FIGs
Scenario 3 - Add gene from bread wheat (OxO) to AC				
Normative acceptance[1]	.97	.98		
should not allow/should allow			.96	.96
unacceptable/acceptable			.97	.99
Human risks[2]	.98	.94		
yourself			.92	.92
other humans or society in general			.99	.96
Environmental risks[2]	.99	.99		
trees/forests			.99	.99
the broader environment			.99	.98
Human benefits[3]	.96	.89		
yourself			.93	.82
other humans or society in general			.97	.97
Environmental benefits[3]	.97	.98		
trees/forests			.92	.96
the broader environment			.99	.99
Trust in federal government agencies[4]	.85	.87		
US Forest Service			.80	.91
US Bureau of Land Management			.95	.83
Trust in nonfederal government agencies[4]	.84	.79		
local govt. agencies (city, county, town)			.84	.71
state govt. agencies			.88	.95

[1] Measured on 5-point semantic differential scales.
[2] Measured on 9-point scales from "no risk" to "high risk."
[3] Measured on 9-point scales from "no benefit" to "highly benefit."
[4] Measured on 9-point scales from "no trust" to "high trust.
[5] First number is figure for public sample; second number is figure for forest interest group sample.

Table 10. Descriptives and group comparisons (public vs. FIGs) for each concept for each of the three GE scenarios.

	Public	FIGs	*t*-value	*p*-value	Effect size (r_{pb})
Scenario 1 - Change existing AC genes					
Normative acceptance[1]	2.89	4.00	6.13	< .001	.40
Human risks[2]	3.02	1.37	5.69	< .001	.37
Environmental risks[3]	4.25	2.78	4.58	< .001	.31
Human benefits[4]	2.42	3.31	2.87	.005	.20
Environmental benefits[5]	3.37	4.61	3.61	< .001	.25
Scenario 2 – Add genes from distant species to AC					
Normative acceptance[1]	2.77	3.47	3.65	< .001	.26
Human risks[2]	3.51	1.81	5.19	< .001	.35
Environmental risks[3]	4.51	3.46	3.14	.002	.22
Human benefits[4]	2.11	2.71	1.99	.048	.14
Environmental benefits[5]	3.05	3.91	2.45	.015	.17
Scenario 3 - Add gene from bread wheat (OxO) to AC					
Normative acceptance[1]	2.93	3.42	2.45	.015	.17
Human risks[2]	3.13	1.99	3.49	.001	.25
Environmental risks[3]	4.14	3.55	2.01	.046	.14
Human benefits[4]	2.56	2.72	.53	.598	.04
Environmental benefits[5]	3.47	4.01	1.56	.121	.11
Trust in federal government agencies[6]	5.17	5.00	.66	.511	.04
Trust in nonfederal government agencies[7]	3.29	4.20	3.57	< .001	.24

[1] Measured on two 5-point semantic differential scales from "unacceptable" to "acceptable" and "should not allow" to "should allow."
[2] Measured on two 9-point scales (yourself, other humans/society in general) from "no risk" to "high risk."
[3] Measured on two 9-point scales (trees/forests, broader environment) from "no risk" to "high risk."
[4] Measured on two 9-point scales (yourself, other humans/society in general) from "no benefit" to "highly benefit."
[5] Measured on two 9-point scales (trees/forests, broader environment) from "no benefit" to "highly benefit."
[6] Measured on two 9-point scales (USFS, BLM) from "no trust" to "high trust."
[7] Measured on two 9-point scales (local, state agencies) from "no trust" to "high trust."

References

Banas, J. A., & Rains, S. A. (2010). A meta-analysis of research on inoculation theory. *Communication Monographs*, *77*(3), 281–311.

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations, *Journal of personality and social psychology*, *51*(6), 1173.

Blaine, K., Kamaldeen, S., & Powell, D. (2002). Public perceptions of biotechnology. *Journal of Food Science*, *67*(9), 3200–3208.

Bottrill, M. C., Mills, M., Pressey, R. L., Game, E. T., & Groves, C. (2012). Evaluating perceived benefits of ecoregional assessments: Evaluation of ecoregional assessments. *conservation biology*, *26*(5), 851–861.

Burdon, R. D., & Libby, W. J. (2006). *Genetically modified forests*. Durham, North Carolina, USA: Forest History Society.

Byrne, B. M. (2006). *Structural equation modeling with EQS: Basic concepts, applications, and programming*. New York, NY: Routledge.

Ceurvorst, R. L., & Needham, M. D. (2012). Is “acceptable” really acceptable? Comparing two scales for measuring normative evaluations in outdoor recreation. *Leisure Sciences*, *34*(3), 272–279.

Chang, S., Mahon, E. L., MacKay, H. A., Rottmann, W. H., Strauss, S. H., Pijut, P. M., … Jones, T. J. (2018). Genetic engineering of trees: Progress and new horizons. *In Vitro Cellular & Developmental Biology - Plant*, *54*(4), 341–376.

National Academies of Sciences, Engineering, and Medicine Committee on the Potential for Biotechnology to Address Forest Health, Board on Agriculture and Natural Resources, Division on Earth and Life Studies (NASEM). (2019). *Forest health and biotechnology: Possibilities and considerations*. Washington, D.C.: National Academies Press.

Connor, M., & Siegrist, M. (2010). Factors influencing people’s acceptance of gene technology: The role of knowledge, health expectations, naturalness, and social trust. *Science Communication*, *32*(4), 514–538.

De Groot, J. I. M., Steg, L., & Poortinga, W. (2013). Values, perceived risks and benefits, and acceptability of nuclear energy: Acceptability of nuclear energy. *Risk Analysis*, *33*(2), 307–317.

Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes* (Vol. xxii). Orlando, FL, US: Harcourt Brace Jovanovich College Publishers.

Frewer, L. J., van der Lans, I. A., Fischer, A. R. H., Reinders, M. J., Menozzi, D., Zhang, X., … Zimmermann, K. L. (2013). Public perceptions of agri-food applications of genetic modification – A systematic review and meta-analysis. *Trends in Food Science & Technology*, *30*(2), 142–152.

Frewer, L., Lassen, J., Kettlitz, B., Scholderer, J., Beekman, V., & Berdal, K. G. (2004). Societal aspects of genetically modified foods. *Food and Chemical Toxicology*, *42*(7), 1181–1193.

Friedman, S. T., & Foster, G. S. (1997). Forest genetics on federal lands in the United States: Public concerns and policy responses. *Canadian Journal of Forest Research*, *27*(3), 401–408.

Gaskell, G., Allum, N., Wagner, W., Kronberger, N., Torgersen, H., Hampel, J., & Bardes, J. (2004). GM Foods and the Misperception of Risk Perception. *Risk Analysis*, *24*(1), 185–194.

Gupta, N., Fischer, A. R. H., & Frewer, L. J. (2011). Socio-psychological determinants of public acceptance of technologies: A review. *Public Understanding of Science*, *21*(7), 782–795.

Hajjar, R., & Kozak, R. A. (2015). Exploring public perceptions of forest adaptation strategies in Western Canada: Implications for policy-makers. *Forest Policy and Economics*, *61*, 59–69.

Hajjar, R., McGuigan, E., Moshofsky, M., & Kozak, R. A. (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. *Canadian Journal of Forest Research*, *44*(12), 1525–1533.

James, A. S., Campbell, M. K., & Hudson, M. A. (2002). Perceived barriers and benefits to colon cancer screening among African Americans in North Carolina: How does perception relate to screening behavior? *Cancer Epidemiology Biomarkers & Prevention*, *11*(6), 529–534.

Jepson, P., & Arakelyan, I. (2017a). Exploring public perceptions of solutions to tree diseases in the UK: Implications for policy-makers. *Environmental Science & Policy*, *76*, 70–77.

Jepson, P. R., & 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 and Economics*, *80*, 167–177.

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-Biogeosciences and Forestry, 9(2), 344.*

Kazana, V., Tsourgiannis, L., Iakovoglou, V., Stamatiou, C., Alexandrov, A., Araújo, S., ... & Boutsimea, A. (2016). Public knowledge and perceptions of safety issues towards the use of genetically modified forest trees: a cross-country pilot survey. In *Biosafety of Forest Transgenic Trees* (pp. 223-244). Springer, Dordrecht.

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. *Science Communication*, *36*(1), 106–130.

McFarlane, B. L., Parkins, J. R., & Watson, D. O. T. (2012). Risk, knowledge, and trust in managing forest insect disturbance. *Canadian Journal of Forest Research*, *42*(4), 710–719.

McFarlane, B. L., & Witson, D. O. T. (2008). Perceptions of ecological risk associated with mountain pine beetle (Dendroctonus ponderosae) infestations in Banff and Kootenay national parks of Canada. *Risk Analysis*, *28*(1), 203–212.

Merkle, S. A., Andrade, G. M., Nairn, C. J., Powell, W. A., & Maynard, C. A. (2006). Restoration of threatened species: A noble cause for transgenic trees. *Tree Genetics & Genomes*, *3*(2), 111–118.

Nash, R. F. (2014). *Wilderness and the American mind*. Yale University Press.

Needham, M. D., & Vaske, J. J. (2008). Hunter perceptions of similarity and trust in wildlife agencies and personal risk associated with chronic wasting disease. *Society & Natural Resources*, *21*(3), 197–214.

Needham, M. D., Vaske, J. J., & Petit, J. D. (2017). Risk sensitivity and hunter perceptions of chronic wasting disease risk and other hunting, wildlife, and health risks. *Human Dimensions of Wildlife*, *22*(3), 197–216.

Neumann, P. D., Krogman, N. T., & Thomas, B. R. (2007). Public perceptions of hybrid poplar plantations: Trees as an alternative crop. *International Journal of Biotechnology*, *9*(5), 468–483.

Nilausen, C., Gélinas, N., Bull, G., Nilausen, C., Gélinas, N., & Bull, G. (2016). Perceived acceptability of implementing marker-assisted selection in the forests of British Columbia. *Forests*, *7*(11), 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 - Biogeosciences and Forestry*, *8*(5), 714–718.

Perry, E. E., Needham, M. D., & Cramer, L. A. (2017). Coastal resident trust, similarity, attitudes, and intentions regarding new marine reserves in Oregon. *Society & Natural Resources*, *30*(3), 315–330.

Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology*, *88*(5), 879–903.

Powell, W. (2016). New genetically engineered American chestnut will help restore the decimated, iconic tree. *The conversation, Jan, 19*, 2016.

Savadori, L., Savio, S., Nicotra, E., Rumiati, R., Finucane, M., & Slovic, P. (2004). Expert and public perception of risk from biotechnology. *Risk Analysis*, *24*(5), 1289–1299.

Shew, A. M., Nalley, L. L., Danforth, D. M., Dixon, B. L., Nayga Jr, R. M., & Delwaide, A.C. (2015). Are all GMO's the same? Consumer acceptance of cisgenic rice in India. *Plant Biotechnology Journal*, *14*(1), 4-7.

Shindler, B., Brunson, M., & Stankey, G. (2002). Social acceptability of forest conditions and management practices: A problem analysis. *Gen. Tech. Rep. PNW-GTR-537. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest Research Station. 68 p*, *537*.

Shindler, B., & Mallon, A. (2011). *Public acceptance of disturbance-based forest management: A study of the Blue River landscape strategy in the central cascades adaptive management area*. DIANE Publishing.

Siegrist, M. (2000). The influence of trust and perceptions of risks and benefits on the acceptance of gene technology. *Risk Analysis*, *20*(2), 195–204.

Siegrist, M., Cvetkovich, G., & Claudia Roth. (2000). Salient value similarity, social trust, and risk/benefit perception. *Risk Analysis*, *20*(3), 353–362.

Sjöberg, L. (1998). Risk perception: Experts and the public. *European Psychologist*, *3*(1), 1.

Sjöberg, L. (2004). Principles of risk perception applied to gene technology. *EMBO Reports*, *5*, S47–S51.

Slovic, P., Fischhoff, B., Lichtenstein, S., & Roe, F. J. C. (1981). Perceived risk: Psychological factors and social implications [and discussion]. *Proceedings of the Royal Society of London. Series A, Mathematical and Physical Sciences*, *376*(1764), 17–34.

Slovic, P. (2000). *The perception of risk*. London; Sterling, VA: Earthscan Publications.

Slovic, P. (2010). *The feeling of risk: New perspectives on risk perception*. London; New York, NY: Routledge.

Steiner, K. C., Westbrook, J. W., Hebard, F. V., Georgi, L. L., Powell, W. A., & Fitzsimmons, S. F. (2017). Rescue of American chestnut with extraspecific genes following its destruction by a naturalized pathogen. *New Forests*, *48*(2), 317–336.

Stern, M. J., & Coleman, K. J. (2015). The multidimensionality of trust: Applications in collaborative natural resource management. *Society & Natural Resources*, *28*(2), 117–132.

Strauss, S. H., Jones, K. N., Lu, H., Petit, J. D., Klocko, A. L., Betts, M. G., … Needham, M. D. (2017). Reproductive modification in forest plantations: Impacts on biodiversity and society. *New Phytologist*, *213*(3), 1000–1021.

Tenbült, P., de Vries, N. K., Dreezens, E., & Martijn, C. (2005). Perceived naturalness and acceptance of genetically modified food. *Appetite*, *45*(1), 47–50.

Tew, C., & Barbieri, C. (2012). The perceived benefits of agritourism: The provider's perspective. *Tourism Management*, *33*(1), 215–224.

Thompson, P. B., & Dean, W. (1996). Competing conceptions of risk. *Risk*, *7*, 361.

Tsourgiannis, L., Kazana, V., & Iakovoglou, V. (2016). A comparative analysis of consumers' potential purchasing behaviour towards transgenic-derived forest products: the Greek case. In *Biosafety of Forest Transgenic Trees* (pp. 245-261). Springer, Dordrecht.

Vaske, J. J. (2008). *Survey research and analysis: Applications in parks, recreation and human dimensions*. Venture Publishing State College, PA.

Vaske, J. J., Absher, J. D., & Bright, A. D. (2007). Salient value similarity, social trust and attitudes toward wildland fire management strategies. *Human Ecology Review*, 223–232.

Vaske, J., & Whittaker, D. (2004). Normative approaches to natural resources. *Society and Natural Resources: A Summary of Knowledge*, 283–294.

Visschers, V. H. M., Keller, C., & Siegrist, M. (2011). Climate change benefits and energy supply benefits as determinants of acceptance of nuclear power stations: Investigating an explanatory model. *Energy Policy*, *39*(6), 3621–3629.

Wheeler, N., & Sederoff, R. (2008). Role of genomics in the potential restoration of the American chestnut. *Tree Genetics & Genomes*, *5*(1), 181–187.

Whitfield, S. C., Rosa, E. A., Dan, A., & Dietz, T. (2009). The future of nuclear power: Value orientations and risk perception. *Risk Analysis*, *29*(3), 425–437.

Williams, K. J. H. (2014). Public acceptance of plantation forestry: Implications for policy and practice in Australian rural landscape. *Land Use Policy*, *38*, 346–354.

Xiao, Q., Liu, H., & Feldman, M. W. (2017). How does trust affect acceptance of a nuclear power plant (NPP): A survey among people living with Qinshan NPP in China. *PLOS ONE*, *12*(11).

Zhang, B., Oakes, A. D., Newhouse, A. E., Baier, K. M., Maynard, C. A., & Powell, W. A. (2013). A threshold level of oxalate oxidase transgene expression reduces Cryphonectria parasitica-induced necrosis in a transgenic American chestnut (Castanea dentata) leaf bioassay. *Transgenic Research*, *22*(5), 973–982.

Zinn, H. C., Manfredo, M. J., Vaske, J. J., & Wittmann, K. (1998). Using normative beliefs to determine the acceptability of wildlife management actions. *Society & Natural Resources*, *11*(7), 649–662.

