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ORIGINAL PAPER

Barriers to participation in aquatic invasive species prevention among Illinois, USA recreational water users

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Abstract The spread of invasive species is a globally relevant challenge for environmental management agencies. There have been considerable investments in outreach campaigns that encourage recreationists to minimize the spread of aquatic invasive species as they move between waterbodies. However, widespread behavior change has yet to take hold. Empirical evidence of the barriers that impede pro-environmental behaviors among water-based recreationists is thus urgently needed. With theoretical guidance from the Health Belief Model, we sought to understand how risk perceptions, perceived benefits, self-efficacy, and response-efficacy influenced aquatic invasive species prevention behavior, how barriers moderated those relationships, and how socio-demographic characteristics relate to the level of barriers experienced. Among all respondents, self-efficacy and response-efficacy had the strongest positive relationships with behavioral intentions; however, different relationships emerged for subgroups defined by the strength of perceived barriers. For recreationists who experienced low barriers, perceived benefits were the sole predictor of intended behavior, whereas for recreationists experiencing moderate barriers, only self-efficacy was a significant predictor. Recreationists who perceived high and very high barriers were influenced by risk perceptions, self-efficacy, and response-efficacy. Strength of perceived barriers was negatively correlated with years of fishing and boating experience. Additionally, a comparison between boating and angling behaviors indicated that boaters need more information about how to complete prevention steps, whereas anglers need more information about why such actions are necessary. Ultimately, outreach campaigns should aim to boost self-efficacy and response-efficacy in order to support diverse audiences faced with barriers that impede engagement in invasive species prevention.

Keywords Health belief model · Efficacy · Risk perceptions · Invasive species · Fisheries management

Introduction

Preventing the spread of aquatic invasive species (AIS) is an increasingly urgent challenge for environmental management agencies given the negative consequences of these organisms, such as interference with food webs and native habitat, destruction of human infrastructure, and damage to the economic sectors of agriculture and fisheries (Gallardo et al. 2016; Bailey et al. 2020). On a global scale, the

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total costs of AIS have been estimated to be at least $345USD (Cuthbert et al. 2021). It is nearly impossible to eradicate AIS once they have become established, thus preventing the initial introduction of AIS is critically important (Vander Zanden and Olden 2008; Keller et al. 2011; Smith et al. 2022). The large-scale vectors of shipping (Firestone and Corbett 2005) and the bait trade (Killian et al. 2012) have previously been prioritized by environmental management agencies; however, recreational boaters and anglers are also at risk of spreading AIS when they move between waterbodies (Connelly et al. 2016). For instance, zooplankton can survive in standing water within boats while they are transported (Kelly et al. 2013), and eggs can survive on fishing lines for weeks (Jacobs and MacIsaac 2007). Given that biological invasions are increasing over time (Pagnucco et al. 2015; Seebens et al. 2017, 2021), numerous outreach campaigns have been developed to teach recreational water users how they can prevent the spread of AIS (Seekamp et al. 2016; Shannon et al. 2019; Melly and Hanrahan 2020). Though modest increases in awareness have been observed (Cole et al. 2016; Eiswerth et al. 2011), many recreationists still do not take AIS-prevention action (i.e., biosecurity behavior) and thus remain at risk of inadvertently introducing AIS into new water bodies (Cole et al. 2019; Anderson et al. 2014). There is a critical need to close this so-called, "knowledge-action gap" (Kollmuss and Agyeman 2002) and identify pathways that will enable recreational water users to overcome the barriers that may be preventing largescale behavior change.

Recreational water users are encouraged to perform voluntary biosecurity behaviors to minimize the spread of AIS. Although there are some AIS policies that target individuals by prohibiting the transport of high risk AIS, it is not always feasible to enforce such policies and thus encouraging voluntary behavior is essential (Shannon et al. 2020). A three-step voluntary process known as *clean-drain-dry* was developed by the US Fish and Wildlife Service through their "Stop Aquatic Hitchhikers" prevention campaign (US Fish and Wildlife Service 2017). To follow these recommendations, recreationists should perform three steps after leaving a waterbody: 1) clean off all visible plants and animals from boats and equipment; 2) drain or dump water; and 3) dry all equipment thoroughly (Pradhananga et al. 2015). Managers recommend that the *clean-drain-dry* process is completed on both watercraft and fishing equipment, though few studies differentiate between the two vectors (Cole et al. 2016). Additionally, while these guidelines are broadly targeted at boat users, there is a fourth guideline—"dispose of unwanted bait, worms, and fish parts in the trash"—specific to anglers (US Fish and Wildlife Service 2017). Past research assessing engagement in AIS prevention (e.g., Pradhananga et al. 2015; Witzling et al. 2016) has measured differences in types of behavior such as inspecting a boat for AIS and disposing of bait properly. However, the drivers of these AIS prevention behaviors have only recently begun to receive research attention (Golebie et al. 2021a, b; van Riper et al. 2019). Moreover, these behaviors may vary between fishing and boating contexts given that boats may require more time and effort to clean, infrastructure (e.g. wash stations) may be easier to find at common access points such as boat launches, and boaters and anglers may be exposed to different information sources (Capizzano et al. 2022). Thus, there is a pressing need to understand the drivers of both fishing and boating behaviors across contexts that are susceptible to biological invasions.

Behavioral change strategies to prevent the spread of AIS can be informed by social science theories, such as the Health Belief Model (Rosenstock 1974; Fig. 1). This model posits that behavior can be predicted by a suite of beliefs, including risk perceptions, self-efficacy, benefits, response-efficacy, and barriers, and has been applied to several environmental contexts (Lindsay and Strathman 1997; Begum et al. 2022). Risk perceptions, defined as the perceived severity of possible harms to an entity, are positively associated with behavior (Rogers 1975; Kothe et al. 2019; O'Connor et al. 1999). Previous research has suggested that higher perceived risk leads to higher levels of engagement in AIS-prevention behaviors (Golebie et al. 2021a, b). However, research examining other biosecurity contexts, such as animal disease prevention have found mixed relationships between risk and behavior depending on context (Bucini et al. 2019), information source (Cui et al. 2019), and temporal dynamics (Hidano et al. 2018). Often considered in parallel to risk perceptions (Rogers 1975), self-efficacy is defined as a person's belief in their ability to take action (Bandura 1977). Self-efficacy is a strong and positive predictor of behavior (see Kothe et al. 2019 for a review), making it a centerpiece of environmental outreach campaigns (Pradhananga and

