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Examining park users' support for emerald ash borer (*Agrilus planipennis*) control in urban parks

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Abstract

Emerald ash borer (*Agrilus planipennis* Fairmare; EAB) is a woodboring beetle that is considered one of the most damaging invasive forest insects in North America, causing near-complete mortality of native ash (*Fraxinus* spp.) trees across multiple states. Management options include both biological control using parasitoid wasps from EAB's native range, and chemical control with systemic insecticides. Although both strategies are being used to control EAB, the public's support for these methods is not well understood. In 2023, we surveyed 174 urban park users in northeastern Georgia, United States, to identify determinants of their support for EAB control. Most respondents were not previously aware of EAB and ash trees, although they valued the ecosystem services provided by park trees. Respondents were more supportive of biological control than chemical control, perceiving greater ecological and human well-being risks from chemical control. Respondents' risk perceptions pertaining to control methods and EAB, and their attitudes towards ash trees influenced their support for EAB control. Birdwatchers were less likely to support chemical control and individuals who like to sit and enjoy nature were more likely to support biological control. Our results suggest that park managers' outreach about EAB control should emphasize the aesthetic appeal and ecosystem services provided by urban ash trees and the invasion impacts of EAB. Outreach should also highlight that EAB control does not pose ecological or human well-being risks, that parasitoid wasps help to secure ecosystem function through pest control and do not pose a risk to people, and that EAB control will not adversely impact recreational activities within the park.

KEYWORDS

attitudes, biological and chemical control, knowledge, parasitoid wasps, recreation, risk perceptions

1 | INTRODUCTION

The invasion by non-native species into novel ecosystems is a global problem which can lead to wide-ranging ecological, economic, and human well-being impacts (Mack et al., 2000; Simberloff, 2014). Invasive species may cause loss of native biodiversity and ecosystem services (Boyd et al., 2013), income losses for the agricultural and forestry sectors (Crystal-Ornelas et al., 2021), decreased human well-being (i.e., self-reported reductions in life satisfaction; Jones, 2019), and increased disease and mortality risks (Donovan et al., 2013; Jones, 2017). Invasive forest insects are a particular concern as they have eliminated tree species and genera from forests, resulting in altered forest structure, species composition, and ecosystem functions (Lovett et al., 2016). Invasive forest insects have also negatively impacted urban and suburban areas where the loss of street trees and trees in yards and parks has adversely affected property values, shade, and aesthetics, and has increased stormwater runoff (Lovett et al., 2016). Healthy urban trees provide multiple benefits to urban residents, including cooling, pollutant removal, and improved mental health and wellness (Chiesura, 2004; Donovan et al., 2013; Tzoulas et al., 2007). Residential parks are important hotspots of biodiversity in urban and peri-urban environments (Blood et al., 2016; Nielsen et al., 2014) that help to secure ecosystem services (Boyd et al., 2013; Cardinale et al., 2012).

One of the costliest invasive forest insects in the United States (US) is the emerald ash borer (EAB), *Agrilus planipennis* Fairmare (Coleoptera: Buprestidae; Aukema et al., 2011). The EAB is an invasive wood-boring beetle that has led to the widespread mortality of North America's ash trees since it was first detected near Detroit, Michigan in 2002 (Cappaert et al., 2005; Haack, 2006; Herms & McCullough, 2014). Tree mortality occurs as larvae feed beneath the bark, which disrupts the flow of nutrients and water and can lead to individual tree death in 2–5 years (Klooster et al., 2014; Poland & McCullough, 2006). To date, EAB has been detected in 36 US states and six Canadian provinces (Emerald Ash Borer Information Network, 2024). The continued spread of EAB threatens 16 native North American ash species in their range (Herms & McCullough, 2014). Multiple non-native ash species such as European ash (*Fraxinus excelsior* L.), European flowering ash (*Fraxinus ornus* L.) and cultivars (namely, "Raywood" and "Desert") of narrow-leafed ash (*Fraxinus angustifolia* Vahl), which are often planted as street trees and ornamentals, are also at risk (MacFarlane & Meyer, 2005; Subburayalu & Sydnor, 2018). Ash mortality causes economic damage through the loss of street and residential trees, which reduces property values (Aukema et al., 2011; Kovacs et al., 2010), ecological impacts associated with shifts in tree and insect community composition (Gandhi & Herms, 2010a, 2010b; Klooster et al., 2014), and human well-being risks such as increased ambient temperatures due to loss of shade trees (Jones, 2019). Importantly, EAB poses an increasing threat to residential parks and urban ecosystems (Lovett et al., 2016). The emerald ash borer may disperse rapidly down linear greenways with ash corridors (Jones et al., 2019), which are common in urban and suburban settings where trees are intentionally planted along paved paths. In parks, EAB spread is primarily based on distance and nearby ash phloem area, and dispersal is not necessarily directional (Siegert et al., 2010). Managing EAB-induced ash mortality will be crucial for natural resource professionals as EAB spreads to new areas of the country, including the southeastern US (hereafter, Southeast).

