Alaska
Harmful Algal Bloom Network

Action Plan for Harmful Algal Bloom Monitoring, Research, Outreach, and Event Coordination in Alaska

Incorporating outcomes from the 2016 and 2019 Alaska HAB workshops, and 2020 informal listening sessions

August 2021

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Acknowledgments

This report and the workshops that contributed to its production were supported by Alaska Ocean Observing System (AOOS) and Alaska Sea Grant. Thank you to all of the workshop participants for their efforts to review and discuss management, research and communication of HAB events in Alaska and determining the next steps forward. Special thanks to the workshop steering committees for their efforts in organizing these events and providing guidance in identifying the workshop objectives. Thank you to the AHAB Network members who participated in the informal listening sessions and shared their views. And thank you to all the organizations, institutions, individuals, and tribal governments who work on HABs in Alaska – your work is an invaluable source of information.

Through the efforts of NOAA's National Centers for Coastal Ocean Science (NCCOS) and the Integrated Ocean Observing System (IOOS) and using congressionally appropriated funds, the National HAB Observing Network provided funding to AOOS to hire an Alaska Harmful Algal Bloom Network Coordinator, and support improved HAB monitoring, event coordination, outreach and research collaboration.

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Table of Contents

Executive Summary

The presence of harmful algal blooms (HABs) and their biotoxins in Alaska's waters threatens the availability and safety of important commercial and subsistence shellfish resources, as well as the wild populations of fish, birds, marine mammals, and other species foraging in the marine environment. In recent years, the importance of monitoring for HABs and testing local shellfish for toxins has become increasingly apparent. To address this need on a statewide scale, the Alaskan HAB research and management community came together in a series of workshops and established the Alaska Harmful Algal Bloom (AHAB) Network in 2017. In late 2020, the first full-time AHAB Coordinator was hired through the Alaska Ocean Observing System to formalize the AHAB Network and coordinate HAB activities in Alaska.

The objective of the AHAB Action Plan is to establish the goals and actions needed for the AHAB Network to meet its mission. This document will help members of the AHAB Network, the general public, and funding agencies better understand the role, structure and activities of the AHAB Network, and will help the Coordinator efficiently achieve the goals and mission of the Network.

Through workshops in 2016 and 2019 and informal listening sessions with Network members in 2020, the following AHAB Network goals were developed:

- Community sampling programs for HABs in all regions of Alaska
- Sufficient lab facilities and testing equipment to meet Alaska's needs
- Innovative technology used for research and monitoring
- A central repository for HAB and biotoxin data and products for the state
- Forecasting models and tools for HABs in multiple regions
- Outreach and training materials developed, aggregated, and publicly available
- Effective communication and coordination plans for HAB events
- Long-term funding for the AHAB Network framework secured
- Extending AHAB activities to the Arctic

Each goal is further described in the document and specific actions to achieve these goals are outlined.

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Background

The presence of harmful algal blooms (HABs) and their biotoxins in Alaska's waters threatens the availability and safety of important commercial and subsistence shellfish resources, as well as the wild populations of fish, birds, marine mammals and other species foraging in the marine environment. The most severe and persistent HAB problem in Alaska is in the Gulf of Alaska waters with paralytic shellfish poisoning (PSP), caused by a group of neurotoxins categorized as paralytic shellfish toxins (PST) produced by marine dinoflagellates in the genus *Alexandrium*. Also of concern is amnesic shellfish poisoning (ASP) caused by domoic acid (DA), which is produced by diatoms from the genus *Pseudo-nitzschia*. Another harmful alga present in Alaska's coastal waters but at lower densities is the dinoflagellate *Dinophysis*, which can produce okadaic acid and cause diarrhetic shellfish poisoning (DSP), although cases of DSP have not yet been reported in Alaska. HABs can also form in fresh and brackish waters, primarily caused by cyanobacteria (commonly called "blue-green algae" even though they are photosynthetic bacteria rather than algae). A group of toxins called cyanotoxins can be produced and threaten fish as well as the potability of water – a serious concern for remote areas of Alaska that rely on untreated sources of drinking water. Although unrecorded in Alaska, the cyanotoxin risk will increase with a warming environment and needs to be addressed in this action plan.

Seasonal blooms of the toxic dinoflagellate *Alexandrium catenella* occur annually along the coastlines of the northeastern U.S. states (Maine to New York), temperate west coast states (Washington to California), British Columbia, and most of Alaska (Townsend et al. 2005, Lewitus et al. 2012, Vandersea et al. 2018). *A. catenella* cells produce saxitoxins (STXs), a group of more than 50 compounds collectively referred to as PSTs, which accumulate most notably in bivalves (Wiese et al. 2010). Human ingestion of shellfish tainted with these toxins may result in paralytic shellfish poisoning (PSP), a potentially fatal illness causing a variety of severe neurological and gastrointestinal symptoms (Cusick & Sayler 2013). PSTs have also been implicated in mortality of marine biota, including protected/endangered marine mammals and seabirds (Armstrong et al. 1978, Nisbet 1983, Reyero et al. 1999, Shearn-Bochsler et al. 2014, Geraci et al., 1989, Durbin et al., 2002; Scarratt et al., 2014, Lefebvre et al. 2016, Van Hemert et al. 2021).

PSTs are a serious public health threat that have been documented to cause human illness and death in the Gulf of Alaska and Aleutian Islands waters since 1799, with the most recent human fatalities recorded in 2010 (RaLonde 1996; ADHSS 2016; Trainer et al. 2014) and 2020 (ADHSS press release 07/15/2020). Occurring regularly, but exacerbated by certain environmental conditions, *Alexandrium* species can occur in abundance along the coast from southeastern Alaska through the Aleutian Islands archipelago. Coastal communities in these areas are particularly vulnerable to PST-related illness because of their dependence on shellfish for subsistence and economic and cultural livelihood. Coastal Alaska Native populations in the Gulf of Alaska / Aleutian Islands have been found to be twelve times more likely to be affected by PST than the Alaska population as a whole because of their greater use of subsistence foods (Gessner and Schloss, 1996). Recent studies in northern regions of Alaska have documented *Alexandrium* presence in these Arctic and Subarctic areas, with high cell concentrations in waters and extremely high cyst concentrations in Chukchi Sea sediments (Natsuike et al. 2013, Alaska Sea Grant 2019, Anderson unpublished data).

Increasing ocean temperature is a dominant driver of recent large-scale ecological perturbations (Pörtner & Farrell, 2008), and has contributed to a worldwide increase in the duration, frequency, and geographical distribution of HABs, a trend that is expected to continue over the next few decades (Dale et al., 2006; Edwards et al., 2006; Moore et al., 2008; Paerl & Huisman, 2008; EPA 2013, McCabe et al., 2016, Gobler et al. 2017). Given the length of Alaska's coastline and the Gulf of Alaska/Aleutian Island communities' reliance on shellfish, the increased prevalence of HABs will have serious implications for resource managers charged with protecting human health, as well as for the Alaska shellfish growing industry.

Historically, Alaska Native communities in the Gulf of Alaska/Aleutian Islands have used traditional knowledge to identify toxic shellfish; however, that practice is also becoming unreliable with recent environmental changes in the North Pacific Ocean. The maxim that it is safe to harvest shellfish during the months that contain the letter "R" is invalid and has become more dangerous with the expansion of PST events into late fall and winter months (Litaker et al., 2020). The unpredictability of PSTs in Southeast Alaska is emphasized with Alaska Department of Environmental Conservation (ADEC) shellfish toxin data showing a high percentage of commonly eaten shellfish containing toxins far above the regulatory limit of 80 micrograms (µg) of toxin/100 grams (g) of shellfish tissue.

In recent years, the importance of monitoring for HABs and testing local shellfish for toxins has become increasingly apparent. However, the interest in HABs and the need and capacity for monitoring and research differ substantially across Alaska's 6,640 miles of coastline. For this reason, seven regions are identified to better tailor the efforts of the AHAB Network: Southeast, Southcentral, Kodiak, Southern Bering Sea, Northern Bering Sea/Bering Strait region, Chukchi Sea, and Beaufort Sea (Fig. 1). Each region has at least one local organization involved in HAB research, monitoring, or outreach.

