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Aligning Audience Needs with Scientists' Information in the Complex Harmful Algal Bloom Outreach to Engagement Continuum

Erica Clites[1], *Heather Triezenberg[2], Diane Doberneck[3]

[1]*Michigan Sea Grant, Michigan State University Extension, Detroit, MI*
[2]*Michigan Sea Grant, Michigan State University Extension, Fisheries and Wildlife Department, East Lansing, MI*
[3]*University Outreach and Engagement, Community Sustainability Department, Michigan State University, East Lansing, MI*
**Corresponding author*

Abstract: Algae, an important foundation of aquatic ecosystems, can become a nuisance or harmful when it grows in excess. Many government agencies have a role in monitoring, responding to, and confirming a harmful algal bloom (HAB). HAB scientists have important information to share, however, given the complexities of HABs, which often involve decoupled drivers from observed impacts, presents challenges to outreach and engagement. Understanding key audience information needs can help scientists prioritize key science communication and engagement opportunities to maximize the impact of such efforts. Scientists may need additional science communication training or support for scientist-community partnerships. This will be evermore important into the future with the likely range expansion of HABs due to climate change.

Keywords: *harmful algal blooms, science communication, outreach to engagement continuum, scientists, audiences*

Algae is an important foundation to the aquatic ecosystem and is dependent upon nitrogen or phosphorus (EPA 2024a). However, too much nutrient input can produce too much algae, resulting in nuisance algal blooms that often contain toxins (i.e., cyanotoxins, etc.) that cause them to be labeled harmful (EPA 2024a). Harmful algal blooms (HABs) occur in inland waters, the Great Lakes, and around the world (Carmichal and Boyer 2016). HABs are expected to increase in frequency due to warming temperatures and abundant nutrient inputs from point sources (e.g., wastewater treatment plants) or nonpoint sources (e.g., agricultural, residential, or commercial land uses) (Carmichal and Boyer 2016; EPA 2024b). In the Great Lakes region, this means range expansion to northern parts of lakes Michigan-Huron and Superior, as well as inland waters of the Upper Midwest. Through direct or indirect exposure, HABs can have many impacts on aquatic ecosystems, human and animal health (e.g., livestock or companion animals), as well as recreational activities such as swimming, fishing, boating, or kayaking (Hird and Baden 2023).

In the Great Lakes region, harmful algal blooms are annually persistent in Lake Erie's western basin (Stumpf et al. 2012). On August 2, 2014, a half million residents of Toledo, OH and the surrounding area woke to a message that they should not use their drinking water starting immediately due to the presence of algal toxins in the municipal water. It took three days to resolve the issues and restore safe municipal water supply. While it has been nearly a decade since that event, HAB risk remains because of available nutrients. Point sources of wastewater treatment, resuspended legacy phosphorus in Western Lake Erie, and excess agricultural nutrients from the surrounding watershed are driving Western Lake Erie basin's HABs. In response, nutrient reduction targets were established, and much progress has been made. The agricultural community is a leader

Research Implications

- Key audiences of lake associations and local governments need information on general aquatic ecology and the role of algae, harmful algal bloom (HAB) monitoring and responses, and treatment options. Making the information visual and easily shareable on social media will improve the likelihood of its use.
- HAB scientists rate science communication highly, so ample opportunity exists to bridge the science policy implementation gap. However, scientists do not have to do it all. When they understand the needs of key audiences, they can prioritize efforts for effective science communication to maximize the impact of their work.
- Coordinating with local governments who have shared responsibility for HAB responses can be useful to overcome unintentionally providing misleading information on who has what role in HAB monitoring and response.
- Resources are available to help scientists on the continuum of outreach to engagement, including science communication training or facilitating partnerships.

in recommending the 4R system to help cropping systems producers determine the right fertilizer to use, at the right rate, at the right place, and at the right time (Bruulsema et al. 2009) to achieve nutrient reduction targets. However, additional research is needed to address remaining questions such as predicting HAB occurrence and toxicity, who is most at risk, what information they need, etc.