Eradication is the ideal response when a novel invasive insect is introduced. However, eradication is often infeasible, and the response strategy must shift to control and mitigation of adverse impacts (Simberloff et al., 2013). The public may support sanitation cutting (removal of infested ash), wood regulations (preventing long-range movement of potentially infested ash wood), and progressive thinning (Schlueter & Schneider, 2016) to prevent the spread of EAB, but these measures have not eradicated or slowed the spread of EAB, and EAB can still cause complete mortality in stands regardless of density (Smith et al., 2015). A pre-emptive tree removal program in Ontario was widely unpopular with affected residents (Mackenzie & Larson, 2010). Accordingly, both biological control and chemical control are being used to mitigate the impacts of EAB. Biological control is conducted through the release of hymenopteran parasitoids (*Oobius agrili* Zhang and Huang, *Spathius agrili* Yang, *S. galinae* Belokobylskij and Strazanac, *Tetrastichus planipennisi* Yang) imported from China (USDA-APHIS, 2021). These parasitoids have been released across 31 U.S. states and three Canadian provinces to protect North American ash trees in forested areas (Duan et al., 2023). Chemical control involves the direct application of compounds such as emamectin benzoate or imidacloprid to target trees by trunk injection, soil drench, or soil injection. The translocation of the chemical throughout the tree kills vulnerable EAB life stages (Herms et al., 2019; Mota-Sanchez et al., 2009). Chemical control is an effective strategy for protecting a few high-value trees or as part of an integrated pest management program (McCullough, 2019; Sadof et al., 2021).

Although both control strategies may be used to prevent the spread of EAB, it is important to consider people's perceptions of EAB, biological control, and chemical control to identify which management responses the public is more likely to support (Bennett et al., 2017; Estévez et al., 2015; Marzano et al., 2017; Vaz et al., 2017). Accordingly, we conducted a social sciences study to ascertain whether users of residential parks in Georgia, US, support the use of biological or chemical control—an important consideration as both control methods are likely to be implemented in parks and recreational areas as EAB spreads to urban and residential parks in the Southeast (Sun et al., 2024). Opposition to biological or chemical control may result in conflicts between park users and park managers that delay mitigation efforts (Crowley et al., 2017). Conflicts may also arise if park users are concerned about the spread of EAB, but managers are not willing to implement control actions (Gozlan et al., 2013).

Consistent with prior research, we predicted that people's support for biological control and chemical control would depend on demographics (Bremner & Park, 2007; Chang et al., 2009; Sharp et al., 2011), use of parks (Gobster, 2011), their awareness of ash trees and species invasions (Bremner & Park, 2007; Estévez et al., 2015), attitudes towards ash trees (Mackenzie & Larson, 2010) and insects (Sumner et al., 2018), and risk perceptions (McFarlane & Witson, 2008; Steele & Pienaar, 2021). Prior research suggests that younger (<40 years old) park users may be less supportive of invasive species control because they believe in coexistence between humans and other species, whereas older (≥40 years old) individuals may be more supportive of control methods because they believe management is necessary for ecological integrity (Sharp et al., 2011). Prior research also suggests that men may be more supportive of the management of invasive species (Bremner & Park, 2007) and forest insect pests than women. A study conducted in Canada showed that men were more supportive than women of the control of spruce budworm, *Choristoneura fumiferana* Clemens (Lepidoptera: Tortricidae), and forest tent caterpillar, *Malacosoma disstria* Hübner (Lepidoptera: Lasiocampidae; Chang et al., 2009). Thus, we predicted that men and older members of the public would be more supportive of EAB control.

Park users' support for EAB control may also depend on their proximity to parks, how frequently they use parks, and which recreational activities they engage in at parks (Gobster, 2011). For example, hikers are more likely to oppose biological control of the hemlock woolly adelgid, *Adelges tsugae* Annand (Hemiptera: Adelgidae), through releases of predatory beetles along hiking trails (Poudyal et al., 2016). Anglers are more likely to prefer trunk injections of chemical insecticides along lakes and streams as opposed to biological control, soil drench insecticides, and individual branch treatment with soaps (Poudyal et al., 2016). Consistent with these findings, we predicted that park users would be more likely to oppose control methods that they believed would adversely affect their preferred recreational activities in the park.

The public's awareness of the scale and impacts of species invasions is generally low (Gozlan et al., 2013; Verbrugge et al., 2021), which may undermine their support for invasive species management (Estévez et al., 2015). People are more likely to support invasive species control if they recognize and understand the invasive status of species (Cordeiro et al., 2020) or how invasive species impact native species (Jaríc et al., 2020), especially if these native species (i.e., ash trees) are beautiful or charismatic. We predicted that people would be more supportive of EAB control if they were aware of invasive species, EAB, and ash trees.

Although people tend to dislike or fear wasps, their attitudes towards wasps depend on their understanding that wasps are regulators of insect pests (Sumner et al., 2018). Thus, we predicted that people would be more supportive of EAB control if they had more positive attitudes towards insects, especially wasps. We also predicted that people would be more likely to support EAB control if they had positive attitudes towards trees.

Risk perceptions are an important determinant of people's support for invasive species management (Steele & Pienaar, 2021) and pest control (McFarlane, 2005; McFarlane & Witson, 2008). People's risk perceptions encompass the hazard they are evaluating (i.e., ash tree mortality related to the spread of EAB), their familiarity with or knowledge of risk (i.e., their prior knowledge of EAB), their risk susceptibility (i.e., the perceived likelihood of ecological, economic, or human well-being impacts associated with the spread of EAB to residential areas and parks), and their risk sensitivity (i.e., the weight they place on risk; Haimes, 2009; Hanisch-Kirkbride et al., 2013). We predicted that people with higher risk perceptions pertaining to EAB-related ash tree mortality would be more likely to support EAB control.