CHAPTER 4

EFFECTS OF MESSAGE FRAMING ON PERCEPTIONS OF USING GENETIC ENGINEERING TO RESTORE AMERICAN CHESTNUT TREES

Introduction

Genetic engineering (GE) is a technology that has shown promise for addressing global issues related to human health, industrial production, and conservation of natural resources (NR) such as forest restoration. For example, GE has been used in medicine for identifying relationships between genes and diseases to aid in developing new treatments (Pin, Gutteling, & Kuttschreuter, 2009). GE has also been applied extensively in agriculture to increase the quality and quantity of food (Kempken & Jung, 2010). For example, GE is touted as having saved the papaya industry from a devastating disease (Chang et al., 2018), and it has also been used for imparting pesticide-resistance traits in crops such as corn (Pilcher et al., 2002).

In recent years, GE has also shown potential for addressing conservation issues such as mitigating forest health threats (e.g., diseases, pests) (NASEM, 2019). For example, GE has shown promise for mitigating chestnut blight (CB), a tree disease caused by a fungal pathogen that has decimated American chestnut (AC) (*Castanea dentata*) trees (up to 99% mortality), a once-dominant keystone species in the eastern forests of the United States (US) (Powell, 2016; Steiner et al., 2017). Researchers have been most successful in using GE in this context by inserting a gene from bread wheat containing oxalic oxidase (OxO), an enzyme that breaks down the chemical agent oxalic acid that kills AC trees (Zhang, Newhouse, McGuigan, Maynard, & Powell, 2011). These resulting transgenic (i.e., inserting genes from sexually incompatible species) AC trees are resistant to CB and are currently being reviewed for regulatory approval and eventual commercial release (Powell, 2016; Steiner et al., 2017).

The utility of technologies such as GE partly depends on public opinions (i.e., attitudes, normative acceptance). In functional democratic societies, political leaders are tasked with regulating in accordance with the will and best interest of the majority of their public constituents (Shindler & Cheek, 1999). Therefore, it is important to assess the extent that the public thinks of these technologies as good or bad, or acceptable or unacceptable to ensure that policies and legislation reflect public sentiment. However, messaging that uses either positive or pejorative terminology, or provides either scientifically accurate information or biased viewpoints lacking scientific consensus (e.g., “climate change is a hoax and is not influenced by human actions”) can influence these attitudes and levels of acceptance (Boykoff & Boykoff, 2004). Framing message information from trustworthy or credible sources (e.g., scientists) and providing quantitative substantiation of scientific consensus (e.g., “98% of scientists agree”) can also impact these cognitions (Nan, 2009; Yu, 2012). This article examines public attitudes and acceptance of using GE to restore AC trees, and any potential effects of message framing (e.g., positive vs. pejorative terminology, scientific information and consensus) on these cognitions.

Conceptual Foundation

Attitudes and Normative Acceptance

Attitudes are psychological tendencies to evaluate a particular object or issue, such as GE, with some degree of disfavor or favor (i.e., bad to good, negative to positive, dislike to like) (Eagly & Chaiken, 1993). Norms are standards that individuals use for evaluating their acceptance of an object or issue, and whether or not they think it should be allowed (Vaske & Whittaker, 2004). These attitudes and norms can predict behavioral intentions and actual behaviors (Fishbein & Ajzen, 2011; Whittaker, Vaske, & Manfredo, 2006).

A small number of recent studies, especially in Canada and Europe, have investigated attitudes and normative acceptance of using GE for addressing forest health threats (e.g., pests, diseases, climate change)(see NASEM, 2019 for review). Jepson and Arakelyan (2017a,b), for example, examined public acceptance of GE in the United Kingdom (UK) and found that applications for addressing tangible global threats (e.g., poverty, forest diseases) were generally acceptable. Jepson and Arakelyan (2017a,b) also found that 30-38% of the public approved of GE ash trees resistant to ash dieback and planting them in woodlands across the countryside, whereas larger percentages approved of planting these trees in plantations. Hajjar et al. (2014) and Hajjar and Kozak (2015) found that approximately 50% of residents in Western Canada supported planting trees with traits introduced via GE to enhance the resistance of trees to climate change.

Message Framing

Biased processing and strength of cognitions. Research has shown that attitudes, norms, and intentions can be susceptible to change from messaging and other persuasion approaches (Eagly & Chaiken, 1993; Petty & Cacioppo, 1986). For example, weaker or less stable attitudes, norms, and intentions are less resistant to change, so they can be more susceptible to messaging campaigns aimed at changing these cognitions. Conversely, cognitions that are more salient, accessible (i.e., retrievable), or strongly held (e.g., attitude strength or certainty) can be more resistant to contradictory information and more predictive of higher order cognitions and behaviors (Howe & Krosnick, 2017; Basman, Manfredo, Barro, Vaske, & Watson, 1996). Lusk et al. (2004), for example, found that existing attitudes were important determinants of how respondents viewed information about GE foods.

Psychological phenomena such as biased processing (i.e., the selective processing of information skewed by existing beliefs, values, or other cognitions) can reduce the impact of persuasive messages on attitudes, norms, and intentions, especially when these cognitions are strongly held and highly accessible, or when personal involvement is high (Fazio, 1986; Wood, Rodes, & Biek, 1995). McFadden and Lusk (2015), for example, showed that prior cognitions biased respondent interpretation of messages about GE foods, as information incongruent with these cognitions was selectively ignored or refuted. In another study, Teel, Bright, Manfredo, and Brooks (2006) presented respondents with exaggerated information about drilling for oil in the Arctic National Wildlife Refuge framed as expert testimony to Congress, but found that attitudes were not influenced much by this messaging. These results are examples of biased processing and this phenomenon is similar to cognitive dissonance (Festinger, 1957), which contends that people can ignore messages (i.e., a behavior) that opposes their attitudes (Knobloch-Westerwick & Meng, 2009). In other words, people sometimes compare their existing opinions with new messaging and then refute any observed inconsistencies (Wright, 1973).

Positive versus pejorative framing. Despite these potential biases, framing messages using positive terminology can cause more favorable cognitions (e.g., attitudes, norms), whereas negative terminology can have the opposite effect (Lu, Siemer, Baumer, & Decker, 2018). Research has examined whether positive (e.g., benefits) or negative (e.g., risks) information is more influential on attitudes, norms, or intentions (see Frewer et al., 2016 for a review). Theories such as prospect theory (Tversky & Kahneman, 1979) and gain / loss or risk aversion theories (Tversky & Kahneman, 1991) propose that losses and other forms of negative framing can be more influential over decision making compared to gains or positive messaging. Other research, however, has shown that positive framing can be more influential when detailed processing is not required, whereas negative information can be more influential when complex processing is activated (Maheswaran & Meyers-Levy, 1990). Gain / loss framing and goal pursuit theories such as regulatory focus theory (Higgins, 2000) suggest that describing issues positively (i.e., promotion, gains, emphasizing benefits) or negatively (i.e., prevention, losses, emphasizing risks) can have corresponding positive or negative effects on related cognitions that can result in risk seeking or risk averse decision making, respectively (Cesario, Grant, & Higgins, 2004).

Other work has investigated the extent that the amount and quality of information might influence attitudes. For example, the inoculation effect (McGuire & Papageorgis, 1961) demonstrates that persuasion attempts are sometimes more effective when messaging also contains a weak counter-argument, rather than being solely based on unidirectional (i.e., one-sided) information in support or opposition of a particular attitude object (see Banas & Rains, 2010 for a review). Counterintuitive at face value, this discrepancy can occur when people resist messaging that is perceived as lopsided or disingenuous (e.g., a sales pitch).

Providing scientific information. Providing factual or scientific information in persuasive messaging can also influence attitudes, norms, and intentions. Petty and Cacioppo (1984), for example, examined the influence of quality and quantity of messaging on agreement and found that providing more factual information led to enhanced persuasion. Other work by Davidson, Yantis, Norwood, and Montano (1986) found that the amount of scientific information presented also influenced the relationship between attitudes and behavior. Other research, however, has found few substantive effects of providing more scientific information (Chaiken, 1980). Research based on well-known information processing and persuasion models (e.g., elaboration likelihood [ELM], heuristic-systematic) has also shown that the perceived credibility or trustworthiness of information sources (e.g., scientists, managing agencies) can influence attitudes, norms, and other cognitions (see Eagly & Chaiken 1993 and Petty & Caccioppo, 1984 for reviews). For example, Zuwerink-Jacks and Cameron (2003) found that "source derogation" and reduced cognitive change can occur when individuals determine that a messaging source lacks credibility.

Balance as bias. Scientific consensus about issues can also influence attitudes, norms, and intentions because consensus among people perceived as experts is an important heuristic when processing messages, as demonstrated by various persuasion models (e.g., ELM)(Eagly & Chaiken, 1993; Kahneman & Tversky, 2013; Petty & Cacioppo, 1984). When there is scientific agreement about an issue, public sentiment should seemingly reflect this consensus. Lewandowsky, Gignac, and Vaughan (2013), for example, assessed public acceptance of the validity of issues such as anthropogenic climate change and HIV / AIDS, and found increasing acceptance when scientific consensus was highlighted. However, public opinions toward some issues do not always mirror this consensus due to various biases and misrepresenting issues as contentious (i.e., scientific disagreement) in some media coverage. In addition, psychological theories, such as the cultural cognition of risk (Kahan, 2012; Kahan, Braman, Slovic, Gastil, & Cohen, 2009) and cultural cognition of scientific consensus (Kahan, Jenkins-Smith, & Braman, 2011), suggest that societal values can shape public perceptions of scientific consensus regardless of the actual amount of objective consensus, especially for controversial issues receiving substantial media attention such as climate change and handguns.

Media exposure of largely discredited viewpoints toward some NR issues (e.g., climate change is a hoax and is not influenced by humans) can influence public opinions despite these viewpoints being refuted by scientific consensus. The balance as bias (i.e., false balance, balance fallacy) phenomenon occurs when messaging (e.g., a contentious televised debate between one climate change believer and one denier) communicates a false lack of expert consensus, leaving public opinion susceptible to misinformation. Boykoff and Boykoff (2004), for example, examined US press coverage of climate change and found that despite scientific consensus on this issue, providing equal balance to both sides of the issue created polarization that contributed to public uncertainty. Likewise, risk theories, such as the social amplification of risk (Kasperson et al., 1988), suggest that negative attention toward an issue (e.g., GE, nuclear power, air travel) can increase public concern, regardless of science demonstrating extremely low risks. Frewer et al. (2002), for example, found evidence supporting a change in perceived risks and negative views with increased media about GE foods, whereas positive views of benefits did not change.

Research Questions

This article uses data from two studies to examine two research questions. First, what are the current attitudes, norms, and intentions of people regarding the use of GE for mitigating CB and restoring AC trees? Second, to what extent are these cognitions susceptible to some message framing approaches (e.g., positive vs. pejorative wording, scientific information and consensus)?

Methods

Study 1 (Representative Sample)

To address the first research question, data were obtained from a mixed-mode survey of the US public between January and June 2015. The public was sampled randomly and proportionally to county-level populations using zip code information. Six contacts were used for maximizing responses: (a) an initial postcard with an option to complete the questionnaire online, (b) a full mailing (questionnaire, cover letter, postage-paid reply envelope), (c) a postcard reminder with an option to complete the questionnaire online, (d) a personal telephone call to encourage participation, (e) a second full mailing, and (f) a final full mailing. In total, 278 completed questionnaires were received (11% response rate). A telephone non-response bias check (n = 107) was conducted to determine if non-respondents differed from respondents, but no substantive differences were observed. Demographic characteristics of respondents were compared to current US Census data to investigate potential differences. Minor differences in age (sample was slightly older) and education (sample was slightly more educated) required weighting the data to ensure this sample was representative of the target population.

A scenario was embedded within the questionnaire describing the forest health threat (i.e., impacts of CB on AC) and intervention (i.e., GE) (Figure 5). This scenario was worded as neutrally as possible to avoid potential framing effects. Following this scenario were questions measuring *normative acceptance* and *attitudes* using 5-point semantic differential scales (i.e., "should not allow" to "should allow" and "bad" to "good," respectively). *Voting intentions* (i.e., behavioral intentions) were measured with two questions assessing directionality (i.e., "for" or "against") and certainty (i.e., 4-point scale from 1 "not certain" to 4 "extremely certain").

Study 2 (Experiment)

To address the second research question, data were obtained from a Qualtrics online panel of respondents (i.e., purposive self-selected sample) from the eastern US where AC trees and CB were most common (Pennsylvania, Massachusetts, Connecticut, New York, New Jersey, West Virginia, Kentucky, Tennessee, Virginia). These respondents completed online (i.e., internet) questionnaires between May and October 2016. In total, 528 completed questionnaires were obtained. Given the experimental approach of this study, sample representativeness was not an issue (i.e., not generalizing findings to broader US population). Response rates were not recorded because it is difficult to do so with an online panel where people self-select and are paid for participating (Brandon, Long, Loraas, Mueller-Phillips, & Vansant, 2014).

Six versions of the questionnaire were developed to experimentally measure the influence of different message framing approaches on attitudes and norms. Each version contained one scenario providing framing effects: (a) simple descriptions of both GE and CB (version / scenario 1); (b) the descriptions plus factual and neutrally worded scientific information about using GE for mitigating CB (version / scenario 2); (c) the descriptions and scientific information plus positively worded expert (i.e., from a fictitious distinguished university professor) testimony to Congress about benefits of this use of GE (version / scenario 3); (d) the descriptions, scientific information, and positively worded testimony plus a statement about 98% of scientists supporting this use of GE (version / scenario 4); (e) the descriptions and scientific information plus pejoratively worded expert testimony to Congress about drawbacks of this use of GE (version / scenario 5); and (f) the descriptions, scientific information, and pejoratively worded testimony plus a statement about 98% of scientists opposing this use of GE (version / scenario 6). By way of example, Figure 6 shows version / scenario 2 and Figure 7 shows version / scenario 6. There was only one scenario per questionnaire version and Qualtrics randomly assigned one version to each respondent (n = 84-91 or 16-17% of sample per version / scenario).

These scenarios are examples of narrative or storytelling messages, which have been used in previous attitude change research (Teel et al., 2006). Research has shown that narrative messages can yield less resistance to persuasive information (Dahlstrom, 2012). These messages can also serve to dissuade counterarguments and increase interest (i.e., salience, importance), comprehension, and both reading and recall speeds (Green, 2006). Contemporary information processing and persuasion models, such as the more recent Extended ELM (E-ELM), have incorporated these narratives and found them to be among the most useful approaches for facilitating cognitive change (Slater & Rouner, 2002). The framing of some of these narratives from an arguably credible and neutral source (i.e., distinguished university professor) is also consistent with persuasion models (e.g., ELM, E-ELM, heuristic-systematic) showing that sources perceived as more credible or trustworthy can be more effective at changing cognitions (Chaiken, 1980; Yu, 2012).

To allow both within- and between-subjects analyses, *normative acceptance* was measured both before (i.e., pre-treatment) and after (i.e., post-treatment) each scenario with the statement "Genetic modification of trees should be allowed to help them resist chestnut blight" and responses on a 5-point scale from 1 "strongly disagree" to 5 "strongly agree." *Attitudes* were also assessed both before and after each scenario with the statement "I am in favor of using genetic modification of trees to help them resist chestnut blight" and responses on the same scale. *Voting intentions* were measured after each scenario (between-subjects post-treatment analysis only) with two questions assessing directionality (i.e., "for" or "against") and certainty (i.e., 4-point scale from 1 "not certain" to 4 "extremely certain").