In addition to organizations that work on a local or regional level, several state and federal agencies are involved in HAB work in Alaska as well. At the state level, the ADEC monitors and regulates the safety of commercial shellfish and provides lab services to analyze toxin levels, while the Alaska Department of Health and Social Services (ADHSS) provides support when there is a human health impact due to HAB toxins. At the federal level, the United States Geological Survey (USGS), Fish and Wildlife Service (FWS), and

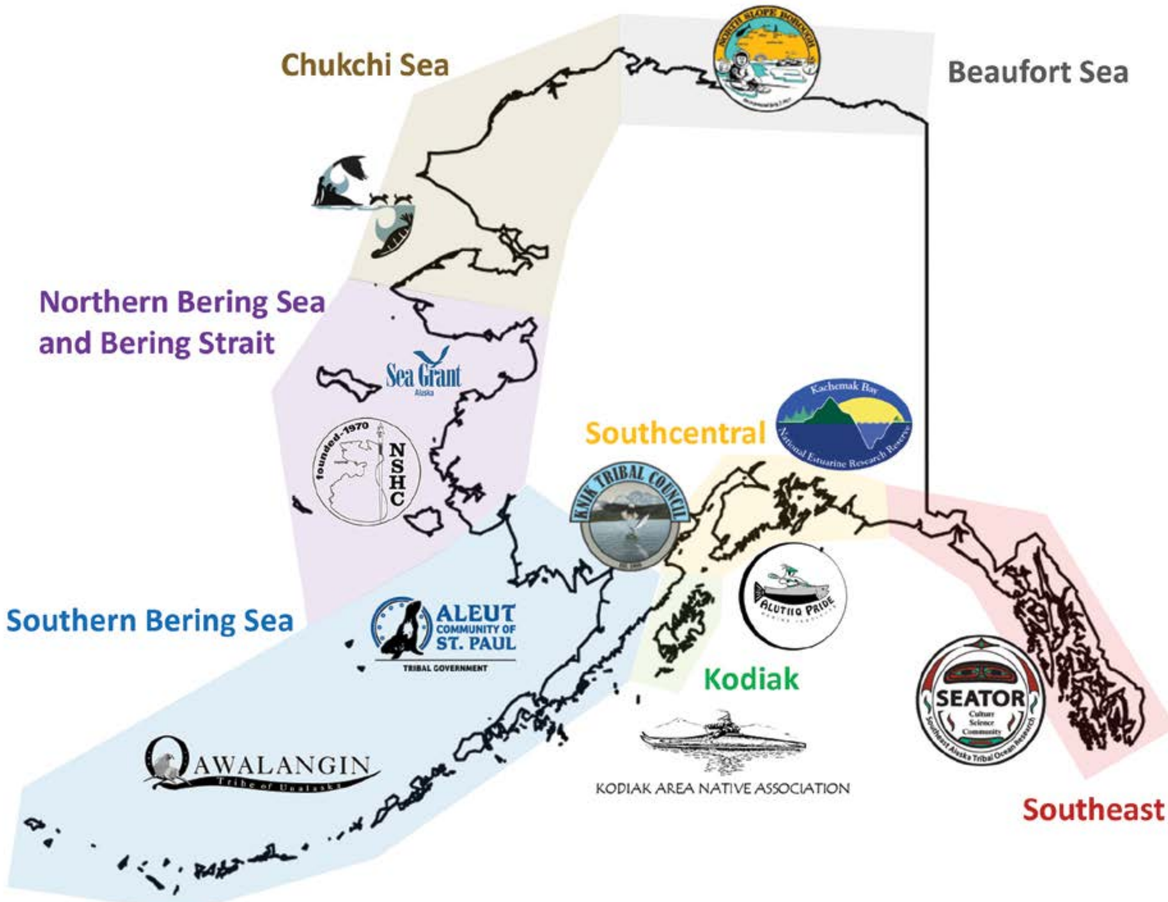
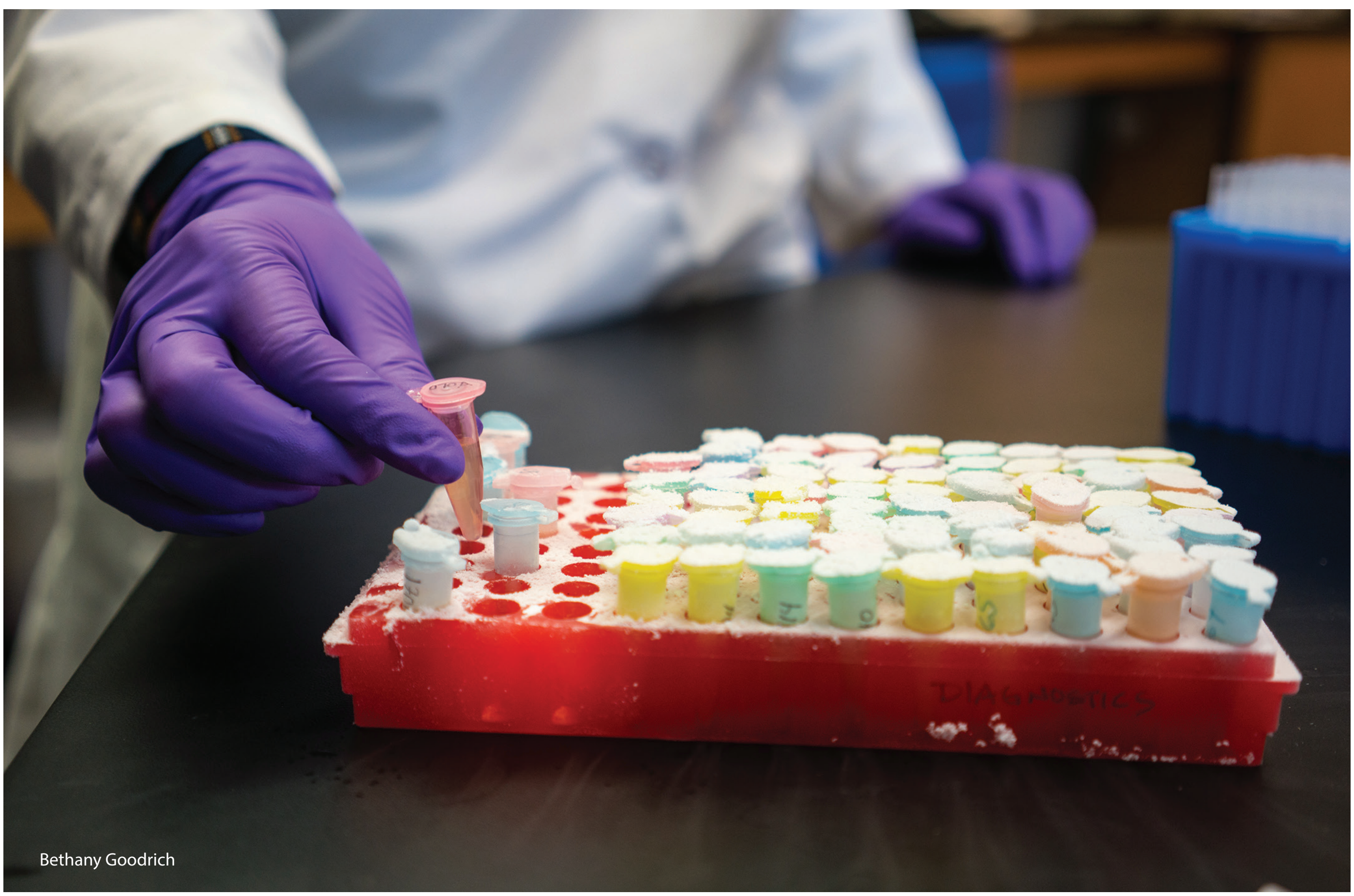


FIGURE 1. Map of Alaska's coastline separated into regions based on the specific HAB needs, interests and capacity of each region; these partitions may evolve over time. Local organizations conducting HAB work in each region are represented with logos.

National Oceanic and Atmospheric Administration (NOAA) conduct research on the ecosystem impacts of HABs, while the Centers for Disease Control (CDC) examines the impacts on human health (NOAA's research and monitoring is also used to help protect human health from HABs). The Environmental Protection Agency (EPA) is also involved in HAB monitoring and research, usually with a focus on freshwater HABs. Finally, the Bureau of Indian Affairs (BIA) supports Alaska Native entities wanting to conduct HAB monitoring activities on tribal lands.

The safety of Alaska's shellfish is critically important for environmental health regulators, as well as recreational and subsistence consumers. Commercial shellfisheries have rigorous and well-coordinated monitoring programs for PSTs and other sanitation issues, and testing is mandated and implemented by the ADEC Division of Environmental Health, Food Safety and Sanitation Program. Many local communities are also sampling for the presence of HAB species along the coast and collecting shellfish samples for testing in the small number of labs that have the required equipment. A full list of the current HAB programs and resources in Alaska can be found in the Appendix of this document. Despite several well-developed sampling programs in Alaska, and routine testing of commercial samples for PST and domoic acid (DA) by the ADEC, **there is no statewide monitoring of any HABs and/or biotoxins in recreational or subsistence harvests.**

To address this gap, the Alaskan HAB research and management community came together in a series of workshops to form the Alaska Harmful Algal Bloom (AHAB) Network. For a summary of the activities that led to the formation of the AHAB Network, see the Appendix of this document. The objective of this AHAB Action Plan is to formalize goals and actions needed for AHAB to meet its mission. This document will help members of the AHAB Network, the general public, and funding agencies better understand the role, structure and activities of the AHAB Network, and will help the Coordinator efficiently achieve the goals and mission of the Network.



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AHAB Role and Structure

AHAB Network Mission

The Alaska Harmful Algal Bloom Network (AHAB) provides a statewide approach to HAB awareness, research, monitoring, and event coordination in Alaska, supporting a diverse group of coastal stakeholders addressing human and wildlife health risks from toxic blooms.