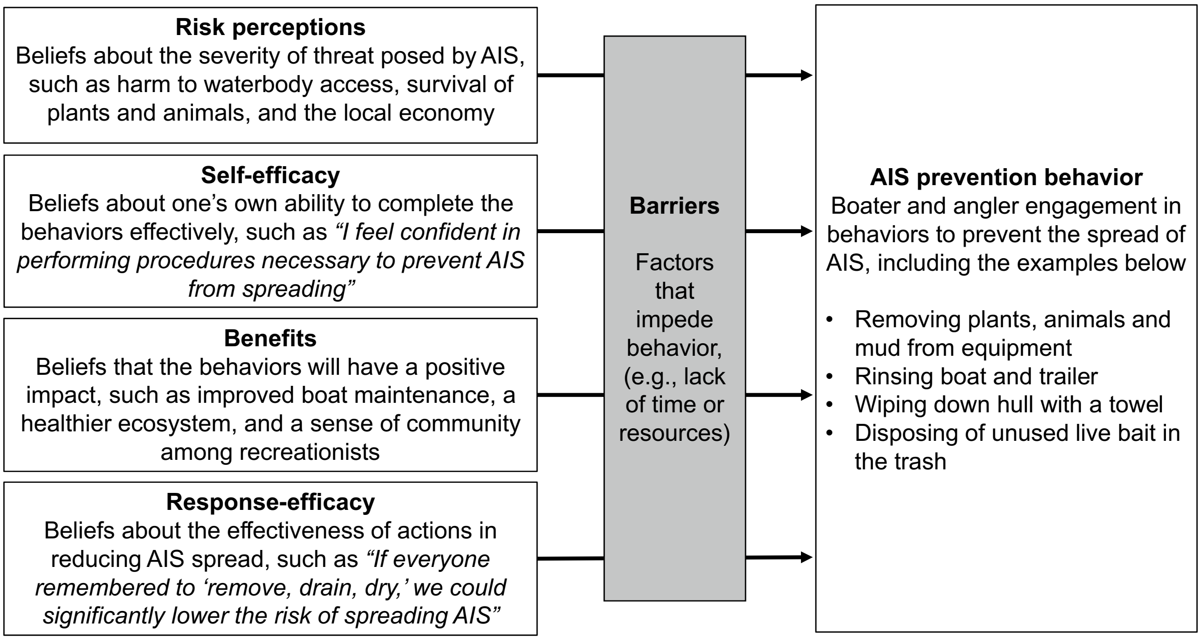

Fig. 1 Conceptual diagram illustrating the relationships among variables in the Health Belief Model, their definitions, and examples

Davenport 2022). Past research has highlighted the relevancy of self-efficacy to help change AIS-related behaviors among landowners (Clarke et al. 2021) and bait shop owners (Howell et al. 2015). The line of research examining risk and self-efficacy has yet to examine their influence on the suite of behaviors explicitly recommended by environmental management agencies. This is an important research gap because educational campaigns that promote AIS prevention behaviors could be redesigned to emphasize risk and self-efficacy to different degrees, depending on how this information would be received among relevant groups (Kemp et al. 2017; Seekamp et al. 2016).

Within the Health Belief Model, perceived benefits and response efficacy are related concepts that influence behavior. Perceived benefits, defined as the positive outcomes expected from a particular behavior, are thereby theorized to increase behavior as individuals seek to obtain such outcomes (Rosenstock 1974). When making decisions to engage in AIS-prevention behavior, recreationists may consider perceived benefits such as improved boat maintenance and a better recreational experience. Considered by some researchers to be a sub-category of perceived benefits (Champion and Skinner 2008), response-efficacy indicates that an individual believes their actions will have the intended effect. Examining response-efficacy as a separate variable from perceived benefits has been empirically justified (Yoon and Kim 2016), and results in nuanced implications. For instance, if response efficacy is driving behavioral decisions, outreach campaigns should emphasize the success of *clean-drain-dry* in minimizing the spread of AIS. In contrast, benefits as the predominant predictor of AIS behavior would suggest that campaigns should highlight the broader personal benefits of the *clean-drain-dry* process, such as having a well-maintained boat. To better understand the various drivers of AIS prevention behavior, future research should therefore distinguish between perceived benefits and response efficacy.

There are many barriers that impede behaviors even when the individual sees the importance of performing a given activity (Sutcliffe et al. 2018). Past work guided by the Health Belief Model has indicated that barriers are one of the most influential predictors of behavior (Carpenter 2010). Studies have found that pro-environmental behaviors are hindered by several types of barriers, such as a) beliefs that the behavior is too time consuming or financially costly (Keshavarz and Karami 2016); b) a lack of necessary

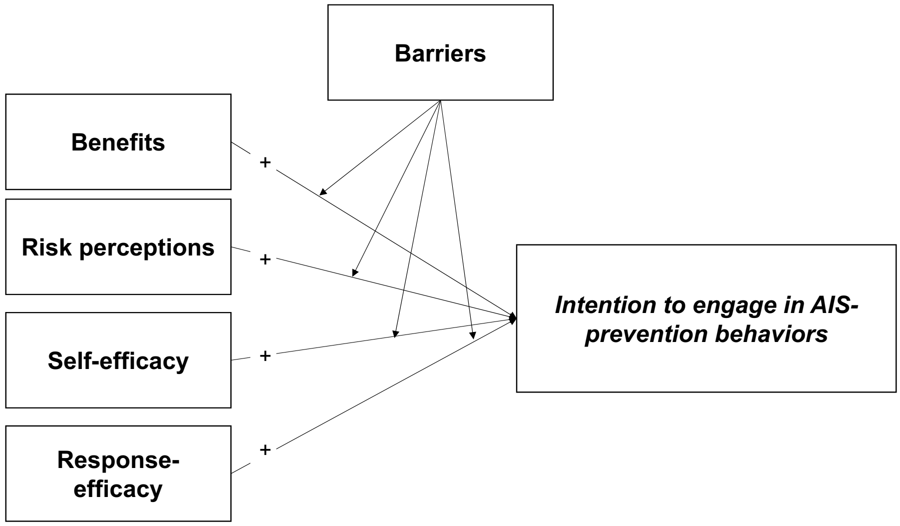

Fig. 2 Hypothesized model illustrating the expected relationships between AIS-prevention behaviors and a suite of beliefs including benefits, risk perceptions, self-efficacy, and response efficacy. Barriers were hypothesized to moderate these relationships