Results

Study 1 (Representative Sample)

On average, respondents thought that GE should be allowed for mitigating CB and restoring AC trees (*M* = 3.16, *SD* = 1.23 norms on scale of 1 "should not allow" to 5 "should allow"). The largest proportion (41%) thought this use of GE should be allowed, whereas 23% thought it should not be allowed and 36% were neutral. Attitudes were also positive (*M* = 3.30, *SD* = 1.35 on scale of 1 "bad" to 5 "good") with 44% viewing this use of GE favorably, 30% negatively, and 26% neutral. The majority (57%) of respondents would vote for this use of GE (43% would vote against) and 71% were moderately or extremely certain of these intentions (*M* = 2.94, *SD* = .90 on scale of 1 "not certain" to 4 "extremely certain").

Study 2 (Experiment)

Between-subjects post-treatment comparisons. On average, norms and attitudes were positive (i.e., agree GE should be allowed for trees to resist CB, in favor of this approach) after reading questionnaire scenarios 1 through 4 (i.e., descriptions, scientific information, positive framing, scientific consensus in support; Table 11 and Figure 8). Although the most positive responses (M = 4.12 and 4.14 on scale of 1 "strongly disagree" to 5 "strongly agree") were after reading scenario 4 (descriptions, scientific information, positive framing, scientific consensus in support), the Tamhane's T2 post-hoc tests showed that responses across these first four scenarios were statistically equivalent (p >.05) for each concept. However, the two negative treatments (i.e., scenarios 5 and 6; descriptions, scientific information, pejorative framing, scientific consensus in opposition) yielded significantly less favorable and negative norms and attitudes, with the most negative responses (M = 2.61) after reading scenario 6 (descriptions, scientific information, pejorative framing, scientific consensus in opposition). These between-subject comparisons showed that norms and attitudes differed significantly among the scenarios (F = 43.05 and 44.13, p < .001), and the eta (η) effect sizes of .53 and .54 suggested that these differences were "substantial" based on effect size guidelines provided by Vaske (2008).

Almost all respondents (80–93%) would vote for this use of GE after reading scenarios 1 through 4 (i.e., descriptions, scientific information, positive framing, scientific consensus in support), but this dropped dramatically to 40% for scenario 5 (i.e., descriptions, scientific information, pejorative framing) and even further down to 29% for scenario 6 (i.e., descriptions, scientific information, pejorative framing, scientific consensus in opposition). This difference among scenarios was significant (χ^2 = 158.90, p < .001) and "substantial" (Cramer's V = .55; Vaske, 2008). Certainty of these intentions was lowest (M = 2.84 on scale of 1 "not certain" to 4 “extremely certain”) for scenario 1 (i.e., descriptions only) and highest (*M* = 3.21 and 3.25) for scenarios 3 and 4 (e.g., descriptions, scientific information, positive framing, scientific consensus in support) and these differences were significant ($F = 2.18$, $p = .008$), but not strong ($\eta = .17$).

Within-subjects pre- and post-treatment comparisons. On average, norms and attitudes were positive (i.e., agree GE should be allowed for trees to resist CB, in favor of this approach) before reading (i.e., pre-treatment) each of the six scenarios (Tables 12 and 13, Figures 9 and 10). These cognitions, however, became even more positive after reading (i.e., post-treatment) scenarios 1 through 4 (i.e., descriptions, scientific information, positive framing, scientific consensus in support) with mean responses increasing from *M* = 3.20–3.52 pre-treatment to *M* = 3.87–4.14 post-treatment. Conversely, normative acceptance and attitudes declined dramatically for the two negative treatments (i.e., scenarios 5 and 6; descriptions, scientific information, pejorative framing, scientific consensus in opposition) with mean responses decreasing from *M* = 3.30–3.40 pre-treatment to *M* = 2.61–2.72 post-treatment. These changes in cognitions were all statistically significant (paired *t* = 4.70–7.70, $p < .001$) and the Cohen’s *d* effect sizes (*d* = .50–.75) indicated that the strength of these can be interpreted as “typical” to “substantial” (Vaske, 2008). The largest changes in attitudes and norms (pre vs. post treatment) resulted from the two scientific consensus scenarios (i.e., scenarios 4 and 6; Cohen’s *d* = .67–.75, change in *M* = .62–.79 for norms and change in *M* = .69–.76 for attitudes).

For scenarios 1 through 4 (i.e., descriptions, scientific information, positive framing, scientific consensus in support), norms and attitudes for the largest proportions of respondents either: (a) stayed positive (i.e., agree GE should be allowed for trees to resist CB, in favor of this approach; 41–56%), or (b) increased from neutral to positive (23–32%; Tables 14 and 15). Among these four scenarios, the largest proportion of respondents changed their norms (44%)

and attitudes (45%) after reading scenario 3 (i.e., descriptions, scientific information, positive framing) with most of these becoming more positive. Conversely, norms and attitudes for 29–33% of respondents declined from neutral or positive to negative (i.e., disagree GE should be allowed for trees to resist CB, disagree they favored this approach) after reading scenario 5 (i.e., descriptions, scientific information, pejorative framing), and 40–45% changed their cognitions to negative after reading scenario 6 (i.e., descriptions, scientific information, pejorative framing, scientific consensus in opposition). Norms and attitudes for 17–27% of respondents, however, remained positive after reading these two negatively framed scenarios. In addition, 3–8% remained opposed after reading the positively framed messages, and 3–13% remained neutral.

Discussion

Findings from the representative sample of the US public (Study 1) showed that this sample, on average, thought that using GE for mitigating CB and restoring AC trees was positive and should be allowed. The majority of respondents (57%) would also vote for this use of GE and 71% were moderately or extremely certain of these intentions. Similarly, Study 2 results showed that, on average, norms (i.e., agree that GE should be allowed for AC trees to resist CB), attitudes (i.e., in favor of this GE approach), and intentions (i.e., would vote for this approach) were positive before reading any of the scenarios (i.e., pre-treatment). Taken together, these results are similar to Hajjar et al. (2014) and Hajjar and Kozak (2015) who found that about 50% of residents in Western Canada supported planting trees with traits introduced via GE. These results are also similar to other studies showing majority public support for using GE in forestry (see NASEM, 2019 for a review).

However, this support for using GE to help AC trees resist CB is sensitive to information messaging and susceptible to persuasion campaigns, as both the between- and within-subjects comparisons in Study 2 showed that support dropped dramatically as soon as messages provided any negative or opposing arguments (i.e., pejorative language) about this topic. In fact, the first scenario to include pejorative framing (i.e., scenario 5) caused voting intentions and average attitudes and norms to switch from being supportive to opposed. These cognitions became even more negative when message framing included scientific consensus in opposition (i.e., scenario 6). These results are consistent with theories such as prospect theory (Tversky & Kahneman, 1979) and gain / loss or risk aversion theories (Tversky & Kahneman, 1991), which propose that losses and other forms of negative message framing can be most influential over cognitions.

The between-subjects comparisons also showed that responses to the first four scenarios (i.e., descriptions, scientific information, positive framing, scientific consensus in support) were statistically equivalent. This may be because the majority of respondents had positive initial perceptions about this use of GE to begin with (i.e., pre-treatment), so receiving positive messages or learning there was scientific consensus in support only served to reinforce these cognitions. Responses to these four scenarios, however, differed dramatically from the final two scenarios that presented negative or pejorative information. Maheswaran and Meyers-Levy (1990) examined student attitudes toward health issues and found that positive framing was more influential when detailed processing was not required, whereas negative information was more influential when complex processing was activated. Although speculative, the high complexity of understanding both CB and GE likely required such detailed processing for respondents here, which may explain why the negative messages had such a large influence on cognitions.

The within-subjects comparisons showed that the two treatments depicting scientific consensus (scenarios 4 and 6) yielded the strongest pre- versus post-treatment changes in both attitudes and norms. The positively worded treatment coupled with scientific consensus in support received the most favorable attitudes and greatest acceptance of using GE for helping to mitigate CB and restore AC trees. Conversely, the negatively worded treatment coupled with scientific consensus in opposition yielded the least favorable attitudes and acceptance. These findings are consistent with previous research showing that scientific consensus can influence public responses to controversial issues. Lewandowsky, Gignac, and Vaughan (2013), for example, examined public acceptance of the validity of climate change and other global issues, and found increasing acceptance when scientific consensus was emphasized. Theories and concepts such as the social amplification of risk (Kasperson et al., 1988), cultural cognition of risk (Kahan, 2012), cultural cognition of scientific consensus (Kahanm Jenkins-Smith, & Braman, 2011), and balance as bias (Boykoff & Boykoff, 2004) suggest that public opinion toward controversial issues can be skewed away from scientific consensus when messages and viewpoints lacking this consensus are given a communication platform (e.g., a televised debate).

Despite these findings, some Study 2 respondents did not change their cognitions, as 17–27% remained supportive of this use of GE even after reading messages containing negative framing, 3–8% remained opposed even after reading the positively framed messages, and 3–13% remained neutral. Although these percentages are smaller compared to those whose cognitions were susceptible and changed in response to message framing, they suggest some respondents likely engaged in biased processing by comparing their existing opinions with the messaging and then refuting any observed inconsistencies (e.g., McFadden & Lusk, 2015; Teel et al., 2006).

In addition, approximately one-third of Study 1 respondents had neutral norms and attitudes toward this issue and were only slightly certain of their intentions. Likewise, similar percentages of Study 2 respondents (34–35%) had neutral attitudes and norms before reading any of the scenarios (i.e., pre-treatment). These results suggest that cognitions about this topic for some people may not be well formed, salient, accessible, or strongly held (Basman et al., 1996; Howe & Krosnick, 2017). In fact, the within-subjects comparisons in Study 2 showed that simply adding a short and simple description of this use of GE had a significantly positive influence on cognitions with most respondents being more likely to favor this approach and think it should be allowed. Adding a small amount of scientific information to this description had an even greater effect on these cognitions. In other words, responses became more positive after providing just simple descriptions and scientific information about this topic. These findings are consistent with some previous research (e.g., Davidson et al., 1986; Petty & Cacioppo, 1984).

Interestingly, respondents who received the first positive treatment (scenario 3 containing descriptions, scientific information, and positive framing) were slightly less supportive of this use of GE compared to those who received only these descriptions and the scientific information. This result seems counterintuitive and paradoxical. Although this difference was not statistically significant in this study, research has shown that persuasive messages containing only positive information can sometimes be resisted or perceived as disingenuous or lopsided, thereby diminishing support and favorability. The inoculation effect (Eagly & Chaiken, 1993; McGuire & Papageorgis, 1961) demonstrates that persuasion attempts are sometimes more effective when messaging contains a weak counter-argument, rather than favorable information alone.

These findings also have implications for practitioners who may use technologies such as GE to manage complex NR issues. Attitudes and normative acceptance of using GE in this forest conservation context (i.e., to mitigate CB and restore AC trees) appear to be favorable, but they also appear to be malleable to communication messaging and persuasion attempts. The within-subjects comparisons, for example, showed that each of the six message framing treatments had a statistically significant influence on baseline (i.e., pre-treatment) cognitions. Differences were also observed with the between-subjects comparisons where responses to the negative treatments (i.e., pejorative framing, scientific consensus in opposition) differed significantly from all other treatments with attitudes shifting from favorable to unfavorable and norms changing from agreement to disagreement that this use of GE should be allowed. Results also showed that highlighting scientific consensus in support of this use of GE is an effective persuasion tactic for improving public acceptance, whereas highlighting consensus in opposition reduces acceptance. Taken together, these results suggest that communication campaigns can succeed in modifying cognitions associated with this issue by using targeted message framing. For example, if a goal is to increase public favorability and acceptance, communication from scientists and other experts is needed that not only focuses on potential benefits, but also articulates any actual objective risk assessments to ameliorate any misinformation that can accentuate common perceived risks.

In conclusion, GE has been used for mitigating CB and restoring AC trees in controlled laboratory and field trials, and researchers are currently pursuing regulatory approval for wider commercial release of transgenic AC trees (Powell, 2016; Steiner et al., 2017; Zhang et al., 2011). Results presented here suggest that the majority of the public would respond positively to this, but these responses could be susceptible to communication and persuasion campaigns. These results and implications, however, are limited to using GE for addressing a single forest health threat (i.e., CB) in a single tree species (i.e., AC). The applicability and generalizability of these findings to other forest health threats, such as climate change and other diseases and pests (e.g., emerald ash borer, mountain pine beetle), remain topics for further empirical investigation.

SCENARIO: Imagine both of the following are happening:

- ***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.

- ***Genetic modification*** 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 or add new genes from another organism. These new genes may come from closely related trees, other plants, or distantly related organisms such as bacteria. 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 or added. 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.

Figure 5. Scenario presented to respondents in Study 1.

Imagine ***both*** of the following are happening:

- Chestnut blight is a disease that has killed more than 99% of adult American chestnut trees within their native range. This disease:
  - Is caused by a fungus that generally enters trees through wounds or cracks in the bark.
  - Was accidentally introduced to the United States from Asia around the year 1900.
  - Is most commonly found in the eastern region of the United States.
- Genetic modification (also known as genetic engineering) 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 or add new genes from another organism.
  - These new genes may come from closely related trees, other plants, or distantly related organisms such as bacteria.
  - The genetically modified trees contain thousands of genes from the original tree, plus one or a few genes that have been changed or added.

Figure 6. Scenario 2 (descriptions and scientific information) in Study 2.

Mr. Speaker and Members of Congress:

It is a privilege to be here. I oppose the use of genetic modification (also known as genetic engineering) to help trees resist chestnut blight and restore American chestnut forests. Chestnut blight is a disease that has killed more than 99% of adult American chestnut trees within their native range. This disease:

- Is caused by a fungus that generally enters trees through wounds or cracks in the bark.
- Was accidentally introduced to the United States from Asia around the year 1900.
- Is most commonly found in the eastern region of the United States.

Genetic modification 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 or add new genes from another organism.
- These new genes may come from closely related trees, other plants, or distantly related organisms such as bacteria.
- The genetically modified trees contain thousands of genes from the original tree, plus one or a few genes that have been changed or added.

I will make my testimony brief by listing the following facts in opposition to using genetic modification to help trees resist chestnut blight. Importantly:

- 98% of scientists and other experts agree that genetic modification is not safe and not effective for helping trees resist chestnut blight.

This genetic modification also:

- Adds dangerous traits to trees that can contaminate forests.
- Has been shown to be unsuccessful in helping American chestnut trees resist chestnut blight.
- Poses risks to humans and the environment.
- Is just as harmful as approaches used for modifying many fruit, vegetables, and nuts we eat.
- Is not safe.
- Does not improve the quality of wood products from forests.
- Does not improve forests for outdoor recreation.
- Does not protect forests from negative impacts such as diseases, insects, and environmental change.
- Harms the overall health of forests by introducing alien genes that can spread across forests.
- Is unethical.
- Is morally unacceptable.

For these reasons, I strongly oppose using genetic modification to help trees resist chestnut blight, and I feel that genetic modification should not be allowed. This is an important issue, especially given the benefits of forests for wood products, wildlife habitat, outdoor recreation opportunities, and other services. After all, this resource belongs to all Americans, and it is time that we protect forests for the enjoyment and health of future generations.

Thank you for your time today.

Dr. John Chapman
Distinguished University Professor of Natural Resources

Testimony to Congress on January 11, 2016

Figure 7. Scenario 6 (descriptions, scientific information, pejorative wording, 98% consensus in opposition) in Study 2.

