Beyond the message: Examining how engaging message mediums impact visitor displacement in emerald ash borer-treated woodlands

Brett Rannow
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Program Advisor: Dr. Ingrid Schneider
University of Minnesota
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Abstract

A variety of factors, including aesthetics, can significantly influence a recreator's decision to revisit or displace from a setting. Invasive species can significantly change an area's appearance and, unless visitors are informed about and understand the change, discourage visitation (McFarlane & Watson, 2008; Müller and Job, 2009; Schneider et al., 2019). Moving beyond static signs, advanced communication technologies like augmented and virtual reality show promise to meaningfully engage visitors (Ahn et al., 2014; Petty & Cacioppo, 1986), increasing understanding of landscape changes and potentially retaining visitation. However, limited work addresses if and how such technologies significantly influence visitor behavior. To address this gap, four informational interventions about forest management treatments utilized in response to emerald ash borer (*Agrilus planipennis)* were tested. Informational interventions included photos with text, augmented reality (AR), virtual reality (VR), and a control group that received no treatment information. State park visitors were randomly assigned to interventions and indicated displacement intentions following intervention exposure. Displacement intentions in response to the treated landscapes ranged from 12-26%. A Chi-Square Test compared displacement intentions across informational interventions and found more engaging technologies changed displacement intentions in only one of four management responses assessed. Future research with other outcomes and management topics will be useful to refine the utility of AR and VR in this realm.

Introduction

Outdoor recreation is a critical forest ecosystem service (Daniel et al., 2012; Filyushkina et al., 2017; Slee, 2005) that contributes nearly $375 billion (1.8%) to the United States' Gross Domestic Product (GDP; Bureau of Economic Analysis, 2021). Viewing aesthetically pleasing landscapes is one of the many experiences that people seek when recreating outdoors (Ajzen & Driver, 1991; Driver & Brown, 1986; Hendee et al., 1971; Manfredo et al., 1996; Palmer & English, 2019; Sotomayor et al., 2014). In fact, the public's acceptance, or rejection, of forest management strategies is influenced by aesthetic values. Forest managers consider aesthetic value when managing forests, especially near areas that experience high visitor volume (Kearny, 2001; Kovacs et al., 2006; Ribe, 2002; Stankey & Clark, 1992) and visual management frameworks are included in the outdoor recreation management suite (Bureau of Land Management, 1984; National Park Service, 2016; US Forest Service, 1996; Washington State Department of Natural Resources et al., 2017).

Terrestrial invasive species can negatively impact forest recreation site aesthetics (Arnberger et al., 2018). Invasives can kill trees and leave behind dead wood, open up forest canopies, and facilitate the production of dense forest understories. Among such invasive species, emerald ash borer (EAB, *Agrilus planipennis*) is one of the most damaging and costly borer insects to establish in the United States since its 2002 introduction (Aukema et al., 2011; Marzano et al., 2020; University of Minnesota Extension, 2019). The ash borer consumes tissue that restricts water and nutrient flow, impacting the tree's appearance. Once a tree is infested, its canopy becomes thin or bare and typically the tree will die within four years (Hahn, 2021). Widespread borer consumption within a forest can kill off entire ash stands (Marshall, 2020). Such forest impacts interfere with visitors' desired, positive experiences (Filyushkina et al., 2017; Lee, 2001; Ribe, 1989; Robertson & Regula, 1994; Schneider et al., 2019).

Similarly, forest management negatively impacts aesthetics and can interfere with visitor experiences. Four commonly-employed forest management strategies in response to EAB produce such landscape elements: complete harvest, natural regrowth; select harvest, natural regrowth; select harvest, planted trees; and do nothing. “Complete harvest, natural regrowth” is akin to clearcutting - all trees within a determined stand are harvested and natural growth ensues. “Select harvest, natural regrowth” treatment is when trees are “removed in small groups up to half an acre in size and form uneven-aged stands” and the stand regrows without forester assistance (Russell, 2019). “Select harvest, planted trees" is similar to the treatment “select harvest, natural regrowth,” trees are selected and planted by foresters. While it is difficult to substitute ash trees in ecosystems where their presence is critical, such as black ash (*Fraxinus nigra)* swamps, the need to replace trees in anticipation of mass die-offs resulting from EAB is urgent. Thus, foresters deliberately plant a diverse range of trees including American Elm (*Ulmus americana*) and Arborvitae (*Thuja occidentalis*) to increase the resilience of these inevitably-impacted forests (D’Amato et al., 2018). “Do nothing” is a non-intervention approach where the stand is left as is. These forest management treatments, adopted from silvicultural practices in the US Lake States, can create canopy gaps, produce logging residue, and leave behind bare soil and exposed tree trunks.

Based on these negatively perceived impacts (Arnberger et al., 2017; Edwards et al., 2012; Gundersen & Frivold, 2008; Ribe, 1990; Verlič et al., 2015), recreationists may ‘be displaced’ and choose to avoid visiting or returning to certain sites. In turn, communities may experience tourism revenue losses, visitors face sub-optimal experiences, and crowding may take place at other locations, exacerbating social and biophysical impacts (Arnberger et al., 2018; Flint et al., 2009; Robertson & Regula, 1994; Schneider et al., 2019). To reduce this displacement and loss, park and forest supervisors can provide information about forest management (Kearney, 2001; Pierskalla et al., 2007; Ryan, 2012; Sumner & Lockwood, 2020) and increase support for invasive species management (Eriksson et al., 2019; García-Llorente et al., 2011; Sharp et al., 2012). How that information is shared is important as increasingly engaging information can impact attitudes, behavioral intentions, and actual behaviors more than less-engaging information (Ahn et al., 2014; Alyahya & McLean, 2021; Cai, 2013; Marto et al., 2019).

While available and increasingly of interest (National Park Service, 2020; Winter et al., 2020), the impact of engaging information and information technologies in the context of forest management, particularly displacement, remains understudied. In response to calls for expanded research (Rodríguez-Rey et al., 2022; Ryan, 2012; Schlueter & Schneider, 2016; Schneider et al., 2019), this project addressed if and how increasingly engaging information impacts recreationist displacement intentions resulting from select forest management strategies utilized in response to EAB.

Literature Review

A comprehensive literature review is required to understand the logic behind the project's research question and hypothesized results. Therefore, this section highlights forest landscape preferences, visitor displacement, persuasive communication, and engaging messaging.

Forest landscape preferences

To understand why visitors displace from certain settings, comprehending forest landscape preferences is necessary. Landscape preference research has a rich history and flourished after the 1960s U.S. environmental movement (Ryan, 2005). Since then, researchers have developed multiple models to understand and predict landscape preferences: The Scenic Beauty Estimation Model, a psychoevolutionary framework for landscape preferences, the

Preference Matrix, and the Northern Hardwoods Scenic Beauty Model. A brief review of them follows.

In the 1970s, the Scenic Beauty Estimation (SBE) Model was developed to predict landscape beauty from the aesthetic components of forested landscapes (Daniel & Boster, 1976). By developing and evaluating visual slide sets across multiple U.S. Southwest-based samples, the authors found greater tree density, average tree diameter, and crown-canopy cover increased the perceived beauty of forests. In contrast, the amount and distribution of downed wood and the presence of stumps detracted from perceived forest beauty. Nearly two decades later, Ribe's (1990) ratio-scaled Northern Hardwoods Scenic Beauty Model emerged. Ribe (1990, p.87) contributed toward the production of a more "generally valid, useful, and meaningful psychophysical" forest beauty estimation model across the region. Similar to the SBE method, participants reviewed forested landscapes that possessed a variety of aesthetic elements and rated each landscape on a scale of -5 to +5, with -5 the most 'ugly' landscape and +5 the most 'beautiful' landscape. Based on participant responses, characteristics of aesthetically pleasing forests included: open forest structures, big trees, the presence of ground vegetation, and species variety.

Beyond aesthetics, Ulrich (1983) developed a psychoevolutionary framework for visual stimuli, in this case, landscapes. In addition to aesthetic responses, a "preference or like-dislike affect" (p.87) was predicted to interact with and impact landscape preferences. Ulrich's framework proposed that aesthetically pleasing landscapes include moderate to high complexity, moderate to high depth, homogenous ground surface texture, no appraised threats, and the presence of water. In related work from a cognitive approach, Kaplan and Kaplan (1989) developed the Preference Matrix which predicts landscape preferences on the interplay of two human information needs: understanding and exploration. The resultant matrix creates four landscape elements: coherence, legibility, complexity, and mystery. According to the Preference Matrix, viewers prefer settings that are highly coherent and legible, moderately complex, and "cognitively comfortable" (p.69). The researchers argue that "without realizing it, humans interpret the environment in terms of their needs and prefer settings in which they are likely to function more efficiently" (p.69). In sum, the models concur visitors prefer structurally open, biologically diverse forests possessing unrestrictive ground vegetation (Daniel & Boster, 1976; Kaplan & Kaplan, 1989; Kaplan et al., 1989; Ribe, 1990; Ulrich, 1983).

