



Predicting preferences for chemical treatment of aquatic invasive species and implications for outreach

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Abstract The spread of aquatic invasive species (AIS) poses many challenges to local, state, and federal government agencies in the United States and worldwide, as well as individuals living on lakeshore properties on which they are found. Lakeshore property owners, in particular, face significant economic damage when invasive species are discovered adjacent to their properties. However, little research has been conducted on the perceptions lakeshore property owners have about managing aquatic invasive species. To examine this, a survey was administered to 1200 individuals identified as owning a property on a lake in Wisconsin, USA. A regression model was

constructed to examine the impact of political ideology, perceived environmental threat, familiarity with AIS, trust in institutions that advise about AIS management, and the emotions participants feel when thinking about managing AIS on the lakes that they live by on their preferences for chemical treatment management strategies. It was found that preference for chemical treatment strategies was predominantly driven by negative emotions about AIS and the perception that AIS were present in the lake that they live by. Political ideology was also found to be a significant predictor of preference for chemical treatment, with socially conservative participants more likely to favor this treatment compared to more socially liberal participants. Perceived AIS impact and trust in institutions tasked with advising on AIS management approaches were not found to be significant predictors of preference for chemical treatment strategies. Implications for outreach efforts are discussed.

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Introduction

Aquatic invasive plants may have substantial impacts on waterfront property owners. These aquatic invasive species (AIS) can impede recreation (Horsch

and Lewis 2009; Eiswerth and Johnson 2002; Rothlisberger et al. 2010; Schultz and Dibble 2012) and enjoyment of their waterfront property while also reducing its economic value (Horsch and Lewis 2009; Johnson and Meder 2013; Olden and Tamayo 2014; Zhang and Boyle 2010). A variety of management options exist to manage aquatic invasive plants, including monitoring, manual and mechanical removal, physical control methods, and chemical treatments. Chemical treatments are a popular option due to their relatively affordable cost, reported selectivity, and ability to treat an entire lake. However, chemical treatments can have side effects that often aren't considered by people advocating for treatment and can have ecosystem impacts that may be as problematic as the invasive plants themselves (Mikulyuk et al. 2020). Other work has found that herbicides can cause a reduction of both native and invasive aquatic plant species (Crowell et al. 2006) and that invasive species often reappeared several years after herbicide treatments (Wagner et al. 2007). Additionally, populations of invasive species often are not found at the high abundances associated with large impacts (Hansen et al. 2013), so the best response action may often be simply monitoring the population. Because of this, integrated pest management approaches that utilize a variety of management methods are promoted by natural resource managers since they can help achieve desired environmental outcomes while limiting the negative impacts.

However, most outreach about AIS in inland lakes is focused on prevention and targeted toward recreational boaters because they are the most likely to contribute to their spread. This leads to a lack of targeted outreach for lakeshore property owners who may be more concerned with managing invasive species present in the lake they live on. Therefore, it is essential to understand lakeshore property owner perceptions in order to communicate with them more effectively and provide recommendations that help manage AIS while also maintaining the ecological integrity of the lakes they live on. The current study addresses a gap in the literature by exploring the perceptions of AIS that lakeshore property owners in the state of Wisconsin (United States) have, and what factors drive preferences for chemical treatment.

Research questions and focus

Our research focuses on the question: what factors influence lakefront property owners' attitudes about AIS management using chemical treatments? Although it is well documented that invasive species can have a negative impact on local ecosystems, it is also evident that factors that go beyond the biology of an invasive species determine what AIS management approaches lakeshore property owners are willing to support. In this study, we focus on the influence of political ideology, familiarity with AIS including belief that the lake they live on has an AIS, perceived AIS impact or threat, trust in institutions that advise about and/or contribute to AIS management, and emotional responses to AIS as they relate to preference for herbicide treatment.

Political ideology

There is currently little research on the potential influence of political ideology on attitudes towards invasive species management strategies. However, because political ideology has been shown to influence environmental attitudes (Gromet et al. 2013; Kellstedt et al. 2008) and trust in sources of scientific information about the environment (Brewer and Ley 2013), we explore whether lakeshore property owners' preferences for chemical treatments will be impacted by political ideology.