resources and infrastructure (Kollmuss and Agyeman 2002); and c) concerns that others do not want an individual to take action (Prinbeck et al. 2011). Barriers to fishing participation may also be relevant and have spanned issues such as weather (Ritter et al. 1992), health or safety concerns (Freudenberg and Arlinghaus 2009), disabilities (Lindsay et al. 2022), and lack of time (Sutton 2007; Schroeder et al. 2008; Ritter et al. 1992). Work guided by the Health Belief Model generally positions barriers as direct predictors of behavior alongside risk perceptions, efficacy, and benefits (Champion and Skinner 2008). However, some scholars have suggested that barriers are moderators or mediators rather than direct predictors of behavior (Hubbard and Mannell 2001; Jones et al. 2015). In summary, there is a robust body of research indicating that barriers influence behavior, but mixed support for how they operate within the Health Belief Model. Future research should therefore seek to understand how barriers function and how they can be overcome to promote AIS-prevention behavior.

This study sought to test the theoretical relationships among beliefs, barriers, and behaviors to understand why anglers and boaters take steps to minimize their risks of transporting AIS. Specifically, we examined the moderating effects of barriers on the relationships between beliefs and behaviors to illuminate the disparate ways that people experiencing different levels of barriers may be influenced by their beliefs (Fig. 2). With this information, environmental management agencies will be better equipped to provide tailored outreach materials that recognize the different types of barriers faced by groups of recreationists and encourage stronger performance of actions that are recommended to minimize the spread of AIS. We addressed the following objectives:

1. Determine how risk perceptions, benefits, self-efficacy, and response-efficacy influence intentions to engage in AIS-prevention behavior among recreational water users in Illinois
2. Understand how perceived barriers to engagement in recommended AIS-prevention behaviors moderate relationships between beliefs and behavior
3. Evaluate the characteristics of recreational water users who report different levels of barriers to develop management priorities

Methods

Study context

This research was conducted in the U.S. state of Illinois, where at least 60 aquatic invasive species have been established, such as Zebra mussels *Dreissena polymorpha* and Curly-leaf pondweed *Potamogeton crispus*, with other species such as quagga mussels *Dreissena rostriformis bugensis* and spiny waterflea *Bythotrephes longimanus* at risk of establishment and spread (Jacobs and Keller 2017). Large populations of filter feeding zebra mussels can cause dramatic effects in the food web and alter water clarity, affecting habitat conditions (Higgens and Vander Zanden 2010). Zebra mussels also attach to surfaces, which in high numbers can affect human access to waterbodies and impede waterflow through pipes (Connelly et al. 2007; Hosler 2011). These species are commonly spread by boaters and anglers (Rothlisberger et al. 2010). In Illinois, recreational anglers and boaters have a high rate of transport between waterbodies, resulting in a high risk of AIS spread from invaded to uninvaded waterbodies (Cole et al. 2019). In addition to national-level campaigns like 'Stop Aquatic Hitchhikers' (US Fish and Wildlife Service 2017), a regional campaign encouraging AIS-prevention behavior under the brand "Be a Hero Transport Zero" has been in use since 2013 (Zack et al. 2014). Past work has shown moderate awareness of this campaign among boaters (Cole et al. 2016).

Sampling methods

Data were collected through an online survey administered through the Qualtrics platform. The Qualtrics platform offers access to survey panels, which are groups of individuals who have agreed to take surveys in exchange for compensation. This methodology was selected due to low and declining response rates to the more traditional mailback surveys (Coon et al. 2020; Stedman et al. 2019). Although our sample was therefore not randomly selected from the general population, we follow trends in previous research that increasingly use online survey panels in the environmental social sciences (Landon et al. 2020; van der Linden et al. 2019), and that found Qualtrics panels best approximate standard sampling methods when nonprobability samples are needed (Zack et al. 2019).

For this study, respondents were recruited from a survey panel comprised of individuals who lived in Illinois, were at least 18 years old and had gone fishing or participated in a recreational water activity (e.g., sailing, kayaking, canoeing, boating, jetskiing) on at least one occasion since 2018. The survey was administered through the Qualtrics platform from May–June 2021. Responses were recorded only when the entire survey was completed and when two "attention check" questions were answered correctly (Berinsky et al. 2014). All panel members who completed the survey received compensation via the Qualtrics platform. Data collection procedures resulted in a final sample size of 507. These research procedures were approved by University of Illinois at Urbana Champaign Office for the Protection of Research Subjects (protocol #20679); in line with our protocol, all respondents provided informed consent and their responses have been anonymized.

The socio-demographics of respondents were evaluated and compared to previous studies that

Table 1 Characteristics of recreational water users from Illinois who participated in this study

	Valid %
Gender	
Male	40.7
Female	59.1
Other (Gender-fluid)	0.2
Education	
Some high school	2.0
High school graduate	29.0
Two-year degree	16.0
Bachelor's degree or higher	53.0
Annual Household Income (USD)[a]	
< $50,000	35.3
$50,000–$99,999	32.1
$100,000–$149,999	17.4
$150,000 +	9.8
Race and ethnicity[b]	
White	86.0
Black or African American	7.7
American Indian or Alaska Native	1.4
Asian	3.9
Native Hawaiian or Pacific Islander	0.2
Hispanic	5.3
Age	
Ages (*M, SD*)	45.36 (17.72)
Days fished in the past year	
Days (*M, SD*)	11.60 (19.97)
Years of fishing experience	
Years (*M, SD*)	21.46 (19.09)
Days boating in the past year	
Days (*M, SD*)	9.71 (15.96)
Years of boating experience	
Years (*M, SD*)	14.97 (14.77)

[a]Approximately 5% of respondents indicated they preferred not to reply

[b]Respondents could select all that apply

have relied on different survey modes. The majority of respondents were White (86%), while more than half were female (59%) and held a bachelor's degree or higher (53%; Table 1). The individuals engaged in our study were less experienced than respondents engaged in previous research that sampled from fishing license databases (e.g., Cole et al. 2016; Pradhananga et al. 2015; see Golebie et al. 2021b for more detailed analysis). Specifically, days fished ($M = 11.60$, SD = 19.97) and years of fishing experience ($M = 21.46$, SD = 19.09) were significantly lower from a past study of license holding anglers in Illinois (van Riper et al. 2020) wherein average levels of experience (M = 27.2 days fished; M = 37.7 years fished) were higher (days: $t(765) = 7.58$, $p < .001$; years: $t(765) = 12.87$, $p < .001$). Thus, the Qualtrics sample enabled us to understand the drivers of behavior among recreationists with lower experience levels, which are not necessarily captured in traditional sampling methods. That is, the reported levels of beliefs and behaviors are likely lower, and barriers higher, than would have been the case with a random sample of license-holding anglers. While results indicate trends within each subgroup, they do not reflect the size of each subgroup in the broader population, or the relative proportion of the beliefs and behaviors measured.

