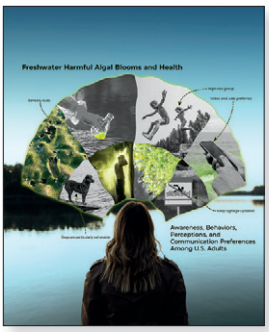

Freshwater Harmful Algal Blooms and Health: Awareness, Behaviors, Perceptions, and Communication Preferences Among U.S. Adults

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Abstract **Freshwater harmful algal blooms (HABs) are a growing health risk for children, adults, and their dogs. To inform more effective illness prevention strategies, this study examined awareness, behaviors, perceptions, and communication preferences related to health and HABs. Four focus groups were conducted in March 2024 with U.S. adults who frequent freshwater bodies (e.g., lakes, rivers) for recreation. Focus group participants, who included dog owners and parents of children or teenagers, reported moderate awareness of HABs and perceived low personal risk from HAB exposure. When deciding if to enter bodies of water, most individuals relied on sensory cues more than official recommendations such as water advisories. In general, participants reported trusting officials and following water advisories if they saw them. They preferred timely information that described HABs using simple terms and information available through multiple channels. Public health practitioners can consider the insights we gained from the focus group participants to inform future audience research, HAB risk communication, and illness prevention.**

Keywords: harmful algal blooms, cyanobacteria, risk communication, risk perception, public awareness, recreational water

Introduction

Harmful algal blooms (HABs) can be dangerous for people, animals, and ecosystems. HABs result from rapid growth of certain types of algae or cyanobacteria in water, many of which make toxins. These blooms occur throughout the U.S. in bodies of fresh, marine, and brackish water (Anderson et al., 2021; Lopez, 2008) and are becoming more common in many bodies of water (Smucker et al., 2021; U.S. Environmental Protection Agency, 2024). Rising water temperatures and extreme weather exacerbate HAB growth, leading to more frequent and dangerous HABs in more locations (Gobler, 2020; Merder et al., 2023; Smucker et al., 2021).

Cyanobacteria, a type of phytoplankton that is also called blue-green algae, cause most HABs in freshwater bodies, such as lakes and rivers (Backer et al., 2015; Lopez, 2008). These freshwater HABs cause mild to life-threatening illnesses, as well as environmental and economic damage (Bingham et al., 2015; Brooks et al., 2016; Centers for Disease Control and Prevention [CDC], 2024a). Although water containing HAB toxins can smell foul, look discolored, and be scummy, it can also smell and appear normal (Chorus & Welker, 2021).

People who visit freshwater bodies for recreation (e.g., swimming, boating) and pets that swallow water or eat algae from freshwater bodies have a higher risk of HAB exposure (Backer et al., 2013; Figgatt et al., 2017; Hardy et al., 2021; Lavery et al., 2023). Dogs are particularly vulnerable to serious HAB-associated illnesses, and people ≤18 years might be more susceptible than adults (Backer et al., 2013; CDC, 2024a, 2024b). Most reported human illnesses caused by freshwater HABs are mild to moderate, resulting from skin contact, ingestion, or inhalation (Backer et al., 2015; CDC, 2024a, 2024b; Lavery et al., 2023). In contrast, illnesses in dogs and other animals often are severe or fatal and can be indicators of potential human health risks (Hilborn & Beasley, 2015; CDC, 2024a).

As HABs are a growing public health threat, it is important to consider the factors that influence people's decisions related to HAB exposure across different population groups (Borbor-Córdova et al., 2018; Van Dolah et al., 2016). Previous research among U.S. adults has focused primarily on understanding local or regional HAB perspectives, particularly in areas with severe or frequent HABs (Ames et al., 2023; Gill et al., 2018; Kirkpatrick et al., 2014; Larkin & Adams, 2008). Research exploring views of freshwater HABs among adults in different U.S. regions, however, is limited.