Familiarity with AIS

The belief that AIS are present or absent in the lake adjacent to a respondent's property may also impact the salience of risk information and the belief that AIS poses a threat, for example, of decreasing enjoyment of the lake or lowered property values. Proximity to an invasive species has been found to influence risk perceptions in prior research (Robinson et al 2017). Due to the potential impact of believing there is an AIS on the lake one lives by, we explore how these beliefs influence preferences for chemical treatment. Additionally, a lack of information on management approaches and subsequent lack of familiarity has been found to be one of the main barriers to reducing or controlling the spread of invasive species among individuals who expressed concern

about them (Ansong and Pickering 2015). Due to the ways in which familiarity with an invasive species can impact attitudes towards their management, we also explore how familiarity with AIS relates to preferences for herbicide treatment as a management solution.

Perceived AIS impact

As discussed previously, beliefs about the impact of AIS may impact how lakeshore property owners perceive the risks of AIS, gather information, react to treatment approaches, and form behavioral intentions (Hart and Larson 2014; Wallen and Kyle 2018; Shaw et al. 2021). Understandably, people who perceive a greater threat may be more likely to opt for more aggressive measures to control AIS on the lake that they live by.

Trust in scientific institutions

Interactions with scientists and other staff from institutions such as universities and AIS management professionals at natural resource management agencies may contribute to the way individuals perceive preferences for herbicidal treatment of AIS. Trust in the source of the communication is broadly known to be important in science communication (Weingart and Guenther 2016). Because invasive species management is a collective effort, it is important that residents trust institutions with expertise in AIS management. Trust in invasive species managers has been found to be related to positive attitudes about invasive species management initiatives (Wald et al 2019). In an aquatic invasive species context, homeowners with higher levels of trust in local government officials may be more inclined to consider recommendations about managing invasive species that may appear less proactive such as monitoring whether the species are spreading in a manner that poses real threats to the ecological integrity of the lake they live on and avoiding using chemicals that may harm native plants if it is not necessary. Additionally, individuals tend to support management activities they can take part in directly, favoring more funding for activities like community invasive pulls and native species planting (Nguyen et al. 2020). While research on terrestrial invasive species has found mixed interest in coordinating with government officials on invasive species

management, increasing with greater confidence in officials (Clarke et al. 2019; Wald et al. 2019), attitudes of lakeshore property owners have received relatively less attention in the academic literature, so we also explore how trust in institutions influences lakeshore property owners' preferences for herbicidal treatments of AIS.

Negative affect

Studies in human behavior have found that the threat of undesirable risks, especially those that trigger negative emotions like frustration or anger, can influence human behavior (Loewenstein and Lerner 2003; Sunstein and Zeckhauser 2011). Additionally, some research suggests that use of more emotionally laden phrases to describe an invasive species is linked to the perception that it is a more immediate, tangible threat (Cottet et al. 2015). Interactions with nature can also contribute to the emotions an individual feels. For instance, positive interactions with wildlife influenced a feeling of "wonder" in some respondents (Schänzel and McIntosh 2000). Conversely, individuals who reported feelings of anger towards house sparrows were more likely to favor lethal management methods than those who felt positively (Larson et al. 2016). Negative emotions surrounding invasive species could be an effect of the way they are presented in outreach materials, campaigns, or the media (Otieno et al. 2014). Due to the potentially negative consequences associated with invasive species, it is important to explore the impact of emotions on preferences for chemical treatment of AIS, which could have unintended environmental consequences.

Hypotheses

Given research on the influence of political ideology on environmental attitudes, we pose our first research question.

R1: What is the relationship between political ideology and chemical treatment preferences among lakeshore homeowners?

Familiarity with invasive species, particularly a belief that one has invasive species in their own lake, is expected to be associated with preferences for chemical management of AIS, leading to our first hypothesis.