Role of the AHAB Network

The AHAB Network plays two primary roles in Alaska: 1) it is a framework for organizations and institutions working on HABs to communicate, collaborate, and synergize, and 2) it facilitates the consolidation and synthesis of local, regional and statewide data into resources and products (e.g. maps, databases, reports, outreach materials) for use both within Alaska and at a national and international level (Fig. 2). Through this coordination, the profile of HAB work in Alaska can be elevated, helping to bring additional resources into the state. Consolidating data from across the state can also streamline the reporting process to national-level efforts, such as contributing to the CDC One Health HAB System, Harmful Algal Event database (HAEDAT), and the National HAB Observing Network. Once fully implemented and realized, the AHAB Network will work as a force multiplier for all of the important work being conducted by local and regional organizations in Alaska.

Coordinator

The Coordinator provides support to Network members by identifying and securing funding for AHAB activities, ensuring effective and clear communication throughout the Network, and developing initiatives in pursuit of the AHAB Network mission. At least one full-time coordinator is required, especially during the formal establishment of the AHAB Network.

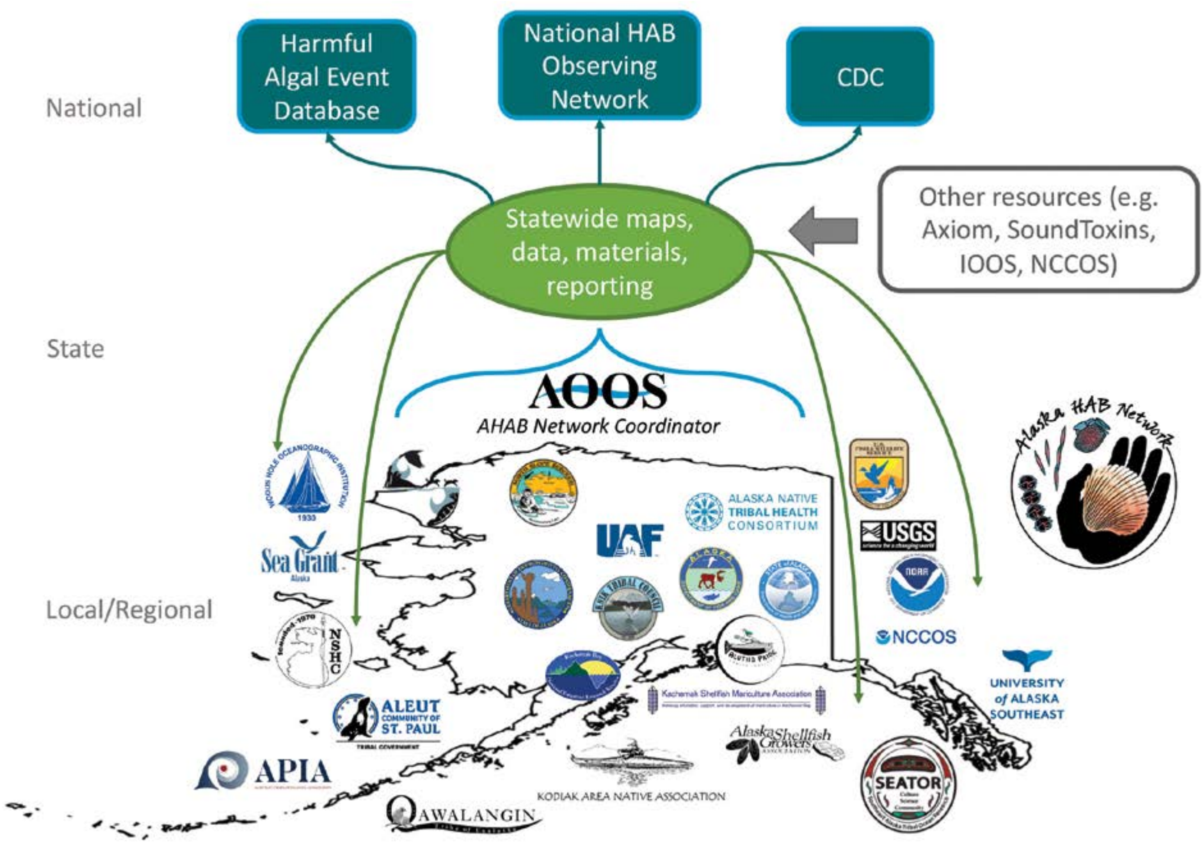


FIGURE 2. The AHAB Network acts as a central hub that facilitates communication and collaboration between Network members, aggregates publicly available data and information from members and other sources and redistributes materials across the Network. The Network also helps spread local, regional and state-level products to national and international audiences, databases and funding sources.

Steering Committee and Working Groups

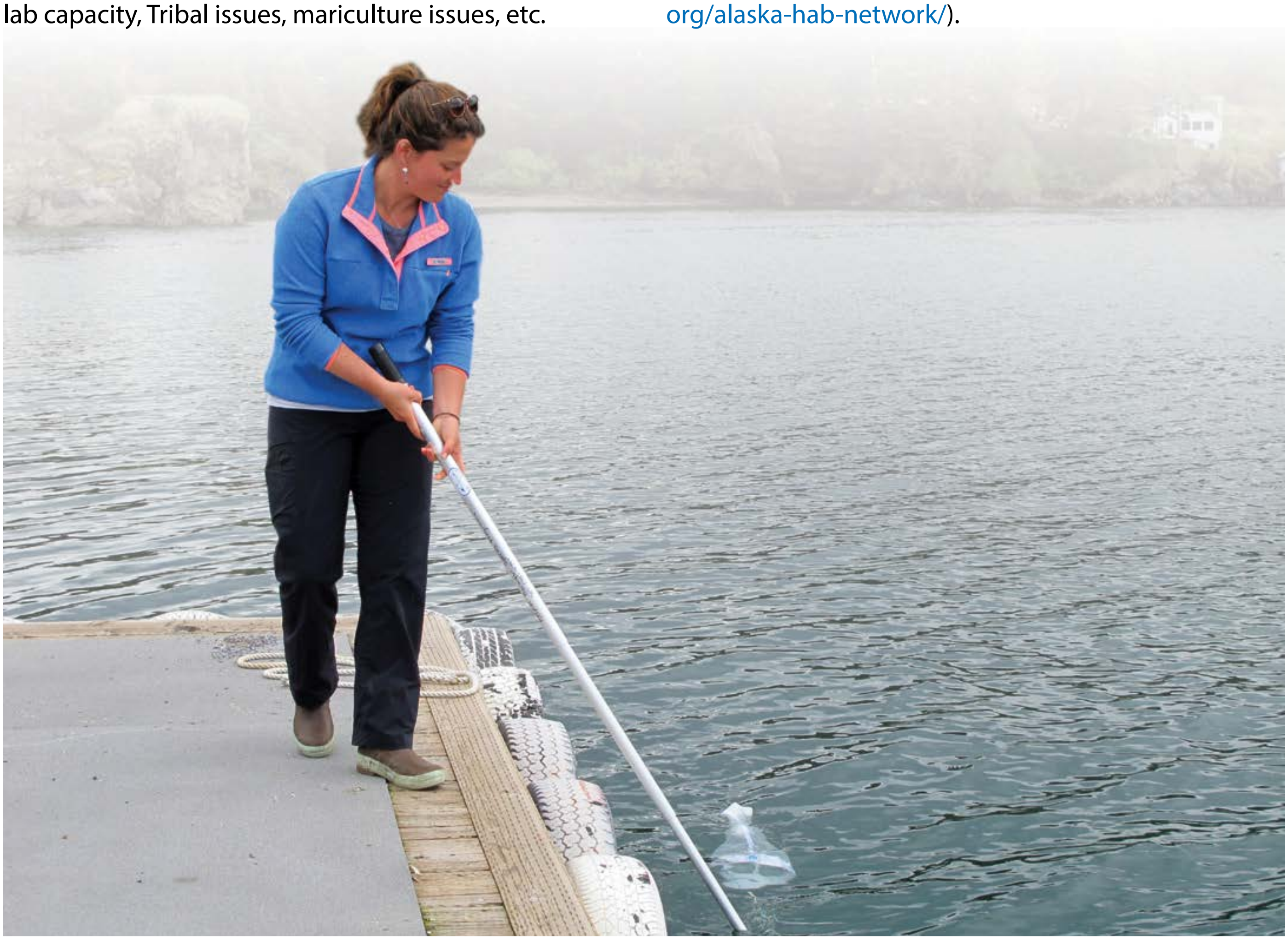
The AHAB Network is structured with a Steering Committee and a varying number of Working Groups. The makeup of the Steering Committee should strive to represent the diversity of regions, perspectives, and organization types of the Network. The Committee's role is to advise the Coordinator on activities and products to best meet the AHAB mission, and provide regular and timely feedback on the direction of the Coordinator's work.