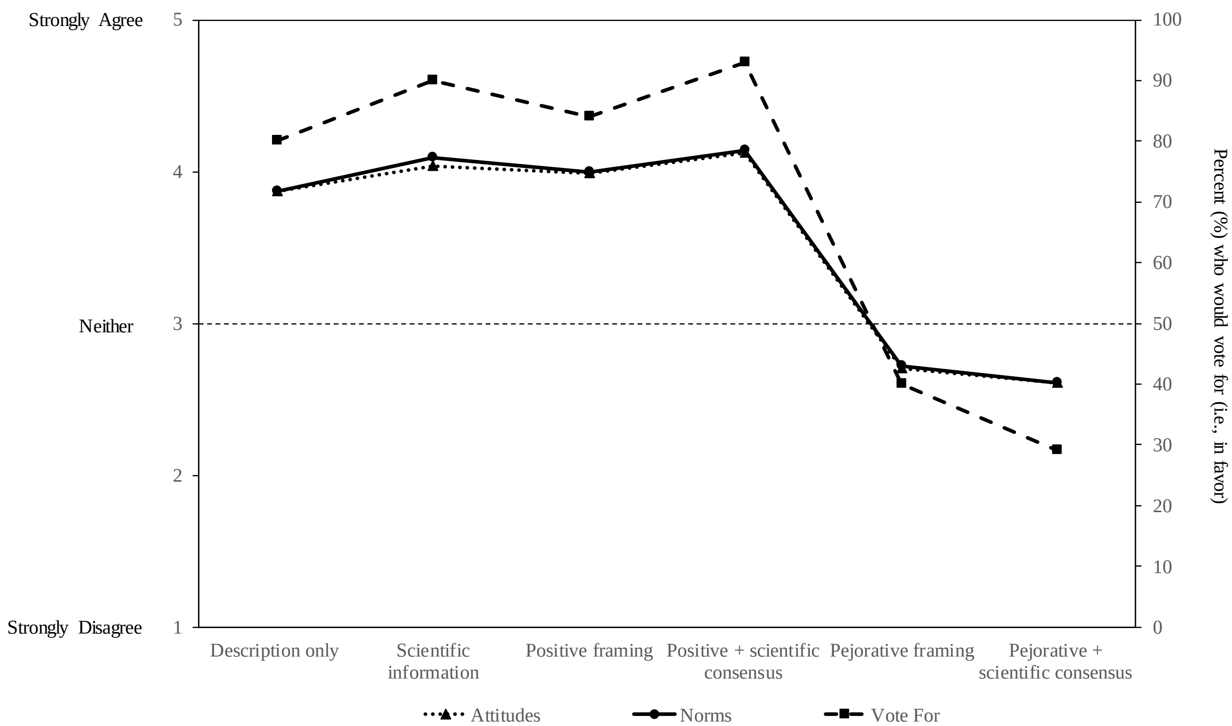

Figure 8. Between-subjects post-treatment attitudes, norms, and voting intentions toward using GE for restoring AC trees from Study 2.

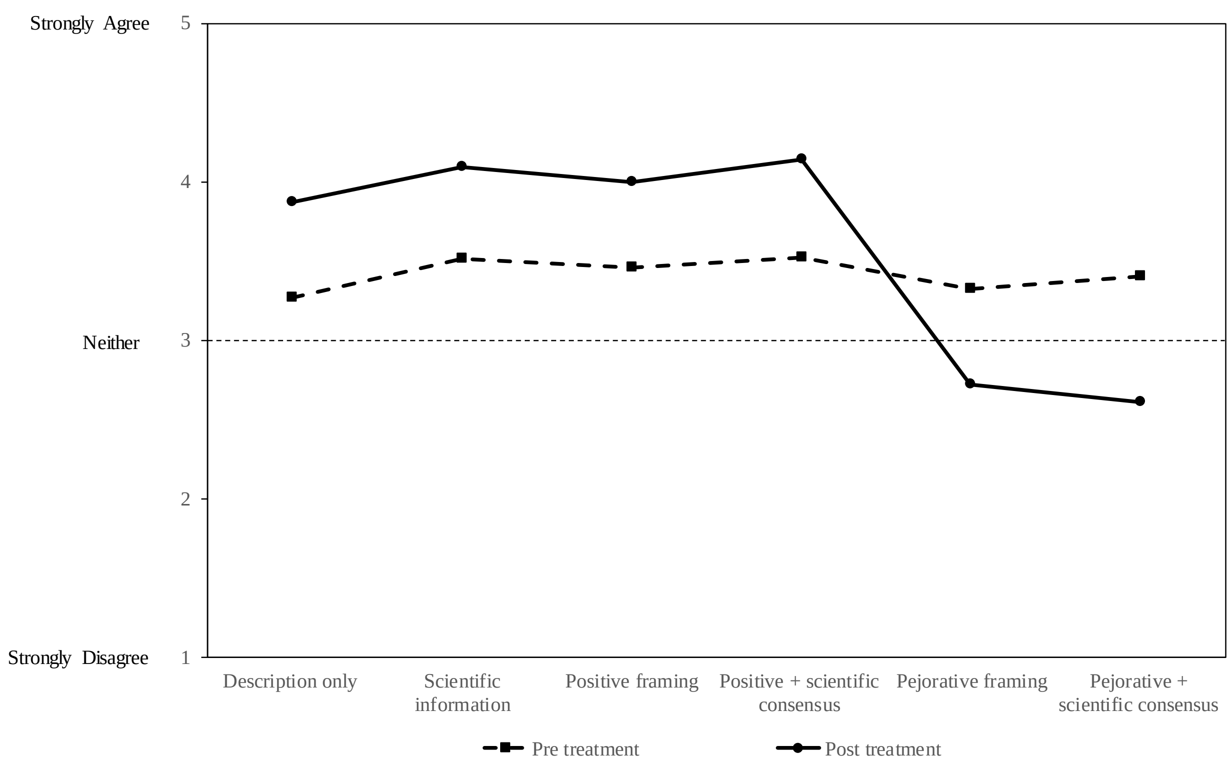

Figure 9. Within-subjects pre- and post-treatment normative acceptance of using GE for restoring AC trees from Study 2.

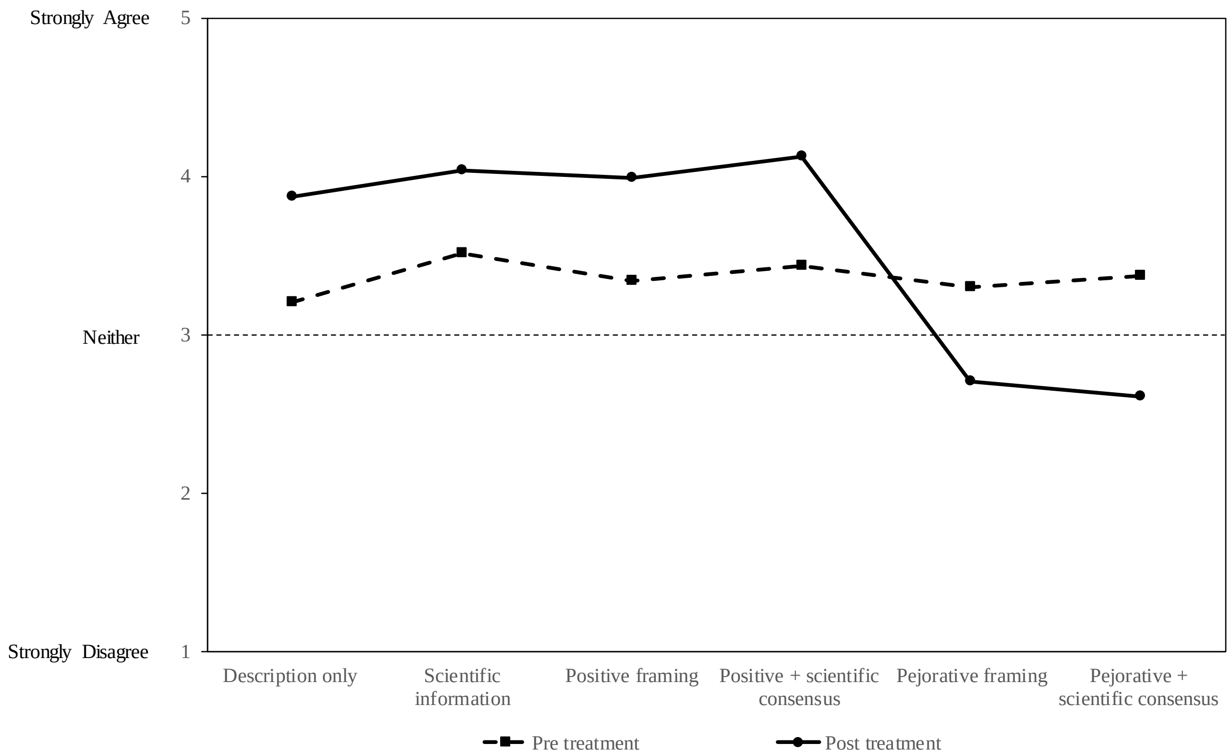

Figure 10. Within-subjects pre- and post-treatment attitudes toward using GE for restoring AC trees from Study 2.

Table 11. Between-subjects analyses comparing post-treatment attitudes, norms, and voting intentions toward using GE for restoring AC trees across six experimental framing treatments from Study 2.

	Description only	Scientific information	Positive framing	Positive + scientific consensus	Pejorative framing	Pejorative + scientific consensus	*F* or χ^2 value	*p* value	η or *V* effect size
Attitudes [1]	3.87 [a]	4.04 [a]	3.99 [a]	4.12 [a]	2.70 [b]	2.61 [b]	43.05	< .001	.53
Norms [1]	3.87 [a]	4.09 [a]	4.00 [a]	4.14 [a]	2.72 [b]	2.61 [b]	44.13	<.001	.54
Voting intention [2]	80	90	84	93	40	29	158.90	< .001	.55
Voting certainty [3]	2.84 [a]	2.96 [ab]	3.21 [b]	3.25 [b]	3.10 [ab]	3.09 [ab]	2.18	.008	.17

[1] Cell entries are means on 5-point scale of 1 "strongly disagree" to 5 "strongly agree." Means with different letter superscripts across each row differ at $p < .05$ using Tamhane's T2 post-hoc test for unequal variances.
[2] Cell entries are percentages (%) who would vote for using GE to help trees resist chestnut blight.
[3] Cell entries are means on 4-point scale of 1 "not certain" to 4 "extremely certain." Means with different letter superscripts differ at $p < .05$ using Tamhane's T2 post-hoc test for unequal variances.

Table 12. Within-subjects analyses comparing pre- and post-treatment normative acceptance of using GE for restoring AC trees from Study 2.

	Pre treatment [1]	Post treatment [1]	Paired *t* value	*p* value	Cohen's *d* effect size
Description only	3.27	3.87	6.94	< .001	.60
Scientific information	3.51	4.09	7.20	< .001	.60
Positive framing	3.46	4.00	4.82	< .001	.58
Positive framing + scientific consensus in support	3.52	4.14	6.19	< .001	.70
Pejorative framing	3.32	2.72	4.75	< .001	.50
Pejorative framing + scientific consensus in opposition	3.40	2.61	5.39	< .001	.73

[1] Cell entries are means on 5-point scale of 1 "strongly disagree" to 5 "strongly agree" that "genetic modification of trees should be allowed to help them resist chestnut blight." Pre-treatment was measured before the scenario in the questionnaire, post-treatment was measured after.

Table 13. Within-subjects analyses comparing pre- and post-treatment attitudes toward using GE for restoring AC trees from Study 2.

	Pre treatment [1]	Post treatment [1]	Paired *t* value	*p* value	Cohen's *d* effect size
Description only	3.20	3.87	7.70	< .001	.67
Scientific information	3.51	4.04	6.49	< .001	.56
Positive framing	3.34	3.99	5.54	< .001	.66
Positive framing + scientific consensus in support	3.43	4.12	6.89	< .001	.75
Pejorative framing	3.30	2.70	4.70	< .001	.51
Pejorative framing + scientific consensus in opposition	3.37	2.61	4.87	< .001	.67

[1] Cell entries are means on 5-point scale of 1 "strongly disagree" to 5 "strongly agree" that "I am in favor of using genetic modification of trees to help them resist chestnut blight." Pre-treatment was measured before the scenario in the questionnaire, post-treatment was measured after.

Table 14. Within-subjects changes in normative acceptance of using GE for restoring AC trees between pre- and post-treatments from study 2. [1]

Pre-treatment vs. post-treatment changes	Description only	Scientific information	Positive framing	Positive + scientific consensus	Pejorative framing	Pejorative + scientific consensus
Became negative (disagree)						
From neutral to disagree	1	0	1	0	16	25
From agree to disagree	0	0	2	0	13	20
Became positive (agree)						
From neutral to agree	24	24	32	25	3	7
From disagree to agree	8	7	3	7	1	2
Became neutral						
From disagree to neutral	6	4	3	0	2	2
From agree to neutral	1	0	2	0	9	6
No change						
Stayed disagree	8	6	3	5	17	10
Stayed neutral	8	4	6	7	11	9
Stayed agree	44	55	47	56	27	18

[1] Cell entries are percentages (%). $\chi^2 = 241.00$, $p < .001$, $V = .29$. Initially measured on 5-point scale of 1 “strongly disagree” to 5 “strongly agree” that “genetic modification of trees should be allowed to help them resist chestnut blight.”

Table 15. Within-subjects changes in attitudes toward using GE for restoring AC trees between pre- and post-treatments from study 2.[1]

Pre-treatment vs. post-treatment changes	Description only	Scientific information	Positive framing	Positive + scientific consensus	Pejorative framing	Pejorative + scientific consensus
Became negative (disagree)						
From neutral to disagree	0	0	1	0	22	23
From agree to disagree	0	0	2	0	11	17
Became positive (agree)						
From neutral to agree	25	23	29	25	6	5
From disagree to agree	9	6	7	8	1	5
Became neutral						
From disagree to neutral	4	6	5	0	2	2
From agree to neutral	0	2	1	1	11	9
No change						
Stayed disagree	8	6	3	5	15	12
Stayed neutral	13	3	8	7	8	10
Stayed agree	41	55	44	54	24	17

[1] Cell entries are percentages (%). $\chi^2 = 248.60$, $p < .001$, $V = .29$. Initially measured on 5-point scale of 1 “strongly disagree” to 5 “strongly agree” that “I am in favor of using genetic modification of trees to help them resist chestnut blight.”

References

Amos, T., & Daniel, K. (1979). Prospect Theory: An Analysis of Decision under Risk. *Econometrica*.

Banas, J. A., & Rains, S. A. (2010). A meta-analysis of research on inoculation theory. *Communication Monographs*, *77*(3), 281–311.

Basman, C. M., Manfredo, M. J., Barro, S. C., Vaske, J. J., & Watson, A. (1996). Norm accessibility: An exploratory study of backcountry and frontcountry recreational norms. *Leisure Sciences*, *18*(2), 177–191.

Boykoff, M. T., & Boykoff, J. M. (2004). Balance as bias: global warming and the US prestige press. *Global Environmental Change*, *14*(2), 125–136.

Brandon, D. M., Long, J. H., Loraas, T. M., Mueller-Phillips, J., & Vansant, B. (2014). Online instrument delivery and participant recruitment services: Emerging opportunities for behavioral accounting research. *Behavioral Research in Accounting*, *26*(1), 1–23.

Cesario, J., Grant, H., & Higgins, E. T. (2004). Regulatory fit and persuasion: Transfer from "feeling right." *Journal of Personality and Social Psychology*, *86*(3), 388–404.

Chaiken, S. (1980). Heuristic versus systematic information processing and the use of source versus message cues in persuasion. *Journal of Personality and Social Psychology*, *39*(5), 752.

Chang, S., Mahon, E. L., MacKay, H. A., Rottmann, W. H., Strauss, S. H., Pijut, P. M., … Jones, T. J. (2018). Genetic engineering of trees: Progress and new horizons. *In Vitro Cellular & Developmental Biology - Plant*, *54*(4), 341–376.

National Academies of Sciences, Engineering, and Medicine Committee on the Potential for Biotechnology to Address Forest Health, Board on Agriculture and Natural Resources, Division on Earth and Life Studies (NASEM). (2019). *Forest health and biotechnology: Possibilities and considerations*. Washington, D.C.: National Academies Press.

Dahlstrom, M. F. (2014). Using narratives and storytelling to communicate science with nonexpert audiences. *Proceedings of the National Academy of Sciences*, *111*(Supplement 4), 13614–13620.