H1: The more familiar lakeshore property owners are with invasive species, the more likely they are to prefer chemical treatment.

Past research also suggests that higher threat perceptions may lead to preferences for a more aggressive AIS management approach, leading to our second hypothesis.

H2: The more lakeshore property owners perceive AIS will have a negative impact on the lake they live on, the more they will prefer chemical treatment.

Given a growing body of science that chemical herbicides may produce unintended negative consequences for native plants and wildlife, we pose our third hypothesis.

H3: A higher trust in institutions with expertise in AIS management will be associated with a lower preference for chemical management of AIS.

Finally, given research that negative emotions can play in influencing our beliefs, preferences and behaviors, we pose our fourth and final hypothesis.

H4: The more negatively a lakeshore property owner feels about AIS, the more they will favor chemical treatment options to manage them.

Materials and methods

Study area

Wisconsin was chosen as our study location due to the large number of lakes in the state, the millions of dollars spent each year on lake management, and the availability of invasive species presence data generated by the Wisconsin DNR AIS monitoring program. These factors, along with a large community of natural resource managers, university staff, and NGOs interested in improving invasive species management

through this kind of work, led to Wisconsin being used as our study area.

Study design

A survey was developed to assess lakeshore owners' attitudes towards various AIS management approaches. Questions were selected to address the themes in the literature. The researchers conducted 13 initial semi-structured phone interviews with Wisconsin lakefront property owners, selected using stratified random sampling by region and lake AIS status, which also informed question development. Following development of the survey, we solicited feedback from natural scientists with expertise in AIS and then pilot tested the survey with a group 20 of lakeshore property owners, and we integrated feedback from both groups to refine the instrument.

We developed our sample by randomly selecting 1200 individuals identified through public records as owning a lakeshore property in Wisconsin, USA. The original data set, provided by the Statewide Parcel Map Initiative at the University of Wisconsin-Stevens Point (<https://www.sco.wisc.edu/parcels/data/>), used surface water layer data from the Wisconsin Department of Natural Resources to match individuals identified as owning a property on a Wisconsin lake with a unique water body identification code (WBIC). After this initial data set was compiled, properties identified as belonging to businesses, organizations, or other non-individual entities were removed from the sampling frame.

The research design and instrument were approved for human research subjects by the Institutional Review Board at the University of Wisconsin-Madison (UW Madison IRB 2020-0090). The University of Wisconsin-Madison's Survey Center administered the paper mail survey using the Dillman method (Dillman et al. 2014), where the survey, a description of the study, a \$1 incentive, and a self-addressed, stamped envelope were mailed with a reminder sent several weeks later. Four individuals contacted the research team to notify them that they no longer owned the property and were removed from response rate calculations. The response rate was 63% (as calculated with the AAPOR Outcome Rate Calculator Version 4.0), resulting in a total sample of 747 responses used for this study.

Independent variables

Political ideology

Two questions assessed an individual's position on economic and social issues. The first question, which asked individuals to rate their level of conservatism or liberalism on economic issues asked, "In terms of economic issues, would you say that you are...", and asked individuals to rate themselves on a scale ranging from 1 (Very Liberal) to 5 (Very Conservative). The second question asked participants "In terms of social issues, would you say that you are..." and asked participants to rate themselves on the same 5-point Likert scale.

Heard about AIS

We measured how much an individual reported hearing about aquatic invasive species by asking them to answer the following question on a 5-point Likert scale: "Prior to receiving this survey, how much have you heard, read, or seen about aquatic invasive species?". The response options for this item were written as follows: "Nothing at all", "A little", "Some", "Quite a bit" and "A great deal".

Familiarity with AIS prevention

This item assessed an individual's self-reported familiarity with ways to prevent the spread of AIS between lakes. The question asked respondents "Personally, how familiar are you with ways to prevent the spread of invasive species between lakes?". It was measured on a 5-point Likert scale with the following response options: "Not at all familiar", "A little familiar", "Somewhat familiar", "Very familiar" and "Extremely familiar".