Survey measures

Survey measures were drawn from past work that has been guided by the Health Belief Model (Rosenstock 1974) and refined through preliminary research (Golebie et al. 2021b). Specifically, six focus groups were held, four of which included recreational anglers (n = 26) and two of which included boaters (n = 7). The angling focus groups occurred in-person and were coupled with a fisheries workshop. In contrast, the boating focus groups were stand-alone events that occurred online, shortly after the COVID pandemic began, resulting in comparatively lower participation. During the focus groups, participants were asked to share beliefs about the impacts of invasive species, the benefits of *clean-drain-dry* behavior, and the barriers to performing such behaviors (Golebie et al. 2021b). Results from these focus groups informed development of scales that were included in the questionnaire. All scales were evaluated through confirmatory factor analysis. Reliability was tested using Cronbach's alpha (α) and McDonald's omega (Ω) and considered acceptable when coefficients were greater than .70 (Bagozzi and Yi 1988; Cortina 1993). Convergent validity was considered acceptable with average variance extracted (AVE) values that exceeded .50 (Hair et al. 2011).

Five constructs were hypothesized to predict behavior: risk perceptions, self-efficacy, response-efficacy, barriers, and benefits (Table 2). Risk perceptions were assessed by asking participants to report the perceived severity of threats to personal and social entities (Golebie et al. 2021a, b), as well as to the non-human environment. The resulting nine-item scale was reliable (α = .908; Ω = .910; AVE = .531). A three-item scale measured self-efficacy (Bandura 1977), was adapted to the context of AIS management and deemed reliable (α = .865; Ω = .865; AVE = .682). To measure response-efficacy, three items developed during the focus groups were refined in response to past research (Landon et al. 2018), which resulted in a reliable scale (α = .845; Ω = .847; AVE = .648). Barriers were drawn directly from the focus groups, resulting in a five-item scale that was reliable (α = .872; Ω = .872; AVE = .578). The focus group indicated that participants perceived benefits to the self, to others, and to the environment; a nine-item reliable scale (α = .919; Ω = .919; AVE = .557) was thus developed.

Two scales were used to measure AIS-prevention behavior, in line with past work that has distinguished between vectors of AIS transport (Cole et al. 2016). In particular, one scale measured behaviors that prevent AIS transport via boats, and another scale measured behaviors that prevent AIS transport via fishing equipment. Items within each scale were drawn from past work (Pradhananga et al. 2015), and updated to represent the current behavioral recommendations from the *clean-drain-dry* campaign. Both the boating vector (α = .903; Ω = .902; AVE = .606) and fishing vector (α = .909; Ω = .902; AVE = .606) scales were found to be reliable.

Analysis

Multiple linear regression was used to analyze the effect of risk perceptions, benefits, self-efficacy, and response-efficacy on intentions to perform AIS-prevention behavior. The mean value of all items measuring each construct was calculated. Mean values

Table 2 Means (SD in parentheses) for the intended behavior, benefits, barriers, risk perceptions, self-efficacy, and response-efficacy reported by recreational water users in Illinois

	λ	M (SD)
Behaviors: boating vector[a] (α = .903; Ω = .902; AVE = .606)		
Drain all standing water from the boat	.758	4.10 (1.22)
Conduct visual inspections of boats for invasive species	.768	3.90 (1.28)
Remove plants, animals, and mud from the boat	.845	4.18 (1.13)
Rinse boat and trailer	.767	3.98 (1.19)
Wipe down hull with a towel	.747	3.77 (1.28)
Allow boat to dry before entering a different body of water	.792	3.99 (1.25)
Behaviors: fishing vector[a] (α = .909; Ω = .902; AVE = .606)		
Remove any non-bait fish, plants, and other "hitchhikers" from bait bucket	.816	4.19 (1.06)
Dispose of unused live bait in the trash	.653	4.11 (1.19)
Drain water from bait bucket before moving to another waterbody	.759	4.12 (1.78)
Conduct visual inspections of fishing equipment for invasive species	.794	4.08 (1.15)
Remove plants, animals, and mud from fishing equipment	.838	4.35 (0.96)
Rinse fishing equipment	.728	4.06 (1.10)
Wipe down fishing equipment with a towel	.667	3.88 (1.25)
Allow fishing equipment to dry before fishing in a different body of water	.765	4.14 (1.10)
Barriers[2] (α = .872; Ω = .872; AVE = .578)		
I do not have enough time to complete the recommended cleaning tasks that minimize the spread of AIS	.781	2.38 (1.14)
I feel pressure from other recreationists to leave the site without cleaning my boat or equipment	.678	2.55 (1.21)
I lack the necessary equipment to effectively clean my boat or equipment	.837	2.36 (1.21)
Poor weather conditions often interfere with my ability to complete the recommended cleaning tasks	.724	2.78 (1.15)
My health or physical abilities prevent me from effectively cleaning my boating or fishing equipment	.771	3.26 (1.20)
Self-efficacy[b] (α = .865; Ω = .865; AVE = .682)		
I understand what I need to do in order to remove AIS from my boat or equipment	.836	4.11 (0.85)
I am capable of performing the tasks required to remove possible AIS from my boat and equipment	.832	4.18 (0.84)
I feel confident in performing procedures necessary to prevent AIS from spreading	.809	4.08 (0.83)
Response-efficacy[b] (α = .845; Ω = .847; AVE = .648)		
Cleaning my boat and equipment helps to prevent AIS from spreading	.826	4.36 (0.73)
My own actions to remove, drain, dry will protect fishing waters from AIS	.812	4.30 (0.77)
If everyone remembered to "remove, drain, dry", we could significantly lower the risk of spreading AIS	.778	4.38 (0.77)
Risk perceptions[c] (α = .908; Ω = .910; AVE = .531)		
Quality of habitat and natural environments	.722	3.52 (0.88)
Environmental processes (e.g., water cycle)	.727	3.46 (0.95)
Survival of plants and animals	.670	3.69 (0.92)
Your appreciation of the beauty of the landscape	.695	3.33 (1.10)
Your own enjoyment of recreational activities	.717	3.40 (1.05)
Your own access to the waterbody	.754	3.22 (1.14)
The local economy	.733	3.14 (1.12)
The community in the region	.769	3.16 (1.11)
Recreational opportunities for future generations	.746	3.66 (1.02)
Benefits[b] (α = .919; Ω = .919; AVE = .557)		
Increasing my own knowledge and understanding of the ecosystem	.835	4.06 (0.85)
Improved maintenance of my boat or equipment	.801	4.24 (0.74)
Knowing I have done the right thing to be a responsible water user	.727	4.37 (0.74)
A sense of community among water-based recreationists	.612	4.09 (0.83)