Finally, we predicted that people's support for EAB control would differ based on whether chemical control or biological control is proposed, especially if people perceive the risks associated with the control method to exceed the invasion risks associated with the spread of EAB (Bremner & Park, 2007). Prior research shows that people's support for the use of chemical pesticides is negatively correlated with their risk perceptions pertaining to chemical control (Höbart et al., 2020; McFarlane et al., 2006) even if they support pest control (McFarlane et al., 2006). Chemical control may be seen as less natural than biological control and hence may be less preferred (Chang et al., 2009; Fuller et al., 2016; Jetter & Paine, 2004).

2 | METHODS

2.1 | Study sites

We administered in-person questionnaires (see Supporting Information S1) to visitors at four parks in Clarke (Sandy Creek Nature Center) and Gwinnett Counties (McDaniel Farm Park, George Pierce Park, Yellow River Park), Georgia (Figure S1). EAB was first identified in both Clarke and Gwinnett Counties in 2015, two years after EAB was first found in the state of Georgia. Each park contained ash trees as a forest component, although they differed in the density (74–181 trees per ha) and size of ash trees (mean diameter at breast height ranged from 15.8 ± 0.39 to 45.1 ± 0.40 cm) and the level of ash mortality due to EAB (18.2–57.1%). The parks varied in total size from 54.2 ha (McDaniel Farm Park) to 279.6 ha (Yellow River Park).

2.2 | Data collection

We administered surveys on both weekdays and weekends from 23 January to 12 April 2023. We varied the time of day we administered surveys at each park. We expected that many park users would tend to visit these parks at similar times of day, so failing to vary the times that we administered surveys could exclude potential respondents. We intercepted respondents in areas of high pedestrian traffic close to the park entrances. We asked all adults (≥18 years old) we encountered if they would participate in our survey. Participants completed surveys on iPads using the Qualtrics Offline Survey app. We also created QR-coded postcards that we provided to individuals who might be interested in the survey but did not have the time to complete the survey in the park.

2.3 | Questionnaire design

The questionnaires were designed to be completed in ~8 min to increase completion rates and reduce cognitive fatigue (completion time averaged 8 min and 15 s). We first captured respondents' gender and age, the distance that they lived from the park, and the number of times they visited the park. We also asked respondents which recreational activities they engaged in most frequently in the park. Respondents could select up to three of the following activities: walking/hiking; running/jogging; cycling; birdwatching; picnics/barbeques; and sitting and enjoying being outside (activity selected = 1, activity not selected = 0).

To measure respondents' knowledge of ash trees, we asked if they had heard of ash trees prior to taking the survey (effects coded as no = −1, unsure = 0, yes = 1), and their ability to identify trees (scale of 1–10; I cannot identify any tree species = 1, I am extremely confident in my ability to identify tree species = 10). If respondents had heard of ash trees and rated their ability to identify trees ≥7, we asked them to select the picture of an ash tree from four images, where the other pictures showed a ginkgo tree (*Gingko biloba* L.), a tulip poplar (*Liriodendron tulipifera* L.), and a sweetgum (*Liquidambar styraciflua* L.). We measured respondents knowledge of invasive species by asking if they had heard the term invasive species before taking the survey (no, I'm not sure, yes). We presented respondents with the following definition of invasive species: "Invasive species are species that have been introduced from other regions of the world. A non-native species is considered invasive if it causes harm to the environment, economic damage, or harms people and pets." We then asked if they were previously aware that non-native species were considered invasive if they cause (1) harm to the environment, (2) economic damage, or (3) harm to people and pets (no, I'm not sure, yes). We also asked respondents if they had heard of EAB (no, I'm not sure, yes). Respondents who answered yes were then asked how confident they were that they could identify an EAB (not at all confident = 1, slightly confident = 2, moderately confident = 3, confident = 4, very confident = 5).

To capture respondents' attitudes towards park trees, we asked how important it was to them that the park contained trees that (1) provide shade, (2) flower, and (3) are different shapes and heights, and that (4) the park contained a variety of trees with different leaf shapes and colors (not at all important = 1, slightly important = 2, moderately important = 3, important = 4, very important = 5). We showed a picture of an ash tree and asked respondents their level of agreement with the statement, "I would like it if my street had trees like this" to measure their attitudes towards ash trees (effects coded as strongly disagree = −2, disagree = −1, neither agree nor disagree = 0, agree = 1, strongly agree = 2). We measured respondents' attitudes towards insects by presenting pictures of insects (ants, bees, beetles, butterflies, flies, mosquitoes, and wasps) and asking whether they liked or disliked these insect groups (effects coded as strongly dislike = −2, dislike = −1, neutral = 0, like = 1, strongly like = 2).

