Title

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Journal
Ethnicity & disease, 32(4)

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Publication Date
2022

DOI
10.18865/ed.32.4.285

Peer reviewed

Original Report:
Global and Rural
Health Disparities

Knowledge Sharing to Reduce Toxin Exposure Risks from Harmful Algal Blooms: Global Networks and Political Barriers

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Harmful algal blooms (HABs) are a significant global environmental management challenge, especially with respect to microalgae that produce dangerous natural toxins. Examples of HAB toxin diseases with major global health impact include: ciguatera poisoning, paralytic shellfish poisoning (PSP), amnesic shellfish poisoning (ASP), diarrhetic shellfish poisoning (DSP), and neurotoxic (brevetoxin) shellfish poisoning (NSP). Such diseases affect communities globally and contribute to health inequalities within the United States and beyond. Sharing data and lessons learned about the factors determining bloom occurrence and associated exposure to contaminated seafood across locations can reduce public health risks. Knowledge sharing is particularly important as ongoing global environmental changes seem to alter the intensity, location, and timing of toxic HAB events, reducing the reliability of conventional guidance where toxin risks have been endemic and leading to emerging challenges in new settings. Political changes that disrupt membership in knowledge-sharing networks may impede efforts to share scientific expertise and best practices. In this commentary, we stress the importance of community and expert knowledge sharing for reducing HAB risks, both for vulnerable communities in the United States and globally. Considering the impacts of political changes, we note the indirect engagement sometimes required for continued participation in international coordination programs. As an example, we highlight how lessons learned from a Native-led toxin monitoring and testing program (the Southeast Alaska Tribal Ocean Research partnership) can inform programs in other settings. We also describe how international knowledge is mutually valuable for this program in Southeast Alaska. *Ethn Dis*.2022;32(4):285-292; doi:10.18865/ed.32.4.285

Introduction: Harmful Algal Blooms and Health Impacts

Harmful algal blooms (HABs) occur in all aquatic ecosystems and are a significant global environmental management challenge for coastal and inland communities, especially with respect to algae that produce dangerous natural toxins. In freshwater environments, HABs threaten drinking water availability and recreational activities, while in marine and estuarine habitats, HABs may trigger foodborne poisonings. Here, we focus on marine HAB toxin-linked diseases with major global health impact, namely, diarrhetic shellfish poisoning (DSP), ciguatera poisoning, amnesic shellfish poisoning (ASP), paralytic shellfish poisoning (PSP), and neurotoxic (brevetoxin) shellfish poisoning (NSP).[1–4] Together with ciguatera poisoning, DSP is regarded as the most common harmful algal toxin-linked marine poisoning, with gastrointestinal symptoms that typically resolve after 2-3 days.[4] DSP-linked toxins include okadaic acid, which is a tumor promoter that may also increase risks of colon cancer.[5] Ciguatera poisoning affects 10,000-50,000 people annually and is most commonly tied to the consumption of carnivorous reef fish, although outbreaks have

Keywords: Harmful Algal Blooms; Shellfish Poisoning; Ciguatera Poisoning; Information Dissemination; International Agencies; Alaska Natives

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also been tied to the consumption of some invertebrates (eg, giant clams).[3] ASP leads to gastrointestinal and/or neurological symptoms and death in severe cases.[2] PSP can also be fatal, with death within 2-12 hours after consumption and child mortality rates are as high as 50%.[2,6] In addition to gastrointestinal and/or neurological symptoms with the consumption of contaminated shellfish, brevetoxin exposure contributes to respiratory ailments, particularly among populations at increased risk from preexisting conditions such as asthma; and, the distribution areas of brevetoxin-linked blooms are expanding.[7,8]

> *Primary prevention of algal toxin poisonings and associated health disparities requires anticipation of when and where the blooms and toxins that cause disease are likely to occur, which necessitates data collection, modeling, and knowledge sharing.*[11]

HAB toxin-caused diseases also contribute to health inequalities. Within the United States, the culturally central consumption of non-commercial shellfish elevates PSP risk for Alaska Native communities. Approximately 20% of Alaska Natives report a history of PSP, and the prevalence ratio for PSP history comparing Alaska Natives to non-Natives is 11.6.[9] In Florida, Hispanics have high exposure to ciguatera risk factors and disproportionately high ciguatera poisoning incidence rates.[10] Primary prevention of algal toxin poisonings and associated health disparities requires anticipation of when and where the blooms and toxins that cause disease are likely to occur, which necessitates data collection, modeling, and knowledge sharing.[11]