The Great Lakes Center for Fresh Waters and Human Health (hereafter Great Lakes Center) was established with funding from the National Institute of Environmental Health Sciences (NIEHS) and the National Science Foundation (NSF) in 2018. The Great Lakes Center is a collaborative effort among ten research institutions to understand and prevent toxic algal blooms. Community engagement cores are common in the NIEHS funded centers with the purpose of fostering university-community partnerships, conveying community voice to researchers, and producing innovative and culturally appropriate research translation outputs (NIEHS 2023). The range of relationships between university researchers and communities can be described as a continuum from lower levels to higher levels of community participation. Lower levels may be referred to as outreach (e.g., alert or inform), with higher levels referred to as engagement (e.g., collaboration or co-create) on the continuum (Carson et al. 2022). At different stages on the continuum, public participation achieves different purposes, is organized in different ways, and employs different techniques–all aligned to achieve community and university results. Community is defined as entities beyond college or university campuses, who share an identity defined by geography, identity, affiliations, interests, professions, practice, faith, family, or circumstance and include multiple intersections of community identity (Ife 1995; Mattessich and Monsey 1997; Wenger 1998; Marsh 1999; Wenger et al. 2002; Fraser 2005; Gilchrist 2009; Doberneck 2022). Public engagement requires specificity and nuanced understanding of "the public audiences" so that outreach and engagement efforts are effective.

One of the Great Lakes Center community engagement goals was to conduct a stakeholder needs assessment for the Great Lakes and environmental health literacy to inform general outreach information needs. Given the challenges of decoupled sources of excess nutrients from likely impacts of HABs now or in the future, it is important to understand the perspectives and needs of the people who are likely experiencing impacts from HABs or responding to HABs in Western Lake Erie and more generally throughout the Great Lakes region, including inland waters. Each audience has a specific communication mode, preferred content, and evidence for credibility, accessibility, and timeliness (Baron 2010; Bogenschneider and Corbett 2010; Doberneck et al. 2017). Clarifying the audience, their information needs, when they need the information, and their preferred format to receive information in are all important aspects of oceans and human health community engagement (Carson et al. 2022). Two audiences in particular are notable because of their unique roles and interests: (1) lake associations, representing waterfront

homeowners, and (2) local governments, including drain and water commissions, lake improvement boards, etc. Segmenting the public into specific groups based on what they have in common can lead to more effective science communications and outreach strategies. In HAB work, for example, scientists would use different strategies to reach K-12 teachers (community of profession/practice), recreational boaters (community of interest), or homeowners on inland lakes (community of circumstance). Outreach goals informed by the end user and strategies in alignment with their preferences will help reduce failures, including eroding time and trust (Carson et al. 2022). Effectively achieving outreach goals also depends on the preparation and skill of the science communicator. In the context of science relevant for society, as in the case of HAB researchers, they may be asked to communicate about their research or do so because of their interest in informing policy or practice. In other cases, a HAB researcher may collaborate with others to produce important public health monitoring information such as the case of Lake Champlain community science for cyanobacteria (Vaughan et al. 2021).

In this manuscript, we start with the end in mind and: (1) describe information needs from key audiences likely impacted by or responding to HABs, (2) document HAB scientists' interests in and approaches to science communication, (3) align audience information needs with scientists' assets in two recommended practice case examples, and (4) conclude with training and support opportunities for HAB scientists.

Methods

Three open-ended group interviews were held with four individuals total representing key audiences of lake associations (i.e., waterfront homeowners). One open-ended group interview was held with four individuals from agencies responsible for responding to HABs. The agency representatives had public health or natural resource management expertise but were not conducting research. Both sets of interviews were conducted during February - May 2021 (Appendix A; IRB #5273). They were asked three basic questions about what they already know about HABs, what types of data and figures are and are not useful to them, and what do researchers need to know in order to successfully communicate with them, along with several follow-up probing questions. Interviews were conducted and recorded using Zoom video conferencing software. The recording audio was used in the analysis, which consisted of one of the authors conducting a thematic analysis (Sovacool et al. 2023). Thematic analysis involves identifying emergent themes and patterns from the data that might overlap and lack consistency, yet tell an important story (Rubin and Rubin 2005; Sovacool et al. 2023).