We provided participants with the following brief explanation of the ecological risks associated with EAB: "The emerald ash borer is an invasive insect that comes from Asia. It was first detected in Georgia in 2013. It is a small green beetle and the larvae feed on ash trees. Once they arrive in an area, emerald ash borers can completely kill all healthy ash trees within 2–5 years." We measured respondents' risk sensitivity to the ecological effects of

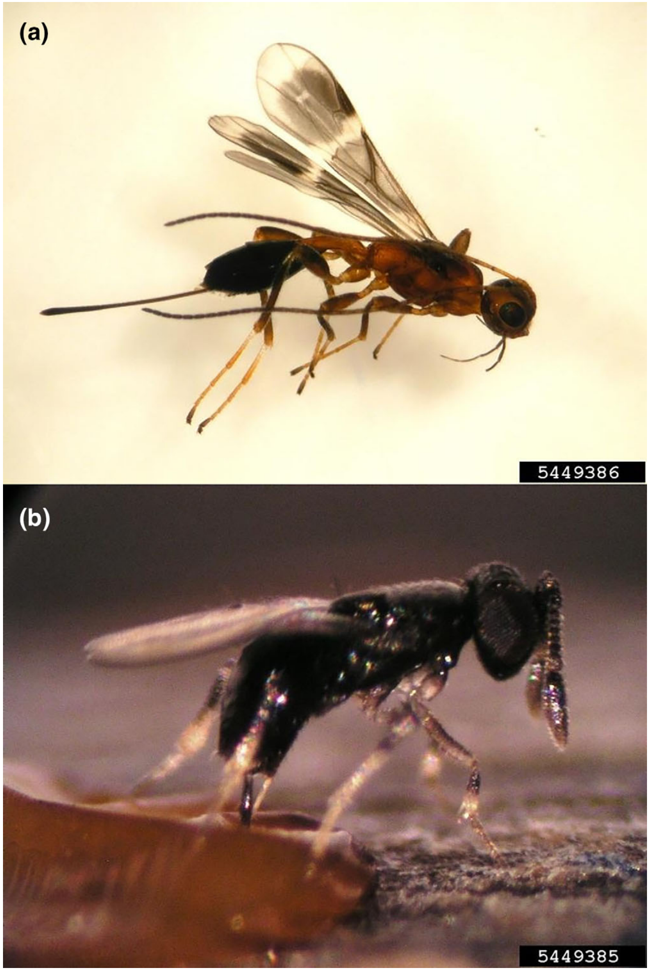

FIGURE 1 Pictures of EAB parasitoids shown to respondents following an explanation of biological control in our survey instrument. (A) The larval parasitoid *Spathius agrili*, which has been released in the US since 2007, and is currently being released in Georgia and Tennessee (Houping Liu, Michigan State University, Bugwood.org). (B) The egg parasitoid *Oobius agrili*, which has been released in the US since 2007, and is currently released across the invaded range of EAB (Debbie Miller, USDA Forest Service, Bugwood.org).

EAB by asking "how concerned are you about the loss of ash trees from EAB in this park" (not at all concerned = 1, somewhat concerned = 2, moderately concerned = 3, concerned = 4, very concerned = 5).

We then explained biological control to respondents as follows: "One option for controlling the emerald ash borer is through biological control (biocontrol). Wasps that eat the ash borer larvae could be released into parks to find and kill ash borers. The wasps, like ash borers, come from Asia. These wasps are very small, do not sting or affect humans, and have little to no effect on native insects" (Figure 1). We explained chemical control as follows: "Another option for controlling the emerald ash borer is through the use of chemical insecticides.

FIGURE 2 Picture of the researcher conducting a trunk injection of imidacloprid for EAB control shown to respondents following an explanation of chemical control in our survey instrument (David Cappaert, Bugwood.org).

Chemicals can either be applied into the soil around a tree or injected straight into the trunk. They are known as "systemic" insecticides since they mostly stay within the tree and kill all insects that feed upon the tree" (Figure 2). We then measured respondents' risk susceptibility by asking them to indicate their perceived risk that wasps used for biological control will harm (1) the environment, (2) humans (stinging, allergies), and (3) pets (stinging, allergies), or that applying chemicals in or around trees will harm (1) the environment, (2) humans, and (3) pets (ingestion, contact; no risk = 1, low risk = 2, moderate risk = 3, high risk = 4). We measured respondents' risk sensitivity to biological control and chemical control by asking how concerned they were that wasps used for biological control will (1) attack native species in the park, (2) harm human health, or (3) harm pets, and chemical control will (1) have unintended environmental consequences, (2) harm human health, or (3) harm pets (not at all to very concerned). We measured respondents' stated support for chemical control and biological control on a five-point scale (strongly oppose = 1, oppose = 2, neutral = 3, support = 4, strongly support = 5).

The Institutional Review Board at the University of Georgia reviewed our survey and determined it to be exempt (ID: 00006160). All respondents were provided with informed consent language that detailed their rights as research participants and how data would be used and reported. Prior to finalizing the survey, we pre-tested it with two experts in survey design and 25 members of the public in Clarke County, Georgia, to ensure that the questionnaire was the appropriate length and that questions were interpreted as we intended.