Davidson, A. R., Yantis, S., Norwood, M., & Montano, D. E.. Amount of information about the attitude object and attitude–behavior consistency. *Journal of Personality and Social Psychology*, *49*(5), 1184.

Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes* (Vol. xxii). Orlando, FL, US: Harcourt Brace Jovanovich College Publishers.

Fazio, R. H. (1986). How do attitudes guide behavior? *Handbook of motivation and cognition: Foundations of Social Behavior*, *1*, 204–243.

Fishbein, M., & Ajzen, I. (2011). *Predicting and changing behavior: The reasoned action approach*. Taylor & Francis.

Frewer, L. J., Fischer, A. R. H., Brennan, M., Bánáti, D., Lion, R., Meertens, R. M., … Vereijken, C. M. J. L. (2016). Risk/benefit communication about food: A systematic review of the literature. *Critical Reviews in Food Science and Nutrition*, *56*(10), 1728–1745.

Frewer, L. J., Miles, S., & Marsh, R. (2002). The media and genetically modified foods: Evidence in support of social amplification of risk. *Risk Analysis*, *22*(4), 701–711.

Green, M. C. (2006). Narratives and cancer communication. *Journal of Communication*, *56*(1), 163–183.

Hajjar, R., & Kozak, R. A. (2015). Exploring public perceptions of forest adaptation strategies in western Canada: Implications for policy-makers. *Forest Policy and Economics*, *61*, 59–69.

Hajjar, R., McGuigan, E., Moshofsky, M., & Kozak, R. A. (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. *Canadian Journal of Forest Research*, *44*(12), 1525–1533.

Higgins, E. (2000). Making a good decision: Value from fit. *The American Psychologist*, *55*, 1217–1230.

Jacks, J. Z., & Cameron, K. A. (2003). Strategies for resisting persuasion. *Basic and Applied Social Psychology*, *25*(2), 145–161.

Jepson, P., & Arakelyan, I. (2017a). Exploring public perceptions of solutions to tree diseases in the UK: Implications for policy-makers. *Environmental Science & Policy*, *76*, 70–77.

Jepson, P. R., & 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 and Economics*, *80*, 167–177.

Kahan, D. M. (2012). Cultural cognition as a conception of the cultural theory of risk. In *Handbook of Risk Theory* (pp. 725–759). Springer.

Kahan, D. M., Braman, D., Slovic, P., Gastil, J., & Cohen, G. (2009). Cultural cognition of the risks and benefits of nanotechnology. *Nature Nanotechnology*, *4*(2), 87–90.

Kahan, D. M., Jenkins-Smith, H., & Braman, D. (2011). Cultural cognition of scientific consensus. *Journal of Risk Research*, *14*(2), 147–174.

Kahneman, D., & Tversky, A. (2013). Choices, values, and frames. In *Handbook of the Fundamentals of Financial Decision Making: Part I* (pp. 269–278). World Scientific.

Kasperson, R. E., Renn, O., Slovic, P., Brown, H. S., Emel, J., Goble, R., … Ratick, S. (1988). The social amplification of risk: A conceptual framework. *Risk Analysis*, *8*(2), 177–187.

Kempken, F., & Jung, C. (2010). *Genetic modification of plants agriculture, horticulture and forestry*. Heidelberg; New York: Springer.

Lewandowsky, S., Gignac, G. E., & Vaughan, S. (2013). The pivotal role of perceived scientific consensus in acceptance of science. *Nature Climate Change*, *3*(4), 399–404.

Lu, H., Siemer, W. F., Baumer, M. S., & Decker, D. J. (2018). Exploring the role of gain versus loss framing and point of reference in messages to reduce human–bear conflicts. *The Social Science Journal*, *55*(2), 182–192.

Lusk, J. L., House, L. O., Valli, C., Jaeger, S. R., Moore, M., Morrow, J. L., & Traill, W. B. (2004). Effect of information about benefits of biotechnology on consumer acceptance of genetically modified food: Evidence from experimental auctions in the United States, England, and France. *European Review of Agricultural Economics*, *31*(2), 179–204.

Maheswaran, D., & Meyers-Levy, J. (1990). The influence of message framing and issue involvement. *Journal of Marketing Research*, *27*(3), 361–367.

McFadden, B. R., & Lusk, J. L. (2015). Cognitive biases in the assimilation of scientific information on global warming and genetically modified food. *Food Policy*, *54*, 35–43.

McGuire, W. J., & Papageorgis, D. (1961). The relative efficacy of various types of prior belief-defense in producing immunity against persuasion. *The Journal of Abnormal and Social Psychology*, *62*(2), 327–337.

Nan, X. (2009). The influence of source credibility on attitude certainty: Exploring the moderating effects of timing of source identification and individual need for cognition. *Psychology & Marketing*, *26*(4), 321–332.

Petty, R. E., & Cacioppo, J. T. (1984). The effects of involvement on responses to argument quantity and quality: Central and peripheral routes to persuasion. *Journal of Personality and Social Psychology*, *46*(1), 69.

Petty, R. E., & Cacioppo, J. T. (1986). *The elaboration likelihood model of persuasion*. Springer.

Petty, R. E., & Krosnick, J. A. (2014). *Attitude strength: Antecedents and consequences*. Psychology Press.

Pilcher, C. D., Rice, M. E., Higgins, R. A., Steffey, K. L., Hellmich, R. L., Witkowski, J., … Gray, M. (2002). Biotechnology and the European corn borer: Measuring historical farmer perceptions and adoption of transgenic bt corn as a pest management strategy. *Journal of Economic Entomology*, *95*(5), 878–892.

Pin, R. R., Gutteling, J. M., & Kuttschreuter, M. (2009). Determinants of reactions to gene technology: A generic approach. *New Genetics and Society*, *28*(1), 51–65.

Powell, W. (2016). New genetically engineered American chestnut will help restore the decimated, iconic tree. *The Conversation*, Jan, 19, 2016.

Shindler, B., & Cheek, K. A. (1999). Integrating citizens in adaptive management: A propositional analysis. *Conservation Ecology, 3*(1), 9.

Slater, M. D., & Rouner, D. (2002). Entertainment—education and elaboration likelihood: Understanding the processing of narrative persuasion. *Communication Theory*, *12*(2), 173–191.

Steiner, K. C., Westbrook, J. W., Hebard, F. V., Georgi, L. L., Powell, W. A., & Fitzsimmons, S. F. (2017). Rescue of American chestnut with extraspecific genes following its destruction by a naturalized pathogen. *New Forests*, *48*(2), 317–336.

Teel, T., Bright, A., Manfredo, M., & Brooks, J. (2006). Evidence of biased processing of natural resource-related information: A study of attitudes toward drilling for oil in the Arctic National Wildlife Refuge. *Society & Natural Resources*, *19*(5), 447–463.

Tversky, A., & Kahneman, D. (1991). Loss aversion in riskless choice: A reference-dependent model. *The Quarterly Journal of Economics*, *106*(4), 1039–1061.

Vaske, J. J. (2008). *Survey research and analysis: Applications in parks, recreation and human dimensions*. Venture Publishing State College, PA.

Vaske, J., & Whittaker, D. (2004). Normative approaches to natural resources. *Society and Natural Resources: A Summary of Knowledge*, 283–294.

Whittaker, D., Vaske, J. J., & Manfredo, M. J. (2006). Specificity and the cognitive hierarchy: Value orientations and the acceptability of urban wildlife management actions. *Society & Natural Resources*, *19*(6), 515–530.

Yu, H. (Jay). (2012). Producing more persuasive antiviolence messages for college students: Testing the effects of framing, information sources, and positive/negative fact appeal. *Journal of Interpersonal Violence*, *27*(9), 1631–1654.

Zhang, B., Newhouse, A., McGuigan, L., Maynard, C., & Powell, W. (2011). Agrobacterium-mediated co-transformation of American chestnut (Castanea dentata) somatic embryos with a wheat oxalate oxidase gene. In *BMC Proceedings* (Vol. 5, p. O43). BioMed Central Ltd.

CHAPTER FIVE

CONCLUSION

Summary of Findings

This dissertation investigated perceptions associated with using genetic engineering (GE) for mitigating chestnut blight (CB) and restoring American chestnut (AC) trees. Three standalone articles assessed: (a) the potential cognitive and socio-demographic drivers of attitudes toward this use of GE (Chapter 2); (b) the extent that normative acceptance of this use of GE is related to perceptions of risks and benefits to humans and the environment, and trust in those charged with managing this application of GE (Chapter 3); and (c) whether these cognitions can change as a result of message wording or framing effects (Chapter 4).

Specifically, Chapter 2 explored three research questions: (a) what are the attitudes of people toward this use of GE; (b) what socio-demographic characteristics and other cognitions are related to these attitudes, and which of these variables are the strongest predictors of these attitudes; and (c) to what extent do these cognitions and socio-demographic characteristics differ between the US public and other forest interest groups (FIGs)? Multiple regression analyses examined relationships between cognitions (e.g., perceived risks and benefits, trust, self-assessed and factual knowledge, beliefs, value orientations toward the environment in general and forests in particular), socio-demographic characteristics (e.g., age, income, education, race, involvement in forestry, political orientation), and attitudes toward three GE applications for mitigating CB and restoring AC trees (change existing genes, add genes from distantly related species, add genes from bread wheat). Results showed relatively positive attitudes toward these GE applications for both the public and FIG samples, although the FIGs felt more positively. Perceptions of risks and benefits, trust, and value orientations were among the most consistent predictors of these attitudes, with environmental risks and benefits often most strongly related to these attitudes for both groups. Proximity to a forest was negatively related to favorable attitudes for the public sample.

Building on this previous chapter, Chapter 3 investigated the concepts of risks, benefits, and trust in more detail by examining the extent that normative acceptance (i.e., norms) is related to perceptions of risks and benefits (toward humans and the environment) associated with these uses of GE and trust in those charged with managing these technologies. Based on previous research, five hypotheses were advanced: (a) perceived risks (to humans, to the environment) of using GE to mitigate CB and restore AC trees will be negatively related to normative acceptance of this use of GE; (b) perceived benefits (to humans, to the environment) of this use of GE will be positively related to normative acceptance; (c) trust in agencies (federal, nonfederal) will be negatively related to these perceived risks; (d) trust in these agencies will be positively related to these perceived benefits; and (e) trust in agencies will be positively related to normative acceptance. Multigroup structural equation models (SEM) assessed relationships among these concepts for each of the same three GE applications examined in Chapter 2. The public sample considered adding genes from distant species to be the riskiest, least beneficial, and most unacceptable, whereas the FIGs generally viewed adding a gene from bread wheat (OxO gene) in this manner. Public respondents, however, viewed all of the scenarios as riskier, less acceptable, and less beneficial than did the FIGs. Other results showed that: (a) perceived environmental risks and benefits were the strongest predictors of GE acceptance across all three GE applications and both the public and FIG samples, (b) human risks and benefits were not strong drivers of acceptance, and (c) increasing trust in government agencies charged with managing forests was generally associated with higher benefits and lower risks, especially for the public sample.

Chapter 4 then assessed the extent these cognitions (i.e., attitudes, norms) can be modified by various message wording and framing effects. Two research questions were examined: (a) what are the current attitudes, norms, and intentions of people regarding the use of GE for mitigating CB and restoring AC trees; and (b) to what extent are these cognitions susceptible to some message framing approaches (e.g., positive vs. pejorative wording, scientific information and consensus)? Data from a representative sample of the US public (study 1) showed that this sample, on average, thought that using GE for mitigating CB and restoring AC trees was positive and should be allowed. The majority of respondents would also vote for this use of GE and were moderately or extremely certain of these intentions. However, data from an experiment conducted with other members of the US public (study 2) showed that cognitions are sensitive to information messaging and susceptible to persuasion campaigns, as both the between and within-subjects comparisons showed that support dropped dramatically as soon as messages provided any negative or opposing arguments (i.e., pejorative language) about this topic. Positively worded information coupled with messages about scientific consensus in support of this use of GE received the most favorable attitudes and greatest acceptance, whereas negatively worded information coupled with messages about scientific consensus in opposition yielded the least favorable attitudes and lowest acceptance.

Taken together, these three chapters: (a) demonstrate majority support (i.e., positive attitudes, normative acceptance) for using GE to mitigate CB and restore AC trees; (b) show that perceived environmental benefits and risks are most strongly related to this support; and (c) suggest that although these cognitions are generally positive, they are highly unstable and susceptible to negative messaging and wording effects aimed at persuading people to change their opinions. Broadly speaking, these results advance scientific understanding of attitudes and normative acceptance of using GE in forest conservation. Other uses of GE (e.g., medicine, agriculture) are often viewed with varying degrees of support and opposition, so results may not be transferable across contexts and it is important to understand cognitions in this specific context, especially given the importance of forests globally. Furthermore, the limited research examining what people think about using GE for addressing forest health threats has largely occurred in Canada and Europe (Hajjar & Kozak, 2015; Hajjar et al., 2014; Jepson & Arakelyan, 2017a,b; NASEM, 2019). Differences among regions in societal responses toward natural resource (NR) issues in general and biotechnologies such as GE in particular have been demonstrated in other fields (Hohl & Gaskell, 2008; McCluskey, Curtis, Li, Wahl, & Grimsrud, 2004; Oreg, 2006), which could suggest that social values, media coverage and tone (e.g., positive vs. negative press), and other contextual factors might be important in shaping attitudes and acceptance. This research provides insight regarding sentiment among the US public and other FIGs toward using GE in forest conservation initiatives, as well as the stability of these opinions when exposed to persuasive messaging.

Theoretical Implications

Findings presented in this dissertation also have implications for social psychological concepts and theories central to human dimensions of NR research. This research increases scientific understanding of human responses to complex NR issues and the underlying cognitive and demographic drivers of these responses.

Persuasion, messaging, and risk communication. Results in this dissertation advance persuasion theory related to messaging and framing effects. A takeaway from this research is that attitudes and norms associated with using GE to address CB are relatively unstable and susceptible to persuasion. Results in Chapter 4 demonstrated that providing information about GE (i.e., basic neutral description, negative, positive) influenced attitudes, norms, and intentions. Presenting information on potential drawbacks associated with this use of GE yielded a large change in attitudes and norms with these cognitions becoming more negative. Providing a numerical indicator of scientific consensus (i.e., "98% of scientists disagree") reduced support even further. In fact, negative framing (i.e., wording treatments) was far more influential in modifying attitudes and norms than was positive framing. This is consistent with existing risk communication theories and literature, such as prospect theory (Tversky & Kahneman, 1979) and gain / loss or risk aversion theories (Tversky & Kahneman, 1991), which suggest that framing information negatively (i.e., losses) can be more influential over decision making versus positive messaging (i.e., gains). Furthermore, results are consistent with research showing that messages providing positive arguments, pejorative terminology, scientifically accurate information, or biased viewpoints lacking scientific consensus (e.g., "climate change is not influenced by human actions") can influence attitudes and social acceptance (Boykoff & Boykoff, 2004). Findings were also similar to other studies showing that framing information from credible or trusted sources (e.g., scientists) and providing quantitative substantiation of scientific consensus (e.g., "98% of scientists agree") also impacts cognitions (Nan, 2009; Yu, 2012).