Extensive research also examines undesirable forest landscape features including evidence of death, mono-species stands, immature forest stands, too much or too little canopy coverage, and bare soil exposure (Edwards et al., 2012; Filyushkina et al., 2017; Gundersen & Frivold, 2008; Ribe, 1990). In terms of evidence of death, elements like standing and downed deadwood, bare soil, and slashing evidence are negatively perceived by forest visitors (Arnberger et al., 2017; Daniel & Boster, 1976; Daniel & Schroeder, 1979; Ribe, 1989, 1990; Ryan, 2005; Schneider et al., 2019). In addition, forest characteristics such as high densities of small trees and highly dense understory vegetation are considered undesirable (Edwards et al., 2012; Ribe 1989).

Landscape changes emanate from a number of sources, including invasive species and silvicultural management. In particular, invasive infestations produce a "wide variety of visual effects depending on the forest type, the specific pest, and many other factors including the temporal stage and biophysical conditions" (Sheppard & Picard, 2006, p.325). Particular to EAB, once the borer establishes within an ash tree, the crown's foliage thins, vertical cracks appear on the tree's trunk, and excessive woodpecker holes are observed. EAB's consumption of vital ash tree tissue can cause individual trees to go from healthy to completely dead in as little as two years and rapid spread can kill off entire ash forest stands in less than a decade (Hahn, 2021; Marshall, 2020) leaving behind swaths of dead standing trees that visitors may negatively perceive (Edwards et al., 2012; Ribe, 1990). In terms of silvicultural practices, large cuts (>15 acres according to Haakenstad, 1972), logging residue, left-behind tree trunks, and the immediate aftermath of controlled burns are typically disliked by the public and can negatively impact recreation experiences (Arnberger et al., 2017; Edwards et al., 2012; Gundersen & Frivold, 2008; Ribe, 1989; Ryan, 2005).

Despite these impacts, limited existing research reveals visitors generally accept and support invasive species management (Schlueter & Schneider, 2016) or that which addresses episodic infestations of endemic species (McFarlane & Watson, 2008). In the lone work on EAB, Schlueter and Schneider (2016) found state park visitors deemed five out of eight management treatments in response to EAB as acceptable, regardless of application area: wood regulations, sanitation cutting, progressive thinning, biological control, and creating sinks. Additionally, six out of eight treatments were significantly more acceptable when applied in “use” areas compared to “natural” areas.

More research examines visitor responses to other landscape-altering insect outbreaks like the mountain pine beetle (MPB; *Dendroctonus ponderosae*) and bark beetle (*Scolytinae*). Both Arnberger et al. (2018) and McFarlane and Watson (2008) found visitors generally prefer forest management over non-intervention in the face of extensive insect infestations. McFarlane and Watson (2008) identified support for general management in response to mountain pine beetle infestations whereas Arnberger et al. (2018) identified that US and German park visitors visually preferred landscapes depicting a range of specific management treatments in response to bark beetle. In fact, Arnberger et al.’s (2018) sample preferred any managed landscape, including clear-cut landscapes, over non-managed landscapes depicting a forest ‘collapse’ scenario. In contrast, Müller and Job (2009) found tourists generally held neutral perceptions of bark beetle, were weakly unsupportive of management action, and accepted the beetle’s role as a natural disturbance agent. One explanation for these differences is that bark beetle outbreaks are common in Germany while Canada was experiencing novel, historic levels of mountain pine beetle outbreaks. As a result, this familiarity could cause German respondents to prefer the natural causes of the now-normalized altered landscape compared to respondents in McFarlane and Watson’s (2008) study.

Visitor Displacement

If recreation conditions are negatively appraised, visitors experience stress and cope in response (Johnson & Dawson, 2004; Kay & Jackson, 1991; Kuentzel & Heberlein, 1992; Schneider & Hammitt, 1995; Schneider & Wilhelm-Stanis, 2007; Schneider & Wynveen, 2015). One such response is displacement: temporal or spatial (Anderson & Brown, 1984; Becker, 1981). Temporal displacement is when a visitor alters the timing of their visit whereas spatial displacement is when visitors alter their visitation by either leaving a site within an area (intrasite) or an area altogether (intersite) (Hall & Shelby, 2000; Kuentzal & Heberlein, 1994). Examples of spatial displacement include leaving a crowded site to visit a less-crowded site, removing oneself from eroded trail conditions, or changing a destination to avoid certain managerial regulations such as fees. Most displacement research focuses on social and managerial conditions with less emphasis on environmental conditions. Displacement resulting from altered forest landscapes is the primary interest of this study.

Social settings have perhaps the most displacement research, considering how crowding, visitor behavior, and user type influence it. Displacement in the face of crowding persists: Rice et al. (2019) found that visitors chose intersite, intrasite, and temporal displacement in response to crowded conditions in Grand Teton National Park. Hall and Shelby (2000) reveal that, in a high-use reservoir, nearly half of the study's participants coped with social conflicts via displacement. Visitor behaviors, such as off-leash dogs or visible litter, are undesirable social conditions that can degrade a visitor's experience and incite displacement (Anderson & Brown, 1984; Bakhtiari et al., 2014; Mann & Absher, 2008; Verlič et al., 2015). In a Danish study, Bakhtiari et al. (2014) found a majority of respondents reported feeling disturbed by other users during their forest visits and one-fifth cited spatial displacement intentions; additionally respondents were willing to travel up to 10 kilometers from their original site to avoid other user groups.

Managerial setting research also reveals displacement patterns. Negative interactions with administrative staff, confusing site regulations, and campsite/parking fees are primary stressors that contribute to displacement within wilderness areas; additionally, stressors related to managerial conditions are more likely to cause visitors to displace than social stressors (Peden & Shuster, 2009). Newly introduced policies can also incite displacement. Spatial displacement emerged among 56% of persons when a no-take fishing zone was implemented at a Great Barrier Reef park (De Freitas et al. 2013) and 22% of US national park visitors were estimated to displace over the course of five years after a fee program was introduced to select sites (Schwartz & Lin, 2006). In a similar vein, nearly one-third of respondents visiting a non-fee area displaced from a national forest site in response to a fee program (Schneider & Budruk, 1999). Visitors are less likely to displace in response to fees if they possess positive beliefs about the reason for their implementation and hold positive attitudes towards fees themselves (Taylor et al., 2002).

Adverse changes in the physical environment are a primary displacement condition across area types (Anderson, 1980; Anderson & Brown, 1984; Schreyer, 1979). In the Boundary Waters Canoe Area Wilderness, degraded wilderness campsite features, such as eroded portages and worn-out sites, detracted from visitor experiences and led to spatial and temporal displacement (Anderson & Brown, 1984) and in a more developed area, Robertson and Regula (1994) observed similar displacement behavior arising from increased siltation of an Iowa reservoir. Schroeder and Fulton (2010) found environmental changes to a site, such as loss of aquatic vegetation and development, were more likely to induce displacement among Minnesota anglers compared to undesirable social conflicts.

Despite its importance in impacting visitor behavior, research pertaining to displacement in response to terrestrial landscape conditions is extremely limited (Schneider et al., 2019). Schneider et al. (2019) found that visual landscape changes caused by bark beetles, such as standing dead trees, interfered with up to 80% of respondents' experiences and 70% of respondents indicated that they intended to displace from an area heavily impacted by bark beetle infestation. Hot summer temperatures impacted visitor displacement in Vermont (Perry et al., 2021) while warming winter temperatures impacted displacement in Minnesota (McCreary et al. 2019). Related, the presence of biting insects influenced spatial and temporal displacement intentions among Vermont State Park visitors (Perry et al., 2021) and constrained Minnesota resident visits (Minnesota Department of Natural Resources, 2017).

Beyond site conditions, certain visitor characteristics play a role in displacement, including experience or visitation. As recreationists repeatedly visit a setting, they are more sensitive to site conditions (Eder & Arnberger, 2012; White et al., 2008). Behaviorally, as first-time visitors do not have pre-existing experiences attached to a recreational setting and are less sensitive to impacts compared to experienced visitors, they should be less likely to displace in the face of undesirable environmental conditions (White et al., 2008). Indeed, studies have shown that local, experienced visitors are more likely to engage in temporal displacement over spatial displacement in response to crowded conditions (Arnberger & Brandenburg, 2007; Manning & Valliere, 2001). However, Peden and Schuster (2009) found that, in wilderness environments, first-time visitation's impact on displacement was non-existent with the exception of one site where first-time visitors were more likely to engage in intersite displacement. Further research is needed in this area as well as the role of information impacting displacement.