2.4 | Data analysis

All analyses were conducted in R (v4.2.3; R Core Team, 2023). We used Cronbach's alpha (Cronbach, 1951) and exploratory factor analysis to determine whether survey items could be combined to generate socio-psychological constructs (e.g., risk sensitivity, risk susceptibility). Consistent with the Kaiser criterion (Kaiser, 1960), we combined survey items that loaded onto factors with an eigenvalue ≥1 to generate socio-psychological constructs. We created weighted scores by multiplying survey items by their factor loading, summing weighted items to generate a total score, and dividing the total score by the number of items used to generate the score. We confirmed the reliability and internal consistency of these constructs by ensuring that Cronbach's alpha ≥0.7 (Shrestha, 2021). After confirming that the responses to the invasive species knowledge questions were correlated (Pearson correlation coefficients ranged from 0.624 to 0.715), we summed the items and divided by three to generate an invasive species knowledge score. To evaluate whether respondents were more supportive of biological control or chemical control, we conducted a Wilcoxon rank sum test. We also tested whether respondents perceived greater risk from biological control or chemical control by comparing the mean risk sensitivity and risk susceptibility scores for these control methods using t-tests.

Finally, we estimated ordinal logistic regression models to determine how respondents' socio-psychological and demographic characteristics (explanatory or independent variables) influenced their stated support for biological control and chemical control (response or dependent variable). Ordinal logistic regression analysis (also referred to as proportional odds logistic regression) is used when analyzing ordinal response variables (Harrell, 2015). This regression approach does not assume spacing between levels of the ordinal response variable (i.e., the model does not interpret a response of 'strongly support' = 5 as indicating five times greater support for EAB control than a response of 'strongly oppose' = 1; Harrell, 2015). Rather, the model uses the rank ordering of values for the response variable to determine how respondents' levels of support for EAB control are influenced by their socio-psychological and demographic characteristics (Harrell, 2015). We used maximum likelihood estimation to identify model parameters. Regression coefficients are interpreted as the odds (or likelihood) that respondents support or oppose EAB control based on their socio-psychological or demographic characteristics (e.g., the odds that respondents' risk sensitivity or risk susceptibility related to chemical or biological control influence their support for EAB control). We used backwards stepwise model selection to identify best-fit models, based on the lowest Akaike Information Criterion (AIC) values. We considered coefficients statistically significant at $p \leq 0.05$.

3 | RESULTS

In total, we received 174 completed surveys from 412 invited participants (42% response rate). Most surveys ($n = 158$, 90.8%) were completed by respondents at the park. Responses were fairly evenly split across male and female respondents (51.1% female, Table S1). The median age range for responses was 45–54 years of age. On average, respondents visited the park five times in the past month and lived ≤10 min driving distance from the park. Respondents most frequently engaged in walking or hiking ($n = 158$, 90.8%), sitting and enjoying nature ($n = 55$, 31.6%), and running or jogging ($n = 53$, 30.5%) when they visited the park.

3.1 | Awareness

In total, 102 respondents (58.6%) had heard of ash trees but, on average, respondents did not rate their ability to identify trees highly (mean ± standard error: 4.4 ± 0.17). Of the individuals who rated their ability to identify trees highly ($n = 34$, 19.5%), only 12 respondents (6.7%) correctly identified the ash tree when presented with images of different trees. Most respondents ($n = 149$, 85.6%) had heard of invasive species, but only 23 respondents (13.2%) had heard of EAB prior to taking the survey. Most respondents were aware that non-native species are considered invasive if they cause harm to the environment ($n = 138$, 79.3%), economic damage ($n = 126$, 72.4%), or harm to people and pets ($n = 122$, 70.1%; Table S2). Respondents' median 'knowledge of invasive species' score was 1 (0.60 ± 0.05).

3.2 | Attitudes

On average, respondents stated that having shade-providing trees in the park was very important to them, and that having trees that flower, with different leaf shapes and colors, and of different shapes and heights was important (Table S3). We combined these items to measure respondents' 'attitudes towards park trees' (3.13 ± 0.05, eigenvalue = 2.78, Cronbach's alpha = 0.85). Most respondents agreed that they would like ash trees in their parks (median response = 1; 0.87 ± 0.07). On average, respondents strongly liked butterflies, liked bees,

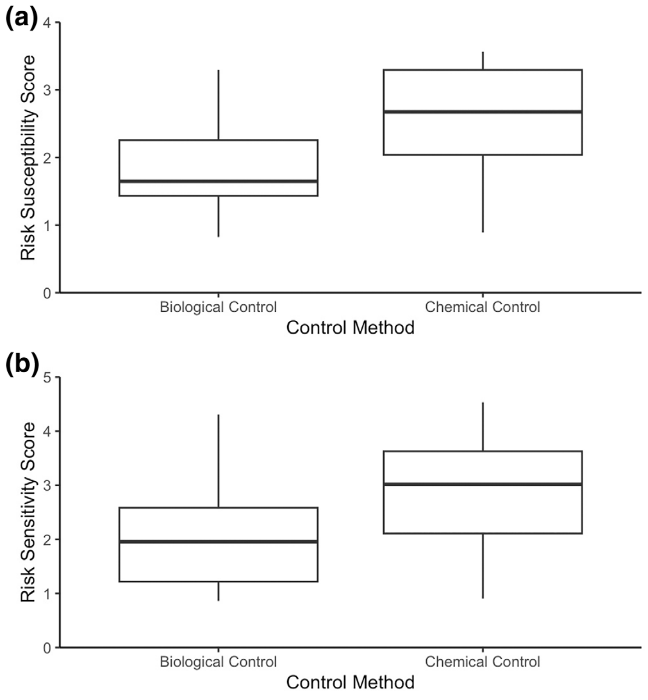

FIGURE 3 Comparison of respondents' risk perceptions pertaining to biological control and chemical control of emerald ash borer (EAB), northeastern Georgia, 2023. (A) Respondents expressed more susceptibility to risk from chemical control using systemic insecticides than biological control with parasitoid wasps ($t = -9.795$, $p < 0.001$). (B) Respondents expressed more risk sensitivity to chemical control than biological control ($t = -8.513$, $p < .001$).

disliked flies and wasps, strongly disliked mosquitoes, and were neutral in their attitudes towards ants and beetles (Table S4). Respondents' attitudes towards all insects (except butterflies) could be combined to generate a measure of their 'attitudes towards insects' (-0.20 ± 0.04, eigenvalue = 3.33, Cronbach's alpha = 0.83).