Hierarchical nature of cognitions. Results in this dissertation also provide additional support for research on the hierarchical nature of human cognitions. Social psychologists have utilized various theories that order cognitions from those that are more general, fewer in number, and slower to change (e.g., environmental value orientations) to those that are more context specific (e.g., attitudes toward using GE to address CB) and proximally related to human actions and behaviors (Fishbein & Ajzen, 2011; Fishbein & Manfredo, 1992). Theories such as the cognitive hierarchy (Whittaker et al., 2006) and the value-attitude-behavior model (Homer &

Kahle, 1988; Vaske & Donnelly, 1999) demonstrate how broader or more general cognitions can shape and provide context for more specific correlates of behavior. Chapter 2 assessed relationships between attitudes toward using GE for mitigating CB and restoring the AC tree and potential correlates of these attitudes, and found that more specific cognitions, such as perceived environmental risks and benefits, were most predictive of these attitudes, whereas more general cognitions (e.g., general environmental value orientations) were less predictive. Results in Chapter 3 demonstrated that perceptions of specific risks and benefits were more predictive of normative acceptance than were more general concepts such as trust in federal and nonfederal agencies, which also supports these hierarchical conceptual interrelationships.

Trust, risk, and benefits. Related to the hierarchical nature of cognitions, this dissertation also provides unique insights on associations among technology acceptance, risk and benefit perceptions, and social trust. Empirical studies examining acceptance of GE in other contexts has consistently found positive relationships between benefits and both trust and acceptance, and negative associations between risks and both trust and acceptance (e.g., Vaske et al., 2007; Visschers et al., 2011; Xiao et al., 2017). Trust in managers of hazards or technologies has generally been associated with lower perceived risks, greater benefits, and higher acceptance (Connor & Siegrist, 2010; Perry, Needham, & Cramer, 2017; Stern & Coleman, 2015; Vaske et al., 2007; Xiao et al., 2017). These relationships have also been examined in the context of forest conservation in general and the use of GE in forests in particular, as research conducted mostly in Europe and Canada has shown that trust can be negatively associated with perceived risks of using GE in forestry, and positively associated with both perceived benefits and acceptance of these uses of GE (Connor & Siegrist, 2010; Hajjar & Kozak, 2015; Jepson & Arakelyan, 2017; Neumann, Krogman, & Thomas, 2007). This trend was generally supported in bivariate analyses in Chapter 2, but the multivariate path analyses in Chapter 3 yielded different directionality among some of these conceptual relationships, thus informing this field of research.

Specificity principle. This research also adds to the body of knowledge on the role of measurement specificity in social science research. The principle of specificity states that cognitions are better predictors of other cognitions and behaviors when measured (e.g., items in a questionnaire) at similar levels of contextual specificity (Crespi, 1971; Whittaker et al., 2006). Results from both Chapters 2 and 3 support this principle. In Chapter 2, for example, the strongest predictors of attitudes toward three distinct uses of GE for addressing CB were specific risks and benefits to the environment. It makes sense that these attitudes were more highly associated with cognitions specific to forests and the environment (e.g., environmental risks and benefits) rather than more general cognitions (e.g., general value orientations). Although research has shown perceived risks to humans as the principal driver of favorability toward GE (e.g., in agriculture and food), this dissertation found that environmental risks and benefits were the strongest predictors and this finding might be partially explained by this principle. Chapter 3 also showed that more proximal or specific cognitions (e.g., perceived environmental benefits and risks) were stronger drivers of GE acceptance compared to more distant or general cognitions (e.g., trust in agencies).

Management Implications

In addition to these theoretical and conceptual contributions, this research also has practical applications, as managers, science communicators, and politicians might gain insight from this research in terms of addressing the human dimensions of complex NR issues such as CB and other forest health threats (e.g., diseases, pests, climate change).

Expert versus public opinion. Information campaigns aimed at informing and educating the public about complex topics (e.g., genetic technologies, NR management initiatives) can be be strengthened by an empirical understanding of the diversity of public opinions, their associated cognitive and demographic correlates, and how these differ from other interest groups (e.g., scientists, managers). Research has shown that public perceptions toward modern technologies such as GE do not always align with those of scientists or others deemed as experts (Sjöberg, 1998; Sjöberg & Drottz-Sjöberg, 2008). For example, scientists tend to rate risks more in-line with objective estimates of probabilities and consequences, whereas risk perceptions by members of the general public are often based on more subjective and emotional responses toward hazards (Kunreuther & Slovic, 1996; Sjöberg, 1998; Wilson & Arvai, 2006). Results in Chapters 2 and 3 of this dissertation showed that FIGs such as scientists tended to view using GE to mitigate CB and help restore AC trees much more favorably than did the general public. It is also important to understand the drivers of these differences in opinions. Findings from Chapters 2 and 3 revealed these drivers and provided insights on how information and communications can be targeted to better align public opinion with scientific opinion about this issue.

The role of message framing. This dissertation's findings have implications for those aiming to inform or change attitudes toward these uses of GE. Specifically, to modify attitudes, managers should communicate with stakeholders before strong opinions are formed (Eagly & Chaiken, 1993) and tailor communications to specific target audiences relative to their familiarity with a given issue and the complexity of the issue. The low public awareness of CB in this study (30%), for example, necessitates focusing on increasing awareness of forest health stressors such as CB. In addition, certain uses of GE, such as transgenics between distantly related organisms, can be perceived as riskier partially because they are less well-known, more complex, or are seen as tampering with nature (Mielby, Sandøe, & Lassen, 2013). Jepson and Arakelyan (2017a), for example, found that cisgenic approaches were viewed more favorably than transgenic methods for addressing ash dieback in the UK. Similar results were found here where technologies perceived to be more natural or requiring less modification of nature, such as changing existing AC genes (i.e., cisgenic between plant species), were viewed more favorably in comparison to other GE applications (e.g., transgenics between distant species). Thus, informational and educational messaging aimed at enhancing favorability might consider using wording and other framing approaches emphasizing techniques that are perceived as more natural.

Results in this dissertation (e.g., Chapters 2 and 3) also showed that environmental benefits were strongly related to attitudes and acceptance of each GE approach for addressing CB, suggesting that informational and educational messaging aimed at increasing acceptance and support should primarily emphasize environmental factors, such as helping to restore historic tree species or mitigate tree diseases and pests. It is also important to recognize that openly addressing potential risks of using GE in this context is warranted given that risk perceptions were also significant drivers of attitudes and norms. Incorporating any known risks in messaging will aid in maintaining transparency and communicating a sense of accountability and balance (i.e., objectivity). Furthermore, researchers have shown that communication is generally most effective when messaging uses a type of “inoculation effect” that includes some potential negatives (e.g., risks, concerns) accompanying favorable information (e.g., benefits, positive outcomes) (Banas & Rains, 2010; Eagly & Chaiken, 1993).

Findings from Chapter 4 showed that although attitudes and normative acceptance of using GE in this forest conservation context (i.e., to mitigate CB and restore AC trees) are somewhat favorable, these cognitions are susceptible to messaging aimed at persuading people to change their attitudes and norms. The within-subjects comparisons, for example, showed that each of six different message framing treatments had a statistically significant influence on baseline (i.e., pre-treatment) cognitions. Differences were also observed in the between-subjects comparisons where responses to the negative treatments (i.e., pejorative framing, scientific consensus in opposition) dramatically shifted from favorable and supportive to unfavorable and opposed toward this use of GE. Highlighting scientific consensus in support and opposition (i.e., "98% of scientists agree") were also effective at changing cognitions (i.e., consensus in support yielded more favorable cognitions, consensus in opposition yielded less favorable cognitions). Taken together, these results suggest that managers may be able to use well-designed communication campaigns to modify cognitions associated with this issue. For example, if an objective is to increase favorability and acceptance, communication from scientists and other experts is needed that not only focuses on potential benefits, but also articulates any objective risk assessments to reduce the impact of any misinformation that can exacerbate common perceived risks.

The role of socio-demographic characteristics. Findings from Chapter 2 also shed light on the extent that socio-demographic characteristics are associated with public attitudes toward these uses of GE. These characteristics include age, race, sex (male, female), income, education, residential location, political orientation, residential proximity to a forest, and forestry industry involvement (e.g., employment). Multiple regression analyses revealed some significant relationships where age was positively associated with these attitudes and residential proximity to a forest was negatively related. Previous research has shown some relationships between demographic characteristics and attitudes toward biotechnologies such as GE. For example, males, whites (versus nonwhites), those with higher incomes, more educated people, and younger individuals tend to be (although not always; see Tsourgiannis, Kazana, & Iakovoglou, 2016 for exceptions) more supportive of complex NR management efforts and associated technologies such as GE in forestry (Frewer et al., 2013; Hajjar & Kozak, 2015). Managers can use these findings to target specific sociodemographic populations with different message framing associated with using GE in forestry and other NR contexts.

Trust-building efforts should align with value orientations and context. Results in Chapter 3 showed that although both the public and FIG samples had moderate trust in federal government agencies, they only slightly trusted state and local agencies. This finding is noteworthy, as these nonfederal agencies serve as day-to-day managers of many public lands and often cooperate with federal agencies to manage forests and other natural resources on a larger scale. Some of these nonfederal agencies may also be responsible for regulating and monitoring GE trees if regulatory approval is granted, as well as informing the public about management activities (Chang et al., 2018). To enhance trust between the public and agencies, researchers have recommended: (a) emphasizing clear and open dialogue between agency members and the public, (b) including the public in planning processes, (c) highlighting local benefits of management actions, (d) minimizing turnover in agency personnel who regularly interact with the public, and (e) assessing and tailoring management to local contextual factors that can shape or inhibit these actions (Shindler, Brunson, & Stankey, 2002; Shindler & Mallon, 2011).

Results in this dissertation also showed that trust can be a driver of attitudes and norms toward using GE to help mitigate CB and restore AC trees. Some of the models in Chapter 2, for example, showed that trust in federal agencies was positively associated with favorable attitudes. Chapter 3 showed that trust in federal agencies was also a driver of perceived risks (negative associations) and benefits (positive associations) associated with using GE in this context. Other researchers have also found that acceptance of using GE in different contexts (e.g., agriculture) is often positively associated with perceived benefits and negatively associated with perceived risks, and these perceptions can be related to trust in managers of these technologies (Connor & Siegrist, 2010; Frewer et al., 2013; Hajjar & Kozak, 2015; Jepson & Arakelyan, 2017a; Neumann et al., 2007; Peterson St-Laurent, Hagerman, & Kozak, 2018; Strauss et al., 2017). Although this dissertation did not uncover these same patterns in relation to trust in nonfederal agencies, it did for federal agencies and this discrepancy might simply relate to contextual differences. Researchers have highlighted this role of context in shaping public responses to NR issues (e.g., fire management) (Shindler, 2000; Shindler et al., 2002). Although speculative, results in this dissertation might relate to the nature of regulatory frameworks associated with technologies such as GE where these technologies are typically managed and regulated at the national level (e.g., US Department of Agriculture, Food and Drug Administration, Environmental Protection Agency).

In functional democratic republics (e.g., US), public sentiment can guide policies that, in turn, directly and indirectly influence the utility of strategies and technologies used by managers for addressing NR issues (e.g., elected officials enact legislation prohibiting or allowing use) (Shindler & Cheek, 1999). Therefore, understanding drivers of public support for these technologies and the role of trust in agencies (i.e., federal, nonfederal) charged with managing their use is of significant practical importance. Taken together, trust is undoubtedly a key element in effective relationship-building and open communication between NR managers and the public (NASEM, 2019; Shindler et al., 2014). In this case, managers and political representatives should clearly and openly communicate potential risks and benefits of using GE for addressing forest health issues, maintain lasting dialogue, and understand public sentiment that can guide legislation and policy determining the utility of any available tools and management strategies.

Future Research

This dissertation contributes to the small body of existing literature examining what people think about using GE in forest contexts (see NASEM, 2019 for a review), and informs future research on assessing cognitions associated with technological applications for mitigating forest health threats. Results in this dissertation, for example, may inform future research on understanding correlates of support and opposition toward other contemporary genetic technologies in forestry (e.g., CRISPR, genomics) and the role of framing messages to influence these responses. The three articles in this dissertation outline a number of other possible avenues for future research that would expand on the results presented and discussed here.

Results in this dissertation may also inform future research related to releasing GE trees into the wild, especially given that transgenic AC trees are currently being sought for regulatory approval and commercial availability (Powell, 2016; Steiner et al., 2017). If these trees become available, concerns related to the release of these trees into natural or wild forests may increase. Previous research has shown higher concern associated with introducing other GE plants and trees into wild settings (e.g., public lands) in comparison to controlled settings such as laboratories and plantations (Jepson & Arakelyan, 2017a,b; Kazana et al., 2015; Kazana et al., 2016). Given the wide dispersal range and life span of the AC (several hundred years), potential unintended consequences of releasing transgenic AC trees into various ecosystems will likely be of public concern and should be investigated in more detail.

This dissertation also provides insight into potential public responses to future applications of GE for addressing other forest health threats. Researchers in Europe, for example, have examined public reactions to using GE for mitigating ash dieback in ash trees (Jepson & Arakelyan, 2017a,b). This dissertation may also aid managers in the US and abroad in addressing other tree diseases such as blister rust, and or other stressors such as naturally occurring and non-native insect outbreaks including pine beetle and emerald ash borer. In addition, results here may help to understand how people would respond to genetic technologies for mapping species' genomes (e.g., genomics) and correlating desirable traits (e.g., habitat range, draught tolerance) that might be used when anticipating future changing environmental gradients due to climate change. Assisted migration (i.e., the managed relocation of trees into zones based on predicted climatic regimes) is another area where this research might also be applied. Future work, for example, might investigate public perceptions toward assisted migration, as well as tools (e.g., genetic technologies) that might be used in these efforts.

In closing, this dissertation advances the small body of literature on what people think about using GE in forests in general and for forest conservation in particular (see NASEM, 2019 for a review). In three standalone articles, this research identified majority support for using GE techniques to mitigate CB and restore AC trees in the US, and showed that perceived environmental benefits and risks were the most important correlates of this support. Results also showed, however, that this support is highly susceptible to possible messaging campaigns designed to change opinions. These findings can inform managers and scientists, and aid in communication with the public regarding this and other related complex NR issues.

References

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica, 47*(2), 263-292

Banas, J., & Rains, S. (2010). A meta-analysis of research on inoculation theory. *Communication Monographs*, *77*(3), 281–311.

Chang, S., Mahon, E. L., MacKay, H., Rottmann, W., Strauss, S., Pijut, P., … Jones, T. (2018). Genetic engineering of trees: Progress and new horizons. *In Vitro Cellular & Developmental Biology - Plant*, *54*(4), 341–376.

Connor, M., & Siegrist, M. (2010). Factors influencing people's acceptance of gene technology: The role of knowledge, health expectations, naturalness, and social trust. *Science Communication*, *32*(4), 514–538.

Crespi, I. (1971). What kinds of attitude measures are predictive of behavior? *Public Opinion Quarterly*, *35*(3), 327–334.

Eagly, A., & Chaiken, S. (1993). *The psychology of attitudes*. Orlando, FL, US: Harcourt Brace Jovanovich College Publishers.

Fishbein, M., & Ajzen, I. (2011). *Predicting and changing behavior: The reasoned action approach*. Taylor & Francis.

Fishbein, M., & Manfredo, M. (1992). A theory of behavior change. *Influencing Human Behavior*, 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 in Food Science & Technology*, *30*(2), 142–152.

Hajjar, R., & Kozak, R. (2015). Exploring public perceptions of forest adaptation strategies in western Canada: Implications for policy-makers. *Forest Policy and Economics*, *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. *Canadian Journal of Forest Research*, *44*(12), 1525–1533.

Hohl, K., & Gaskell, G. (2008). European public perceptions of food risk: Cross-national and methodological comparisons. *Risk Analysis*, *28*(2), 311–324.

Homer, P., & Kahle, L. (1988). *A structural equation test of the value–attitude–behavior hierarchy*. *54*(4), 638–646.

Jepson, P., & Arakelyan, I. (2017a). Exploring public perceptions of solutions to tree diseases in the UK: Implications for policy-makers. *Environmental Science & Policy*, *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 and Economics*, *80*, 167–177.