HABs and related toxin exposures are sensitive to environmental conditions, and anthropogenic forces seem to alter the intensity, location, and timing of toxic HAB events.[12–14] While there may or may not be more HAB risks from climate change,[15] climate change is driving increasing heterogeneity in exposures, including previously lesser-known exposures. For example, polar latitudes that do not currently have high exposure risks may experience increasing HAB events unexpected to local populations.[16–18] In addition to changing temperatures, currents, and other dynamics associated with climate change, nutrient run-off related to other anthropogenic factors also contributes to HAB events, with increasing spatial variation as globalization drives new human exposures.[19,20] These environmental shifts reduce the reliability of conventional guidance where toxin risks have been endemic and lead to new unexpected exposures for which knowledge is lacking. Given this dynamic context, studying HABs on a case-by-case basis that considers location-specific environmental parameters is critical. A need for context-specific study makes data sharing among experts and affected communities all the more important.

Importance of Knowledge Sharing

Recent research has made the case for robust and transparent risk communication, including the sharing of scientific research and monitoring data to facilitate public education and notification and reduce exposure risks.[21] This includes calls for scaling up existing HAB monitoring and forecasting to a global observing system.[22] Comprehensive knowledge sharing ensures that existing knowledge can be applied to understand new exposures. For new climate change-related risks, an improved understanding of how temperature and hydrological shifts associate with HAB events in different places can inform HAB risk assessment in places where HABs have previously not been a concern. Similar calls for global surveillance systems have been made for tracking crop diseases, also citing changing environmental conditions and gaps in information sharing.[23]

Despite the crucial importance of global knowledge sharing, national and international political changes have disrupted membership in knowledge-sharing networks and have impeded efforts to share scientific expertise and best practices. In 2017, the United States' withdrawal from UNESCO[24,25] ended US financial contributions to UNESCO Intergovernmental Oceanographic Commission (IOC), which maintains a global HAB expertise network. In this specific instance, the United States leaving UNESCO did not prevent knowledge sharing since alternative pathways enabled continued engagement with the IOC-HAB network. However, curtailed direct funding and more complicated involvement in UNESCO IOC HAB management, research, and capacity development opportunities undermined knowledge sharing. Greater difficulty accessing global networks may particularly hurt Indigenous communities and other vulnerable communities that experience chronic state disinvestment and rely on global connections to offset this abandonment. These communities especially may also welcome insights and support from similar social-cultural contexts globally.

Transparency around data monitoring, management, and availability can be turned into increased confidence in commercial markets and among the general public. However, as data on HAB events are often, but not always, linked to harvest opening and closing, product marketing, and even legal conflicts, there is some hesitation among countries and communities to share HAB monitoring data on species occurrences or toxins. Difficult-to-harmonize data and minimal reporting of environmental and human impacts data across contexts further reduce response capacities.[26] In recent decades, the trend is toward more open and timely sharing of HAB monitoring data. Nevertheless, gaps such as no established sharing mechanism for large HAB-specific datasets (eg, time-series data for deeper analysis of patterns in HAB occurrences in specific systems or locations) and claims of commercially proprietary data can limit network effectiveness.

The HAB Network within the Intergovernmental Oceanographic Commission of UNESCO

The HAB expertise network within the IOC (IOC-HAB) is a global network that aims to meet pressing knowledge sharing needs. IOC-HAB formed following growing recognition in the late 1980s and early 1990s that harmful algae and their causes and impacts were important to study to identify new monitoring and management techniques. As HAB research is necessarily interdisciplinary and as expertise was initially dispersed both within countries as well as regionally and globally, HABs became the focus of a new program in UNESCO IOC in 1991.

The IOC-HAB[27] and its governing body, the IOC-FAO Intergovernmental Panel on HABs, today provide the framework for setting international priorities for HAB research collaboration, data exchange, and capacity development. An early priority was sharing HAB event data to understand and document local, regional, and global impacts and trends, particularly events harmful to human health. Today, this global initiative is a principal component of the Harmful Algal Information System (HAIS), which combines HAB species occurrence data from the Ocean Biodiversity Information System (OBIS) with HAB event data primarily from national and regional HAB monitoring programs for seafood safety, as well as scientific research and monitoring. To develop a strong research component, the IOC partnered with the Scientific Committee on Oceanic Research (SCOR) in 2000 to develop the Global Ecology and Oceanography of HABs (GEOHAB) program,[28] which, over the following 10 years, implemented a global plan for HAB research, transcending national efforts and enabling interdisciplinary, comparative study across regions, ecosystems, and HAB species. In 2013, GEOHAB transitioned into its successor, GlobalHAB, which continues to facilitate communication among scientists and community stakeholders across the world via sponsored initiatives and a consolidated network of HAB-relevant international and regional programs and organizations. This network includes, for example, the North Pacific Marine Science Organization (PICES), the International Council for the Exploration of the Sea (ICES), the US National Oceanic and Atmospheric Administration (NOAA), the Food and Agriculture Organization of the United Nations (FAO), the International Atomic Energy Agency (IAEA), the Global Ocean Observing System (GOOS), and the Intergovernmental Panel on Climate Change (IPCC).