3.3 | Risk perceptions

On average, respondents expressed concern about the loss of ash trees due to EAB (3.56 ± 0.09). On average, respondents expressed low levels of risk susceptibility to biological control using parasitoid wasps, namely that wasps would harm the environment, humans, or pets (Table S5). By contrast, respondents expressed higher levels of risk susceptibility to the use of chemical control, indicating that they considered the risk that applying chemicals to ash trees would harm the environment, humans, or pets to be moderate. Based on exploratory factor analysis, we combined survey items to generate two constructs, namely 'risk susceptibility to biological control' (1.80 ± 0.05, eigenvalue = 2.35, Cronbach's alpha = 0.86) and 'risk susceptibility to chemical control' (2.55 ± 0.06, eigenvalue = 2.59, Cronbach's alpha = 0.92). Respondents tended to be slightly concerned that wasps used for biological control would attack native species in the park, harm human health, or harm pets, but tended to be moderately concerned that chemical control would have unintended environmental impacts, harm human health, and harm pets (Table S6). We combined these survey items to generate measures of respondents' 'risk sensitivity to biological control' (2.07 ± 0.07, eigenvalue = 2.48, Cronbach's alpha = 0.89) and 'risk sensitivity to chemical control' (3.01 ± 0.08, eigenvalue = 2.65, Cronbach's alpha = 0.93). Tests confirmed that respondents' risk perceptions pertaining to chemical control were higher than their risk perceptions pertaining to biological control. Respondents' mean risk susceptibility to chemical control was significantly higher than their mean risk susceptibility to biological control ($t = -9.795$, $p < 0.001$, Figure 3A). Similarly, their mean risk sensitivity to chemical control score was significantly higher than their mean risk sensitivity to biological control ($t = -8.513$, $p < 0.001$, Figure 3B).

3.4 | Support for control methods

Respondents indicated significantly higher levels of support for biological control (median = 'support') compared to chemical control (median = 'neutral') ($W = 22{,}562$, $p < 0.001$, Table 1, Figure 4).

3.5 | Ordinal logistic regression analysis of respondents' support for control methods

Respondents who expressed higher risk sensitivity ($\beta = -0.433$, $p = 0.017$) and risk susceptibility to biological control ($\beta = -0.899$, $p = 0.002$) were less likely to support biological control (Table 2). Similarly, respondents who were more sensitive ($\beta = -0.512$, $p = 0.012$) and susceptible to risks from chemical control ($\beta = -0.500$, $p < 0.001$) were less likely to support chemical control. Respondents who were not at all concerned ($\beta = -3.479$, $p < 0.001$), somewhat concerned ($\beta = -1.446$, $p = 0.003$), moderately concerned ($\beta = -1.153$, $p = 0.014$) or concerned about EAB ($\beta = -0.767$, $p = 0.048$) were less likely to support biological control than respondents who were very concerned about EAB. Respondents who expressed more positive attitudes toward ash trees were more likely to support chemical control ($\beta = 0.340$, $p = 0.045$). Respondents who used

TABLE 1 Survey respondents' support for potential management options to control emerald ash borer (EAB) in urban parks, Northeast Georgia, 2023 ($n = 174$). Respondents answered the question "Please indicate your level of support for the following two control measures."

		Strongly oppose		Oppose		Neutral		Support		Strongly support	
Control method	**Median**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Biological control through the use of parasitoid wasps	Support	2	1.1	11	6.3	62	35.6	68	39.1	31	17.8
Chemical control through the use of systemic insecticides	Neutral	36	20.7	43	24.7	53	30.5	33	19.0	9	5.2

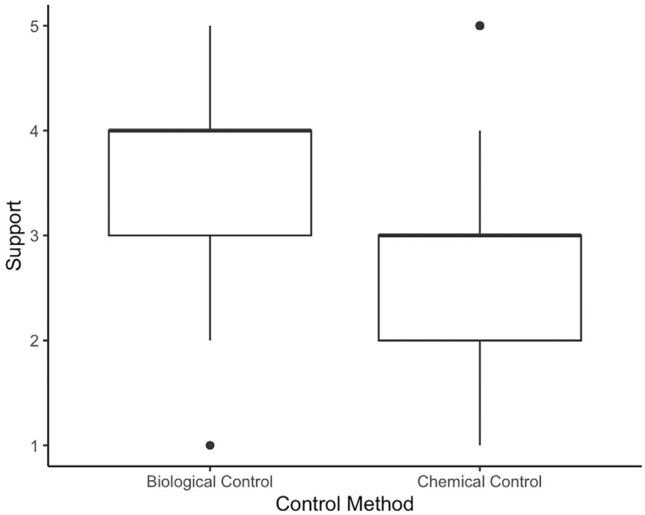

FIGURE 4 Comparison of respondents' median support for biological control of emerald ash borer (EAB) using parasitoid wasps and chemical control using systemic insecticides, northeastern Georgia, 2023. Respondents expressed greater levels of support for biological control than chemical control ($W = 22,562$, $p < 0.001$).