Table 2 (continued)

	λ	M (SD)
Teaching younger generations about the impact of our behaviors on the environment	.725	4.34 (0.73)
Preserving aquatic resources for my community	.789	4.33 (0.70)
A healthier ecosystem	.683	4.40 (0.70)
More sustainable populations of plants and animals	.786	4.33 (0.72)
Better water quality	.806	4.37 (0.74)

Measures of internal consistency including Cronbach's alpha (α), MacDonald's omega (Ω), and average variance explained (AVE), and factor loading scores (λ) for scale items. *AIS* aquatic invasive species

[a]Measured on a 5-point scale from 'Never' (1) to 'Every time I go fishing/boating' (5)

[b]Measured on a 5-point scale from 'strongly disagree' (1) to 'strongly agree' (5)

[c]Measured on a 5-point scale from 'no impacts' (1) to 'very severe impacts' (5)

Table 3 Results of multiple regressions predicting each type of AIS prevention behavior

	Dependent variable	
	AIS prevention via boating vector	AIS prevention via fishing vector
Independent variables (β values)		
Benefits	ns	ns
Risk perceptions	.097	ns
Self-efficacy	.273	.190
Response-efficacy	.216	.338
Regression statistics		
Constant		
Adjusted R^2	.297	.290
F-value	48.017	40.807
df	4, 441	4, 385
p	< .001	< .001

were then centered and used in the model. Two separate models were run to examine the effects on fishing-vector behaviors and boating-vector behaviors. To test the moderating effect of barriers, four subgroups were identified based on natural breaks in the data that resulted in approximately 25% of respondents in each group. A regression model was run for each subgroup to determine differences in regression paths.

The assumptions of linear regression were tested prior to analyzing results. The normal P–P plot indicated that the data contained approximately normally distributed errors. No variables exhibited multicollinearity (Tolerance was greater than .10 and VIF was less than 10 for all variables). The data met the assumption of independent errors (Boating vector model: Durbin-Watson value = 1.968; Fishing vector model: Durbin-Watson value = 1.857). Finally, the scatterplot of standardized residuals indicated that the assumptions of homogeneity of variance and linearity were met.

Regression coefficients were compared among subgroups using ANOVA. Chi-square and ANOVA tests, with Dunnett's T3 post-hoc tests, were also used to identify differences among recreational water users that reported low, moderate, high, and very high perceived barriers. The Dunnett's T3 tests were chosen because these variables did not exhibit equal variances. All analyses were conducted in SPSS v27.

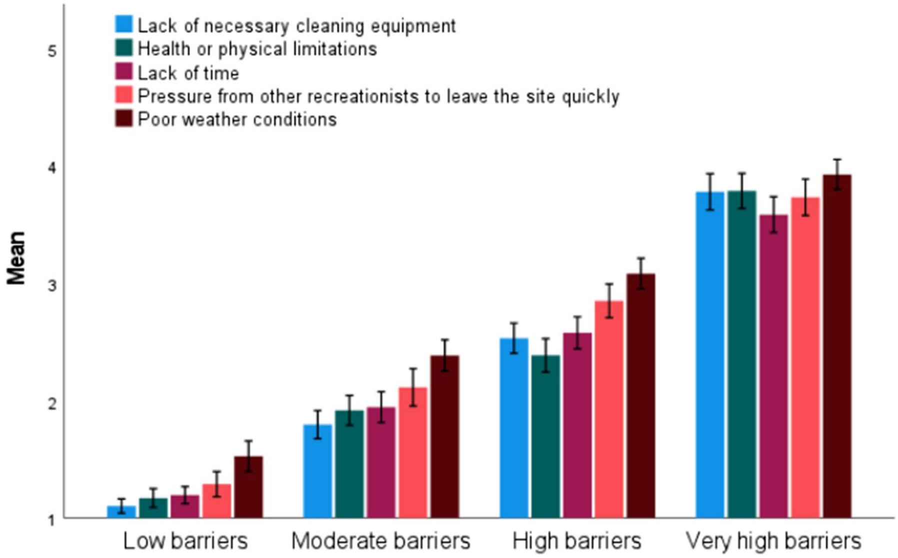

Fig. 3 Average perceived barriers across four subgroups of respondents that were identified by their responses to these five barrier items. The response scale ranged from 1 (strongly disagree) to 5 (strongly agree). Error bars show 95% confidence intervals

Results

The hypothesized relationships between beliefs and behavior were largely supported (Table 3). Self-efficacy (β = .273), response-efficacy (β = .216), and to a lesser degree, risk perceptions (β = .097) significantly predicted AIS prevention behaviors via boating vectors ($F = 48.017$, $p < .001$). Prevention behaviors via fishing vectors were likewise influenced by self-efficacy (β = .190) and response-efficacy (β = .338). To examine the potential moderating role of barriers on these relationships, four subgroups were

Table 4 Mean for each subgroup of recreational water users defined by perceived barriers