Influencing displacement through information

Information aims to increase a visitor's knowledge and familiarity with issue-relevant topics (Marzano et al., 2020; Ryan, 2012; Wiles & Hall, 2005). With more information, visitors are presumed to support management (Jensen, 2000; Ryan, 2012; Tyrväinen et al., 2003) and displace less; however, findings are mixed.

Visitors tend to prefer familiar landscapes (Hammitt, 1979), and familiarity with forest management can influence the public's approval of landscape management practices (McCaffrey, 2006). Related to invasive species, individuals aware of invasive pests and the problems they pose exhibit greater management intervention acceptance (Eriksson et al., 2019). Beyond awareness, both general and specific knowledge about invasive species positively influenced visitor support for invasive species management (García-Llorente et al., 2011; Sharp et al., 2011). In contrast, Müller and Job (2008) found that knowledge about bark beetles, an insect native to the study area, was strongly associated with decreased support to manage German forests in response to them.

Specific to forest management, knowledge of management projects, terms, and processes positively influenced support for disturbance-based management treatments (Shindler & Mallon, 2006). Aiming to bolster public knowledge, informational interventions have influenced perceptions toward invasive species management (Novoa et al., 2017) and enhanced landscape preferences for scenes including clear cuts (Kearny, 2001; Pierskalla et al., 2007) and prescribed fires (Ryan, 2012). Thus, their forest management applications related to managing EAB infestations seem warranted.

The Elaboration Likelihood Model and Persuasive Messaging

Outdoor recreationists most frequently receive information through static content like pamphlets and signs, which are preferred by natural resource managers due to low costs (Guo et al., 2015). While such static information can improve participant knowledge levels (Guo et al., 2017; Sharp et al., 2012; Young & Witter, 1994), their persuasive influence on behavior change varies (Guo et al., 2017; Price et al., 2018). The potential to influence attitudes and behaviors requires effective message design and presentation (Young & Witter, 1994). Strong, persuasive messages incorporate personal relevance and result in greater message elaboration, or thinking about issue-relevant information (Petty & Cacioppo, 1986), which is more likely to influence attitudes and behaviors. This persuasion system is illustrated through the Elaboration Likelihood Model (ELM; Petty & Cacioppo, 1986).

The ELM presents two persuasion routes: 1) central and 2) peripheral (Figure 1). Central-route persuasion takes place when the recipient's motivation and ability to cognitively elaborate on a message is high. The central processing route requires one's "careful and thoughtful consideration of the true merits of the information presented in support of an advocacy" (Petty & Cacioppo, 1986, p. 3). Recipients utilize a diverse range of prior knowledge and issue-related thoughts to evaluate an argument through the central route. In contrast, peripheral-route persuasion takes place when the recipient's motivation and ability to elaborate on a presented message is low and they rely on peripheral cues to form judgments. As motivation and/or ability to process arguments decreases, peripheral cues become more important. As argument scrutiny increases, peripheral cues become less important attributes of persuasion. Attitude changes via the central route tend to "show greater temporal persistence, greater prediction of behavior, and greater resistance to counter persuasion than attitude changes that result mostly from peripheral cues" (Petty & Cacioppo, 1986, p. 5).

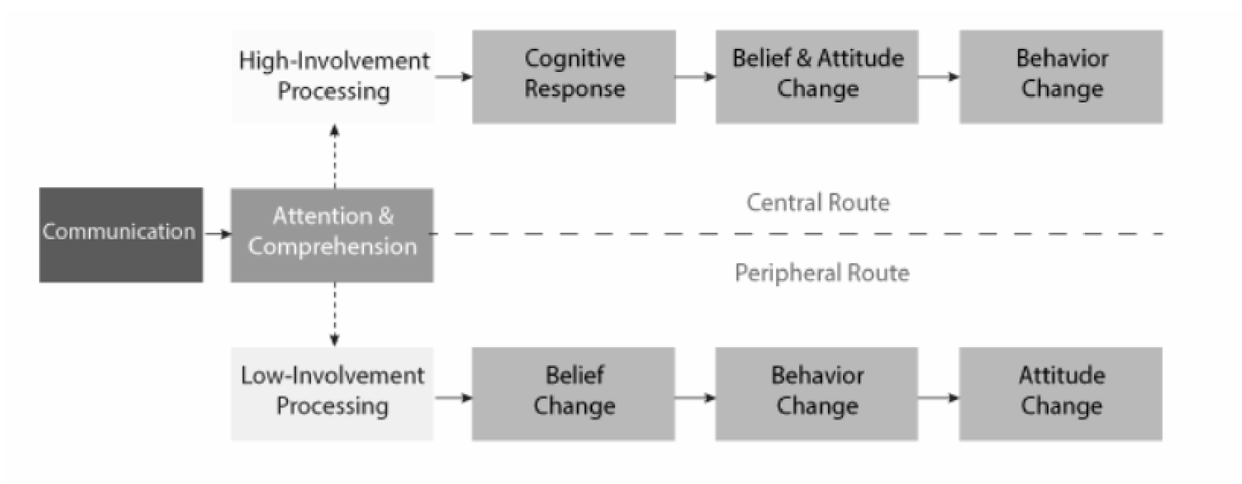

Figure 1: The Elaboration Likelihood Model of Persuasion (ELM) (Maharjan, 2018)

ELM use in recreation contexts supports its application in invasive species management communication. For example, environmental infographics containing a combination of text and pictures led viewers to engage in higher levels of issue-relevant thinking compared to text or graphics alone (Lazard & Atkinson, 2015). Similarly, greater elaboration of interpretive program messages predicted both in-park and at-home pro-environmental behavioral intentions (Vezeau, 2014). Building off this study, a combination of communication materials designed to increase interest, awareness, and cognitive engagement (collective elaboration factors) regarding bear safety had a direct effect on behavioral intentions related to actually using bear spray in the field (Miller et al., 2019).

Of particular interest to this project are interactivity and elaboration. Interactivity encourages engagement and elicits greater levels of central-route elaboration. Steuer (1992, p.84) defines interactivity as the “extent to which users can participate in modifying the form and content of a mediated environment in real-time.” A static message does not allow any modification. However, interacting by browsing through a website containing different persuasive messages can influence behaviors (Sundar, 2003; Xu & Sundar, 2014). Oh and Sundar (2015) found message interactivity enhanced message elaboration, led to greater cognitive absorption, and contributed to favorable attitudes towards both the medium and topic itself.

Message engagement can take a number of definitions including one’s involvement with a message’s content (Shin, 2019) or attention to narrative and content (Bitgood, 2009). In a persuasive context, Oh and Sundar (2015, p.215) define engagement as “a psychological state where users are either cognitively or emotionally involved in a task at hand.” Clearly, increasingly interactive messages require more cognitive effort to process.

Engagement and persuasiveness can be enhanced through technology that virtually immerses a recipient within a message. For example, Fonseca and Kraus (2016) found that the level of immersion within a virtual environment positively influenced a message's emotional impact and recipients' environmental attitudes. Two features define immersion: social presence and telepresence. Social presence is the "extent to which other beings, living or synthetic, exist in a virtual environment" (Schuemie et al., 2001, p.184) and can include hearing spoken audio of other voices or seeing a person within the virtual environment. One such example includes using conversational human voices in a podcast tour to elevate visitors' overall experience (Kang & Gretzel 2012). Telepresence "determines the degree of users' immersion in a virtual environment, which can shape… information-gathering efficiency" (Nowak & Biocca 2003; Steuer 1992; Ying et al., 2022, p.1739). Determined by sensorially-rich environments and interactivity (Steuer, 1992), telepresence tends to play a larger role in revisit intentions compared to social presence – highlighting its utility in messages pertaining to displacement (Ying et al., 2022).

Technological advances have made creating interactive and engaging messaging easier, more affordable, and more accessible than before. One such advancement is augmented reality (AR). AR enriches reality and "allows the user to see the real world, with virtual objects superimposed upon or composited with the real world" (Azuma, 1997, p.2; Klopfer & Squire, 2008). AR is relatively accessible, as users can download AR applications on their personal devices and use them onsite (Chung et al., 2018; Harley et al., 2020), which is preferred over using dedicated AR systems (Pascoal et al., 2018). AR can help bridge the gap of knowledge between experts and non-experts in landscape decision-making (Ghadirian & Bishop, 2008). As a result, learning experiences are enhanced and reflected via desired attitude and behavioral changes (Cai, 2013; Howard, 2017). In a recreation and tourism context, AR use elevates overall tourist experiences (Harley et al., 2020; Marto et al., 2019), producing more positive attitudes about a destination and leading to stronger revisit intentions (Chung et al., 2018).