parks to sit and enjoy nature were more likely to support biological control ($\beta = 0.893$, $p = 0.006$), whereas birdwatchers were less likely to support chemical control ($\beta = -0.899$, $p = 0.012$). Respondents' age, gender, proximity to parks, knowledge of ash trees and invasion risks, attitudes toward park trees and insects, and attitudes toward butterflies did not influence their support for either biological control or chemical control.

3.6 | Limitations

Although our study is informative, it cannot be used to make inferences for park users across Georgia or the US because we only focused on four parks in two counties of northeastern Georgia. Our sample size is small, but we started to see many of the same individuals at the parks by the end of our data collection period, which suggests that we had invited consistent park users to participate in our study.

4 | DISCUSSION

Biological and chemical control of EAB are two important management actions to prevent the spread of EAB and to protect urban trees, including trees in urban parks. We found that park users in Clarke and Gwinnett counties, Georgia, were more supportive of biological control using parasitoid wasps than chemical control of EAB. Respondents also expressed higher risk sensitivity and risk susceptibility to chemical control than to biological control. Our findings are consistent with other studies in which the public ranked chemical control as least preferred in targeting spruce budworm and forest tent caterpillar (Chang et al., 2009), and opposed chemical control when targeting EAB in Minnesota's state parks (Schlueter & Schneider, 2016). People considered biological control of EAB 'acceptable' in both natural and use areas of Minnesota state parks, whereas chemical control was considered 'unacceptable', even though the impacts of EAB are more likely to be visible to park users in Minnesota than in Georgia. Black ash (*Fraxinus nigra* Marshall) forms dense single-species stands in Minnesota (Palik et al., 2021) and ash represents 8% of all trees in Minnesota versus <1% of all trees in Georgia (Lambert et al., 2023; Miles et al., 2016), which means that park visitors in Minnesota are more likely to see dead ash trees.

Opposition to chemical control presents management challenges for park officials and municipalities because chemical and biological control operate at different spatial scales. Although chemical and biological control can be used in conjunction as part of an integrated pest management strategy (McCullough, 2019), biological control is better suited to parks with large, forested areas containing ash trees where chemical control is logistically and financially challenging. By contrast, chemical control is the appropriate strategy in parks with only a few high-value ash trees. As such, park managers need to communicate why specific control measures are used, taking park attributes as well as the attitudes, risk perceptions, and recreational preferences of park users into account.

Consistent with our prior predictions, we found that respondents' support for both chemical and biological control was negatively correlated with their risk

TABLE 2 Ordinal logistic regression analyses of respondents' support for biological control of emerald ash borer (EAB) using parasitoid wasps (model 1) and chemical control of emerald ash borer with systemic insecticides (model 2), Northeast Georgia, 2023 ($n = 174$).

	Support for biological control			Support for chemical control		
	β	**SE**	***p***	***β***	**SE**	***p***
Attitudes towards ash trees	0.265	0.187	0.157	0.340	0.170	0.045
Risk perceptions						
Risk susceptibility to control method[a]	−0.899	0.287	0.002	−1.500	0.301	<0.001
Risk sensitivity to control method[a]	−0.433	1.182	0.017	−0.512	0.204	0.012
Concern about EAB[b]						
Not at all concerned	−3.479	0.753	<0.001			
Somewhat concerned	−1.446	0.487	0.003			
Moderately concerned	−1.153	0.468	0.014			
Concerned	−0.767	0.388	0.048			
Recreational activities in park						
Birdwatching[c]	−0.669	0.375	0.074	−0.899	0.360	0.012
Sitting and enjoying nature[c]	0.893	0.324	0.006			
Gender[d]	0.428	0.300	0.154			
Intercepts						
β_1	−8.139	1.052	<0.001	−7.214	0.765	<0.001
β_2	−5.996	0.771	<0.001	−5.407	0.664	<0.001
β_3	−3.171	0.655	<0.001	−3.355	0.573	<0.001
β_4	−0.807	0.603	0.181	−1.204	0.597	0.044
Log-likelihood	−187.552			−208.626		
AIC	403.104			435.253		

Note: If no coefficients are presented for a variable, then that variable was not included in the best fit model (i.e., concern about EAB, sitting and enjoying nature, and gender were not included in the best-fit model of respondents' support for chemical control of EAB). Coefficients can be converted to odds ratios by exponentiating the coefficients.

[a]Weighted scores generated by combining survey items designed to measure respondents' risk perceptions related to EAB control (see Table S5).

[b]Binary coded responses to the question "The emerald ash borer is present in this park. How concerned are you about the loss of ash trees in this park from the emerald ash borer?" such that the reference level was 'extremely concerned'. Ordinal data cannot be treated as numerical or interval data because the intervals between response categories are not necessarily equal. Thus, we converted ordinal responses to this question to four binary variable to measure how level of concern about EAB influenced support for biological and chemical control of EAB.