Familiarity with AIS management

This item assessed an individual's self-reported familiarity with ways to manage AIS once they are present in one's lake. This question asked respondents to respond to the following question: "Personally, how familiar are you with ways to manage invasive species once they are present in a lake?". The question was measured on a 5-point Likert scale with the following response options: "Not at all familiar", "A

little familiar", "Somewhat familiar", "Very familiar" and "Extremely familiar".

Perceived AIS impact

This item measured a participant's perception of the environmental impact of finding new AIS in the lake they live on. It was created by combining participants' responses to eight survey questions, all of which shared the same question stem "How would you expect finding a new invasive plant to affect the following qualities of your lake?". Questions included the impact of finding new AIS plants on the "scenic beauty of your lake", "the clarity of the water?", "the health of plants or animals in lake?", "the health of humans or pets?", "property values?", "the quality of the lake for swimming", "the quality of the lake for boating?", and "the quality of the lake for swimming?". Each question was measured on a 7-point Likert scale with response options "Very negatively", "Somewhat negatively", "A little negatively", "Neither negatively or positively", "A little positively", "Somewhat positively" and "Very positively". Cronbach's alpha coefficient was used to measure the reliability of this eight-item scale, and the result was calculated to be 0.95.

Perception of AIS presence in lake

This item measured a participant's perception of the presence of AIS in the lake they live on. The question asked respondents "To your knowledge, does your lake currently have any invasive plants?" with response options "Yes", "No" and "Don't Know." If participants selected either of the latter two options, they were directed to skip to the next set of questions. For analysis purposes, this question was transformed into a dummy variable with the reference group being participants who selected the "Don't Know" option. About half (51.6%) of respondents perceived AIS in the lake they live on, with 16.4% perceiving no AIS and 32% of respondents reported they "don't know" whether the lake they live on has AIS or not. The "don't know" group was chosen as the reference group based on the assumption that there are differences with regards to treatment approaches between people who perceive AIS on the lake they live on and those who do not.

Trust

The trust variable was created by averaging responses to two questions measuring a participant's level of trust in institutions involved with providing science and advice about managing AIS. The first question asked, "How much do you trust university staff and scientists?", while the second question asked, "How much do you trust Wisconsin Department of Natural Resources staff and scientists?". Both questions were measured on a 7-point Likert scale, with response options "Strongly distrust", "Moderately distrust", "Slightly distrust", "Neither trust nor distrust", "Slightly trust", "Moderately trust" and "Strongly trust". Because this scale consisted of two items, the Spearman-Brown coefficient, which is commonly used to calculate reliability for two-item scales (Eisinga et al. 2013), was calculated to be 0.85.

Negative affect

Negative emotions were assessed with three survey items, all part of the same question stem which read "When you think about preventing or managing invasive plants on your lake, how strongly do you feel any of the following emotions, if at all?". The 5-point options were "Not at all", "Slightly", "Somewhat", "Very" and "Extremely". The emotions used to create the negative affect scale included "Angry", "Sad" and "Frustrated". The responses to these items were averaged to form the scale and Cronbach's alpha was calculated to be 0.87.

Dependent variables

Preference for chemical treatment

A participant's preference for chemical treatment of AIS was measured using two items from the survey, which were combined and averaged into a scale. The first survey item asked participants to rate their perception of the risks and benefits of the chemical approach to managing AIS on a 5-point scale ranging from "Risks greatly outweigh the benefits" to "Benefits greatly outweigh the risks". The second survey item asked respondents to rate their agreement with the statement "If an herbicide can temporarily reduce the amount of an invasive plant in a lake, it is worth using" on a 5-point scale ranging from "strongly

disagree" to "strongly agree". The Spearman-Brown reliability coefficient for this scale was found to be 0.80.

To examine our hypotheses, we used hierarchical ordinary least squares (OLS) regression to test the relationship between independent and dependent variables using a linear model. Independent variables were entered in blocks according to their assumed relationship to one another. We started with an initial regression model, Block 1, which only included demographic variables. Block 2 included social and economic political ideology variables. Block 3 was perceived familiarity with invasive species. Block 4 included perceived AIS impact and perceived presence of invasive species on the participant's lake. Block 5 included a scale measuring trust in institutions that advise on AIS management. Block 6 included a scale measuring negative affect.