One of the main limitations to international HAB networks now is economic investment. While the United States supports GlobalHAB via the US National Science Foundation (NSF), the United States is absent from and does not contribute to UNESCO, GlobalHAB's other primary funding source. Active participation in international and regional knowledge-sharing networks and in international projects to analyze and share HAB data can increase general understanding of HAB risks, enhance prediction capabilities, and protect public health. However, political changes that disrupt national membership in knowledge-sharing networks impede efforts to share scientific expertise and best practices and hamper HAB risk management progress across scales, from the local to national level.

Lessons from Toxin Monitoring in Southeast Alaska

Examples of toxin monitoring and efforts to reduce exposure risks illustrate why knowledge sharing is important. We draw on a new program in Southeast Alaska to emphasize co-benefits of knowledge sharing.[29,30] In the community of Sitka, the Alaska Department of Fish and Game Division of Subsistence recorded 146,387 pounds of marine invertebrates harvested for subsistence use in 2013.[31] Shellfish harvesting features in Alaska Native artwork[32] and is part of traditional foods education for Native youth.[33,34] Despite the importance of shellfish harvesting to Native cultures, subsistence and recreational shellfish toxins are not routinely monitored or addressed by the State of Alaska.[35] With the lack of state subsistence and recreational monitoring, local tribal governments have stepped in as local risk managers, creating new partnerships that provide real-time results from samples collected at key community harvest sites.

The Southeast Alaska Tribal Ocean Research (SEATOR) network identifies local gaps in monitoring and laboratory analysis and is a model for regional, Indigenous-led monitoring programs.[36] SEATOR is a partnership of 16 tribal governments throughout Southeast Alaska led by the Sitka Tribe, which serves more than 4,000 citizens of Tlingit, Haida, Aleut, and Tsimshian heritage.[37] The SEATOR network is integral to the National Harmful Algal Bloom Observing Network (NHABON), created by the US National Oceanographic and Atmospheric Administration's (NOAA) Integrated Ocean Observing System (IOOS) and National Centers for Coastal Ocean Science (NCCOS) to promote scientific collaboration and information sharing; identify gaps in local, regional, and state monitoring programs; and support forecast systems and models. Within Alaska, participation in the Alaska Harmful Algal Bloom Network (AHABN) facilitates statewide information and resource-sharing.

The monitoring program in Southeast Alaska involves weekly sampling of coastal waters for toxin-producing algae and at least biweekly sampling of shellfish for algal toxins, with higher intensity sampling during the summer season, when biotoxin spikes are most common.[38] A community science approach is encouraged for subsistence shellfish harvesters to provide shellfish samples for research, as well as food samples for safety testing, but dedicated tribal staff ensure regular data collection. Toxin data from shellfish sampling are managed using the SoundToxins database infrastructure,[36,39] and counts of harmful algae cells from water monitoring are shared with NOAA for their Phytoplankton Monitoring Network database.[40] Toxin risk management also involves culturally relevant education around subsistence shellfish harvesting and shellfish toxins to increase understanding of poisoning risks and reduce harmful exposures. Centering Indigenous culture and values is not only contextually appropriate and important but may also increase community engagement and program sustainability.[41]

The partnership in Southeast

Alaska taps a breadth of knowledge relevant to HAB risks by merging traditional culture, knowledge, and practice with Earth science expertise. Traditional ecological knowledge is a useful starting point for context-specific study that examines exposures and risks and weighs adaptation techniques. However, new climate change impacts, such as increasing ocean temperatures, are expanding the season during which HABs are likely to occur and challenging the applicability of traditional ecological knowledge. In Alaska, HAB exposures are most common in the Southeast, but shifting environmental conditions are expanding HAB risks north, and Arctic and Sub-Arctic communities are already at risk for PSP toxin exposure.[42] Earth sciences complement experiential Indigenous knowledge by pinpointing potential causes of environmental changes and specific pathways of influence and enhancing predictive capabilities.[43]