Working Groups bring together a small number (5-15) of Network members to develop products or address specific goals or actions. The number and objectives of Working Groups are flexible and respond to the needs of the Network. They allow the Coordinator to delegate activities and increase the output of the Network. Ideally, both the Coordinator and at least one member of the Steering Committee would be part of each Working Group. Examples of Working Groups include sampling, outreach, event coordination, testing and lab capacity, Tribal issues, mariculture issues, etc.

Network Members

Membership to the AHAB Network only requires an interest in HABs in Alaska, although the vast majority of AHAB members are actively working on some aspect of HABs. All Network members are invited to monthly AHAB update meetings, where they can share their work and learn about other HAB activities in the state. Members can be part of any Working Group as long as they actively contribute to its objectives. Network members that are collecting data on HAB species or biotoxins in Alaska may also be asked to provide information to the Coordinator for the purposes of putting together reports and data products. There is no obligation or timeline for sharing data, however, the more data contributed to this effort, the more complete and impactful the statewide database will be.

There are currently over 100 individuals from over 30 institutions and organizations that are part of the AHAB Network. A complete, up-to-date list of Network members can be found on the AHAB website (aoos.org/alaska-hab-network/).



Action Plan

The Action Plan is a product of the AHAB community, drafted by the Coordinator with guidance from the Steering Committee. It is based on information, input and comments collected during 2016 and 2019 workshops and 2020 listening sessions. This Action Plan will be used to direct Network activities and fulfill the AHAB Mission. The plan has nine specific, measurable, and attainable goals, and each goal is associated with a timeframe. Goals are further divided into a set of actions, and goals are attained when all the actions are completed. Table 1 outlines each goal and the timeframe to be met. Additional tables (Tables 2 – 10) describe individual goals and delineate the actions to be taken along with the parties responsible, timeframe and other relevant information.

Note: the timeframes listed in the tables below should be viewed more as a general indication of the timeframe in which these goals and actions might be completed, rather than specific deadlines.

Goals 1a – 1e are related to each other in that they all deal with the collection, analysis and dissemination of data and information, and all flow out of the "data collection and research" theme apparent in the listening sessions. Goals 2, 3, and 4 (dealing with outreach, event coordination and funding, respectively) each also flow out of the listening session comments, and together these first eight goals were common to both workshops and the listening sessions. Goal 5 strives to extend the AHAB work deliberately to the Arctic, a region that has only recently become active in HAB activities. This goal was not explicitly evident during the listening sessions but was underlying many of the comments from stakeholders working in the Arctic and was part of the discussions at both workshops.

TABLE 1. Summary table of goals identified to fulfill the AHAB mission. The goals are grouped by broad themes and are not numbered in order of priority.

AHAB Mission: provide a statewide approach to HAB awareness, research, monitoring, and coordination in Alaska, and coordinate a diverse group of coastal stakeholders to address human and wildlife health risks from toxic algal blooms	
Goal	**Timeframe**
1a. Community sampling programs for HABs in all regions of Alaska	5 years
1b. Sufficient lab facilities and testing equipment to meet Alaska's needs	5 years
1c. Innovative technology used for research and monitoring	5 years
1d. A central repository for HAB and biotoxin data and products for the state	2 years
1e. Forecasting models and tools for HABs in multiple regions	5 years
2. Outreach and training materials developed, aggregated and publicly available	2 years
3. Effective communication and coordination plans for HAB events	1 year
4. Long-term funding for the AHAB Network framework secured	3 years
5. Expanding AHAB activities in the Arctic	2 years

GOAL 1a: Community sampling programs for HABs in all regions of Alaska

Collecting data is essential to monitoring HAB presence, species, and toxin levels, determining HAB dynamics, and forecasting HAB threats. In Alaska, data collection is particularly challenging given the extensive coastline, wide variety of environments, and low population densities. Other regions in the United States may be able to utilize high-tech sampling equipment (such as imaging flow cytobots or environmental sample processors), but the harsh conditions and remote nature of Alaska's coastline make this option unfeasible in most areas. Alaska's sampling strength comes from the coastal communities throughout the state that utilize coastal ecosystems daily.

Developing Alaskan community HAB sampling programs requires coordination to ensure standardization across the seven different regions of the state (Fig. 1) while also recognizing the unique needs and logistical constraints in each region. Establishing protocols, engaging with communities, and supporting the data collection process is necessary to successfully reach the community sampling goal. Some communities in the Gulf of Alaska/ Aleutian Islands have already established strong sampling programs; learning from these communities will help completing these actions. In addition, HABs may also form in freshwater and estuarine environments. Although these events are much less frequent in Alaska than in other states, the potential of toxic blooms in freshwater presents a particularly dangerous situation for many remote communities who rely heavily on untreated or untested freshwater supplies. Sampling programs should therefore also include building capacity for monitoring for freshwater HABs in the future.

TABLE 2. Actions to be completed to achieve goal 1a.

1a. Community sampling programs for HABs in all regions of Alaska – 5 years			
Each region in Alaska (Fig. 1) has at least one community sampling program that collects at a minimum water samples and environmental variables.			
Action	**Parties Involved**	**Timeframe**	**Notes**
Determine the current state of community sampling in Alaska	Coordinator, SC	6 months	Reevaluated annually
Identify geographical gaps in community sampling	Coordinator	6 months	
Engage with communities that are currently not sampling for HABs	Coordinator	2 years	
Identify minimum sampling needs across the state	Coordinator, WG, SC	1 year	
Develop standard sampling protocols tailored to regions	Coordinator, WG	2 years	
Secure funding for communities not currently sampling	Coordinator, WG	3 years	
Develop sampling programs and capacity for freshwater HABs	Coordinator, WG	3 years	
Conduct outreach and training in communities	Coordinator, Network members	Ongoing	Aim for annual workshops

SC = steering committee, WG = working group

GOAL 1b: Sufficient lab facilities and testing equipment to meet Alaska's needs

Currently, many of the water or organism samples collected are sent out of Alaska to be tested. This adds shipping costs, time and potential for loss to sample processing. In addition, developing Alaskan lab facilities and testing capacity would encourage human capacity development as well, offering skilled positions and providing training in lab techniques. Initially, this added capacity will likely need to be developed in urban-based areas with current lab equipment and expertise (such as Anchorage and Fairbanks). However, remote coastal communities face significant obstacles to transporting samples to these urban centers in a timely and cost-effective manner due to limited and weather-dependent air service in many communities. In Southcentral and Southeast regions, hub communities have already developed or are initiating development of lab facilities (e.g. Sitka, Kodiak, Seward) which provide a crucial service for their surrounding smaller communities. As community sampling expands into other regions as well, it will be important to assess the possibility of increasing lab capacity in other regional hubs as well (e.g. Unalaska, Kotzebue, Utqiaġvik).

It will also be important to continue the development and trial of field-testing techniques. Field tests are well established for domoic acid, although as enzyme-based tests these could be affected by cold temperatures. There currently aren't any satisfactory field tests for saxitoxins to detect paralytic shellfish toxins. Before using any field tests widely in Alaska, it will be important to ground truth these tests specifically for the species, toxins and conditions present in Alaska.

TABLE 3. Actions to be completed to achieve goal 1b.

1b. Sufficient lab facilities and testing equipment to meet Alaska's needs – 5 years			
There is a developed capacity in-state for testing (including field testing) and laboratory facilities that can meet the needs of samples collected in Alaska, with efforts made to develop that capacity in coastal communities when possible.			
Action	**Parties Involved**	**Timeframe**	**Notes**
Determine the current testing capacity in Alaska	Coordinator, SC, WG	6 months	Reevaluated annually
Assist in obtaining funds to develop additional labs in hub communities and increase the capacity of existing facilities	Coordinator, SC	5 years	
Facilitate the development of standardized lab protocols	Coordinator, WG	2 years	In collaboration with NCCOS
Develop clear guidance regarding which lab to send samples to	Coordinator, WG	1 year	Will need regular updating
Explore developing lab capacity in new regions	Coordinator, SC	3 years	

SC = steering committee, WG = working group

GOAL 1c: Innovative technology used for research and monitoring

Although the bulk of HAB and toxin data across the state will come from sampling by researchers or community members, it will also be important to continually explore and test new technologies that could be appropriate and useful in Alaska. These tools could turn out to be crucial to future sampling, especially in remote areas that are difficult or expensive to sample.

TABLE 4. Actions to be completed to achieve goal 1c.

1c. Innovative technology used for research and monitoring – 5 years			
Cutting edge tools and technologies are being piloted and implemented where appropriate.			
Action	**Parties Involved**	**Timeframe**	**Notes**
Test innovative technology to help samplers (HABscope, AI)	Coordinator, Network members	2 years	With help from other IOOS orgs
Test and ground-truth remote sampling techniques (ESP, IFCB)	Coordinator, Network members	3 years	
Develop capacity for high tech testing (e.g. qPCR, eDNA)	Coordinator, WG, Network members	5 years	In collaboration with NCCOS
Explore the usefulness of new techniques as they become available (e.g. machine learning)	Coordinator	Ongoing	With help from other IOOS orgs

SC = steering committee, WG = working group

GOAL 1d: A central repository for HAB and biotoxin data and products for the state

The work on HABs from all the organizations in Alaska produces a wealth of data on phytoplankton and toxin levels in various organisms, but these data can be difficult to track down and visualize. A central database will facilitate the analysis of state-wide trends and the comparison between regions by researchers, coordinators, and managers. In addition, state-wide materials such as reports, maps and models will be more easily produced and disseminated to the national and international levels. There is no obligation or timeline for AHAB members to share their data, however, the more data contributed to this effort, the more complete and impactful the statewide database will be. Development of a HAB data portal for Alaska will be accomplished through the services of Axiom Data Science, an informatics and software development firm that has development the Ocean Data Explorer data portal for AOOS.