Kazana, V., Tsourgiannis, L., Iakovoglou, V., Stamatiou, C., Alexandrov, A., Araújo, S., ... & Boutsimea, A. (2015). Public attitudes towards the use of transgenic forest trees: A cross-country pilot survey. *iForest-Biogeosciences and Forestry*, *9*(2), 344.

Kazana, V., Tsourgiannis, L., Iakovoglou, V., Stamatiou, C., Alexandrov, A., Araújo, S., ... & Boutsimea, A. (2016). Public knowledge and perceptions of safety issues towards the use of genetically modified forest trees: A cross-country pilot survey. In *Biosafety of Forest Transgenic Trees* (pp. 223-244). Springer, Dordrecht.

Kunreuther, H., & Slovic, P. (1996). Science, values, and risk. *The Annals of the American Academy of Political and Social Science*, *545*(1), 116–125.

McCluskey, J., Curtis, K., Li, Q., Wahl, T., & Grimsrud, K. (2004). Consumer attitudes and willingness to pay for genetically modified foods: A cross-country comparison. *National Agricultural Biotechnology Council*, *15*.

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? *Agriculture and Human Values*, *30*(3), 471–480.

Nan, X. (2009). The influence of source credibility on attitude certainty: Exploring the moderating effects of timing of source identification and individual need for cognition. *Psychology & Marketing*, *26*(4), 321–332.

National Academies of Sciences, Engineering, and Medicine (NASEM). (2019). *Forest health and biotechnology: Possibilities and considerations*. Washington, DC: The National Academies Press.

Neumann, P., Krogman, N., & Thomas, B. (2007). Public perceptions of hybrid poplar plantations: Trees as an alternative crop. *International Journal of Biotechnology*, *9*(5), 468–483.

Oreg, S. (2006). Predicting proenvironmental behavior cross-nationally: Values, the theory of planned behavior, and value-belief-norm theory. *Environment and Behavior*, *38*(4), 462–483.

Perry, E., Needham, M., & Cramer, L. (2017). Coastal resident trust, similarity, attitudes, and intentions regarding new marine reserves in Oregon. *Society & Natural Resources*, *30*(3), 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. *Climatic Change*, *151*(3), 573–587.

Powell, W. (2016). New genetically engineered American chestnut will help restore the decimated, iconic tree. *The Conversation*, *Jan*, *19*, 2016.

Shindler, B. (2000). Landscape-level management: It's all about context. *Journal of Forestry*, *98*(12), 10–14.

Shindler, B., Brunson, M., & Stankey, G. (2002). *Social acceptability of forest conditions and management practices: A problem analysis*. United States Forest Service.

Shindler, B., & Cheek, K. (1999). Integrating citizens in adaptive management: A propositional analysis. *Conservation Ecology*, *3*(1), 9.

Shindler, B. (2011). *Public acceptance of disturbance-based forest management: A study of the Blue River landscape strategy in the central cascades adaptive management area*. DIANE Publishing.

Shindler, B., Olsen, C., McCaffrey, S., McFarlane, B., Christianson, A., McGee, T., … Sharp, E. (2014). *Trust: A planning guide for wildfire agencies and practitioners—an international collaboration drawing on research and management experience in Australia, Canada, and the United States*. Retrieved from http://ir.library.oregonstate.edu/xmlui/handle/1957/45323

Sjöberg, L. (1998). Risk perception: Experts and the public. *European Psychologist*, *3*(1), 1-12.

Sjöberg, L., & Drottz-Sjöberg, B. (2008). Attitudes towards nuclear waste and siting policy: Experts and the public. *Nuclear Waste Research: Siting, Technology, and Treatment*, 47–74.

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 Forests*, *48*(2), 317–336.

Stern, M., & Coleman, K. (2015). The multidimensionality of trust: Applications in collaborative natural resource management. *Society & Natural Resources*, *28*(2), 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 Phytologist*, *213*(3), 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 *Biosafety of Forest Transgenic Trees* (pp. 245–261). Springer.

Tversky, A., & Kahneman, D. (1991). Loss aversion in riskless choice: A reference-dependent model. *The Quarterly Journal of Economics*, *106*(4), 1039–1061.

Vaske, J., & Donnelly, M. (1999). A value-attitude-behavior model predicting wildland preservation voting intentions. *Society & Natural Resources*, *12*(6), 523–537.

Vaske, J., Absher, J., & Bright, A. (2007). Salient value similarity, social trust and attitudes toward wildland fire management strategies. *Human Ecology Review*, 223–232.

Visschers, V., Keller, C., & Siegrist, M. (2011). Climate change benefits and energy supply benefits as determinants of acceptance of nuclear power stations: Investigating an explanatory model. *Energy Policy*, *39*(6), 3621–3629.

Whittaker, D., Vaske, J., & Manfredo, M. (2006). Specificity and the cognitive hierarchy: Value orientations and the acceptability of urban wildlife management actions. *Society & Natural Resources*, *19*(6), 515–530.

Wilson, R., & Arvai, J. (2006). When less is more: How affect influences preferences when comparing low and high- risk options. *Journal of Risk Research*, *9*(2), 165–178.

Xiao, Q., Liu, H., & Feldman, M. (2017). How does trust affect acceptance of a nuclear power plant (NPP): A survey among people living with Qinshan NPP in China. *PLOS ONE*, *12*(11).

Yu, H. (Jay). (2012). Producing more persuasive antiviolence messages for college students: Testing the effects of framing, information sources, and positive/negative fact appeal. *Journal of Interpersonal Violence*, *27*(9), 1631–1654.

BIBLIOGRAPHY

20 years of bio-lox. (2015). *Nature Biotechnology, 33*,(12), 1213.

Abatzoglou, J. T., & Williams, A. P. (2016). Impact of anthropogenic climate change on wildfire across western US forests. *Proceedings of the National Academy of Sciences*, *113*(42), 11770–11775.

Adams, W. T., Neale, D. B., Adams, W. T., Neale, D. B., Adams, W. T. (Wesley T., White, T. L., & White, T. L. (2007). *Forest Genetics*. Wallingford: Wallingford : CAB International.

Amos, T., & Daniel, K. (1979). Prospect Theory: An Analysis of Decision under Risk. *Econometrica*.

Banas, J. A., & Rains, S. A. (2010). A meta-analysis of research on inoculation theory. *Communication Monographs*, *77*(3), 281–311.

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations, *Journal of personality and social psychology*, *51*(6), 1173.

Barrette, M., Leblanc, M., Thiffault, N., Paquette, A., Lavoie, L., Bélanger, L., ... & Tremblay, J. P. (2014). Issues and solutions for intensive plantation silviculture in a context of ecosystem management. *The Forestry Chronicle*, *90*(6), 748-762.

Basman, C. M., Manfredo, M. J., Barro, S. C., Vaske, J. J., & Watson, A. (1996). Norm accessibility: An exploratory study of backcountry and frontcountry recreational norms. *Leisure Sciences*, *18*(2), 177–191.

Blaine, K., Kamaldeen, S., & Powell, D. (2002). Public perceptions of biotechnology. *Journal of Food Science*, *67*(9), 3200–3208.

Boecker, A., Hartl, J., & Nocella, G. (2008). How different are GM food accepters and rejecters really? A means-end chains application to yogurt in Germany. *Food Quality and Preference, 19*(4), 383–394.

Bottrill, M. C., Mills, M., Pressey, R. L., Game, E. T., & Groves, C. (2012). Evaluating perceived benefits of ecoregional assessments: Evaluation of ecoregional assessments. *conservation biology*, *26*(5), 851–861.

Boykoff, M. T., & Boykoff, J. M. (2004). Balance as bias: global warming and the US prestige press. *Global Environmental Change*, *14*(2), 125–136.

Brandon, D. M., Long, J. H., Loraas, T. M., Mueller-Phillips, J., & Vansant, B. (2014). Online instrument delivery and participant recruitment services: Emerging opportunities for behavioral accounting research. *Behavioral Research in Accounting*, *26*(1), 1–23.

Burdon, R. D., & Libby, W. J. (2006). *Genetically modified forests*. Durham, North Carolina, USA: Forest History Society.

Byrne, B. M. (2006). *Structural equation modeling with EQS: Basic concepts, applications, and programming*. New York, NY: Routledge.

Cesario, J., Grant, H., & Higgins, E. T. (2004). Regulatory fit and persuasion: Transfer from "feeling right." *Journal of Personality and Social Psychology, 86*(3), 388–404.

Ceurvorst, R. L., & Needham, M. D. (2012). Is "acceptable" really acceptable? Comparing two scales for measuring normative evaluations in outdoor recreation. *Leisure Sciences, 34*(3), 272–279.

Chaiken, S. (1980). Heuristic versus systematic information processing and the use of source versus message cues in persuasion. *Journal of Personality and Social Psychology, 39*(5), 752.

Chang, S., Mahon, E. L., MacKay, H. A., Rottmann, W. H., Strauss, S. H., Pijut, P. M., … Jones, T. J. (2018). Genetic engineering of trees: progress and new horizons. *In Vitro Cellular & Developmental Biology - Plant, 54*(4), 341–376.

Condit, C. M. (2010). Public attitudes and beliefs about genetics. *Annual Review of Genomics and Human Genetics, 11*(1), 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. *Science Communication, 32*(4), 514–538.

Crespi, I. (1971). What kinds of attitude measures are predictive of behavior? *Public Opinion Quarterly*, *35*(3), 327–334.

Dahlstrom, M. F. (2014). Using narratives and storytelling to communicate science with nonexpert audiences. *Proceedings of the National Academy of Sciences*, *111*(Supplement 4), 13614–13620.

Davidson, A. R., Yantis, S., Norwood, M., & Montano, D. E.. Amount of information about the attitude object and attitude–behavior consistency. *Journal of Personality and Social Psychology*, *49*(5), 1184.

De Groot, J. I. M., Steg, L., & Poortinga, W. (2013). Values, perceived risks and benefits, and acceptability of nuclear energy: Acceptability of nuclear energy. *Risk Analysis, 33*(2), 307–317.

Devine-Wright, P. (2005). Beyond NIMBYism: Towards an integrated framework for understanding public perceptions of wind energy. *Wind Energy*, *8*(2), 125–139.

Dosman, D. M., Adamowicz, W. L., & Hrudey, S. E. (2001). Socioeconomic determinants of health-and food safety-related risk perceptions. *Risk Analysis, 21*(2), 307–318.

Dunlap, R. E. (2008). The new environmental paradigm scale: From marginality to worldwide use. *The Journal of Environmental Education, 40*(1), 3–18.

Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes* (Vol. xxii). Orlando, FL, US: Harcourt Brace Jovanovich College Publishers.

Fazio, R. H. (1986). How do attitudes guide behavior? *Handbook of motivation and cognition: Foundations of Social Behavior*, *1*, 204–243.

Fishbein, M., & Ajzen, I. (2011). *Predicting and changing behavior: The reasoned action approach*. New York, NY, Psychology Press, Taylor & Francis.

Fishbein, M., & Manfredo, M. J. (1992). A theory of behavior change. *Influencing Human Behavior*, *24*(1), 29–50.

Frewer, L. J., Fischer, A. R. H., Brennan, M., Bánáti, D., Lion, R., Meertens, R. M., … Vereijken, C. M. J. L. (2016). Risk/benefit communication about food: A systematic review of the literature. *Critical Reviews in Food Science and Nutrition*, *56*(10), 1728–1745.

Frewer, L., Lassen, J., Kettlitz, B., Scholderer, J., Beekman, V., & Berdal, K. G. (2004). Societal aspects of genetically modified foods. *Food and Chemical Toxicology, 42*(7), 1181–1193.

Frewer, L. J., Miles, S., & Marsh, R. (2002). The media and genetically modified foods: Evidence in support of social amplification of risk. *Risk Analysis*, *22*(4), 701–711.

Frewer, L. J., Van der Lans, I. A., Fischer, A. R. H., Reinders, M. J., Menozzi, D., Zhang, X., … Zimmermann, K. L. (2013). Public perceptions of agri-food applications of genetic modification: A systematic review and meta-analysis. *Trends in Food Science & Technology, 30*(2), 142–152.

Friedman, S. T., & Foster, G. S. (1997). Forest genetics on federal lands in the United States: Public concerns and policy responses. *Canadian Journal of Forest Research*, *27*(3), 401–408.

Fulton, D. C., Manfredo, M. J., & Lipscomb, J. (1996). Wildlife value orientations: A conceptual and measurement approach. *Human Dimensions of Wildlife, 1*(2), 24–47.

Gaskell, G., Allum, N., Wagner, W., Kronberger, N., Torgersen, H., Hampel, J., & Bardes, J. (2004). GM Foods and the Misperception of Risk Perception. *Risk Analysis*, *24*(1), 185–194.

Green, M. C. (2006). Narratives and cancer communication. *Journal of Communication*, *56*(1), 163–183.

Gupta, N., Fischer, A. R. H., & Frewer, L. J. (2011). Socio-psychological determinants of public acceptance of technologies: A review. *Public Understanding of Science*, *21*(7), 782–795.

Hajjar, R., & Kozak, R. A. (2015). Exploring public perceptions of forest adaptation strategies in western Canada: Implications for policy-makers. *Forest Policy and Economics*, *61*, 59–69.

Hajjar, R., McGuigan, E., Moshofsky, M., & Kozak, R. A. (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. *Canadian Journal of Forest Research*, *44*(12), 1525–1533.

Higgins, E. (2000). Making a good decision: Value from fit. *The American Psychologist*, *55*, 1217–1230.

Hohl, K., & Gaskell, G. (2008). European public perceptions of food risk: Cross-national and methodological comparisons. *Risk Analysis*, *28*(2), 311–324.

Homer, P., & Kahle, L. (1988). *A structural equation test of the value–attitude–behavior hierarchy*. *54*(4), 638–646.

Jacks, J. Z., & Cameron, K. A. (2003). Strategies for resisting persuasion. *Basic and Applied Social Psychology*, *25*(2), 145–161.

Jacobs, D. (2007). Toward development of silvicultural strategies for forest restoration of American chestnut (Castanea dentata) using blight-resistant hybrids. *Biological Conservation*, *137*(4), 497–506.

James, A. S., Campbell, M. K., & Hudson, M. A. (2002). Perceived barriers and benefits to colon cancer screening among African Americans in North Carolina: How does perception relate to screening behavior? *Cancer Epidemiology Biomarkers & Prevention*, *11*(6), 529–534.

Jepson, P., & Arakelyan, I. (2017a). Exploring public perceptions of solutions to tree diseases in the UK: Implications for policy-makers. *Environmental Science & Policy*, *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 and Economics*, *80*, 167–177.

Kahan, D. M. (2012). Cultural cognition as a conception of the cultural theory of risk. In *Handbook of Risk Theory* (pp. 725–759). Springer.

Kahan, D. M., Braman, D., Slovic, P., Gastil, J., & Cohen, G. (2009). Cultural cognition of the risks and benefits of nanotechnology. *Nature Nanotechnology*, *4*(2), 87–90.

Kahan, D. M., Jenkins-Smith, H., & Braman, D. (2011). Cultural cognition of scientific consensus. *Journal of Risk Research*, *14*(2), 147–174.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica, 47*(2), 263-292.

Kahneman, D., & Tversky, A. (2013). Choices, values, and frames. In *Handbook of the Fundamentals of Financial Decision Making: Part I* (pp. 269–278). World Scientific.

Kasperson, R. E., Renn, O., Slovic, P., Brown, H. S., Emel, J., Goble, R., … Ratick, S. (1988). The social amplification of risk: A conceptual framework. *Risk Analysis*, *8*(2), 177–187.

Kazana, V., Tsourgiannis, L., Iakovoglou, V., Stamatiou, C., Alexandrov, A., Araújo, S., ... & Boutsimea, A. (2015). Public attitudes towards the use of transgenic forest trees: A cross-country pilot survey. *iForest-Biogeosciences and Forestry*, *9*(2), 344.