Knowledge Sharing and Global and Rural US Populations

HABs occur globally, with still unknown exposures and risks. HAB-causing organisms thrive under specific environmental conditions (eg, temperature, water circulation), and these conditions change across space and time and are influenced by climate change and other anthropogenic factors. Sharing relevant knowledge is thus critical to continued research that seeks to understand and identify the where and when of exposures. Knowledge sharing is particularly important for populations in areas lacking robust local monitoring programs, as identifying exposure risks in these areas must rely on a more general understanding of HAB drivers and mechanisms. Both globally and within the United States, these places may be both more under-resourced and remote. The globalization of food sources makes tracking and sharing HAB data from under-monitored places increasingly important.

Knowledge sharing is particularly important for populations in areas lacking robust local monitoring programs, as identifying exposure risks in these areas must rely on a more general understanding of HAB drivers and mechanisms.

Political factors that jeopardize global knowledge-sharing networks undermine crucial HAB monitoring and predictive capacities, particularly for traditionally underserved communities within the United States and globally. Therefore, to enable communication among scientists, the general public, other stakeholders, and policy makers, these networks must be impervious to the whims of local, national, and international political actions. Essential aspects include funding, infrastructure, personnel, accessible databases, and other resources. One example of a knowledge-sharing network is the ciguatera poisoning surveillance run by the Louis Malardé Institute (French Polynesia), where health professionals and members of the public report poisoning cases to a publicly available online database and mapping system.[44]

Through strong global networks, programs such as SEATOR in Southeast Alaska can inform efforts in similar environmental and social-cultural contexts. The SEATOR partnership might serve as a model to integrate traditional ecological knowledge with analytical capacities to inform community members of toxin risks. Regional networks and projects (eg, Blue Climate Initiative) might draw on aspects of the program's culturally driven and community-led education activities or community-engaged monitoring techniques.[45,46] Other tribal networks within Alaska and California as well as First Nations in Canada have already expressed interest in using the SEATOR partnership as a model to develop similarly robust monitoring programs. These programs can synergize tribal government efforts as well as link back to national networks.

At the same time, knowledge-sharing networks can support community efforts like SEATOR by offering additional expertise and insight to further fill the neglect in state and federal support that local monitoring programs attempt to alleviate. Technology transfers of approved biotoxin testing methods from NCCOS to the SEATOR program have built regional capacity and facilitated an integrated partnership with NOAA. With emerging toxins as a potential threat, the NCCOS partnership will also provide analytical methods for testing domoic acid and okadaic acid. Regional and national networks like AHABN and NHABON have supported SEATOR's activities and are useful to understand impacts in new exposure areas. However, global networks like IOC-HAB and GlobalHAB are also critical as knowledge is rapidly changing and global networks are more expansive and inclusive.

Conclusions

New and persistent challenges to local and global HAB monitoring and poisoning prevention require comprehensive knowledge sharing. Scaling up existing HAB monitoring and forecasting systems to a global observing system may meet this need. However, national and international knowledge-sharing networks alike should be resilient to political changes, particularly those that disrupt member participation and funding. Networks tied to governmental or intergovernmental organizations offer structure and encourage wide participation but are vulnerable to political shifts that cut funding and weaken the institutions behind networks. National and international networks should be made more resilient to politics. The inclusion of local monitoring programs in networks is also invaluable. Besides filing gaps in state monitoring, local programs such as SEATOR critically enrich knowledge-sharing networks by sharing community science practices, traditional ecological knowledge, and context-specific information and data.

Acknowledgments

Funding comes from the National Institutes of Health grant number 7R01ES029165, Prevention of Paralytic Shellfish Poisoning in Subsistence Shellfish Harvest Communities of Southeast Alaska, and the T32 Cancer Prevention and Control Training Program at the University of Alabama at Birmingham.

Conflict of Interest

No conflicts of interest to report.

Author Contributions

Research concept and design: Roland, Whitehead, Berdalet, Gribble; Acquisition of data: Whitehead; Data analysis and interpretation: Enevoldsen, Gribble; Manuscript draft: Roland, Berdalet, Enevoldsen; Acquisition of funding: Whitehead, Gribble; Administrative: Roland, Whitehead, Fleming, Berdalet, Enevoldsen; Supervision: Roland, Berdalet, Gribble

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