TABLE 5. Actions to be completed to achieve goal 1d.

1d. A central repository for HAB and biotoxin data and products for the state – 2 years			
Data on HAB species and biotoxin levels collected in Alaska are accessible from a centralized resource (e.g. data portal), and materials produced from those data (e.g. reports, maps, models, time series) are publicly available.			
Action	**Parties Involved**	**Timeframe**	**Notes**
Engage with groups collecting data in Alaska	Coordinator, WG	6 months	
Develop a portal for HAB data linked to ocean conditions	Coordinator, Axiom, WG	1 year	HAB data include phyto-plankton counts, toxin levels
Publish annual reports and maps of HAB conditions in Alaska	Coordinator, WG	1 year	
Provide a mechanism for data collectors to contribute data	Coordinator, Axiom, WG	2 years	
Develop training materials for users to find and interpret data	Coordinator, WG	2 years	
Actively seek out data from Network members	Coordinator, Network members	Ongoing	

SC = steering committee, WG = working group

GOAL 1e: Forecasting models and tools for HABs in multiple regions

Aggregated HAB data, along with environmental conditions, allow researchers to build models, risk assessments and other tools to evaluate the probability of HAB events. This could help inform subsistence, recreational, and commercial harvesting of seafood, and limit risks to human health. Forecasting models may also be used to help explain the role of HABs in wildlife mortality events. This modeling effort requires fine resolution data, both spatially and temporally, and may therefore be possible in only a few locations in the Gulf of Alaska waters (e.g. Southeast Alaska, Kachemak Bay, Kodiak). It will be critical to make the distinction between correlation and prediction clear, so as not to give a false sense of safety, especially if these tools are used to make decisions that can affect human health.

TABLE 6. Actions to be completed to achieve goal 1e.

1e. Forecasting models and tools for HABs in multiple regions – 5 years			
Models correlating HAB presence and/or intensity with environmental variables are available for regions with sufficient data (i.e. Gulf of Alaska waters), and forecasting tools are available to determine the probability of future bloom/non-bloom conditions.			
Action	**Parties Involved**	**Timeframe**	**Notes**
Determine regions with sufficient data for HAB modeling	Coordinator, WG	6 months	
Engage in discussions with modeling groups (e.g. NCCOS)	Coordinator, WG	2 years	
Provide data (with permission) to modeling efforts	Coordinator	3 years	Permission needed from Network members collecting data
Develop and publish forecasting tools based on HAB models	Coordinator, WG, Axiom	5 years	In collaboration with NCCOS

SC = steering committee, WG = working group

GOAL 2: Outreach and training materials developed, aggregated and publicly available

The AHAB Network should be a source of outreach and training materials to disseminate information about HABs, HAB sampling efforts, and HAB events in Alaska. Many of these materials will have already been produced by organizations in Alaska, but the AHAB Network can act as an added outlet and amplifier for those materials. In some instances, there may be additional materials that need to be produced, and the AHAB Network can facilitate the production of those. The primary outlet for the AHAB Network is the website but developing a larger presence on social media (i.e. Facebook) will be helpful to reach coastal communities.

TABLE 7. Actions to be completed to achieve goal 2.

2. Outreach/training materials developed, aggregated and publicly available – 2 years			
There is an accessible and centralized location for outreach and training materials related to HABs in Alaska, and platforms (e.g. social media) to distribute these materials broadly.			
Action	**Parties Involved**	**Timeframe**	**Notes**
Expand the AHAB website to house outreach/training materials	Coordinator, WG	6 months	
Aggregate materials and assess needs for additional products	Coordinator, WG, Network members	1 year	Reevaluate annually
Produce additional materials (posters, videos, newsletters, etc.)	Coordinator, SC, WG	2 years	
Develop AHAB Facebook page and Youtube channel	Coordinator, WG	6 months	
Ensure materials are accessible to rural coastal residents, with a focus on outreach to subsistence harvesters	Coordinator, WG	Ongoing	
Ensure outreach materials are culturally appropriate for intended audiences	Coordinator, WG	Ongoing	Provide opportunity for feedback

SC = steering committee, WG = working group

GOAL 3: Effective communication and coordination plans for HAB events

During a suspected HAB event (presence of high densities of HAB species in water samples, mass mortality events of wildlife consistent with high toxin levels, or people showing signs of HAB toxin ingestion), the AHAB Network can act as a forum to coordinate messaging at the state level, as well as support the shipping and rapid testing of samples. The Network can also help communities put in place mitigating actions to reduce exposure to toxins if needed (e.g. provide notices to discourage harvesting of shellfish and keep the communities informed of the progress of the bloom).

TABLE 8. Actions to be completed to achieve goal 3.

3. Effective communication and coordination plans for HAB events – 1 year			
When a HAB event is detected, there is a clear plan for communication and information dissemination throughout the AHAB Network, and for coordination to determine the cause of the HAB event, and potential mitigating actions that can be taken.			
Action	**Parties Involved**	**Timeframe**	**Notes**
Identify key players in the response to HAB events	Coordinator, SC, WG	3 months	
Establish clear communication lines between key players	Coordinator, SC, WG, Network members	6 months	
Produce HAB event coordination plans (players, roles, process)	Coordinator, WG	1 year	Reevaluate annually

SC = steering committee, WG = working group

Coastal communities in Alaska have well-established local communication networks. These are the most efficient means of getting notifications out to community members. The AHAB Network should therefore ensure that communication happen with the key contact points in the hub communities. In addition, state agencies (DEC, DHSS) and federal agencies (FWS, USGS, NOAA, CDC) have regulatory obligations during HAB events, and it will be crucial for the AHAB Network to integrate with those efforts to provide support where needed. This integration requires preparation, specifically: establishing communication lines, setting up the process chain from sample collection to data dissemination, and producing materials to share during an event.

GOAL 4: Long-term funding for the AHAB Network framework secured

The majority of the work on HABs in Alaska is conducted by regional, state or national organizations (e.g. tribal governments, state and federal agencies, academic institutions), which have their own funding streams. However, AHAB currently receives funding in part from the Alaska Ocean Observing System and funding for the functioning of the AHAB Network must be secured on a long-term basis. In addition, to ensure that the baseline community sampling program is not at risk of going unfunded, long-term funding for minimum sampling outlined in Goal 1a should be sought and secured.

Potential funding sources for the AHAB Network include national-level organizations such as the Integrated Ocean Observing System (IOOS) and the newly formed National HAB Observation Network, as well as HAB-related funding opportunities from NCCOS. For the community sampling efforts, long-term funding will be sought from a combination of federal agencies including the Bureau of Indian Affairs (BIA), US Environmental Protection Agency (EPA) and NOAA. Ideally, these funding sources will provide support for multiple years at a time to allow for financial stability while these sampling programs are developed and institutionalized.

In addition, the AHAB Network Coordinator will offer to partner on funding proposals developed by Network members and can help organizations develop proposals for HAB work in Alaska. As a project partner, the AHAB Network can provide input on the proposal, help find and nurture collaborations, and be an outlet for dissemination of the data and information produced by the proposed projects.

TABLE 9. Actions to be completed to achieve goal 4.

4. Long-term funding for the AHAB Network framework secured – 3 years			
The AHAB Network is adequately funded for long-term sustainability, allowing for coordination, minimum sampling, statewide data management, and communication to continue in perpetuity, buffered from year-to-year funding variability.			
Action	**Parties Involved**	**Timeframe**	**Notes**
Identify funding needs for the Network and sampling efforts	Coordinator, SC, WG	6 months	Produce white paper on needs
Develop a strategy for long-term funding of the Network	Coordinator, SC	6 months	
Develop a strategy for long-term funding of sampling	Coordinator, SC, WG	1 year	
Establish relationships with funding agencies	Coordinator	2 years	Focus on federal agencies
Secure long-term funding for AHAB and sampling	Coordinator, SC, WG	3 years	
Support proposals for HAB work in Alaska	Coordinator	Ongoing	

SC = steering committee, WG = working group

GOAL 5: Expanding AHAB activities in the Arctic

The previous goals apply to all regions of Alaska, however, different regions have different relationships to HABs, different histories of developing sampling programs and capacity to monitor HABs, and different concerns about HABs and toxins. In the Alaskan Arctic, there has not been a long history of recorded HAB concerns, although there may be some oral histories of HAB events in the past, and recent published and unpublished research has established the presence of HABs. Over the past 10 years, there has been increasing community interest and participation in the AHAB Network by environmental leaders in the region. The continuing warming of the ocean and atmosphere concurrent with the reduction in sea ice extent, duration, and quality is likely to extend the growing season and increase the growth potential of HAB species, particularly in the Arctic. There is a need therefore to pay special attention to the Arctic and ensure that the data collection, outreach, and capacity development are tailored to the region.