Results

Sample demographics

The sample was mostly White (92.5%), with an average age of 65 years ($SD=11.36$). With regards to gender, the sample was mostly male (66.9%). Regarding level of education, a few participants (0.7%) completed some high school, 13.2% completed high school or received a GED, 27% had some college, technical, or trade school education, 31.4% completed a four-year college with a bachelor's degree and 27.8% completed a graduate or professional degree. Politically, on economic issues, 3.2% of participants described themselves as "very liberal," 8.2% as "somewhat liberal," 25.9% as "moderate," 28% as "somewhat conservative," 29.7% as "very conservative" and 5% of respondents reported they "don't know." With regards to social issues, 10.3% described themselves as "very liberal," 17.9% as "somewhat liberal," 27.6% as "moderate," 20.9% as "somewhat conservative" and 18.1% as "very conservative," with 5.2% reporting they "don't know."

The following table (Table 1) features descriptive statistics for variables used in the model (Table 2).

R1, regarding political ideology, we found that social conservatism ($\beta=0.120$, $p=0.036$) was related to preference for chemical treatment, but not economic conservatism.

Table 1 Descriptive statistics for model variables

Variable	M	SD
Independent variables		
Political ideology	3.88	1.17
Heard about AIS	3.52	.918
Familiarity with AIS prevention	3.39	.981
Familiarity with AIS management	2.42	1.14
Perceived AIS impact	2.74	1.78
Trust	5.65	1.40
Negative affect	2.29	1.09
Dependent variable		
Preference for chemical management	3.00	1.20

H1 was partially supported in the full model (Model 6). Self-reported familiarity with ways to manage invasive species once present was a significant factor in influencing people’s preference for chemical treatment ($p=0.013$), however self-reported familiarity with AIS in general, and self-reported familiarity with ways to prevent the spread of AIS were not significant factors in preference for chemical treatment of AIS. However, we did find that the belief AIS are present in one’s own lake was significantly positively associated with preference for chemical treatment approaches compared to those who did not believe AIS were present in the lake they live on ($\beta=0.264$, $p=0.000009$). Additionally, people who reported they “don’t know” whether AIS are present or not also showed a

Table 2 Hierarchical multiple regression model predicting support for chemical treatment approach^a

	Zero order correlations	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Block 1—demographics							
Age	.066	.100	.080	.064	.064	.064	.056
Education	.046	.026	.057	.047	.047	.049	.053
Incremental R^2 (%)		.006					
Block 2—political orientation							
Ideology—social	.135*		.152**	.144*	.118*	.112	.120*
Ideology—economic	.077		.066	.061	.071	.069	.075
Incremental R^2 (%)			.041***				
Block 3—familiarity							
Heard about AIS	.92*			.028	.006	.010	-.002
Familiarity with AIS prevention				-.024	.004	.005	.006
Familiarity with AIS management				.187**	.134*	.134*	.139*
Incremental R^2 (%)				.072***			
Block 4—perception of AIS in lake							
Perceived AIS impact	.015				-.064	-.067	-.038
AIS in lake=yes	.284***				.311***	.311***	.264***
AIS in lake=don’t know	.136*				.154**	.155**	.144*
Incremental R^2 (%)					.121***		
Block 5—trust							
Trust in Institutions	.008					.027	-.010
Incremental R^2 (%)						.120	
Block 6—emotions							
Negative Affect	.156***						.147***
Incremental R^2 (%)							.037***
Total adjusted R^2 (%)							13.7

* $p < .05$; ** $p < .01$; *** $p < .001$

^aAll coefficients in these models are standardized coefficients

preference for chemical treatment approaches compared to those who reported there were no AIS in the lake they live on ($\beta = 0.144, p = 0.015$).