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TABLE **1**

Demographic Characteristics of Focus Group Participants

Demographic Characteristic	Dog Owners (*n* = 8) # (%)	Parents (*n* = 7) # (%)	General Public (*n* = 12) # (%)	All Participants (*N* = 27) # (%)
Average age in years (range)	39 (38–53)	36 (24–46)	44 (22–74)	40 (22–74)
Sex				
Female	3 (38)	3 (43)	6 (50)	12 (44)
Male	5 (63)	4 (57)	6 (50)	15 (56)
Race (select all that apply)				
Black/African American	1 (13)	1 (14)	1 (8)	3 (11)
Native Hawaiian/Pacific Islander	0	1 (14)	0	1 (4)
White	7 (87)	4 (57)	8 (67)	19 (70)
Prefer not to answer	0	1 (14)	3 (25)	4 (15)
Ethnicity				
Hispanic	2 (25)	1 (14)	3 (25)	6 (22)
Non-Hispanic	6 (75)	6 (75)	8 (67)	20 (74)
Prefer not to answer	0	0	1 (8)	1 (4)
Education				
Some college/associate's degree	1 (13)	2 (29)	5 (42)	9 (33)
Bachelor's degree	2 (25)	2 (29)	7 (58)	14 (52)
Postgraduate degree	5 (63)	3 (43)	0	4 (15)
Employment				
Full-time	8 (100)	6 (86)	7 (58)	21 (78)
Part-time	0	1 (14)	1 (8)	2 (7)
Retired	0	0	2 (17)	2 (7)
Unemployed	0	0	1 (8)	1 (4)
Other	0	0	1 (8)	1 (4)
Household income				
$25,000–$35,000	1 (13)	0	0	7 (26)
$35,000–$50,000	0	1 (14)	4 (33)	4 (15)
$50,000–$75,000	1 (13)	1 (14)	2 (17)	5 (19)
$75,000–$100,000	3 (38)	1 (14)	3 (2)	1 (4)
$100,000–$150,000	1 (13)	2 (29)	0	6 (22)
>$150,000	2 (25)	2 (29)	2 (17)	3 (11)
Prefer not to answer	0	0	1 (8)	1 (4)
No preexisting health conditions [a]	7 (88)	5 (71)	12 (100)	24 (89)
Average familiarity with HABs (range) [b]	4 (2–6)	5 (1–9)	3 (1–8)	4 (1–9)

[a] Participants were asked if they had any of the following preexisting health conditions: inflammatory bowel disease (IBD), asthma, skin conditions causing rash or hives, or any condition that weakens the immune system (e.g., diabetes, kidney disease, HIV, cancer).

[b] Familiarity with harmful algal blooms (HABs) was a scale question from 1 to 10 (1 = not familiar with HABs at all and 10 = extremely familiar with HABs).

Understanding these broader perspectives is valuable for informing illness prevention efforts nationally and where HABs are an emerging threat. The purpose of our study was to better understand awareness, behaviors, perceptions, and communication preferences related to HABs and health among U.S. adults who recreate in or near freshwater bodies.

TABLE **2**

Water Safety Communication Preferences of Focus Group Participants

Communication Preference	Dog Owners (*n* = 8) # (%)	Parents (*n* = 7) # (%)	General Public (*n* = 12) # (%)	All Participants (*N* = 27) # (%)
Go-to resource for information about water safety [a]				
Park signage	6 (75)	3 (43)	8 (67)	17 (63)
Park, water body, or beach website	7 (88)	3 (43)	5 (42)	15 (56)
State or local government website	4 (50)	3 (43)	4 (33)	11 (41)
Federal government website	2 (25)	2 (29)	1 (8)	5 (19)
Family or friends	2 (25)	1 (14)	6 (50)	9 (33)
Social media	5 (63)	2 (29)	3 (25)	10 (37)
News	2 (25)	3 (43)	7 (58)	12 (44)
Location, weather, or business app	3 (38)	3 (43)	2 (17)	8 (30)
Academic or nonprofit organization website	0	0	0	0
Other	1 (13)	0	0	1 (4)
None	0	0	1 (8)	1 (4)
Trusted source for water safety information [b]				
Staff at beach or park	5 (63)	5 (71)	11 (92)	21 (78)
State or local government	5 (63)	6 (86)	10 (83)	21 (78)
Federal government	4 (50)	3 (43)	9 (75)	16 (59)
Academic or nonprofit organization	5 (63)	4 (57)	10 (83)	19 (70)
Sports or recreation organization	2 (25)	3 (43)	7 (58)	12 (44)
Local news station	3 (38)	3 (43)	3 (25)	9 (33)
Family or friends	3 (38)	1 (14)	3 (25)	7 (26)
Doctor or healthcare professional	4 (50)	1 (14)	8 (67)	13 (48)
Veterinarian (for dog owners)	2 (25)	2 (29)	6 (50)	10 (37)
Other	0	0	0	0