Beyond AR, virtual reality (VR) is "a simulated environment in which a perceiver experiences… presence by means of a communication medium" (Steuer, 1992, p.76). Virtual environments can be viewed in a number of ways but are typically viewed via headsets the user 'wears' over their eyes paired with an electronic device like a phone or computer. Subsequently, VR immerses the user in the virtual setting, completely overtaking their field of vision and reacting to their movement; for example, when a user turns their head in real life, they also 'turn' their head in the virtual environment. When immersed within the environment, users can freely view and, depending on the application, interact with it. Since the start of the twenty-first century, VR has been recognized as a powerful tool in landscape planning, creating a more intimate experience and allowing managers to immerse users in a completely new environment (Orland et al., 2001). VR also has the potential as a communication tool to promote environmental literacy, further garnering support for forest management (Chandler et al., 2021; Fauville et al., 2020; Qi et al., 2004).

Research dating back to the early 2000s supports that VR can influence behaviors in an environmental context. In 2005, Sheppard developed a widely-referenced framework that suggested landscape visualizations, coupled with VR, could be used as an attractive source to educate laypeople about climate change and promote pro-environmental behavioral responses among the public. Building off this framework, a variety of studies have explored landscape visualizations' role in influencing cognitive, affective, and behavioral responses to environmental issues (Burch et al., 2009; Sheppard et al., 2008; van Lammeren et al., 2010). More recent experiments observing actual behavior found that those immersed in and interacting with a virtual forest environment were significantly less likely to use paper napkins after the experience than those who viewed a simple, static informational message (Ahn et al., 2014). In addition, Ahn et al. (2016) found that those who experienced the lives of coral through a first-person virtual environment were more likely to exhibit pro-environmental behaviors and felt stronger feelings of involvement with nature compared to those who viewed videos of the simulations. Specific to recreation and tourism, high levels of immersion elicited significantly stronger revisit intentions than low-immersion VR environments (Ying et al., 2022).

Particular to forests, VR applications can efficiently visualize and communicate forest landscape changes to the public. In an early exploration of virtual forest development, Qi et al. (2004, p.4862) argued that a combination of VR, computer-supported cooperative work, and remote sensing technology "is a feasible and innovative way to support forest management" with realism as a core component in supporting the usability of virtual forest environments. Supporting Qi et al. (2004), Chandler et al. (2021) developed a heralded VR forest experience that incorporated ecosystem changes, and land-use alterations or climatic disturbances, to aid in visualizing dynamic forest changes. Similarly, Huang et al. (2021) developed a positively-reviewed forest landscape simulation model that visualized northern Wisconsin forests under changing climate conditions to aid conservation managers in visualizing and communicating forest changes to the public. However, its application in visitor response to forest management remains untested.

Effective communication about invasive species management is important for visitor understanding and retention. While AR and VR may enhance communication efforts through increased engagement, no research examines this and its impact on displacement. We explore this and hypothesize that experiencing more interactive and immersive messages will result in decreased displacement intentions across forest management responses to EAB.

Methodology

Throughout the summer of 2021, onsite visitor questionnaires were conducted across three Minnesota State Parks: Fort Snelling, Wild River, and Lake Bemidji

Study sites

Located in the Minneapolis-St Paul metropolitan area and along the confluence of the Minnesota and Mississippi Rivers, Fort Snelling State Park lies on the lands of the Dakota people. The 1500-hectare state park hosts more than 700,000 annual visitors (Minnesota Department of Natural Resources, 2022) The park is intended for day use and is accessed via personal vehicles, regional trails, and public transportation. Recreation opportunities available at this park include hiking, non-motorized boating, fishing, and biking. The park contains forests, meadows, marshes, and lakes and is mainly located on the Minnesota River floodplain. Ash (primarily green ash, *Fraxinus pennsylvanica*) trees are estimated to compose between 5 and 30% of the park's forests (Arnberger et al., 2017). EAB was discovered in Ramsey County, the home of Fort Snelling State Park, in 2009 and was detected in the park in 2012 (Quinn, 2022).

Wild River State Park is located 58 miles (93 kilometers) from the Minneapolis-St Paul metropolitan area near Taylors Falls, Minnesota, located on the lands of the Ojibwe and Dakota people. The 2,750-hectare park hosts more than 230,000 visitors per year and is situated adjacent to 18 miles of the Minnesota and Wisconsin border along the Saint Croix National Scenic Riverway. Both non-motorized activities and overnight camping are primary recreation opportunities (Minnesota Department of Natural Resources, n.d.). The park is accessible via personal vehicles, two river landings, and via bike trail. Pine forest, hardwood forest, and oak savannah ecosystems exist at the park. While mostly containing black ash, both black and green ash cover nearly 44% of the park (Schlueter & Schneider, 2016). EAB was discovered in Chisago County, the home of Wild River State Park, in 2015 but, as of 2022, has not been detected within the park.

Situated directly adjacent to Lake Bemidji, seven miles (11 kilometers) from the town of Bemidji and located on the lands of Dakota and Ojibwe people is Lake Bemidji State Park. Lake Bemidji State Park is smaller than the other two study sites (699 hectares) and hosts nearly 150,000 annual visitors. Recreation opportunities include hiking, non-motorized activities, boating, fishing, and camping. Visitors can access the park via personal vehicles, boats, or non-motorized transport through the Paul Bunyan State Trail. Mixed pine uplands, jack pine barrens, and conifer bogs are found within the park, which is part of Minnesota's pine-moraine region. Black ash resides in the park's lowland forests. EAB has not been detected in Beltrami county or Lake Bemidji State Park as of 2022.

Questionnaire

A multi-section onsite questionnaire was developed, pre-tested, and implemented to understand displacement intentions and how increasingly interactive and engaging messaging presentations impacted them. The questionnaire included multiple sections. Of interest to this project are questions focused on displacement intentions in response to photos depicting four management approaches to an EAB infestation, EAB knowledge and familiarity, perceived importance to manage EAB, as well as information about the respondent's visit.

Displacement intentions were assessed in response to photos depicting landscapes resulting from the forest management approaches utilized for EAB: "do nothing," "select harvest, natural regeneration," "select harvest, planted trees," and "complete harvest, natural regeneration." (Figure 2). If respondents indicated they intended to displace or were unsure if they would displace from any of the landscapes, they were asked where they would go instead: an area within the site (intrasite displacement), an area outside the site (intersite displacement), stay home, or other. Photos were acquired through on-site visits of Minnesota forests where they were occurring, about five years after the initial treatment took place.

Figure 2: Landscape treatment images showing 1) complete harvest, natural regeneration; 2) select harvest, natural regeneration; 3) select harvest, planted trees; 4) do nothing

A combination of variables inquired about respondent EAB knowledge and familiarity. Knowledge of EAB was assessed on a 1-4 ordinal scale: 1=never heard of it, 2=heard of it but know nothing about it, 3=heard of it and have some knowledge, and 4=know a lot about it.

Familiarity with the four selected management treatments was assessed on a 1-7 interval scale, with 1=very unfamiliar and 7=very familiar. Importance to manage forests in response to EAB was assessed on a 1-7 interval scale, with 1=very unimportant and 7=very important. Respondents' personal experience with EAB was evaluated via three questions with simple yes, no, or did not know response options: if EAB resided on their property of residence, if EAB resided in their community, or if they have ever visited an area visually impacted by EAB.

Visit information included whether the respondent was a first-time visitor and their motivation to engage in experiences at the park. First-time visitor status was measured by respondents indicating if their current visit was their first time visiting the park. Lastly, respondents were queried about their demographic information and experience with AR and VR prior to finishing the questionnaire.

Respondents were randomly assigned to one of four informational interventions: 1) No management information (control), 2) Text with photo display, 3) Augmented reality (AR), and 4) Virtual reality (VR). The messages' content included the same wording and photos but were communicated through mediums that encouraged increased levels of interactivity, engagement, and, subsequently, central-route elaboration. The photo/text intervention consisted of a four-page laminated informational sheet with photos and text call-out boxes about each management treatment. The AR intervention activated an interactive, 360-degree landscape image via an Android tablet that shared the same information in the photo/text intervention but the written words were spoken by a female voice with nature sounds in the background. Visitors were instructed to 'click through' floating text boxes via a touchscreen that led to additional information accompanied by images or a video in each forest management approach. The VR intervention immersed the participant in the landscapes when they donned VR goggles attached to a supplied Android phone and, again, ‘clicked through’ informative text boxes to receive information about each treatment. In alignment with the ELM (Petty & Cacioppo, 1986), all messages contained first-person words such as “we” and “you” to elicit a sense of personal relevance. Due to the addition of immersion and multisensory cues, the AR intervention was more interactive and immersive than the series of photos and text. Similarly, the VR intervention was even more immersive as it produced a more vivid, sensory-rich virtual environment by occupying the user’s full field of vision (Steuer et al., 1992). The VR intervention was also more interactive as users could ‘follow’ a blue dot that served as their cursor to select informational text boxes, while users of the AR intervention selected text boxes via a touchscreen. The average duration to complete the questionnaire was 14 minutes, with a range from 4.5 to 27 minutes. When receiving no intervention, the average duration to complete the questionnaire was 9.6 minutes. When receiving the photo/text intervention, the average duration to complete the questionnaire was 13.5 minutes. When receiving the AR intervention, the average duration to complete the questionnaire was 17.3 minutes and the average time to complete the questionnaire with the VR intervention was 15.8 minutes (Table 1).