	Subgroups defined by perceived barriers						
	Low	Moderate	High	Very high	F-value	p-value	Eta^2
Barriers	1.256^{a}	2.030^{b}	2.683^{c}	3.754^{d}	1409.689	< .001	.894
Beliefs							
Benefits	4.618^{a}	4.292^{b}	4.151^{b}	4.125^{b}	20.821	< .001	.061
Risk perceptions	3.570^{a}	3.312^{ab}	3.280^{b}	3.455^{ab}	3.721	.001	.001
Self-efficacy	4.607^{a}	4.168^{b}	3.974^{bc}	3.821^{c}	30.332	< .001	.097
Response-efficacy	4.715^{a}	4.355^{b}	4.254^{bc}	4.115^{c}	20.629	< .001	.060
Behavioral intentions							
Fishing vector	4.526^{a}	4.316^{a}	3.960^{b}	3.755^{b}	17.402	< .001	.069
Boating vector	4.518^{a}	4.209^{a}	3.733^{b}	3.641^{b}	20.885	< .001	.061
Characteristics							
Age	47.94^{a}	49.25^{a}	44.37^{ab}	40.72^{b}	5.869	.001	.034
Years of fishing experience	26.02^{a}	25.58^{a}	20.53^{ab}	15.08^{b}	7.479	< .001	.055
Years of boating experience	17.87^{a}	15.91^{ab}	14.73^{ab}	11.89^{b}	2.717	.044	.021
Involvement	3.170^{a}	2.872^{b}	2.858^{b}	3.269^{a}	7.372	< .001	.042
Familiarity	2.804^{ac}	2.326^{b}	2.500^{ab}	2.881^{c}	7.093	< .001	.041
Ecological	2.879^{ab}	2.517^{a}	2.717^{ab}	2.967^{b}	3.752	.011	.022
Recreation	2.884^{a}	2.336^{b}	2.499^{b}	2.910^{a}	6.896	< .001	.040
Management	2.647^{ac}	2.125^{b}	2.283^{c}	2.767^{a}	8.207	< .001	.047

Within each row, different lowercase letters indicate significant differences in mean at $p < .05$, based on Dunnett's T3 post-hoc test. Eta^2 provides a measure of effect size

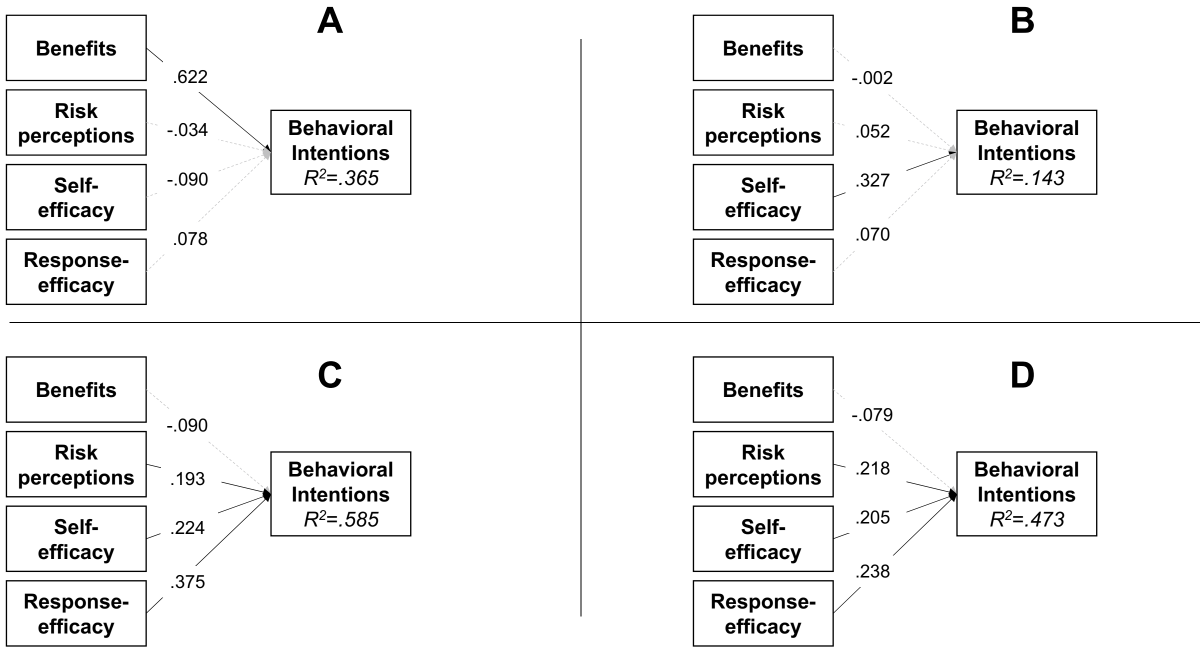

Fig. 4 Regression models estimating the relationship between beliefs and AIS prevention via boating vectors, as moderated by barriers. Panels show results for: **A** Low perceived barriers ($F(4,97)=13.934$, $p<.001$); **B** Moderate perceived barriers ($F(4,89)=3.538$, $p<.001$); **C** High perceived barriers ($F(4,136)=17.728$, $p<.001$); **D** Very high perceived barriers ($F(4,108)=7.795$, $p<.001$). Grey dotted lines indicate non-significant relationships

identified (Fig. 3), including respondents reporting low (M = 1.26), moderate (M = 2.03), high (M = 2.68), and very high barriers (M = 3.75).

The regression models for boating (Fig. 4) and fishing (Fig. 5) related behaviors were analyzed for four subgroups. For respondents reporting low perceived barriers (Group A), only benefits significantly predicted behavioral intentions (boating behaviors: $\beta=.622$, $R^2=.365$; angling behaviors: $\beta=.315$; $R^2=.169$); this variable was not a significant predictor of behavior for respondents with higher perceived barriers. When perceived barriers were moderate (Group B), only self-efficacy was a significant predictor of behavioral intentions (boating behaviors: $\beta=.317$, $R^2=.143$; angling behaviors: $\beta=.269$, $R^2=.387$). Risk perceptions, self-efficacy, and response-efficacy were each positive predictors of behavioral intentions for respondents perceiving high (Group C: boating behaviors $R^2=0.585$; angling behaviors $R^2=.353$) or very high barriers (Group D: boating behaviors $R^2=.473$; angling behaviors $R^2=.198$).

Characteristics of recreational water users who reported different levels of barriers were identified (Table 4). Respondents who perceived low and moderate barriers engaged in AIS-prevention behaviors more frequently than those who perceived high and very high barriers ($F=17.402$, $p<0.001$; $F=20.885$, $p<.001$). Respondents who reported low perceived barriers perceived the highest benefits to completing *clean-drain-dry* ($F=20.821$, $p<.001$), and the highest self- and response- efficacy. The risk perceptions of recreationists who experienced very high barriers were statistically equivalent to those who experienced low barriers. Those who experienced very high barriers also tended to be younger and less experienced than other respondents yet reported relatively high degrees of involvement with AIS-issues and familiarity with AIS.