We did not find support for H2 in our model. While we predicted greater perception of the negative impacts of AIS would be positively correlated with preference for using chemical treatment methods, this variable was not significant ($\beta = -0.038, p = 0.384$).

We also did not find support for H3. While previous research has demonstrated a relationship between trust in institutions and AIS management behavior, we did not find support for our hypothesis that trust in institutions played a role in the preference for chemical treatment.

Finally, H4, that greater negative affect predicts chemical treatment attitudes while controlling for demographics (age, education), political ideology, trust in institutions and familiarity with invasive species was supported ($\beta = 0.147, p = 0.00082$), suggesting the more negatively a person feels towards AIS, the more likely they are to support chemical management strategies.

Model variables found to be significantly associated with lakefront property owner preference for chemical treatment, as well as non-significant variables, are shown in Fig. 1.

Discussion

This is the first systematic study we are aware of to obtain baseline information about the thoughts, opinions, and beliefs of lakeshore property owners regarding AIS management approaches with a focus on preference for chemical treatment. Repeated efforts like this will help gauge and track changes in opinions and beliefs of lakeshore property owners over time, which would aid in continued evaluation of AIS management and outreach efforts. Replication of similar work in other locations can inform more effective outreach designed especially for lakeshore property owners to better address their localized management objectives. Such a strategic approach can increase cooperation between natural resource managers and lakeshore property owners around implementing integrated management approaches for controlling AIS that protect the ecological integrity of inland lakes while avoiding potentially negative unintended consequences of premature herbicide treatments in situations where such methods may be unnecessary and cause more harm than good.

As hypothesized, social conservatism (but not economic conservatism) was associated with a greater preference for chemical treatment of AIS. As noted previously, past research (e.g., Gromet et al. 2013) has found a relationship between conservatism and

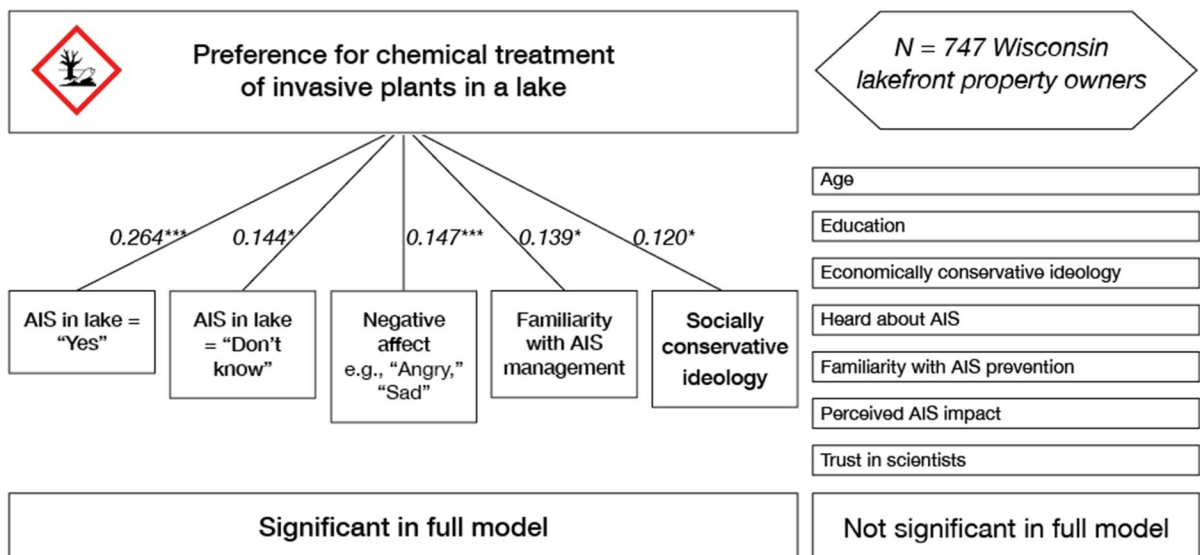


Fig. 1 Property owner preference for chemical treatment of invasive plants in a lake was significantly related to four factors in our model; see Methods for scale measures

less environmentally friendly values in some contexts. This insight is actionable in that AIS managers might gauge the political leanings of their community and potentially allocate more attention to working in these areas to highlight that there are multiple ways to manage AIS, that AIS may not become ‘invasive’ and chemical treatment could produce unintentional consequences such as harming the lake’s ecosystem.