Table 1: Average duration to completely view the four informational interventions, including control/no information (n=92-100)

Informational Intervention	Duration (Minutes)
Augmented Reality	17.3
Virtual Reality	15.8
Photo/Text	13.5
No Information	9.6

Data collection

Sampling took place at commonly visited areas in the three state parks, and surveys were administered by a team of graduate and undergraduate researchers who were trained to follow a script when administering questionnaires. A stratified cluster sample of every other adult respondent (18 years or older) exiting the park and passing by researchers was systematically sampled. Within groups, the group member with the most recent past birthday was asked to participate. Visitors who agreed to participate were randomly assigned to informational interventions at the start of each sampling session and then the interventions rotated after a fully-completed questionnaire was documented (i.e., if a session started with no information, then the next respondent would receive a photo/text intervention, followed by the AR intervention).

A total of 746 park visitors across all three sites were approached and asked to participate in the questionnaire. More than half agreed (388 responses; 52% response rate). Researchers obtained 45% of the responses at Fort Snelling State Park (n=175, 42.2% site response rate), 40% of responses came from Lake Bemidji (n=156, 63.2% site response rate), and 15% of responses from Wild River (n=57, 67.9% site response rate). Fewer responses were obtained at Wild River due to a lower-than expected visitation; therefore, researchers chose to allocate data collection efforts to Fort Snelling and Lake Bemidji.

Non-respondents' observed recreation activity was recorded and they were asked to indicate their general knowledge about EAB, if they were a first-time visitor to the park, and their residential zip code. A moderate (Cramer's V=.54; Cohen, 1988) association between response status and knowledge of EAB emerged, $X^2 (3, N = 698) = 199, p < .001$), where non-respondents knew significantly less about EAB (1.8%) than respondents (31.9%). First-time visitation status among the two groups was quite similar (28.8% of non-respondents and 28.2% of respondents), and non-respondents were significantly more likely to engage in walking/hiking and dog walking compared to respondents.

Data analysis

Data were entered, cleaned, and then analyzed via Statistical Package for Social Sciences (SPSS, version 26). To assess if the site data could be combined, select key variables (age, recreation motivations, importance of managing forests in response to EAB, perceived problem that invasive species pose, and first-time visitor status) were compared with an analysis of variance (ANOVA). Data were combined as only first-time visitation and the perceived problem posed by invasive species differed at one site (Wild River).

As displacement was not prevalent (2.4-10.9% across sites) and those 'unsure' were considered impressionable via information, those who indicated "yes" and "unsure" about displacing were combined. To assess the relationship between message medium and displacement intentions, a Chi-Square Test was performed. If the association was significant, Cramer's *V* identified the effect size.

Spearman's Rho correlation test examined any existing correlations of variables related to displacement: first-time visitor status, knowledge of EAB, perceived importance to manage EAB, landscape preference, motivation to view scenery when recreating, past experience with EAB, as well as familiarity and acceptability of any associated forest management practices.

Results

Sample characteristics, motivations, and experience with AR/VR

Respondents were primarily white (92%), non-Hispanic (97.4%) and evenly distributed by age from 18 to 83 (avg: 47.5 years old). Seventy-two percent of respondents were repeat visitors and 43.5% traveled less than 10 miles from their primary residence to reach the study site(s). Fifty-eight percent of respondents were from the seven-county Minneapolis-St. Paul metropolitan region and nearly 8% of respondents were from out of state. Visitors identified experiencing nature (82.7%), being close to nature (79.5%), and viewing scenery (78.3%) as important/very important experiences to them when visiting the study sites. Respondents were generally inexperienced with AR and VR applications as nearly half had never used AR (49.2%) or VR (46.1%) before and more than 40% reported using them less than 10 times before the day we encountered them.

EAB Knowledge, prior experience, familiarity with management strategies, and importance to manage forests in response to EAB

Over 75% of respondents indicated they were aware of EAB and possessed at least some knowledge of it; however, personal experience with EAB varied. Nearly equal percentages were aware they had visited an area infested with EAB as were unsure (39.1% and 37.8%). Nearly one-quarter of respondents were unaware if EAB existed on their property (23.5%) and half of the respondents (50.8%) indicated they had EAB in their community while 34.2% were unsure.

A majority of visitors believed that managing forests in response to EAB was important or very important (64%), however visitors were generally unfamiliar with such management strategies. Less than 25% of respondents were familiar or very familiar with any of the treatments included in the questionnaire. Among the four treatments of interest, respondents indicated the greatest familiarity with doing nothing (22.7%) followed by select harvests (13.1%-16.3%) and complete harvest (10.6%).

Displacement intentions

Without any information, intentions to displace from landscape photos representing the four management approaches ranged from 12.6% to 25.8% (Table 2). Respondents were most likely to displace in response to landscape photos representing “select harvest, natural regeneration” (25.8%) and least likely to displace from landscape photos representing “complete harvest, natural regeneration” (12.6%). Nearly 20% of respondents indicated they would displace or were unsure if they would in response to “do nothing,” followed by "select harvest, planted trees" (23.7%). When respondents indicated displacement intentions, intrasite displacement was the most commonly cited (52%-66.6%) followed by intersite displacement (32%-43.5%). Very few, if any, respondents indicated they would stay home in response to the four landscapes (0%-4%).

Message medium was significantly and moderately related to displacement intentions in only one of four landscapes representing forest management in response to EAB: "select harvest, planted trees," X^2 (3, N = 382) = 16.6, p = 0.001, Cramer’s V = 0.21) (Cohen, 1988; Table 3). Any information significantly reduced displacement intentions in response to this landscape photo.

Three variables were weakly, significantly, and positively correlated with revisit intentions: landscape preference, knowledge of EAB, and the perceived problem that invasive species pose to Minnesota forests. Among visitors who did not receive an informational intervention, landscape preference for ”select harvest, planted trees” was weakly related to displacement, r(93) = .23, p = .024 (Table 4). Additionally, knowledge of EAB, r(97) = .21, p = .040, and/or the perception that invasive species posed an increasingly severe problem for Minnesota’s forests were positively correlated with the intention to revisit the “select harvest, planted trees” setting, r(70) = .35, p=.003. Still, these were weak associations.

Table 2: Percent of respondents indicating spatial displacement intentions when encountering forested landscapes managed in response to emerald ash borer (n=95-97)

	Displacement intention %	
Forest management treatment	Yes/unsure	Would not
Complete harvest, natural regrowth	12.6	87.4
Do nothing	19.8	80.2
Select harvest, planted trees	23.7	76.3
Select harvest, natural regrowth	25.8	74.2

Table 3: Results and effect size of the Chi-Square Test on the association between informational intervention received and intention to displace from the landscape resulting from “select harvest, planted trees”

	Value	df	Significance (2-sided)
Pearson Chi-Square	16.588	3	.001
Cramer’s *V*	.208		.001
N of valid cases	382		

Table 4: Results of Spearman's rank correlation on past-identified variables associated with displacement (no info respondents only)

	Revisit intentions if encountered "select harvest, planted trees" landscape
	Correlation coefficient
Perceived problem that invasive species pose for Minnesota forests[1] (n=70)	0.35**
Landscape preference[2] ("select harvest, planted trees" vs all other landscapes) (n=93)	0.23*
Knowledge of EAB[3] (n=97)	0.21*
Overall EAB experience[4] (community, property, and recreation) (n=91)	0.15
Perceived importance of viewing scenery when visiting the study site[5] (n=91)	0.13
Familiarity with treatment "select harvest, planted trees"[6] (n=95)	0.09
Perceived importance to manage forests in response to EAB[7] (n=83)	0.08
Perceived acceptability of treatment "select harvest, planted trees" in use areas[8] (n=93)	0.06
Perceived acceptability of treatment "select harvest, planted trees" in natural areas[9] (n=91)	-0.04
First-time visitor status[10] (n=96)	-0.10

* = Significant at the 0.05 level
** = Significant at the 0.005 level

[1] = Perceived problem that invasive species pose for MN forests measured on a 1-7 scale where 1 = not at all a problem and 7 = Serious problem
[2] = Landscape preference where 1 = prefer "select harvest, planted trees" landscapes and 0 = prefer any other landscapes
[3] = Knowledge of EAB measured on a 1-4 scale where 1 = never heard of it and 4 = know a lot
[4] = Experience measured on a 0-3 scale where 0 = no experience with EAB in respondents' community, property, or recreation settings to 3 = experience with EAB in respondents' community, property, and recreation settings
[5] = Importance measured on a 1-7 scale where 1 = very unimportant and 7 = very important
[6] = Familiarity with treatment "select harvest, planted trees" measured on a 1-7 scale where 1 = very unfamiliar and 7 = very familiar
[7] = Perceived importance measured on a 1-7 scale where 1 = very unimportant and 7 = very important
[8,9] = Acceptability measured on a 1-7 scale where 1 = very unacceptable and 7 = very acceptable
[10] = First-time visitor status where 0 = repeat visitor and 1 = first-time visitor

Discussion

Onsite visitor questionnaires at state parks in a U.S. Midwest state assessed if and how increasingly engaging message mediums related to visitor displacement intentions: specifically, messages that communicated about forest management in response to EAB. In contrast to hypotheses, significant changes in displacement intentions emerged in only one of the four management approaches in response to EAB: select harvest with planted trees. Results are discussed related to past literature with insights on managerial implications, study limitations, and opportunities for future research.