Twelve Great Lakes Center scientists were interviewed April - June 2020 (Appendix B; IRB #3910). They were asked 13 open-ended questions, ranging from inviting the scientist to describe their: research; its outcomes; audiences of their research; how they reach their audience; who they work with; how they rank science communication; training needs; what support they needed from the Great Lakes Center community engagement core; what skills; preferred mode and timing of training is preferred; snowball referral to other potential interviewees; and anything else they would like to add. Zoom interviews were conducted and recorded and transcripts were produced. Analysis was completed by one of the authors of this manuscript who reviewed transcripts to identify emergent themes from the interviews (Rubin and Rubin 2005). The other authors reviewed the themes and corresponding descriptions throughout the writing process.

Results

What Do Key Audiences Need, When, and How?

Key audiences have specific needs, regardless of what information is being received, heard, or shared by scientists. Two audiences in particular are notable because of their unique roles and interests: (1) lake associations, representing waterfront homeowners, and (2) local governments, including drain and water commissions, lake improvement boards, etc.

Both audiences need information on the importance and complexity of algae. It is an

important base of the aquatic food web. However, if too much, it becomes a nuisance at best and harmful with cyanotoxins at worst. They also need information on algae identification, lake-nutrient management, and long-term strategies for reducing the likelihood of algae becoming nuisance or harmful. Late winter is the best time to provide this information.

Lake associations need information on understanding the trophic state of their lake and appropriate nutrient management for it. Additionally, lake associations want information on how HABs likely impact property values and perception of the lake. During the summer or fall, when suspected algal blooms are more likely to occur, they need just-in-time resources such as who to contact, testing procedures, treatment options, and how to screen environmental firms. Because local health departments decide when and where to post signage alerting people about the presence of HABs, communication about why they are making those decisions, as well as when county health departments decide to remove the sign, would be beneficial to lake associations.

For lake associations, visual communication, such as social media-ready text, graphics, and brief videos, along with 1-2-page fact sheets on algae and additional resources are the preferred communication approaches. There is much confusion about the roles and responsibilities among state, county, and municipal governments, resulting in people not understanding the different roles and unintentionally providing unhelpful information. Therefore, coordinating with local governments would be an effective approach to facilitate the various entities becoming acquainted with each other, understand their role, and what resources on HABs they can provide to lake associations when asked.

Scientists' Intended Audiences and How They Are Reaching Them

Almost all Great Lakes Center respondents (n=11) described the main output of their research as scientific papers and informing public policy and natural resource managers. The intended audience for their research ranged from other researchers or scientists, specifically bloom toxin forecasting scientists, policy makers, science communicators who provide information to stakeholder groups (e.g., fisheries, tourism, or watershed groups), broader community, general public, news media, anglers, and natural resource managers (e.g., fisheries, land, general agencies).

Respondents identified outreach efforts as including attending annual professional meetings, writing perspective pieces in major publications, inviting people to collaborate, and utilization of traditional media (e.g., press releases, local television and radio broadcasting, such as *Great Lakes Now* or *The [Toledo] Blade*). Respondents also utilize digital media such as websites and social media (e.g., Facebook and Twitter, now called X). Respondents also described traditional outreach materials, such as flyers, one-page fact sheets, or visual infographics. Traditional outreach presentations, such as a student talk at an event, attending small group meetings, or responding to stakeholder inquiries were described as well. Inviting the intended audience to partner with and participate in community science (e.g., charter boat captain study, coast guard sampling, customized data reports) was also described as other outreach efforts.

Respondents noted that the public health and clinical health fields (e.g., public health officials or researchers, toxicologists, emergency room doctors, and pharmaceutical or drug developers) are important audiences, but one that they have not communicated with much. Other audiences including water infrastructure managers, farmers, lake associations, and students (i.e., high school or college) were described by some respondents. Most scientists surveyed were primarily in communication with one or two stakeholder groups, rather than all of the stakeholders identified.