However, we also note that social conservatism per se is likely not a driver of preference for chemical control for AIS but rather that social conservatism is serving as a proxy for other environmental values not measured in this study. Future studies should also measure environmental values that are likely more proximate predictors of preferences of different AIS management approaches (e.g., Dietz et al. 2005; Bouman et al. 2018; Fobissie 2019) than political ideology. Still, to the extent natural resource managers can infer the political leanings of their local constituents, they should consider messaging that accentuates values that may resonate with conservatives regarding pro-environmental behavior. For example, conservative values may prioritize the “purity” of nature, especially when messages are perceived as coming from within their in-group (Wolsko et al. 2016). If non-native plants are perceived as diminishing the “purity” of an ecosystem, prompting a well-intended preference for eradication, concern could be directed towards the impacts of chemical treatments on the integrity of existing plant and animal communities. For example, chemical treatments may not eradicate AIS as planned, but rather create more resistant hybrid varieties (Mikulyuk et al. 2020).

We did not find a statistically significant effect of general familiarity (i.e., how much they had heard about AIS) with preference for chemical treatment, suggesting increasing homeowner’s familiarity with invasive species may not have a significant impact on their willingness to use chemical applications to manage invasive species. However, we did find that familiarity with ways to manage AIS once they are present in a lake was significantly associated with preference for chemical treatments. We also found that the perceived presence of AIS and people who did not know if AIS were present in their lake had a higher preference for chemical treatment. Familiarity has been found to be positively related to AIS-prevention behaviors among transient boaters (Witzling et al. 2016). The relationship between familiarity with AIS

management and preference for chemical treatment may be a spillover effect of fear-based AIS prevention messaging that could potentially lead lakeshore property owners to seek to remove AIS by whatever means are perceived to be most efficient. It also may mean that companies selling chemical herbicides to treat aquatic invasive species are doing a good job building awareness about their products.

To be clear, natural resource managers we spoke with in developing our survey indicated that herbicides could play a valuable role in AIS management; however, they also said it is typically more ecologically sensible to consider all the options before applying herbicides as a first course of action. Lake managers may wish to work more closely with lakeshore property owners on the development and implementation of management strategies, given community involvement can have a significant impact on support and participation in these programs (Nguyen et al. 2020). Relatedly, lake managers and AIS outreach professionals may also consider stressing the importance of a monitoring approach as a viable, active management strategy to lakeshore property owners who may see monitoring whether a non-native plant is likely to become invasive as a passive ‘do nothing’ approach.

Interestingly, and contrary to our hypothesis, perceived negative impacts of AIS were not significantly related to preference for chemical treatment. This suggests that just the perceived presence of AIS and the emotions accompanying this perception may be more influential than any specific impacts people are concerned about in terms of preference for chemical treatment. Future research exploring the relationships between perceived threat/impacts and support for different AIS management strategies should also consider other ways to operationalize this construct.

Trust in institutions involved with advising on AIS management did not play a significant role in attitudes towards chemical management approaches. This could potentially be due to a lack of outreach by these institutions related to managing AIS among lakeshore property owners. Without this outreach, lakeshore property owners might not be thinking of these groups as sources of this information. Given that there is abundant outreach focused on preventing the spread of AIS among transient boaters from these institutions as noted previously, information about managing AIS designed for lakeshore property

owners may be incorporated into these efforts. Additionally, future work may more explicitly explore who lakefront property owners trust regarding this information. Other lakefront property owners and private lake management professionals are people that this audience might interact with on a more regular basis and may be more influential in lakefront property owner preference for AIS management actions.