Overall displacement intentions were rather low among respondents receiving no information (12.6% to 25.8%) compared to those encountering bark beetle infestations and subsequent landscapes produced by non-intervention, complete harvest, and select harvest management treatments (~30% to 68%; Schneider et al. 2019). Adding context to Schlueter and Schneider's (2016) findings, our results show that while visitors may deem "doing nothing" and "complete harvest, natural regeneration" management treatments as unacceptable, they did not impact revisit intentions in this case. Building off past landscape preference research, the landscapes that visitors were most likely to displace from, selective harvesting, contained commonly disliked elements: bare soil, standing and ground-laden dead wood, and large canopy gaps (Edwards et al., 2012; Ribe, 1990). However, whereas past research revealed clearcut landscapes were strongly disfavored and incited the most displacement (Kearney, 2001; Schlueter & Schneider, 2016; Schneider et al., 2019), visitors were least likely to displace from the complete harvest natural regeneration/clearcut landscape presented in this study. One explanation is that the management photos in this study depicted landscapes five years after their initial treatment, allowing the landscape to recover and mitigating the presence of undesirable elements such as abundant dead wood, bare soil, and logging residue (Arnberger et al., 2017; Edwards et al., 2012; Filyushkina et al., 2017; Gundersen & Frivold, 2008; Ribe, 1990). In contrast, the other photo-based studies showed immediate outcomes of the complete harvest scenarios with no recovery (Kearney, 2001; Schneider et al., 2019).

Related to information and displacement intentions, findings partially support previous research that messages incorporating the ELM, when used in an outdoor recreation context, can promote issue-relevant thinking and influence behavior intentions (Lazard & Atkinson, 2015; Miller et al., 2019; Vezeau, 2014). Possible reasons for the lack of significant influence across treatments relate to external, recipient, and source factors that may have impeded respondents' ability and/or motivation to elaborate on the presented message arguments.

External factors may have interfered with the visitors' ability to elaborate at the level encouraged by the interventions, leading to unchanged behaviors. First, we examine distractions. Distractions impact one's ability to elaborate on a message and result in less favorable attitudes toward strong messages; additionally, high levels of distractions negatively impact one's ability to recall message arguments (Petty & Cacioppo, 1986; Slater & Steed, 2000). In this instance, external factors diminishing the impact of the engaging message mediums include fellow group members attempting to interact with the respondent, the presence of biting insects, background noises, and surrounding sights. A variety of recipient factors play into one's ability to elaborate on message arguments including knowledge, relevance and motivations. Individuals are more likely to elaborate if they possess prior knowledge of an argument's topic, allowing them to draw on internal issue-relevant information when evaluating the message (Petty & Cacioppo, 1986). The general lack of familiarity surrounding the management treatments may have impeded respondents' ability to draw on prior knowledge and elaborate on the message arguments

(Haugtvedt & Wegener, 1994). An important factor in elaborative motivation is a message's personal relevance to a recipient (Petty & Cacioppo, 1986). The lack of personal EAB experience and familiarity with management treatments may indicate that EAB management, though important, was not personally relevant to some participants, impacting their elaborative motivation (Celsi & Olson, 1988).

Message source factors are another important factor, particularly message comprehensibility and source-initiated distractions (Petty & Cacioppo, 1986). In the context of technological interventions, ease of use with interactive materials is important, and if an intervention is too interactive or difficult to use then users become frustrated and associate such feelings with the message (Liu & Shrum, 2009). While the interventions were pre-tested to optimize ease of use and ensure user directions were clear, the interventions were nearly half of the respondents' first AR or VR experience. Despite pre-testing and clear directions, some first-time users may have experienced difficulty attaining a sense of presence and comprehending message arguments through the interactive mediums (Sagnier et al., 2020).

Spearman's correlation analysis results provide additional insight into landscape preferences, acceptability, knowledge, and displacement. The positive relationship between respondent preferences for the landscape produced by the treatment "select harvest, planted trees" and revisit intentions aligns with established stress-coping and displacement literature, suggesting that displacement results from the need to cope and remove oneself from unacceptable, negatively-appraised conditions (Anderson & Brown, 1984; Lazarus & Folkman, 1984; Schneider & Hammitt, 1995; Schneider & Wilhelm-Stanis, 2007). If respondents indicated they preferred this type of landscape, it makes sense that they were more likely to perceive the landscape conditions acceptable and did not need to remove themselves (Anderson & Brown, 1984; Schneider & Hammitt, 1995; Schneider & Wilhelm-Stanis, 2007). Additionally, both visitors' knowledge of EAB and their perception of the severity of the problem that invasive species pose for Minnesota's forests were positively correlated with revisit intentions. While research directly related to EAB and displacement is virtually non-existent, other literature shows that possessing knowledge about an invasive species as well as perceiving their impacts to be severe increases overall support for management control (García-Llorente et al., 2011; McFarlane & Watson, 2008; Sharp et al., 2011). Perhaps such respondents positively associated the landscape alteration and presence of tree tubes arising from "select harvest, planted trees" with a beneficial process that aims to control a problematic invasive species, EAB. Resultantly, stress induced by the visual conditions and the need to displace from the landscape were mitigated.

While first-time visitor status did not significantly correlate with displacement, it does reinforce Peden and Shuster's (2009) findings that other possible stressors such as the behavior of other visitors or parking fees are more likely to displace first-time visitors than resource conditions themselves. Surprisingly and in contrast to other work (Eriksson et al., 2019; García-Llorente et al., 2011; Ryan, 2012; Sharp et al., 2011), the perceived importance of managing forests in response to EAB, as well as the perceived acceptance and familiarity with the management treatment "select harvest, planted trees" were not correlated with displacement in response to that treatment. When determining to displace or return, other characteristics, such as the appearance of the landscape photo's foreground, may have taken priority over their perceived importance to manage forests in response to EAB or the acceptability of such a treatment (Arnberger et al., 2018; Schneider et al., 2019).

Management implications include the importance of using information to communicate forest management among visitors and the need for critical evaluation of advanced communication technologies that can deliver such information. In particular, with no information, nearly one-quarter of visitors may displace from selectively-harvested, planted tree landscapes; however, providing the public with even just photo and text information about the treatment can significantly decrease this intention. Informing the public about this treatment appears valuable in both retaining visitation and advancing the general acceptance of forest management practices among laypeople, given the prevalence of this silvicultural treatment's application in public forests.

Information selectively reduced displacement intentions by up to 15% in this study. As the AR/VR interventions did not significantly decrease displacement intentions compared to the photo/text intervention, the investment in more dynamic technological communication materials may not be needed to influence visitor displacement in all settings. Despite past studies finding that incorporating multisensory cues into a virtual environment can positively impact visitors' sense of presence (Guo et al., 2021) and behaviors (Alyahya & McLean, 2021), the multisensory elements utilized in the study did not significantly impact revisit intentions. More broadly, as identified in previous research, minimizing undesirable visual features such as dead wood, bare soil, and large canopy gaps in forest recreation viewscapes (Edwards et al., 2012; Ribe, 1990) remains important.

Limitations

As in most studies, limitations exist in this study. First, sampling was conducted at three state parks all located in one midwestern U.S. state. As a result, geographic demographics were skewed. Additionally, the sampling pool was less diverse than Minnesota's state population but still representative of Minnesota State Park visitors. Given Minnesota's diversifying population and likely increase in diverse state park visitors, efforts to understand visitors with multiple racial and ethnic background seems imperative. Sampling was limited to the summer; as such, intended displacement behaviors were limited to summer recreationists. Additionally, actual displacement behaviors were not recorded, but rather intentions to displace. While behavioral intentions are a useful component in understanding behaviors (Ajzen, 1991), observing actual behaviors in the moment is the most reliable method to inform managers about displacement; however, documenting this behavior can be difficult and time-intensive (Schneider & Budruk, 1999).