continued ▸

Methods

Recruitment

U.S. adults who visited freshwater bodies in the last 12 months, including parents and dog owners, were identified by a recruitment firm through a national panel. Participants were ≥18 years, proficient in English, had access to high-speed internet and a webcam, and visited freshwater bodies at least once a month in the summer. Individuals were excluded if they had participated in any water safety focus groups, interviews, or surveys within the past 6 months; had participated in water safety studies within the past 4 years; worked in market research, graphic or website design, advertising, public relations, media, healthcare, or the federal government within the past 2 years; or had a job involving knowledge of HABs.

Data Collection

Eligible participants completed a screener survey by telephone; the screener survey was designed to ensure demographic diversity in the focus groups. Participants answered questions about their age, sex, race and ethnicity, education level, occupational status, and household income. The screener survey also asked about preexisting health conditions (Table 1) because some conditions could increase people's risk for severe HAB-associated illnesses (Lad et al., 2022). Participants rated their familiarity with HABs and shared their preferences for water safety information (Table 2).

Researchers used Zoom webinars to conduct four virtual focus groups in March 2024 with selected participants, segmented by the following audiences: general public (n = 2), dog owners (n = 1), and parents (n = 1). Each 60-min focus group was audio and video recorded. A trained facilitator conducted the focus groups, joined by a notetaker and silent observers. The facilitator used a semistructured guide to lead the discussions.

Data Analysis

Focus group data were analyzed using a thematic analysis approach to identify cross-audience and audience-specific themes. Two

TABLE **2** continued

Water Safety Communication Preferences of Focus Group Participants

Communication Preference	Dog Owners (*n* = 8) # (%)	Parents (*n* = 7) # (%)	General Public (*n* = 12) # (%)	All Participants (*N* = 27) # (%)
Most helpful social media platform for water safety information [c]				
X (formerly Twitter)	3 (38)	3 (43)	3 (25)	9 (33)
Facebook	5 (63)	5 (71)	9 (75)	19 (70)
Instagram	5 (63)	5 (71)	5 (42)	15 (56)
TikTok	2 (25)	2 (29)	5 (42)	9 (33)
YouTube	4 (50)	4 (57)	7 (58)	15 (56)
Pinterest	0	0	1 (8)	1 (4)
Snapchat	0	0	0	0
Nextdoor	0	0	0	0
Something else	0	0	0	0
Preferred format to learn more about water safety [d]				
Print materials	4 (50)	2 (29)	8 (67)	14 (52)
Webpages	5 (63)	5 (71)	8 (67)	18 (67)
Videos	5 (63)	6 (86)	10 (83)	21 (78)
Email listservs	4 (50)	1 (14)	3 (25)	8 (30)
Text messages	4 (50)	4 (57)	5 (42)	13 (48)
Something else	1 (13)	2 (29)	0	3 (11)
Not interested	0	0	0	0

Note. Participants were able to select all answers that applied for the questions used to collect data presented in this table. Therefore, percentages for each topic could total >100%.

[a] Participants were asked, "Where do you go for information about water safety related to visiting lakes, rivers, or other water bodies?"

[b] Participants were asked, "Who do you trust as a reliable source of information on water safety?"

[c] Participants were asked, "Thinking of the social media platforms you use, where would it be most helpful to get information about water safety? And why?"