[c]Binary coded responses that capture whether the respondent engaged in the recreational activity (1) or not (0).

[d]Gender coded as female = 1, male = 0, prefer not to say = 0.

sensitivity and risk susceptibility related to these control methods. We also found that respondents with higher risk sensitivity to EAB were more likely to support biological control, although risk sensitivity to EAB didn't influence respondents' support for chemical control. By contrast, respondents were more likely to support chemical control if they had positive attitudes towards ash trees, although attitudes towards ash trees didn't influence support for biological control. Finally, respondents' recreational preferences influenced their support for EAB control. Individuals who engaged in birdwatching during park visits were less likely to support chemical control, whereas individuals who visited parks to sit and enjoy nature were more likely to support biological control. Contrary to our prior predictions, respondents' support for biological and chemical control was not influenced by their awareness of invasive species, EAB, or ash trees, their attitudes towards insects or park trees, their proximity to parks, the frequency with which they visited parks, or their gender and age. Our findings thus suggest that communication to park users about biological and chemical control should focus on risk perceptions, the importance of protecting ash trees, and how EAB control helps to support recreational activities in parks.

We expected respondents to be concerned about the use of parasitoid wasps to control EAB based on fear and dislike of wasps (Sumner et al., 2018). People's fear of wasps has largely been shaped by species in the family Vespidae, especially social, aculeate (stinging) wasps, of which people are more aware (Sumner et al., 2018).

However, we informed respondents that the wasps used to control EAB are small and unlikely to sting people or animals. Emphasizing that the wasps that are used in EAB control do not present a risk to people, their pets, or native animals is important in reducing people's risk perceptions pertaining to biological control. Similarly, emphasizing that parasitoid wasps play an important ecological role in regulating EAB, and thus protecting multiple ecosystem services associated with healthy ash trees, may be important in eliciting park users' and public support for biological control. Our finding that respondents who visited parks to enjoy nature were more likely to support biological control is consistent with Sumner et al.'s (2018) finding that people with greater interest in, and engagement with, nature were more likely to recognize the ecological value of wasps. Birdwatchers' attachment to nature and greater engagement in conservation behaviors (Cooper et al., 2015) may also explain their lower support for chemical control, which may have stemmed from the perception that chemical control would harm birds and the environment.

When communicating about chemical control, park managers should highlight that this control method is intended to protect ash trees and does not pose environmental or human well-being risks. It is encouraging that respondents who liked ash trees were more likely to support chemical control and thus did not appear to be concerned that chemical control would harm ash trees. Nonetheless, the public tends to have higher concern about low-probability, high-risk events (Slimak & Dietz, 2006) and has expressed concerns about pest control staff receiving improper training in chemical control and applying chemicals to control EAB inappropriately (Marzano et al., 2020). It is important to communicate to park users and the public that both parasitoid wasps and systemic insecticides have few major non-target effects (Duan et al., 2018; Hahn et al., 2011; Herms et al., 2019) and are intended to protect ash trees, native species, and ecosystem function from EAB invasions.

Consistent with other research (Novoa et al., 2017), our results suggest that increasing park users' and the public's understanding of the invasion impacts associated with the spread of EAB is also important. Respondents who were very concerned about the impacts of EAB were most likely to support biological control. It is notable that only 13.2% of respondents had previously heard of EAB, which demonstrates that increased education and outreach about EAB are needed. Similarly, few respondents (6.7%) could identify ash trees, although respondents highly valued the shade provided by ash trees. Communication about EAB control could emphasize the aesthetic appeal of ash trees (Zhao et al., 2017) and the ecosystem services (especially, cooling from shade) these trees provide (Camacho-Cervantes et al., 2014; Moffat et al., 2024). Providing visual illustrations of both ash trees and EAB (which is likely to engender disgust in people; Sumner et al., 2018) may increase the effectiveness of communication about the necessity of EAB control.

Park managers' decisions on whether to implement biological or chemical control to prevent the spread of EAB may primarily depend on the number and density of ash trees within the park, rather than public or park user preferences—especially since both control methods present low ecological or human well-being risks. However, park users' and public opposition to EAB control can present management challenges. Based on our findings, park managers are most likely to engender support for EAB control if they (1) explain that biological and chemical control methods do not pose ecological or human well-being risks, (2) highlight the aesthetic appeal of ash trees as well as the ecosystem services provided by urban ash trees (e.g., shade, habitat for birds), (3) inform park users and the public about the invasion impacts of EAB, (4) emphasize that parasitoid wasps help to secure ecosystem function through pest control and do not pose a risk to people, and (5) reassure park users that EAB control will not adversely impact recreational activities within the park. For example, park managers who aim to protect a single, high-value ash tree using chemical control could emphasize the beauty of the tree, how chemical control protects the tree, and the important role the tree plays in providing shade to park users and habitat to birds, in order to secure the support of birdwatchers and people who visit the park to enjoy nature. Adopting targeted, appropriate messaging about EAB control across urban parks can ensure that the public and park users support managers' efforts to prevent the spread of EAB into residential areas and urban forests (Crowley et al., 2017).

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

Deidentified data supporting our analysis are published open access on Zenodo. See https://doi.org/10.5281/zenodo.15018002.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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