To address this situation, AHAB Network members will develop a plan, in collaboration with Arctic communities, to expand HAB monitoring, research and capacity building in the Arctic region. Expanding AHAB activities in the Arctic will involve conducting planning efforts with these communities and gauging community awareness of and interest in potential HAB threats to human health and subsistence harvests of marine mammals, birds and shellfish. It will also be important for the AHAB Network to explicitly dedicate resources to increasing the sampling capacity in the Arctic and develop routine community-based monitoring in the region.

TABLE 10. Actions to be completed to achieve goal 5.

5. Expanding AHAB activities in the Arctic – 2 years			
Directed efforts are made to engage with Arctic communities regarding HABs, supporting on-the-ground work, conducting outreach, and sharing training and results.			
Action	**Parties Involved**	**Timeframe**	**Notes**
Produce a synthesis of HAB information in the Arctic including oral history	Coordinator, Network members	1 year	
Dedicate resources to developing Arctic capacity	Coordinator, SC	2 years	
Nurture connections and communication with Arctic communities	Coordinator, Network members	2 years	Use local communication networks

SC = steering committee, WG = working group

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Appendix

Existing Programs and Resources

Programs, capacity, and resources pertaining to HABs vary greatly between each Alaska region. Below is a description of each region and how they are monitoring for HABs. Also included are the current AHAB Network resources, the roles of state and federal agencies in Alaska, and the available laboratory capacity.

REGIONAL PROGRAMS AND RESOURCES

Southeast Alaska

The Southeast Alaska Tribal Ocean Research (SEATOR) partnership was initiated in 2014, with leadership from the Sitka Tribe of Alaska and funding from the EPA Indian General Assistance Program to provide consistent phytoplankton and shellfish HAB toxicity monitoring for subsistence shellfish harvest in Southeast Alaska communities. SEATOR has also focused on capacity building for HAB efforts throughout the state by hosting community training workshops and developing a new marine biotoxin laboratory. SEATOR partners now include 15 Southeast tribes, two Kodiak tribes, three state agencies, two universities, and two federal agencies. The Sitka laboratory has been operating since 2015, has three full-time staff, and supplies all PST shellfish analyses for SEATOR partners using the receptor binding assay method. The laboratory also provides near real-time toxin testing services for state managers, state health departments and research partners from across the state. Researchers and students with the University of Alaska Fairbanks (UAF), College of Fisheries and Ocean Sciences in Juneau Alaska have also conducted long-term HAB research and monitoring efforts in Southeast Alaska. They have also collaborated with the NCCOS national Phytoplankton Monitoring Network on community monitoring efforts in the region.

Southcentral Alaska (Kachemak Bay, PWS)

The Kachemak Bay National Estuarine Research Reserve (KBNERR) has conducted a Harmful Species Community Monitoring Program since 2006. KBNERR partners with community monitors to collect phytoplankton and shellfish tissue samples for early detection of HAB species and toxins and provide routine public updates. Diverse stakeholder participants include oyster farmers, watermen, seasonal residents, wildlife lodge operators, commercial fishermen, hatcheries, wildlife tour operators, tribal organizations, state agencies, and federal agencies. KBNERR coordinates with the NCCOS Kasitsna Bay and Beaufort Laboratories on HAB monitoring and research, and with the NCCOS national Phytoplankton Monitoring Network program for training and data sharing. Community monitors grew from 12 in 2008 to 50 in 2018 and in just one event in 2017, updates were provided to inform over 18,000 stakeholders about high toxin levels.

KBNERR also has a Coastal Training Program (CTP), which is a NERR-wide effort to provide information, access to technologies, and training for coastal decision makers. The KBNERR CTP has supported regional HAB workshops, a Kachemak Bay HAB Response Plan, community monitor trainings, public events, and development of HAB-related communication materials. In 2014, KBNERR hosted two workshops on HABs and bivalves in Homer, Alaska (Buckelew 2014, Cooney 2014) that engaged a broad cross-section of researchers and agency, industry and community stakeholders to identify information gaps and develop strategies for addressing HAB threats to human health, commercial shellfish industries, and recreational and subsistence shellfish harvests. In 2016, following new detections of HABs in Kachemak Bay, KBNERR hosted a multi-agency HAB Response Workshop to coordinate communication and event response roles and responsibilities (Abrahamson 2016) followed by a field-based training in 2017 for decision-makers and research partners around shellfish sustainability (Abrahamson 2017).

NCCOS Kasitsna Bay and Beaufort Laboratory researchers have conducted phytoplankton, HAB toxin and oceanography monitoring, research and HAB detection technology development in Kachemak Bay and Cook Inlet Alaska since 2009. More intensive year-round monthly sampling has been conducted since 2012, leveraging funding from the *Exxon Valdez* Oil Spill Trustee Council, under the Gulf Watch Alaska ecosystem monitoring program. Recent results from these efforts include validation of species-specific qPCR assays for *Alexandrium catenella* abundance

(Vandersea et al. 2017), identification of linkages between environmental conditions, Alexandrium cell abundance and STX levels (Vandersea et al. 2018), and development of a web-based, Kachemak Bay HAB risk assessment tool, based on ocean observing data from a KBNERR water quality station and hosted on the Alaska Ocean Observing System website. Increases in Alexandrium cell abundance, STX, PSP events and oyster farm closures were observed in the bay during the anomalously warm water conditions associated with the 2014-2016 Pacific marine heat wave. Conversely, despite frequent observations of Pseudo nitzschia spp. blooms in the bay, testing of shellfish tissues has shown consistently low levels DA toxins.

Kodiak Region

Some of the highest STX concentrations in the state have been recorded from the Kodiak region and 30% of the 117 documented cases of PSP in Alaska between 1993 and 2014 were from shellfish collected in the Kodiak region (State of Alaska Epidemiology, 2015). Despite severe illness and even human deaths from PSP in the region, some Kodiak residents routinely harvest shellfish for subsistence purposes. Studies over the past seven years, primarily led by the Alaska Sea Grant Marine Advisory Program agent with funding from ADEC, ANTHC and NPRB, have focused on working with Alaska Native tribal organizations on community-based shellfish and environmental monitoring and development of inexpensive and timely toxin testing. Efforts are expanding in Kodiak to include the Kodiak Area Native Association, which is initiating shellfish monitoring for STX and qualitative HAB species monitoring at four sites along the road system using techniques shared by other AHAB programs.

Southern Bering Sea (Aleutian and Pribilof Islands, Bristol Bay)

In an effort to mitigate the increasing HAB-related threats to human health, mariculture and marine resources in Alaska, the Aleutian Pribilof Islands Association (APIA) and Alaska Sea Grant partnered on a North Pacific Research Board (NPRB) project in 2005-2007 to monitor STX in shellfish tissues and water temperatures at over 20 stations along the Gulf of Alaska including the Aleutian and Pribilof Islands. Concurrent surveys of community members revealed that all sites had histories of PSP events, including human illness and death and wildlife mortalities. PI Bruce Wright (APIA) subsequently continued work on PSP, working closely with Alaska Native tribes and outside HAB experts, to build capacity for testing, monitoring, outreach and education. APIA has coordinated PSP monitoring for 12 years with Village Protection Safety Officer (VPSOs; Akutan, Atka, False Pass, Nelson Lagoon and St. George), EPA IGAP (Indian General Assistance Program) tribal environmental coordinators (King Cove and Sand Point), the Alaska Sea Grant Agent in Unalaska, and US Fish and Wildlife staff in Adak. Over this time, the sample collection sites, species collected, and timing of the collections have been refined to adapt to local conditions. In Adak, Nelson Lagoon and St. George the samples are collected from the beaches where mussels are available, though winter ice scouring may remove the mussels and prevent sample collection. In Atka, Adak, False Pass, Nelson Lagoon, Nikolski and Unalaska mussels are the only readily available bivalve, while butter clams are available at King Cove and Sand Point.

In July 2020, there was a human fatality in Dutch Harbor due to the consumption of blue mussels and marine snails. This event led to the Qawalangin Tribe of Unalaska to apply for and receive a HAB Event Response award from NOAA's NCCOS, which provided temporary support to continue and expand regular and consistent testing for PSP toxins in shellfish, and phytoplankton identification along the Aleutian and Pribilof Islands.