Scientists Working Along the Outreach to Engagement Continuum

Respondents rated science communication highly (average = 4, standard deviation = 0.9 on a 1-5 scale with 1 = low priority and 5 = high priority) compared to other research priorities, such as publishing papers, presenting at conferences, processing samples, applying for funding, etc. Three-quarters of Great Lakes Center respondents indicated science communication skills as a high priority need. These included translating research

results for broader audiences, communicating risks and hazards, choosing what to talk about with the public, and how to frame the significance of their work. Moreover, scientists described the need for support to format data sheets for citizen science efforts or to create fact sheets or white papers about human health issues for the public. Respondents also expressed a desire to have an outreach or engagement professional observe a training or lab tour (where algal toxins are analyzed) and provide feedback on what aspects help participants learn about algal science and laboratory procedures. Similarly, some respondents also indicated an interest in having someone evaluate the long-term impacts of their outreach efforts.

Multiple scientists mentioned that their outreach to certain groups grew by working through organizations like Ohio Sea Grant or state environmental agencies. For others, people from local organizations would recognize the scientist's name and contact them directly about interpreting their data. Other scientists described leveraging existing resources, such as their department's communications staff members, to widen their reach. Without partnerships with communications professionals, scientists would not have adequate time, capacity, or funding to do their own outreach. Still, others described finding key allies within the community and to utilize them as communicators to their neighbors and friends to share relevant information. Finally, some respondents recommended coordinating communication within the Great Lakes Center and among the other NIEHS/NSF Oceans and Human Health Centers for consistent messages. The outcomes of such efforts would be amplifying colleagues' work, facilitating conversations about the tools researchers need to do their work, and reminding scientists that communicating with the public is important.

Discussion

The good news is that key audiences likely affected by or responding to HABs do want information that scientists can provide. Scientists do not need to do multiple types of activities along the outreach to engagement continuum themselves. While there are some general education messages about algae as an important foundation of aquatic ecosystems, nuanced messages such as algae is good, when not too much and depending on appropriate nutrients, are also needed. If scientists, science communicators, or boundary spanning organizations ask their key audiences (or partners) what their information needs are, when they would like to receive it, and in what format they need it, they can maximize the impact of limited resources (adapted from Carson et al. 2022). Essentially this is being strategic about outreach and engagement activities, similar to the 4R approach of right time, right place, right amount, right type of fertilizer needed (Bruulsema et al. 2009). Below, we describe two recommended practice case examples.

Suggested Practice Example 1: Providing Needed, Timely Information to Lake Associations (i.e., Waterfront Homeowners).

Lake associations are officially comprised of waterfront property owners for the purpose of maintaining the quality of the inland lakes. They often have a variety of goals for lake management, including monitoring, treatment, fish stocking, aquatic habitat, etc. In the winter months (i.e., January - April), they want general information on aquatic and lake ecology, HAB research, specifics about their lakes, and long-term management and treatment options. Reaching them at the statewide annual conference (i.e., Michigan Lakes and Streams Association meeting) is recommended since representatives from multiple lake associations can access the necessary information and share with their respective lake association members. While conferences often have traditional formats, presenters can also provide algae fact sheets (1-2 pages) along with directions for digital access of resources, such as social media-ready text, graphics, and brief videos, on algae, HABs, and additional resources. Keep the audience in mind, making it easy for them to access and share the information. When a probable HAB outbreak occurs, likely in July - August, lake associations also need access to resources to visually identify the species, determine who to contact, testing procedures, treatment options, and how to screen environmental firms. Additionally, lake associations also need to know why decisions about posting signs alerting HABs are made and when it is appropriate to remove the sign.

Suggested Practice Example 2: Supporting Scientists with Communication and Engagement Skills.