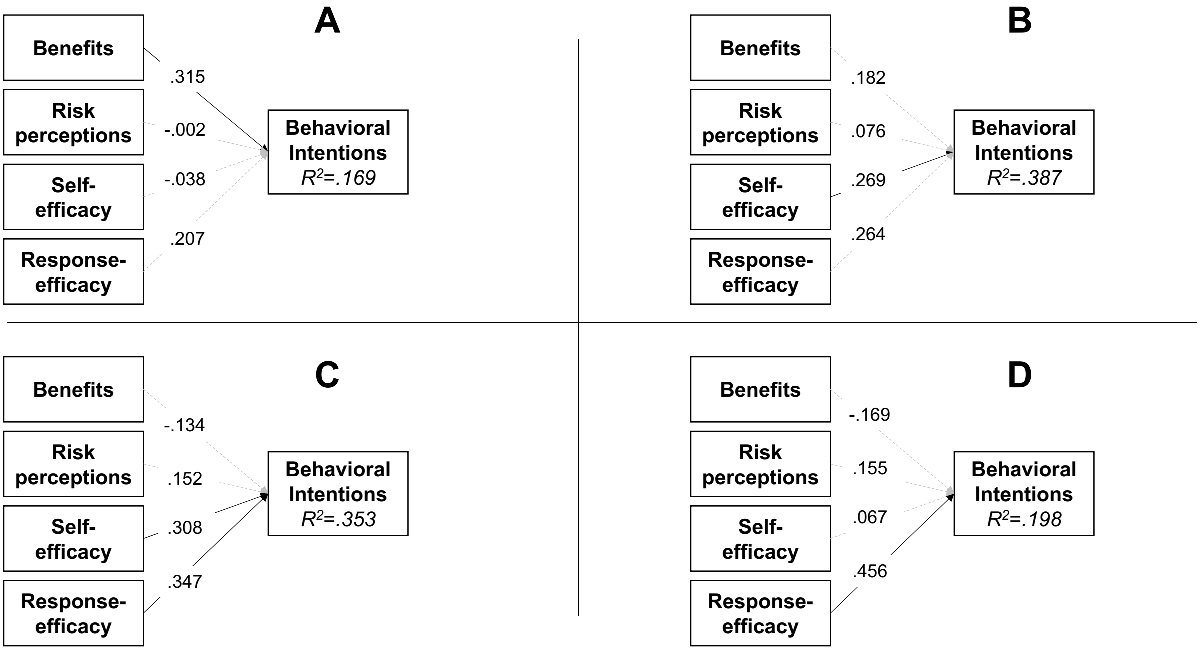

Fig. 5 Regression models estimating the relationship between beliefs and AIS prevention via fishing vectors, as moderated by barriers. Panels show results for: **A** Low perceived barriers ($F(4,88) = 4.478$, $p = .002$); **B** Moderate perceived barriers ($F(4,80) = 12.626$, $p < .001$); **C** High perceived barriers ($F(4,101) = 13.765$, $p < .001$); **D** Very high perceived barriers ($F(4,101) = 6.224$, $p < .001$). Grey dotted lines indicate non-significant relationships

Discussion

We provided empirical evidence that perceived benefits, self-efficacy, response-efficacy, and risk perceptions were instrumental in explaining the reasons why recreational water users in Illinois make behavioral decisions to benefit the environment. In line with previous research (Howell et al. 2015; Pradhananga and Davenport 2022), we observed that self-efficacy and response-efficacy were strong predictors of intended AIS-prevention behavior. The hypothesized relationships tested in this study were informed by the Health Belief Model (Rosenstock 1974) and enabled us to segment respondents into subgroups that reported different levels of perceived barriers. Relationships between beliefs and intended behaviors within these subgroups varied to statistically significant degrees. These results provide insights on how environmental management agencies could re-direct their limited resources in ways that would more effectively engage recreational water users who are facing barriers that limit their behavioral engagement.

Our hypothesized model tested the moderating effects of barriers on the direct relationships between beliefs and behavior (Janz and Becker 1984) because beliefs may enable people to negotiate constraints that are preventing behavioral performance (Hubbard and Mannell et al. 2001; Son et al. 2008). In contrast to past work that has positioned barriers as direct antecedents to behavior (Carpenter 2010; Rosenstock 1974; Yoon et al. 2013), we found that perceived barriers accounted for differences in the relationships between beliefs (i.e. self-efficacy, response-efficacy, benefits, risk perceptions) and intended behavior. We also observed that respondents did not perceive one type of barrier to be more influential than another but perceived all barriers similarly. In other words, the identified subgroups in this study perceived all barriers to be low, moderate, high, or very high rather than being more concerned with a particular topical area such as health versus time or available resources. For each of the four emergent subgroups, we observed different relationships between beliefs and behaviors indicating that tailored approaches should be adopted by environmental managers to engage different groups, especially considering that these collectives may have different degrees of skepticism toward environmental policies (Blake 1999).

Patterns corresponding to different levels of perceived barriers

Among respondents who reported low perceived barriers, benefits were the only significant predictor of behavior. Past work has suggested that people weigh benefits against barriers in deciding whether to act (Janz and Becker 1984; Lower-Hoppe et al. 2022). These theoretical relationships between benefits and barriers were supported by our findings. That is, benefits were a significant predictor of behavior only among those respondents who experienced relatively low levels of barriers to those behaviors. Highlighting benefits associated with AIS prevention such as a well-maintained boat, an enhanced recreational experience, or a sense of pride in protecting the environment would likely compel action among this group. However, when barriers are high, benefits are given less psychological consideration, and factors such as risk perceptions and efficacy are needed to overcome barriers.

When respondents expressed moderate levels of perceived barriers, only self-efficacy was significantly related to AIS-prevention behavior. Within this subgroup, perceived benefits were no longer a sufficient condition to compel behavior. Rather, having confidence in one's own ability allowed this subgroup to overcome barriers and participate in AIS-prevention behavior (Son et al. 2008). Building on recent studies that have underscored the importance of self-efficacy in steering AIS prevention behavior (Clarke et al. 2021; Pradhananga & Davenport 2022); our results demonstrate that an individual's belief in their capacity to take action is crucial for behavior change when perceived barriers are moderate to high. For individuals in this subgroup, instilling confidence that recreationists can successfully complete the recommended *clean-drain-dry* process is likely to serve as a motivating force.