[d] Participants were asked, "How would you want to learn more about water safety? And why?"

researchers applied a set of deductive codes to the four focus group transcripts using Atlas.ti software, achieving a moderate interrater reliability of 72% as measured by the Holsti index, a method well-suited for small data sets that quantifies the agreement between coders (Cole, 2024; McHugh, 2012). When interpreting the qualitative results from the focus groups, "few" refers to >1 and up to approximately 25% of participants, "some" refers to 26–50%, and "most" refers to ≥50%. Excel and RStudio software were used to calculate quantitative descriptive statistics from the participant screener survey.

This activity was reviewed by the Centers for Disease Control and Prevention (CDC), deemed not research, and was conducted consistent with applicable federal law and CDC policy (e.g., 45 C.F.R. Part 46, 21 C.F.R. Part 56; 42 U.S.C. §241(d); 5 U.S.C. §552a; 44 U.S.C. §3501 et seq.).

Results

Sample

In all, 32 U.S. adults who regularly visited freshwater bodies in the last 12 months were recruited, and 27 of these adults were selected to participate. Four focus groups were conducted: one with dog owners who visited freshwater bodies with their dogs (*n* = 8), one with parents who visited freshwater bodies with their children or teenagers (*n* = 7), and two with the general public (*n* = 12). Participants had a mean age of 40 years (range: 22–74 years). Of the participants, 44% identified as female, 70% as White, 74% as non-Hispanic, 78% as employed full-time, and 100% as college-educated (Table 1). In terms of median age, race and ethnicity, and sex, participants reflected the overall U.S. population (<5% difference); however, participants were more educated, more likely to be employed full-time, and had lower incomes than the U.S. population (U.S. Census Bureau, 2023). Three participants (11%) reported having one of the preexisting health conditions: asthma.

Water Safety and HAB Awareness

To determine if water is unsafe to enter, most participants across all focus groups reported relying on sensory cues, such as noticing yellow, orange, or red water; dead fish; bad smells; or an absence of people in the water. Overall, participants reported a moderate level of familiarity with HABs (*M* = 4, range:

Photo 1. Image of a body of water with a harmful algal bloom. Photo credit: iStock/Getty Images via OlyaSolodenko.

1–9; Table 1). Most dog owners had heard of the term HABs from water advisories or by word-of-mouth. Some parents were aware of HABs from internet searches, signage near lakes, or emails from campsites. Some participants in the general public had seen the term on social media or in the news. When shown an image of a body of water with a HAB (Photo 1), most participants in all focus groups reported that the water looked uninviting and unsafe to swallow. Most participants also said that they would not go into the water, but some said they would boat or kayak on the water.

Risk Perception

After the facilitator defined HABs, some participants across all focus groups expressed interest in more information about the causes of HABs and how to protect themselves. Across all focus groups, most participants perceived a low risk of harm from HABs for themselves but thought that animals, children, and immunocompromised people were at higher risk. Most dog owners perceived themselves to be at lower risk than their dogs. A few parents noted that people who were unfamiliar with safe water practices, such as checking water advisories or the color of the water, were also at greater risk. A few participants in the general public thought that being older or having open wounds would also make people more vulnerable to HAB-associated illnesses. Most participants in the general public believed themselves to be at low risk because of their good hygiene (e.g., showering after being in a body of water), young age, and robust immune system. Only a few parents and participants from the general public assumed they had a low risk of harm because they checked water advisories before visiting bodies of water. No participants reported having been sick from HAB exposure.

Terminology Preference and Information Seeking

When presented with different terms to describe HABs (Table 3), most participants in the focus groups preferred the terms toxic algae or harmful algae because they perceived the terms to be easier to understand and more attention-grabbing. Most participants in the focus groups reported looking at park signage for water advisories and complying with advisories. Some participants, however, reported that their compliance was influenced by the condition of signage. Similarly, some dog owners and parents indicated they would disregard signs that looked "deteriorated" or "old." Some general public participants reported that they would still adhere to park signage or verify the information online or with a park employee. Some parents and a few general public participants said they would not check for water advisories if they were familiar with the body of water. Participants across all focus groups also mentioned seeking information about water advisories from social media (e.g., Facebook or Instagram pages of recreational sites), government websites (e.g., CDC, state or local agencies), the news, or their own online research (e.g., Google search).