It is promising that HAB scientists rated science communication skills as a high priority. To support this interest in having their research make an impact on policy and practice, scientists should consider additional training in science communication (Table 1) or engagement and partnerships (Hunnell et al. 2020). If scientists are not comfortable conducting direct outreach to the public, they can work with their university or departmental communications staff to make sure the important ideas emerging from their research are shared with the public. Institutional communications staff can create figures for cover articles in high-profile journals, as well as work with the communications office to send out press releases or other information about their recent research.

Similarly, to support scientists' interest in effective engagement, boundary spanning organizations, such as Sea Grant, Great Lakes Center community engagement cores, or others, can connect scientists with key audiences seeking their relevant science-based information. These professionals can help scientists discern what the best communication approach is for their work, create templates or communication materials using data provided by scientists, assess scientists' efforts, and facilitate partnerships among different groups. Collaborating with partner organizations requires the long-term investment as it involves regularly attending meetings and learning more about the needs of the group before figuring out what gaps in communication or information availability may exist. For example, an online dashboard focusing on

Table 1. Science communication training and other resources, 2023.

Name	Resources
COMPASS https://www.compasssscicomm.org/	Trainings Message Box Toolkit
Alan Alda Center for Communicating Science https://aldacenter.org/	Trainings
American Association for the Advancement of Science-Public Engagement https://www.aaas.org/programs/public-engagement	Toolkit Trainings Fellows Programs
Advancing Research Impact in Science https://researchinsociety.org/	Webinars Annual Summit Fellow Program Small Grants Awards
Portal to the Public https://popnet.instituteforlearninginnovation.org/	Workshops for researchers to learn informal science education teaching techniques to use at museums, zoos, aquariums, and science centers
Scholars Strategy Network https://scholars.org/	Workshops for researchers to communicate with policy makers
The Conversation https://theconversation.com/us	Workshops and online platform for researchers to communicate with journalists
Association of Science Communicators https://www.associationofsciencecommunicators.org/courses-training-opportunities/	Workshops Trainings

human health risks from HABs was an innovative science communication output of the Great Lakes Center partnerships. Eventually, the approach leveraged additional funding and was transferred to inland counties to identify areas where people are at greatest risk from HABs because of the likely prevalence and expansion of HABs due to climate change (EPA 2024b).

Moreover, boundary spanning for engagement with and coordinating among multiple governmental levels are important. Michigan is a local (or home-rule) government comprised of 1,240 townships, 275 cities, 258 villages, 14 planning and development regions, 83 county governments with an equal number of drain commissioners (Michigan Legislature 2010), and over 1,000 intercounty drainage systems with governing boards (MDARD 2022). There are multiple levels of government involved with local water resource issues contributing to a complex and sometimes confusing operating environment, even for those who work within those roles. Helping local units of governments work together to anticipate the occurrence of HABs and respond when HABs do occur is extremely helpful.

Conclusion

Algae is an important foundation of aquatic ecosystems, however, when growth becomes excessive, the algae may become nuisance or harmful to humans or animals. Understanding key stakeholders' information needs is an important step in aligning science communication messages, timing, and format. Moreover, this information will help scientists and other science communicators prioritize the information available to what is relevant and timely for its audience since they have expert knowledge about HABs. Scientists may need some additional support in how to effectively communicate timely, relevant, and nuanced information to key audiences, especially for lake associations (e.g., waterfront homeowners) and local governments. Training and coaching scientists is key so that they can specialize in communication with a particular audience or a particular method of communication, and also help focus and frame their outreach to engagement activities, just like their scientific discipline. Supporting scientists on facilitating or leveraging partnerships is also beneficial in the likely expansion of HABs due to a changing climate. A growth opportunity through partnering with public health officials, medical researchers and clinicians, veterinarians, and livestock farmers could be an important future direction for One Health (CDC 2024) outcomes.

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Author Bio and Contact Information

Erica Clites is an Extension Educator for Michigan Sea Grant with Michigan State University Extension. She works with local communities, agencies, and other partners and networks on initiatives such as habitat restoration and coastal community development. She is also coordinating bi-monthly meetings of partner agencies and organizations who do harmful algal bloom outreach and engagement in Michigan. She may be contacted at 1360 Oakman Blvd., Detroit, MI, USA, Phone: 313-494-4678, clitese1@msu.edu.