Northern Bering Sea and Bering Strait

Though STX and DA toxins have been found in marine mammals (Lefebvre et al. 2016, Alaska Sea Grant 2017) and seabirds (USGS 2018, Van Hemert et al. 2021), the levels are generally low to date. Recently, however, analysis of clams from the Bering Strait region has resulted in the first detection of STX in levels over the seafood regulatory limit (Alaska Sea Grant 2019a). Due to the widespread utilization and consumption of marine mammals and seabirds, food security concerns exist throughout the region due to the emerging threat of HABs as a result of warming ocean temperatures. The northern Bering Sea / Bering Strait region requires HAB monitoring to assess current and emerging HAB risks and develop appropriate response strategies. A small amount of funding was provided to the North Slope Borough by the US Arctic Research Commission and AOOS in 2018 for a project entitled "Water sampling for microcystins in ice associated pinnipeds". Samples from this project are still being analyzed. In 2019, Alaska Sea Grant facilitated a workshop in Nome on algal toxins in the Bering Strait (see summary of the workshop on page 23).

Alaska Sea Grant and the Norton Sound Health Corporation are located in Nome, the transportation and communication hub of the Bering Strait region. As AHAB members, they provide the Network updates on anomalous events as well as collaborate with and/or work directly on HAB-related research efforts that include: a NOAA-Northwest Fisheries Science Center / Woods Hole Oceanographic Institute led food-web toxin study (NCCOS ECOHAB), a Southeast Alaska Tribal Ocean Research (SEATOR) sampling effort at Diomede, and a Norton Sound Health Corporation seawater monitoring effort near Nome.

Chukchi Sea

Routine HAB monitoring programs were not established in northern and western coastal regions of Alaska, because of a perceived lack of threat in the historic colder waters of these Arctic. However, in recent years *Alexandrium* blooms have been observed in the Chukchi Sea (Gu et al. 2013, Alaska Sea Grant 2019), extremely high concentrations of *A. catenella* cysts have been observed on the Chukchi Sea shelf (Natsuike et al. 2013; D. Anderson, pers comm of results from 2018 Arctic research cruises). Members of AHAB network located in Kotzebue are currently working on coordinating sampling efforts for HABs in Kotzebue Sound along with collaborators from Columbia University. In addition to marine HABs, there is interest in this region to also monitor freshwater HABs because the communities in the region rely on natural bodies of water for their freshwater.

Beaufort Sea (including Utqiaġvik)

As with the Northern Bering and Chukchi Sea regions, sampling for HABs and toxins in the Beaufort Sea has been sparse historically, but there are regional experts from this region that are members of the AHAB Network. Despite little shellfish harvesting taking place in this region, specific actions may need to be taken to address the unique conditions of this coast and the emerging HAB risks to marine mammals that are crucial parts of the traditional and subsistence way of life. Recent research cruises have found *Alexandrium* cyst beds near Utqiaġvik, in a well know whale feeding area, and the primary stakeholders in the region are the hunters who understand that HABs may become a problem in the future, and wildlife and fisheries managers. Members of the AHAB Network in this region are also members of the marine mammal stranding network, and are part of the ECOHAB food-web toxin study.

Statewide

Some of the programs and efforts listed above operate in more than one region, or even in every region in Alaska. These are federal agency efforts (NOAA, USGS, USFWS) to respond to HAB events and mortalities anywhere in the state when possible. These agencies also have specific projects studying HABs across the food web (e.g. the ECOHAB project) or in specific taxa (e.g. USGS examining the responses of seabirds to toxins).

CURRENT AHAB NETWORK RESOURCES

As of June 2021, the primary publicly available AHAB Network resources are the AHAB website and the AHAB data portal. The AHAB website is an information, outreach, and training platform where resources are housed for AHAB Network members and the general public. The website (Fig. A1) includes news, alerts, and important dates (which are updated regularly by the Coordinator), background information on HABs in Alaska, contact information, forms to ask questions to experts, and links to more in-depth information.

The AHAB data portal (Fig. A2) was built and is maintained by Axiom Data Science. It is currently set up to visualize shellfish biotoxin and phytoplankton data collected by SEATOR and KBNERR. Further development of the data portal is needed to ingest data from other organizations and entities as well, and to streamline the data entry process.

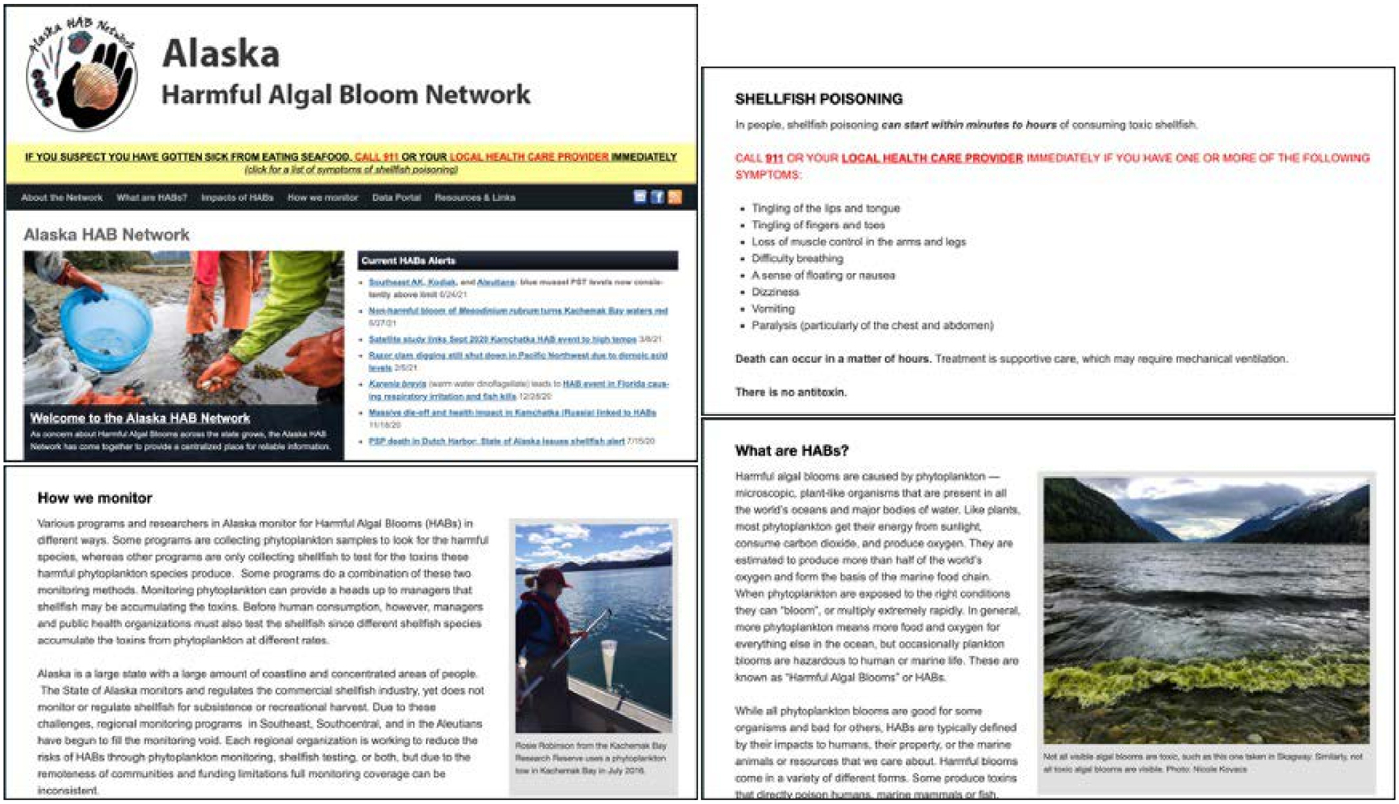

FIGURE A1. Example of four pages from the AHAB Network website.