Among respondents who reported high barriers, both self-efficacy and response-efficacy were significant predictors of behavior. Response-efficacy has accounted for high degrees of variation in behavior across environmental contexts (Kothe et al. 2019), though work related to invasive species prevention behaviors has focused on self-efficacy (Clarke et al. 2021; Howell et al. 2015). As a corollary, our analysis indicated that response-efficacy was instrumental in overcoming high perceived barriers but was a less relevant factor when perceived barriers were moderate to low. Additionally, in the high barriers subgroup, risk perceptions were a significant driver of boating behaviors, but not angling behaviors. Given that respondents were more experienced with angling than boating, it could be that those with more experience had already been exposed to information about the risks of AIS to the point that new information would no longer affect their behavioral decisions (Heberlein 2012). We therefore suggest that recreationists with less experience can be encouraged to take action through learning about the potential negative consequences of AIS.

Among respondents who reported very high barriers, there were stark differences between the predictors of angling and boating behaviors. For boating behaviors, risk perceptions, self-efficacy, and response-efficacy were all useful constructs for better understanding how and why behavioral decisions were made. However, for angling behaviors, only response-efficacy was significant. This finding indicates that the most urgent information needed to promote AIS-prevention behaviors among anglers should focus on why *clean-drain-dry* steps are needed and build confidence that individual actions can make a difference. Cleaning fishing equipment is easier than cleaning a boat, but it may not occur to someone that this is an AIS vector or seem as threatening as a large boat. Boaters, on the other hand, were convinced that cleaning their boats was important, and may instead need more support for self-efficacy—what are the steps needed and how do you know you have completed them correctly?

Implications and areas of future research

We observed that the greater the experience with angling or boating, the fewer barriers individuals were likely to perceive. Specifically, the group reporting the lowest barriers also reported the highest level of experience, and higher self- and response- efficacy as compared to all other groups evaluated in this study. Our findings suggest that invasive species outreach efforts over the past decade (e.g. Nathan et al. 2014) may have led to high self-efficacy among experienced boaters and anglers in the U.S. Midwest. In other words, the greater the levels of experience among recreationists, the more likely the exposure to outreach information, and the less likely these individuals would be to believe that prevention behaviors are prohibitively difficult. Past work has indicated that recreationists who are older and visit sites frequently are more aware of AIS (Le and Campbell 2022), and that awareness of AIS has increased with more exposure to AIS messages (Seekamp et al. 2016). Thus, identifying new ways to disseminate AIS information to less experienced recreationists (e.g., Connelly et al. 2014; Shaw et al. 2014) will make a difference in minimizing perceived barriers and increasing efficacy. Future research should seek to identify the locations and communication channels that are most often used by recreationists with less experience. Additionally, previous research has indicated that campaign awareness has a weak influence on preventative behavior (Smith et al. 2020), indicating an approach that couples outreach with additional tools such as boat washing stations, would be more successful than outreach alone in targeting recreationists with lower levels of experience.

Although we found that barriers decreased with experience, familiarity with issues pertaining to AIS was high across all barrier groups and experience levels. This finding corroborates the knowledge-action gap (Kollmuss and Agyeman 2002) given that relatively high levels of familiarity with AIS are not matched with correspondingly high levels of behavior. Rather, perceived barriers and efficacy are playing a stronger role than familiarity in influencing behavior. That is, despite feeling knowledgeable about the problem of AIS, recreationists perceiving very high barriers may feel helpless in their efforts to make a difference. Given that barriers were associated with experience, it could be that after additional years of recreational experience and exposure to AIS outreach, these individuals may become more familiar with the steps they can take and consequently increase their confidence. Environmental managers can support this process by focusing educational materials in ways that will increase self-efficacy. For instance, signage could be modified to provide more detailed guidance on the steps to completing *clean-drain-dry* and communicating that anyone could successfully clean their boat by following the simple guidelines. Complementing signage with improved infrastructure, such as wash stations that offer recreationists tools to assist in cleaning their boats, is likely to further enhance self-efficacy and enable AIS preventative actions.

Limitations

Recruiting respondents via a Qualtrics panel enabled us to understand the drivers of behavior among recreationists with a range of experience levels, which lies in contrast to traditional sampling methods that tend to be biased towards more experienced individuals who experience low barriers (e.g., Cole et al. 2016; van Riper et al. 2020). However, as Qualtrics panels are not random samples, results should not be assumed to indicate proportions of beliefs or characteristics across a broader population (Wardropper et al. 2021). Additionally, given that respondents were sampled from the U.S. state of Illinois, implications are most directly relevant for this region, and observed relationships among variables may differ in other regions. Future work may seek to use a representative sample to understand the prevalence of each subgroup from our study across other regions of interest.

Conclusions

Preventing the spread of AIS by recreational water users is essential for effective and sustainable management of freshwater ecosystems. However, numerous barriers prevent recreationists from engaging in behaviors that curb biological invasions. We suggest that recreationists who experience different degrees of barriers rely on different cognitive mechanisms to overcome those barriers and engage in AIS prevention. For recreationists who face the fewest barriers, the perceived benefits of taking action are the predominant construct that explains why they intend to engage in behavior. In contrast, respondents who experience high degrees of barriers rely more on efficacy and risk perceptions to overcome barriers and take action. These results suggest AIS campaigns should boost the self-efficacy of recreational water users by providing clear and accessible instructions, and by enhancing infrastructure such as wash stations. Further, response efficacy should also be boosted through disseminating messages that share success stories from recreationists engaged in AIS prevention. Instilling confidence in these actions has great potential for encouraging prevention behaviors and ultimately minimizing the spread of AIS.

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Author contributions All authors contributed to the study conception including the development of research objectives. Carena van Riper and Greg Hitzroth acquired the funding. Elizabeth Golebie and Carena van Riper collected the data with contributions from all authors on survey development. Analyses were performed by Elizabeth Golebie. The first draft of the manuscript was written by Elizabeth Golebie and all authors reviewed and edited the manuscript and approved the final version.

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Data availability The datasets analyzed during this study will be made openly available via Zenodo at https://doi.org/10.5281/zenodo.7725481.

Declarations

Competing interests The authors have no relevant financial or non-financial interests to disclose.

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