Heather A. Triezenberg (corresponding author) is Associate Director and Extension Program Leader for Michigan Sea Grant with Michigan State University Extension. She provides leadership and operations support for Michigan Sea Grant's outreach program through MSU Extension's Community, Food, and Environment Institute, and is jointly appointed with the Fisheries and Wildlife Department and affiliated with the MSU Institute of Water Research. Her research focuses on Extension-based needs assessments, evaluation, and public perceptions using community-engaged approaches. She may be contacted at 446 W. Circle Drive, Justin S. Morrill Hall of Agriculture, Room 73, East Lansing, MI, USA, Phone: 517-353-5508, Fax: 517-884-8511, vanden64@msu.edu.

Diane Doberneck is the director for faculty and professional development in University Outreach and Engagement and Adjunct Associate Professor in the Department of Community Sustainability at Michigan State University. She provides leadership for University Outreach and Engagement educational programs, coordinates a Graduate Certification in Community Engagement, and conducts research about community-engaged scholarship. Her research interests are many, including effective strategies for professional development for stakeholder and community engagement, especially related to sustainable communities and environmental conservation. Connect with her at connordm@msu.edu.

Appendix A. Great Lakes Center for Fresh Waters and Human Health informal needs assessment interview questions for stakeholders, 2021.

1. What do you already know about HABs?
    a. What causes them, why are they harmful, etc.? We can provide 5 "must know" facts about HABs if needed.
    b. Have you sought information on HABs before? If so, where? What was helpful?
    c. If you've had a HAB/nuisance algae, who did you contact?

2. What types of data/figures are useful to you? Which are not?
    a. What is your most requested type of information?
    b. What kinds of outreach products do you use most frequently?
    c. Have any of your constituents/customers commented on a particular outreach product (i.e. Have you had positive/negative feedback on something you've distributed?)
    d. (Understanding the informational needs of these groups).

3. What do researchers need to know in order to successfully communicate with you right now?
    a. What is the most useful product to you to help you reach the rest of your constituency? Pamphlets, powerpoint, video clips, panel discussion (with Q&A?) radio/TV ad, newspaper article, billboards?
    b. Timing of the products (WHEN is it helpful to know this information?)

Appendix B. Great Lakes Center for Fresh Waters and Human Health research communication and engagement interview questions for scientists, 2020.

1. Will you describe your research within the scope of the Great Lakes Center for Fresh Waters and Human Health in 2-3 sentences? That is, give me your "elevator pitch".
    a. How would you describe yourself using an "-ist" term? i.e. microbiologist, ecologist, etc.

2. What are the ultimate outcomes of your research project?
    a. Manuscripts to scientific journals, law/policy implications, land management?

3. Who is the intended audience of your study and/or results?
    a. Scientific community, land managers, community partners, anglers, recreational communities, health professionals

4. How do you currently reach your intended audience? In your opinion, which have been the most successful?
    a. Professional society meetings, reports, flyers, mailings, informational presentations, press releases, white papers, community forums

5. Who are the stakeholders in your work? And do they differ from what you consider your "community" with which you like to engage?

6. How do you currently engage your stakeholders in your work? Does that differ from how you engage your "community"?

7. On a scale of 1 to 5 (1 being low priority, 5 being high), how do you rank communicating your results to the public among your other study priorities?

8. (ASK ONLY IF ASSOCIATED WITH CENTER) How would you like to interact with the CEC? That is, are there particular aspects of your work with which the CEC may be able to help? (generate "wishlist")

9. What concepts would you like to expand on in a training?

   a. Science communication, community engagement

10. What hard skills would you hope to gain through a training?

   a. Meeting facilitation, conflict resolution, creating an effective presentation/one-pager

11. What format do you prefer in a training? What timing works best for you?

   a. In person, webinar, pre-conference session at an existing meeting, online module

12. Is there anyone that you suggest we interview?

13. Is there anything else that you would like to add? Any question you wish I had asked?

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