TABLE **3**

Terms Presented to Focus Group Participants to Describe Harmful Algal Blooms

Term
Blue-green algae
Cyanobacteria
Cyanobacteria (blue-green algae)
Harmful algae
Harmful algal blooms
Harmful cyanobacteria and algae
Toxic algae
Any other terms that participants specified

Additionally, participants reported in the screener survey that park signage (63%); park, body of water, or beach websites (56%); the news (44%); and state or local government websites (41%) were their primary resources for information about water safety (Table 2). Some participants (37%) relied on social media for water safety information, and a majority (70%) identified Facebook as the most useful platform. Most participants considered park staff (78%), state or local government (78%), academic or nonprofit organizations (70%), and the federal government (59%) as trusted sources of water safety information. Videos (78%) and webpages (67%) were the preferred methods to learn more about water safety.

Discussion

Awareness

Our findings add to previous research that has suggested that information on HABs is not consistently reaching U.S. adults and therefore efforts to improve communications about HABs are warranted (Goodrich & Tong, 2024; Jacobi et al., 2024). Further-

more, awareness of HABs is not necessarily indicative of an understanding of the risks of HABs (Goodrich & Tong, 2024; Larkin & Adams, 2008)—but awareness is the first step for people who use bodies of water recreationally to build the knowledge needed to prevent HAB-associated illnesses.

Risk Perceptions and Behaviors

While awareness and knowledge influence perceived risk and behaviors, other factors such as previous experiences, assessments of the pros and cons of compliance, level of trust in public institutions, and social networks also influence behavior (Brisson et al., 2017; Cahyanto & Liu-Lastres, 2020; Gill et al., 2018; Van Dolah et al., 2016).

Even focus group participants who were aware of HABs generally did not think HABs were a significant health risk for them personally. Participants recognized children and dogs as high-risk groups, so parents and dog owners might pay attention to information on HABs related to risks for children or dogs more than information about risks for themselves.

Similar to previous reports (Brisson et al., 2017; Goodrich & Tong, 2024; Kuhar et al., 2009), focus group participants cited personal characteristics and behaviors (e.g., rinsing off after going in bodies of water) as reasons they would be less at risk. Notably, checking for and following water advisories—which is one of the most effective ways to avoid HAB exposure—was cited by only a few participants as a reason they expected not to get sick.

Participants' lack of direct experience with negative health effects from HABs might have been important in shaping these perceptions of low personal risk. Goodrich and Tong (2024) found that people who use bodies of water recreationally who had not experienced HAB-associated health issues felt immune to HAB risks, whereas Kuhar et al. (2009) reported direct experiences with HAB impacts caused higher levels of concern.

Although the appearance and smell of water are not always reliable indicators of quality, most focus group participants judged safety based on these factors. This finding aligns with previous findings that sensory cues are important for assessing water quality (Votruba & Corman, 2020; West et al., 2016). Our results also highlight that these perceptions are subjective; water that looks safe to one person could appear unsafe to another. Likewise, Lavery et al. (2023) examined responses from people who had self-reported HAB exposures, and 45% said the water they were exposed to was discolored, which did not appear to dissuade them from entering.

Our results suggest that there could be opportunities for officials to improve access to HAB advisories, promote advisories as a reliable source of water safety information, and educate the public on the limits of using sensory cues alone to judge water safety.

Advisory Compliance

Advisories help officials communicate risk to people who use freshwater bodies recreationally; these advisories can reduce recreational activities depending on the person and situation (Hardy et al., 2016). Some people will avoid contact with water during HABs to protect their family's health, but other people disregard advisories because avoiding the water entirely would be too disappointing (Brisson et al., 2017; Goodrich & Tong, 2024).

Most focus group participants reported looking at and complying with water advisory signage. Our findings, however, suggest a need to prioritize reaching frequent visitors to local bodies of water and keeping signage updated. Similarly, other researchers have found that the public wants timely HAB information and that signs lose effectiveness over time (Ames et al., 2023; Hardy et al., 2016; Hoagland et al., 2020).