Future research

Several opportunities exist to expand this research including research setting, additional seasonal data collection and variables, as well as the informational interventions themselves. When attempting to persuade via central route elaboration, researchers should still aim to collect data on-site to reach issue-relevant respondents but seek to survey visitors at sites that minimize the presence of distractions such as rooms in visitor centers or naturally quiet areas. Additional factors, such as place attachment and seasonality, should be considered in future studies to inform displacement intentions. Place attachment is impacted by a setting's perceived visual quality (Kaae, 2000) and has shown to influence displacement intentions (Cocolas et al., 2016; Kaae, 2000; Perry et al., 2021; Wang & Chang, 2012). For example, Cocolas et al. (2016) found that those possessing a high place attachment to a winter tourism destination indicated a resistance to spatially displace, despite worsening environmental conditions. Managers would benefit from understanding if these results similarly apply to visitors who possess high levels of place-attachment to parks such as Fort Snelling and Lake Bemidji State Parks. Past research found generally-neutral levels of place attachment to these areas among visitors (Wynveen et al., 2017; Wynveen et al., 2018), but did not examine its potential to influence displacement in the face of managed landscape alterations. Visitor behavioral responses to visual forest alterations are not limited to summer recreationists, as Kaae (2000) found that timber harvests impacted the visual quality of a winter recreation site and negatively influenced displacement intentions. As such, surveying winter recreationists using winter photos would provide managers with a broader understanding of how landscapes altered in response to EAB impact winter recreationists' experiences and potential displacement intentions.

Modifying the interventions to promote heightened immersion would advance understanding of their role in message engagement and behavioral persuasion. One such case includes enhancing or incorporating additional audio and visual cues into the virtual environments, such as exploring different narrative styles. For example, Kang and Gretzel (2012) found that multiple voices speaking in a conversational style within a message increased recipients' level of social presence. Additional visual elements, such as virtual forest landscapes, could also bolster immersion. Yeo (2020) found that computer-generated virtual environments were rated as more engaging than 360-VR videos, similar to the VR environment utilized for this experiment. However, McLean and Barhorst (2022) found minimal significant differences in influential effect between the two VR platforms. Mixed findings surrounding this topic warrant the need for continued research. Perhaps incorporating other factors, such as GIS data, could further aid in providing realistic virtual visualizations of invasive species-induced landscape changes, as Ghadirian and Bishop (2008) suggest. In addition, developing and implementing an informational game through AR and VR mediums may be of interest. Past research found that combining technology, entertainment, and information through platforms such as AR games can positively influence knowledge and stewardship behaviors pertaining to invasive species (Howard, 2017). In fact, AR games elicited significantly more engagement and better learning outcomes than traditional interpretive programs (Cai, 2013). As past studies focused on younger audiences than the Minnesota state park population (Cai, 2013; Howard, 2017), future research could design and test a platform to align with state park visitor demographics or the target audience.

Lastly, to confirm if the AR and VR interventions promoted heightened levels of central-route elaboration compared to receiving no information and the photo/text intervention, future research in this subject should perform post-intervention elaboration assessments such as thought-listing exercises or self-report elaboration scale questions (Miller et al., 2019; Shen & Seung, 2018). Further, follow-up surveys with those that produced high levels of issue-relevant thoughts would help researchers understand the strength and persistence of behavioral intentions produced by the interventions (Ahn et al., 2014; Ahn et al., 2016).

As EAB and other invasive species continue to spread across forests, visual impacts will persist. To maintain high-quality recreation experiences and retain visitation, managers must understand and utilize the best avenues of communication to inform such changes to the public. Past research shows that continually advancing technology can aid in their mission to inform visitors about forest management and reduce undesirable behaviors. Despite this, results from this study showed that visual imagery accompanied with text can aid managers in retaining visitation in “select harvest, planted trees” settings just as effectively as technological methods. While results from this study benefit managers in the context of EAB management, many opportunities still exist to broaden the general understanding of this topic. Additional research is needed to fully realize engaging messaging's role in visitor displacement, as the current body of research on this topic is scant to non-existent.

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Appendix A: Example survey (VR)

EAB Questionnaire - Updated Copy - VR

Start of Block: Administrative information

Q179 Administrative information only

location Location?

- ○ Fort Snelling State Park (1)
- ○ Wild River State Park (2)
- ○ Lake Bemidji State Park (3)

treatment Info treatment?

- ○ No info (1)
- ○ Photo/text (2)
- ○ Augmented Reality (3)
- ○ Virtual Reality (4)

End of Block: Administrative information

Start of Block: Introduction

Q116 Public parks and forests are managed for multiple reasons. Recreationists like you have a special interest In how they are managed. This questionnaire will provide information on recreationist use and preferences to help improve public land and forest management. The information you provide is confidential and voluntary. You may stop the questionnaire at any time.

Q118 Click the arrow in the bottom right to proceed.

End of Block: Introduction

Start of Block: Visitation Questions

Q171 First, a bit about your recreation visit here today.

X→

firstvis Are you a first-time visitor to this park/forest (select the circle next to the best response)?

- ○ Yes (1)
- ○ No (0)

---

disttravel About how far did you travel from your primary residence to get to this park/forest area?

- ○ less than 10 miles (1)
- ○ 11-20 (3)
- ○ 21-30 (4)
- ○ 31-40 (5)
- ○ 41-50 (6)
- ○ 51 or more (7)
- ○ do not know (8)

mainact What was your **main** activity at this park/forest area (check one)?

- Hiking/walking (1)
- Visitor Center (2)
- Dog Walking (3)
- Observing/photographing nature (4)
- Biking (5)
- Running (6)
- Sightseeing (7)
- Camping (8)
- Other (9) ____

Page Break

Motiv Below is a list of possible reasons people recreate outdoors. Please indicate how important or unimportant each experience is to you on your visit to this park/forest area.

	Very Unimportant (1)	Unimportant (2)	Moderately Unimportant (3)	Neither (4)	Moderately Important (5)	Important (6)	Very Important (7)
To be close to nature (Motivclosenat)	○	○	○	○	○	○	○
To be physically active (MotivPhys)	○	○	○	○	○	○	○
To view the scenery (MotivScene)	○	○	○	○	○	○	○
To experience natural sounds (MotivSound)	○	○	○	○	○	○	○
To relax physically (MotivPhysrel)	○	○	○	○	○	○	○
To experience nature (MotivExpNat)	○	○	○	○	○	○	○
To rest mentally (MotivMental)	○	○	○	○	○	○	○
To get/keep physically fit (MotivExer)	○	○	○	○	○	○	○

Page Break

End of Block: Visitation Questions

Start of Block: Management Goals

Q6 Now, a few questions about your thoughts on public forest management goals.

Manage_goals How important or unimportant are each of the following goals for managing Minnesota's public forests?

	Very Unimportant (1)	Unimportant (2)	Moderately unimportant (3)	No Opinion (4)	Moderately important (5)	Important (6)	Very important (7)
Manage timber for forest products like lumber (gltimber)	◯	◯	◯	◯	◯	◯	◯
Increase species diversity (gldiversiy)	◯	◯	◯	◯	◯	◯	◯
Manage plant habitat (glPlantHab)	◯	◯	◯	◯	◯	◯	◯
Manage wildlife habitat (glWildHab)	◯	◯	◯	◯	◯	◯	◯
Manage fisheries (glfisheries)	◯	◯	◯	◯	◯	◯	◯
Prevent wildfire (glwildfire)	◯	◯	◯	◯	◯	◯	◯
Manage cultural resources (glculture)	◯	◯	◯	◯	◯	◯	◯
Provide recreation opportunities (glrec_opp)	◯	◯	◯	◯	◯	◯	◯
Provide beautiful landscapes (gllandscape)	◯	◯	◯	◯	◯	◯	◯

Maintain water quality (glwater_qual)	○	○	○	○	○	○	○
Protect large, big trees & forests (glprotect)	○	○	○	○	○	○	○
Increase climate resilience (glclimate)	○	○	○	○	○	○	○
Decrease invasive species (glinvas_sp)	○	○	○	○	○	○	○
Provide non-timber forest products and forage (e.g., mushrooms, boughs) (glnontimber)	○	○	○	○	○	○	○

Page Break

Q160 Next we're interested in understanding your perceptions of invasive species in Minnesota.

invprob If and how much do you view invasive species as a problem in Minnesota's forests?

	Serious problem						Not a problem at all
	1	2	3	4	5	6	7
Invasive species ()							

invKnowl How knowledgeable are you about invasive species in Minnesota?