Kazana, V., Tsourgiannis, L., Iakovoglou, V., Stamatiou, C., Alexandrov, A., Araújo, S., ... & Boutsimea, A. (2016). Public knowledge and perceptions of safety issues towards the use of genetically modified forest trees: A cross-country pilot survey. In *Biosafety of Forest Transgenic Trees* (pp. 223-244). Springer, Dordrecht.

Kempken, F., & Jung, C. (2010). *Genetic modification of plants agriculture, horticulture and forestry*. Heidelberg; New York: Springer.

Kerns, B., Kim, J., Kline, J., & Day, M. (2016). US exposure to multiple landscape stressors and climate change. *Regional Environmental Change*, *16*(7), 2129–2140.

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. *Science Communication, 36*(1), 106–130.

Kunreuther, H., & Slovic, P. (1996). Science, values, and risk. *The Annals of the American Academy of Political and Social Science*, *545*(1), 116–125.

Lang, J.T., & Hallman, W.K. (2005). Who does the public trust? The case of genetically modified food in the United States. *Risk Analysis, 25*(5), 1241–1252.

Lewandowsky, S., Gignac, G. E., & Vaughan, S. (2013). The pivotal role of perceived scientific consensus in acceptance of science. *Nature Climate Change*, *3*(4), 399–404.

Lu, H., Siemer, W. F., Baumer, M. S., & Decker, D. J. (2018). Exploring the role of gain versus loss framing and point of reference in messages to reduce human–bear conflicts. *The Social Science Journal*, *55*(2), 182–192.

Lusk, J. L., House, L. O., Valli, C., Jaeger, S. R., Moore, M., Morrow, J. L., & Traill, W. B. (2004). Effect of information about benefits of biotechnology on consumer acceptance of genetically modified food: Evidence from experimental auctions in the United States, England, and France. *European Review of Agricultural Economics, 31*(2), 179–204.

Maheswaran, D., & Meyers-Levy, J. (1990). The influence of message framing and issue involvement. *Journal of Marketing Research*, *27*(3), 361–367.

McCluskey, J., Curtis, K., Li, Q., Wahl, T., & Grimsrud, K. (2004). Consumer attitudes and willingness to pay for genetically modified foods: A cross-country comparison. *National Agricultural Biotechnology Council*, *15*.

McFadden, B. R., & Lusk, J. L. (2015). Cognitive biases in the assimilation of scientific information on global warming and genetically modified food. *Food Policy, 54*, 35–43.

McFarlane, B. L., Parkins, J. R., & Watson, D. O. T. (2012). Risk, knowledge, and trust in managing forest insect disturbance. *Canadian Journal of Forest Research*, *42*(4), 710–719.

McFarlane, B. L., & Witson, D. O. T. (2008). Perceptions of ecological risk associated with mountain pine beetle (Dendroctonus ponderosae) infestations in Banff and Kootenay national parks of Canada. *Risk Analysis*, *28*(1), 203–212.

McGuire, W. J., & Papageorgis, D. (1961). The relative efficacy of various types of prior belief-defense in producing immunity against persuasion. *The Journal of Abnormal and Social Psychology*, *62*(2), 327–337.

Merkle, S. A., Andrade, G. M., Nairn, C. J., Powell, W. A., & Maynard, C. A. (2006). Restoration of threatened species: A noble cause for transgenic trees. *Tree Genetics & Genomes, 3*(2), 111–118.

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? *Agriculture and Human Values, 30*(3), 471–480.

Moerbeek, H., & Casimir, G. (2005). Gender differences in consumers' acceptance of genetically modified foods. *International Journal of Consumer Studies, 29*(4), 308–318.

Nan, X. (2009). The influence of source credibility on attitude certainty: Exploring the moderating effects of timing of source identification and individual need for cognition. *Psychology & Marketing*, *26*(4), 321–332.

Nash, R. F. (2014). *Wilderness and the American mind*. Yale University Press.

National Academies of Sciences, Engineering, and Medicine Committee on the Potential for Biotechnology to Address Forest Health, Board on Agriculture and Natural Resources, Division on Earth and Life Studies (NASEM). (2019). *Forest health and biotechnology: Possibilities and considerations*. Washington, D.C.: National Academies Press.

Needham, M. D., & Vaske, J. J. (2008). Hunter perceptions of similarity and trust in wildlife agencies and personal risk associated with chronic wasting disease. *Society & Natural Resources, 21*(3), 197–214.

Needham, M. D., Vaske, J. J., & Petit, J. D. (2017). Risk sensitivity and hunter perceptions of chronic wasting disease risk and other hunting, wildlife, and health risks. *Human Dimensions of Wildlife, 22*(3), 197–216.

Neumann, P. D., Krogman, N. T., & Thomas, B. R. (2007). Public perceptions of hybrid poplar plantations: Trees as an alternative crop. *International Journal of Biotechnology, 9*(5), 468–483.

Nilausen, C., Gélinas, N., Bull, G., Nilausen, C., Gélinas, N., & Bull, G. (2016). Perceived acceptability of implementing marker-assisted selection in the forests of British Columbia. *Forests, 7*(11), 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 - Biogeosciences and Forestry, 8*(5), 714–718.

Oreg, S. (2006). Predicting proenvironmental behavior cross-nationally: Values, the theory of planned behavior, and value-belief-norm theory. *Environment and Behavior, 38*(4), 462–483.

Pardo, R., Midden, C., & Miller, J. D. (2002). Attitudes toward biotechnology in the European Union. *Journal of Biotechnology, 98*(1), 9–24.

Perry, E. E., Needham, M. D., & Cramer, L. A. (2017). Coastal resident trust, similarity, attitudes, and intentions regarding new marine reserves in Oregon. *Society & Natural Resources, 30*(3), 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. *Climatic Change, 151*(3), 573–587.

Petty, R. E., & Cacioppo, J. T. (1984). The effects of involvement on responses to argument quantity and quality: Central and peripheral routes to persuasion. *Journal of Personality and Social Psychology, 46*(1), 69.

Petty, R. E., & Cacioppo, J. T. (1986). *The elaboration likelihood model of persuasion*. Springer.

Petty, R. E., & Krosnick, J. A. (2014). *Attitude strength: Antecedents and consequences*. Psychology Press.

Pilcher, C. D., Rice, M. E., Higgins, R. A., Steffey, K. L., Hellmich, R. L., Witkowski, J., … Gray, M. (2002). Biotechnology and the European corn borer: Measuring historical farmer perceptions and adoption of transgenic bt corn as a pest management strategy. *Journal of Economic Entomology*, *95*(5), 878–892.

Pin, R. R., Gutteling, J. M., & Kuttschreuter, M. (2009). Determinants of reactions to gene technology: A generic approach. *New Genetics and Society*, *28*(1), 51–65.

Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology*, *88*(5), 879–903.

Powell, W. (2016). New genetically engineered American chestnut will help restore the decimated, iconic tree. *The conversation, Jan*, *19*, 2016.

Rabino, I. (1998). Societal and commercial issues affecting the future of biotechnology in the United States: A survey of researchers' perceptions. *Naturwissenschaften*, *85*(3), 109–116.

Savadori, L., Savio, S., Nicotra, E., Rumiati, R., Finucane, M., & Slovic, P. (2004). Expert and public perception of risk from biotechnology. *Risk Analysis*, *24*(5), 1289–1299.

Scott, S. E., Inbar, Y., & Rozin, P. (2016). Evidence for absolute moral opposition to genetically modified food in the United States. *Perspectives on Psychological Science*, *11*(3), 315–324.

Shew, A. M., Nalley, L. L., Danforth, D. M., Dixon, B. L., Nayga Jr, R. M., & Delwaide, A.C. (2015). Are all GMO's the same? Consumer acceptance of cisgenic rice in India. *Plant Biotechnology Journal*, *14*(1), 4-7.

Shindler, B. (2000). Landscape-level management: It's all about context. *Journal of Forestry*, *98*(12), 10–14.

Shindler, B., Brunson, M., & Stankey, G. (2002). Social acceptability of forest conditions and management practices: A problem analysis. *Gen. Tech. Rep. PNW-GTR-537. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest Research Station. 68 p*, *537*.

Shindler, B., & Cheek, K. (1999). Integrating citizens in adaptive management: A propositional analysis. *Conservation Ecology*, *3*(1), 9.

Shindler, B., & Mallon, A. (2011). *Public acceptance of disturbance-based forest management: A study of the Blue River landscape strategy in the central cascades adaptive management area*. DIANE Publishing.

Shindler, B., Olsen, C., McCaffrey, S., McFarlane, B., Christianson, A., McGee, T., … Sharp, E. (2014). *Trust: A planning guide for wildfire agencies and practitioners—an international collaboration drawing on research and management experience in Australia, Canada, and the United States*. Retrieved from http://ir.library.oregonstate.edu/xmlui/handle/1957/45323

Siegrist, M. (1998). Belief in gene technology: The influence of environmental attitudes and gender. *Personality and Individual Differences*, *24*(6), 861-866.

Siegrist, M. (2000). The influence of trust and perceptions of risks and benefits on the acceptance of gene technology. *Risk Analysis, 20*(2), 195–204.

Siegrist, M., Cvetkovich, G., & Roth, C. (2000). Salient value similarity, social trust, and risk/benefit perception. *Risk Analysis, 20(3),* 353–362.

Sjöberg, L. (1998). Risk perception: Experts and the public. *European Psychologist*, *3*(1), 1.

Sjöberg, L. (2004). Principles of risk perception applied to gene technology. *EMBO Reports*, *5*, S47–S51.

Sjoberg, L. (2004). Explaining individual risk perceptions: The case of nuclear waste. *Risk Management, 6*(1), 51–64.

Sjöberg, L., & Drottz-Sjöberg, B. (2008). Attitudes towards nuclear waste and siting policy: Experts and the public. *Nuclear Waste Research: Siting, Technology, and Treatment*, 47–74.

Slater, M. D., & Rouner, D. (2002). Entertainment—education and elaboration likelihood: Understanding the processing of narrative persuasion. *Communication Theory, 12*(2), 173–191.

Slovic, P. (1999). Trust, emotion, sex, politics, and science: Surveying the risk-assessment battlefield. *Risk Analysis, 19*(4), 689–701.

Slovic, P. (2000). *The perception of risk*. London; Sterling, VA: Earthscan Publications.

Slovic, P. (2010). *The feeling of risk: New perspectives on risk perception*. Routledge.

Slovic, P., Fischhoff, B., Lichtenstein, S., & Roe, F. J. C. (1981). Perceived risk: Psychological factors and social implications [and discussion]. *Proceedings of the Royal Society of London. Series A, Mathematical and Physical Sciences, 376*(1764), 17–34.

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 Forests, 48*(2), 317–336.

Stern, M. J., & Coleman, K. J. (2015). The multidimensionality of trust: Applications in collaborative natural resource management. *Society & Natural Resources, 28*(2), 117–132.

Strauss, S. H., Costanza, A., & Séguin, A. (2015). Genetically engineered trees: Paralysis from good intentions. *Science, 349*(6250), 794–795.

Strauss, S. H., Jones, K. N., Lu, H., Petit, J. D., Klocko, A. L., Betts, M. G., … Needham, M. D. (2017). Reproductive modification in forest plantations: Impacts on biodiversity and society. *New Phytologist, 213*(3), 1000–1021.

Teel, T., Bright, A., Manfredo, M., & Brooks, J. (2006). Evidence of biased processing of natural resource-related information: A study of attitudes toward drilling for oil in the Arctic National Wildlife Refuge. *Society & Natural Resources*, *19*(5), 447–463.

Tenbült, P., de Vries, N. K., Dreezens, E., & Martijn, C. (2005). Perceived naturalness and acceptance of genetically modified food. *Appetite*, *45*(1), 47–50.

Tew, C., & Barbieri, C. (2012). The perceived benefits of agritourism: The provider's perspective. *Tourism Management*, *33*(1), 215–224.

Thompson, P. B., & Dean, W. (1996). Competing conceptions of risk. *Risk*, *7*, 361.

Tsourgiannis, L., Kazana, V., & Iakovoglou, V. (2016). A comparative analysis of consumers' potential purchasing behaviour towards transgenic-derived forest products: The Greek case. In *Biosafety of Forest Transgenic Trees* (pp. 245–261). Springer, Dordrecht.

Tversky, A., & Kahneman, D. (1991). Loss aversion in riskless choice: A reference-dependent model. *The Quarterly Journal of Economics, 106*(4), 1039–1061.

Vaske, J. (2008). *Survey research and analysis: Applications in parks, recreation and human dimensions*. Venture Publishing State College, PA.

Vaske, J. J., Absher, J. D., & Bright, A. D. (2007). Salient value similarity, social trust and attitudes toward wildland fire management strategies. *Human Ecology Review*, 223–232.

Vaske, J., & Donnelly, M. (1999). A value-attitude-behavior model predicting wildland preservation voting intentions. *Society & Natural Resources, 12*(6), 523–537.

Vaske, J., Donnelly, M., Williams, D., & Jonker, S. (2001). Demographic influences on environmental value orientations and normative beliefs about national forest management. *Society & Natural Resources, 14*(9), 761–776.

Vaske, J., & Whittaker, D. (2004). Normative approaches to natural resources. *Society and Natural Resources: A Summary of Knowledge*, 283–294.

Visschers, V. H. M., Keller, C., & Siegrist, M. (2011). Climate change benefits and energy supply benefits as determinants of acceptance of nuclear power stations: Investigating an explanatory model. *Energy Policy*, *39*(6), 3621–3629.

Wheeler, N., & Sederoff, R. (2008). Role of genomics in the potential restoration of the American chestnut. *Tree Genetics & Genomes*, *5*(1), 181–187.

Whitfield, S. C., Rosa, E. A., Dan, A., & Dietz, T. (2009). The future of nuclear power: Value orientations and risk perception. *Risk Analysis*, *29*(3), 425–437.

Whittaker, D., Vaske, J. J., & Manfredo, M. J. (2006). Specificity and the cognitive hierarchy: Value orientations and the acceptability of urban wildlife management actions. *Society & Natural Resources*, *19*(6), 515–530.

Williams, K. J. H. (2014). Public acceptance of plantation forestry: Implications for policy and practice in Australian rural landscape. *Land Use Policy*, *38*, 346–354.

Wilson, R. S., & Arvai, J. L. (2006). When less is more: How affect influences preferences when comparing low and high- risk options. *Journal of Risk Research, 9*(2),165–178.

Woodall, C., Amacher, M., Bechtold, W., Coulston, J., Jovan, S., Perry, C., … Will-Wolf, S. (2011). Status and future of the forest health indicators program of the USA. *Environmental Monitoring and Assessment*, *177*(1), 419–436.

World Wildlife Fund. (2019). *Forests: Conserve the world's most important forests to sustain nature's diversity, benefit our climate, and support human well-being*. Retrieved from: https://www.worldwildlife.org/initiatives/forests

Xiao, Q., Liu, H., & Feldman, M. W. (2017). How does trust affect acceptance of a nuclear power plant (NPP): A survey among people living with Qinshan NPP in China. *PLOS ONE*, *12*(11).

Yu, H. (Jay). (2012). Producing more persuasive antiviolence messages for college students: Testing the effects of framing, information sources, and positive/negative fact appeal. *Journal of Interpersonal Violence*, *27*(9), 1631–1654.

Zhang, B., Newhouse, A., McGuigan, L., Maynard, C., & Powell, W. (2011). Agrobacterium-mediated co-transformation of American chestnut (Castanea dentata) somatic embryos with a wheat oxalate oxidase gene. In *BMC proceedings* (Vol. 5, No. 7, p. 43). BioMed Central.

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 Research*, *22*(5), 973–982.

Zinn, H. C., Manfredo, M. J., Vaske, J. J., & Wittmann, K. (1998). Using normative beliefs to determine the acceptability of wildlife management actions. *Society & Natural Resources*, *11*(7), 649–662.