Information Seeking

Consistent with previous research (Ames et al., 2023), our results suggest that people who use freshwater bodies recreationally are receptive to learning more about HABs and how to avoid toxic algae exposure. Capitalizing on this interest to develop clear and resonant risk communications can improve the likelihood that the public will take measures to protect their health (CDC, 2024c).

Terminology

Freshwater HABs are described using a variety of terms, with no single term consistently used in health communications in the U.S. Study participants strongly preferred the descriptive and simple terms harmful algae and toxic algae. Other researchers have also noted that avoiding technical language in risk information for the public can result in better understanding and increased risk mitigation (World Health Organization, 2017) and that public audiences prefer simple language in HAB communications. Gill et al. (2018) reported that Lake Erie anglers described the HAB acronym as unfamiliar and preferred the terms harmful algae or algae. Public health practitioners might want to consider using simple terms such as harmful algae or toxic algae to describe HABs in public communications unless local audience research indicates different preferred terms.

Trusted Sources

Focus group participants reported high trust in officials for information about recreational water safety. Not all public audiences, however, share this trust in officials. Previous research has found that residents near Lake Erie, a body of water with a history of severe HABs, distrusted government officials and institutions that manage water quality issues (Ames et al., 2019; Gill et al., 2018; Guo et al., 2019). Some of these residents reported more trust in people or entities they perceived to have less of an agenda or political stake in HAB communications, such as peers or independent researchers (Ames et al., 2019; Gill et al., 2018). These results highlight the importance of considering local context, previous experiences with HABs, and trusted sources of information for intended audiences when developing HAB communication strategies.

Preferred Channels and Formats

Consistent with other research (Ames et al., 2023; Gill et al., 2018; Goodrich & Tong, 2024; Hardy et al., 2016; Liu-Lastres & Cahyanto, 2021), focus group participants were interested in receiving HAB information and advisories through a variety of channels. Overall, participants identified signage near water, park or government websites, the news, and social media (primarily Facebook) as the most useful channels, and participants reported that videos and webpages were their preferred formats. Preferences varied by audience segment, however, which is consistent with prior research (Clites et al., 2024; Nierenberg et al., 2010; Wolkin et al., 2019).

Application

Although our study was limited in scope, public health practitioners can use these

study insights to guide future research and consider the results when developing HAB communications for the public in the absence of audience research with their intended audiences.

Limitations

Focus group discussions prioritize in-depth understanding over population representativeness that is achievable via rigorous sampling methodologies. Our convenience sample of participants was not representative of U.S. residents who are dog owners, parents, or freshwater recreation users, and therefore the findings cannot be generalized to the general population. Although focus group facilitators aimed to provide a nonjudgmental environment and emphasized confidentiality, participants could have provided socially acceptable responses instead of their true opinions or experiences due to social desirability bias. Last, the moderate interrater reliability indicates some variability in how coders interpreted and categorized responses, potentially introducing subjectivity into the analysis.

Conclusion

Our findings support continued efforts to improve prevention strategies for illnesses caused by freshwater HABs. Public health practitioners might consider using these results to inform HAB risk communications for people who use freshwater bodies for recreation in the U.S., particularly where HABs are a new problem and local research about communication needs is lacking.

Raising awareness about the health risks of HABs and educating the public about reliable ways to assess recreational water safety (e.g., advisories) could encourage individuals to take more protective actions. Officials should consider posting HAB advisories on multiple channels (e.g., official webpages, social media, on-site) and ensure that signage is prominently displayed, includes a date or otherwise appears current, and uses HAB terminology that is preferred by local freshwater recreational users.

Providing risk information that addresses the safety of children and dogs could also help officials reach parents and dog owners. Examining the attitudes, behaviors, communication preferences, and trusted sources of specific audiences could further improve targeted HAB communication strategies and messaging.

Additional research using representative samples is needed to confirm our findings and better understand the nuances of how people perceive HAB advisories issued by officials and what water activities people who use bodies of water recreationally deem safe when they encounter water that looks or smells as if it could have HABs.

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