- Never heard of them until today (1)
- Heard of them but know nothing about it (2)
- Heard of them and have some knowledge of them (3)
- Know a lot about them (4)

EABknowl How knowledgeable are you about emerald ash borer?

- Never heard of it until today (1)
- Heard of it but know nothing about it (2)
- Heard of it and have some knowledge of it (3)
- Know a lot about it (4)

Page Break

Q10

Emerald ash borer is a beetle native to Asia first discovered in Michigan in 2002 which has spread throughout more than half the U.S. The borer tunnels through ash tree bark, killing the tree within 1-6 years. Minnesota has one of the largest concentrations of ash trees in the United States, about 8% of our 4.3 million acres of forests. The picture below is typical of ash forests in Minnesota.

manageOpin Minnesota natural resource managers are interested in your opinions about managing forests in response to the ash borer. Do you think forests should be managed in response to the emerald ash borer?

- Yes (1)
- No (0)
- Do not know (2)

---

manageImport If and how **important** is it to manage forests in response to emerald ash borer?

	High Importance				Low Importance		
	1	2	3	4	5	6	7
Managing for emerald ash borer ()							

EABexper Share a bit about your experience with emerald ash borer.

	Yes (1)	No (0)	Do not know (2)
Do you have emerald ash borer in your community? (EABcomm)	○	○	○
Do you have emerald ash borer on property you rent or own? (EABprop)	○	○	○
Have you ever visited a forested recreation area visually impacted by emerald ash borer? (EABrec)	○	○	○

EABapproach_familar How **familiar** are you with each of these approaches to manage forests in response to the emerald ash borer?

	Very unfamiliar (1)	Unfamiliar (2)	Moderately unfamiliar (3)	Neither (4)	Moderately familiar (5)	Familiar (6)	Very familiar (7)
Complete harvest, natural regrowth (FAMclear)	○	○	○	○	○	○	○
Select harvest, natural regrowth (FAMnatregen)	○	○	○	○	○	○	○
Select harvest, planted trees (FAMartregen)	○	○	○	○	○	○	○
Doing nothing (FAMnothing)	○	○	○	○	○	○	○
Chemical controls (FAMchem_control)	○	○	○	○	○	○	○
Biological controls (FAMbio_control)	○	○	○	○	○	○	○
Wood regulations (FAMwood_reg)	○	○	○	○	○	○	○

End of Block: Management Goals

Start of Block: Managing EAB Forests

Q174 In the next section we invite you to use the supplied virtual reality goggles to view and hear about 4 ways to manage forests in response to the emerald ash borer. After you put the goggles on and 'click through' each approach, we will ask you a few questions. **Please ask the UMN Staff for the goggles.**

Q179 **STOP** and use the virtual reality goggles.

Page Break

Q178 Did you use the virtual reality goggles?

- ○ Yes-great, continue with the questions (1)
- ○ No-ask UMN staff for the goggles (2)

Page Break

Q122 Now, a few questions about managing forests in response to emerald ash borer.

useareas_acceptable How **acceptable** are each of the following forest management approaches in response to emerald ash borer in **use areas**, those that prioritize visitor access?

	Very unacceptable (1)	Unacceptable (2)	Somewhat unacceptable (3)	Neutral (4)	Somewhat acceptable (5)	Acceptable (6)	Very acceptable (7)
Complete harvest, natural regrowth (accuseClear)	○	○	○	○	○	○	○
Select harvest, natural regrowth (accuseNatregen)	○	○	○	○	○	○	○
Select harvest, planted trees (accuseArtregen)	○	○	○	○	○	○	○
Doing nothing (accuseNothing)	○	○	○	○	○	○	○

natural_acceptable How **acceptable** are these same forest management approaches in **natural areas**, those that prioritize natural resource management?

	Very unacceptable (1)	Unacceptable (2)	Somewhat unacceptable (3)	Neutral (4)	Somewhat acceptable (5)	Acceptable (6)	Very acceptable (7)
Complete harvest, natural regrowth (accnatClear)	o	o	o	o	o	o	o
Select harvest, natural regrowth (accnatNatregen)	o	o	o	o	o	o	o
Select harvest, planted trees (accnatArtregen)	o	o	o	o	o	o	o
Doing nothing (accnatNothing)	o	o	o	o	o	o	o

Page Break

Q161 In this next section we share several photos with you and ask about your preferences for and visits to landscapes like them.

photo_prefer Which of the 4 landscapes in the photos below do you visually prefer (choose 1)?

○ (1)

○ (2)

○ (3)

○ (4)

End of Block: Managing EAB Forests

Start of Block: Clear Cut

Page Break

Q37

return_clear If you encountered a landscape that looked like this when recreating, would you return?

- Yes (1)
- No (0)
- Unsure (2)

Skip To: End of Block If you encountered a landscape that looked like this when recreating, would you return? = Yes altactClear Instead of visiting this area, what would you do (select all that apply)?

- ☐ Visit other sites in this park or forest (1) f
- ☐ Visit other sites in other areas (2)
- ☐ Stay home (3)
- ☐ Unsure what I would do (4)

End of Block: Clear Cut

Start of Block: Natural Regeneration

Q127

X→

return_natregen If you encountered a landscape that looked like this when recreating, would you return?

- ○ Yes (1)
- ○ No (0)
- ○ Unsure (2)

Skip To: End of Block If you encountered a landscape that looked like this when recreating, would you return? = Yes

altactNatregen Instead of visiting this area, what would you do (select all that apply)?

- ▢ Visit other sites in this park or forest (1)
- ▢ Visit other sites in other areas (2)
- ▢ Stay home (3)
- ▢ Unsure what I would do (4)

End of Block: Natural Regeneration

Start of Block: Artificial Regeneration

Q131

return_artregen If you encountered a landscape that looked like this when recreating, would you return?

- Yes (1)
- No (0)
- Unsure (2)

Skip To: End of Block If you encountered a landscape that looked like this when recreating, would you return? = Yes

---

altactArtregen Instead of visiting this area, what would you do (select all that apply)?

- Visit other sites in this park or forest (1)
- Visit other sites in other areas (2)
- Stay home (3)
- Unsure what I would do (4)

End of Block: Artificial Regeneration

Start of Block: Do Nothing

Q135

X→

return_nothing If you encountered a landscape that looked like this when recreating, would you return?

◯ Yes (1)

◯ No (0)

◯ Unsure (2)

Skip To: End of Block If you encountered a landscape that looked like this when recreating, would you return? = Yes

X→ X→

altactNothing Instead of visiting this area, what would you do (select all that apply)?

▢ Visit other sites in this park or forest (1)

▢ Visit other sites in other areas (2)

▢ Stay home (3)

▢ Unsure what I would do (4)

End of Block: Do Nothing

Start of Block: Technology

Q45 In this last section, we want to learn about your familiarity with experiencing a landscape through technology, specifically augmented and virtual reality.

Q46 Augmented reality is when an otherwise real environment is “augmented” or enhanced with the use of virtual objects. For example, when you point a camera in a mobile device at a QR code, the augmented reality shares virtual images that you would interact with in the real-world context.

X→

ARknowl How knowledgeable are you about augmented reality?

- ○ Never heard of it before today (1)
- ○ Heard of it but know nothing about it (2)
- ○ Heard of it and have some knowledge of it (3)
- ○ Know a lot about it (4)

X→

ARuse How many times have you ever used augmented reality?

- ○ 0 (0)
- ○ less than 10 (1)
- ○ 10 or more (2)

Page Break

Q50 Virtual reality is a fully immersive computer-generated experience where you navigate a virtual world, requiring the use of goggles to see the virtual world.

VRknowl How knowledgeable are you about virtual reality?

- ○ Never heard of it before today (1)
- ○ Heard of it but know nothing about it (2)
- ○ Heard of it and have some knowledge of it (3)
- ○ Know a lot about it (4)

VRuse Before today, how many times have you ever used virtual reality?

- ○ 0 (0)
- ○ less than 10 (1)
- ○ 10 or more (2)

Page Break

End of Block: Technology

Start of Block: Block 10

Q57 Finally, a few questions about you

forestOwn Do you or your immediate family own any forest land?

- Yes (1)
- No (0)

ForestEmploy Are you or immediate family members employed in the forest industry?

- Yes (1)
- No (0)

HispOrg Are you of Hispanic or Latino origin?

- Hispanic or Latino (1)
- Not Hispanic or Latino (0)

ethnicity Are you (check all that apply)

- ▢ American Indian or Alaskan Native (1)
- ▢ Asian (2)
- ▢ Black or African American (3)
- ▢ Native Hawaiian or Pacific Islander (4)
- ▢ White (5)
- ▢ Other (6) ____

---

year_born In what year were you born?

- ○ 19_ (1) ____
- ○ 20_ (2) ____

---

zip What is your postal code?

____

---

other_comm Anything else you'd like to share with us?

____

End of Block: Block 10