The results of our study suggest Wisconsin lakeshore owners' negative feelings about AIS serve as a main driver in influencing preferences for chemical AIS management approaches. One implication of this finding is that natural resource managers creating AIS outreach materials should consider avoiding sensational language, which has been associated with an increase in negative emotions (Otieno et al. 2014). Although it may be tempting to create attention-grabbing messages in a media environment characterized by competition for attention, sensationalized framing has not been found to perform better than more straight-forward, science-focused framing (Shaw et al. 2021). These include militaristic message frames, which may contribute to good vs evil feelings and encourage actions that promote conflict with the environment (Larson 2005).

Negative affect, which included anger, sadness, and frustration, was statistically significant in our model after controlling for other potential factors, suggesting when individuals feel negatively about an invasive species, they have a stronger desire to use chemical treatment strategies to remove them from the lakes they live on. It is possible this is the result of spillover effects of outreach campaigns aimed at transient anglers or boaters, which may use sensational messages. These messages may also reach lakeshore property owners, amplify their perception of risk and exacerbate negative emotions influencing them to support chemical treatment options to remove an AIS from the lake they live on. Although lakeshore property owners may not themselves be transient anglers or boaters who are spreading AIS, they may nevertheless still be exposed to these materials at community meetings, signage at boat landings, lake association meetings, print or online newsletters, or bait shops. More responsible use of metaphors can help natural resource managers and communicators better balance the various community needs and actions that need to occur for successful management (Verbrugge et al. 2016).

Future research should more closely examine the attitudes and behaviors of lakeshore property owners as an influential partner in the management of invasive species. If lake managers and other decision makers understand what sorts of strategies lakeshore property owners prefer, which they regularly use, and their perceptions of the effectiveness of various management approaches, more comprehensive outreach strategies could be tailored towards these specific needs. Generally, outreach campaigns that focus only on increasing knowledge of AIS are not likely to be effective, as multiple factors can influence adherence to management recommendations (Koob and McGuire 2013). Factors such as the inability to remember campaign messaging or the use of overly complex, technical, language could hinder the ability to effectively communicate with relevant parties (Seekamp et al. 2016; Koob and McGuire 2013).

A better understanding of lakeshore property owners could lead to better partnerships with them. While agency-led and research-driven invasive species surveillance programs detected the highest percentage of new invasives, independent sources, such as homeowners or farm operators, also contributed significantly to the detection of new invasive pests (Epanchin-Niell et al. 2021). Lakeshore property owners already participate in aquatic invasive species monitoring programs like the Citizen Lake Monitoring Network in Wisconsin and the AIS Detectors Program in Minnesota. AIS-training programs that engage community members have been related to desirable learning (Crall et al. 2013; Weber et al. 2022) and behavioral outcomes (Shannon et al. 2020). Strengthening these partnerships between agencies and lakefront property owners could be a fruitful mechanism for monitoring while developing channels for effective communication about management options.

In addition to some of the limitations and directions for future research noted above, another limitation of this study is our response rate. While a 63% response rate is higher than many social science studies, we note that some groups may have systematically responded less to the survey. Future research should continue to seek sampling frames that are as representative as possible while also exploring whether lakeshore property owners with different characteristics are less likely to respond to a survey about managing aquatic invasive species.

To date, there is little research on the attitudes lakeshore property owners have towards AIS management strategies, despite unique challenges and impacts they face from AIS. This research helps fill this gap by showing that, for lakeshore property owners, negative feelings about AIS seem to drive their preference for chemical treatment. More research is needed on lakeshore property owners' attitudes towards AIS management, their preferences for treatment and their perception of the risks and benefits of different treatment approaches. Future research could examine the difference between perceived or actual knowledge of AIS and its role in the perception of the risks of management approaches, or more in-depth analyses of property owners' attitudes towards chemical treatments and other management strategies. Finally, future research should also examine what messaging strategies are most effective in encouraging lakeshore property owners to take a more deliberate, methodical approach to managing invasive species that maintain the ecological integrity of the lakes they live on.

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Data availability Participants in this study did not give consent for their data to be shared publicly.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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