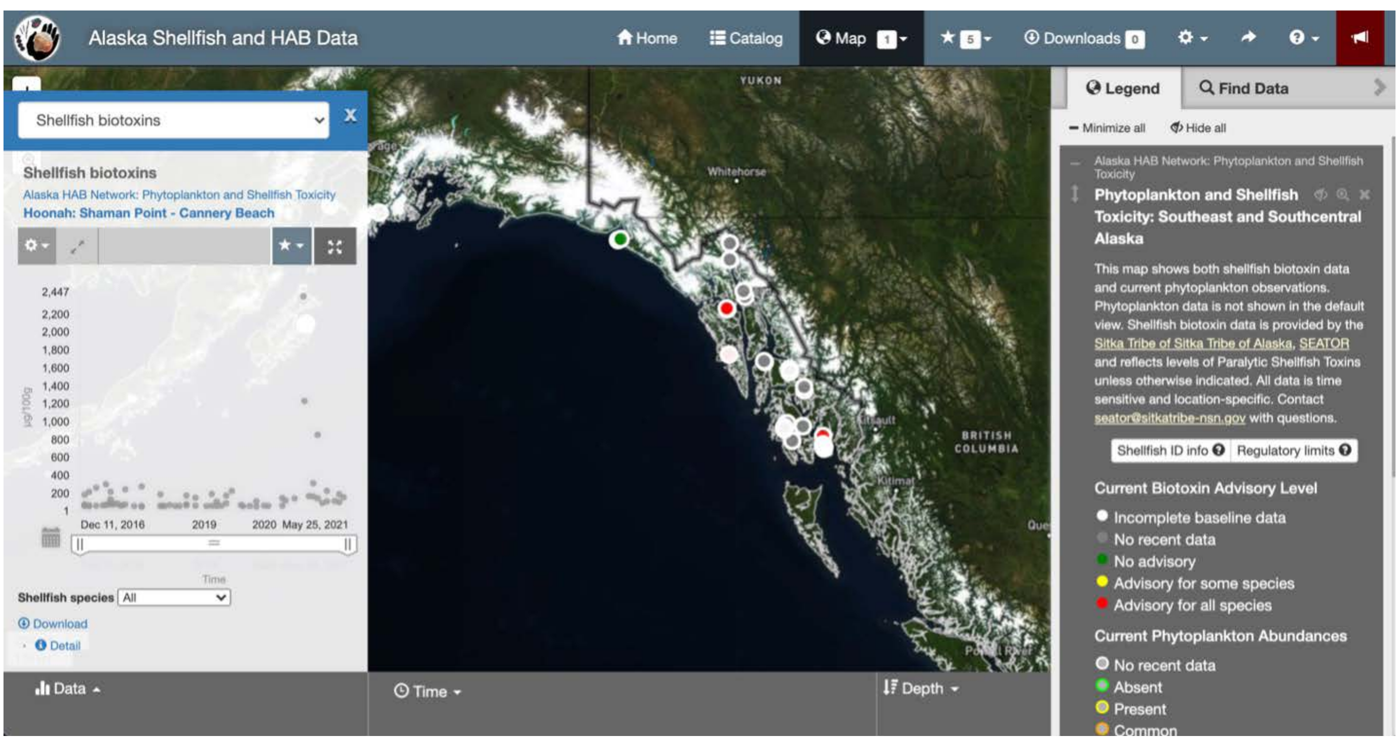

FIGURE A2. The AHAB data portal (currently only with SEATOR data visualized).

TABLE A1. List of lab capacity for HABs in Alaska

Lab name	Location	Current capacity	In development
ADEC EHL	Anchorage, AK	MBA, HPLC	RBA
SEATOR	Sitka, AK	RBA, ELISA, Microscopy	qPCR
KBNERR	Homer, AK	Microscopy	
Alaska Sea Grant	Kodiak, AK	ELISA, HPLC	qPCR
Alutiiq Pride	Seward, AK		qPCR, RBA, HPLC
USGS ASC	Anchorage, AK	ELISA, HPLC	
NOAA NCCOS	Kasitsna Bay, AK	ELISA, Microscopy	
UAF	Fairbanks, AK	qPCR, Microscopy	
City of Unalaska*	Dutch Harbor, AK	qPCR, Microscopy	

MBA = mouse bioassay, HPLC = high-performance liquid chromatography, RBA = receptor binding assay, ELISA = enzyme-linked immunosorbent assay, qPCR = quantitative polymerase chain reaction

* This is the Wastewater Division lab for the City of Unalaska and is not specifically tasked with performing HAB sampling, and it does not currently offer HAB-related testing, so samples still get regularly shipped out.

TABLE A2. List of out-of-state labs that support HAB research and monitoring in Alaska.

Lab name	Location	Current role within AHAB
NOAA WARRN-West	Seattle, WA	Analysis of toxin levels in animal tissues (primarily fish and marine mammals), ecosystem transfer of toxins
NCCOS Beaufort	Beaufort, NC	Monitoring tools, environmental factors regulating HABs, toxin transfer in food webs
NCCOS Charleston	Charleston, SC	Phytoplankton monitoring platform, mapping and detection of toxic species, qPCR assays
USGS NWHC	Madison, WI	Analysis of toxin levels in animal tissues (primarily birds)
WHOI	Falmouth, MA	HAB species identification and quantification in seawater and sediment samples

LAB CAPACITY

Table A1 below shows the nine labs in Alaska with capacity for HAB and/or biotoxin testing. It should be noted that of these, seven are on the coast of the Gulf of Alaska, one is in Interior Alaska, and one is in the Aleutian Islands region. As we develop the community sampling program in Alaska (goal 1a of the AHAB Action Plan), it will be important to ensure that these samples can be tested in Alaska as much as possible. Part of the goals of the AHAB Network will be to promote and support the development of in-state labs to eliminate the need to ship samples out of state which increases cost, time, and the risk of sample loss. However, at this time, labs outside of Alaska are an essential part of the AHAB Network and provide crucial services. Table A2 shows the labs located outside of Alaska that support HAB work in Alaska.

STATE AND FEDERAL AGENCIES

When there is a suspected HAB-related illness or death, ADEC is tasked with performing toxicity analyses on shellfish tissues and consumed food, if available, to help determine if HABs are the cause. Federal and state agencies, including the Centers for Disease Control and Prevention (CDC) and the Alaska Department of Health and Social Services (ADHSS), also investigate

HAB-related human illnesses linked to eating shellfish. State and federal resource management agencies, including ADFG, NOAA, USFWS, and USGS investigate potential contributions by HABs to marine mammal and seabird mortality events. Most of these agencies have also investigated associations between environmental conditions and HAB events after the events have occurred, including following the 2014-2016 Pacific marine heat wave (Walsh et al. 2018; Vandersea et al, 2018; Van Hemert et al. 2020), but to date there has been little use of environmental data for HAB risk assessment or early warning products in the state.

Development of the Alaska Harmful Algal Bloom Network

The AHAB Network is currently composed of over 30 local, regional, state and federal institutions. Some of these institutions have been working on HABs for over a decade, but in 2016, an effort was started to coordinate activities across the state of Alaska. This was accomplished by conducting two workshops (in 2016 and 2019) with stakeholders, and by hiring an AHAB Network Coordinator who conducted listening sessions with Network members in 2020. Summaries from each of these efforts are provided below. The outcomes from these outreach efforts inform the AHAB Action Plan.

2016 ALASKA HAB WORKSHOP

In 2016, Alaska Sea Grant and the Alaska Ocean Observing System organized an Alaska HAB workshop to discuss management, research, and communication of HABs. The workshop

included a commitment to create the AHAB Network, with participation by state, federal, tribal, academic and non-governmental partners to coordinate HAB monitoring efforts and to provide managers, shellfish harvesters, tribal agencies, and commercial mariculture operators with a centralized place for reliable information. AHAB members identified an initial list of priorities for statewide HAB response, including: 1) a statewide HAB Coordinator, 2) improving consistency and timeliness of HAB toxicity testing across multiple monitoring programs, 3) improving early detection of HAB events, 4) using models and targeted sampling to improve predictive capabilities, and 5) improving communication during HAB events. While AHAB members have taken preliminary steps to improve statewide communication and planning for HABs, there is a critical need for more coordination and capacity building for monitoring and event response to address HAB threats to human health and mariculture operations in Alaska.

2019 ALASKA HAB WORKSHOP

In 2019, with AOOS funding, Alaska Sea Grant organized, hosted, and facilitated a workshop in Nome with the goal of educating and providing current research information to the Bering Strait regional public on the issues of HABs (Alaska Sea Grant 2019b).

The first day of the workshop aimed at educating the general public and community of the Bering Strait Region, and around 30 people participated. Nine presenters covered the following topics: introduction to algal toxins; an overview of changing environmental conditions in the Bering Strait; algal toxins and their effects on marine resources such as shellfish, seabirds, and marine mammals; algal toxins and their effects on humans; Bering Strait and Western Alaska response and results focusing on seawater, seabirds, and marine mammals. There were also two group discussions focusing on public health response and harmful algal bloom response and communication.

The second day of the workshop aimed to educate healthcare professionals in the region and 18 healthcare professionals and other people attended. Presentations provided were trainings that focused on symptoms and response to Paralytic Shellfish Poisoning (PSP), and Botulism.

2020 INFORMAL LISTENING SESSIONS

Between November 2020 and January 2021, the AHAB Coordinator conducted individual informal listening sessions with members of the AHAB Network. The objective was for the new Coordinator to establish a relationship with the Network members, to learn about their current work and future goals relating to HABs in Alaska, and to get their perspective on the role and activities of AHAB. This is an ongoing effort, and additional comments will be added to the dataset as discussions continue.

After the initial round of informal listening sessions, over 50 Network members from 30 organizations provided 225 comments, which were categorized and summarized by the AHAB Coordinator. Organizations included five tribal governments, three native corporations, three Alaskan non-governmental organizations, seven academic institutions/departments, six federal agency departments, three state agencies, and two non-governmental organizations. This group of organizations covered all regions around Alaska, as well as state-wide level perspectives.

Thirteen categories of comments were identified within four broad themes: AHAB Network structure and role (11% of comments), data collection and research (57.3%), outreach and training (22.2%), and HAB impacts (9.3%). The top five categories of comments referenced sampling for HABs, outreach, HAB data management and dissemination, testing for toxins and HAB species, and funding sources (Fig. A3). These comments were used to identify the priorities that the AHAB Network should address and guide the development of the AHAB Action Plan.

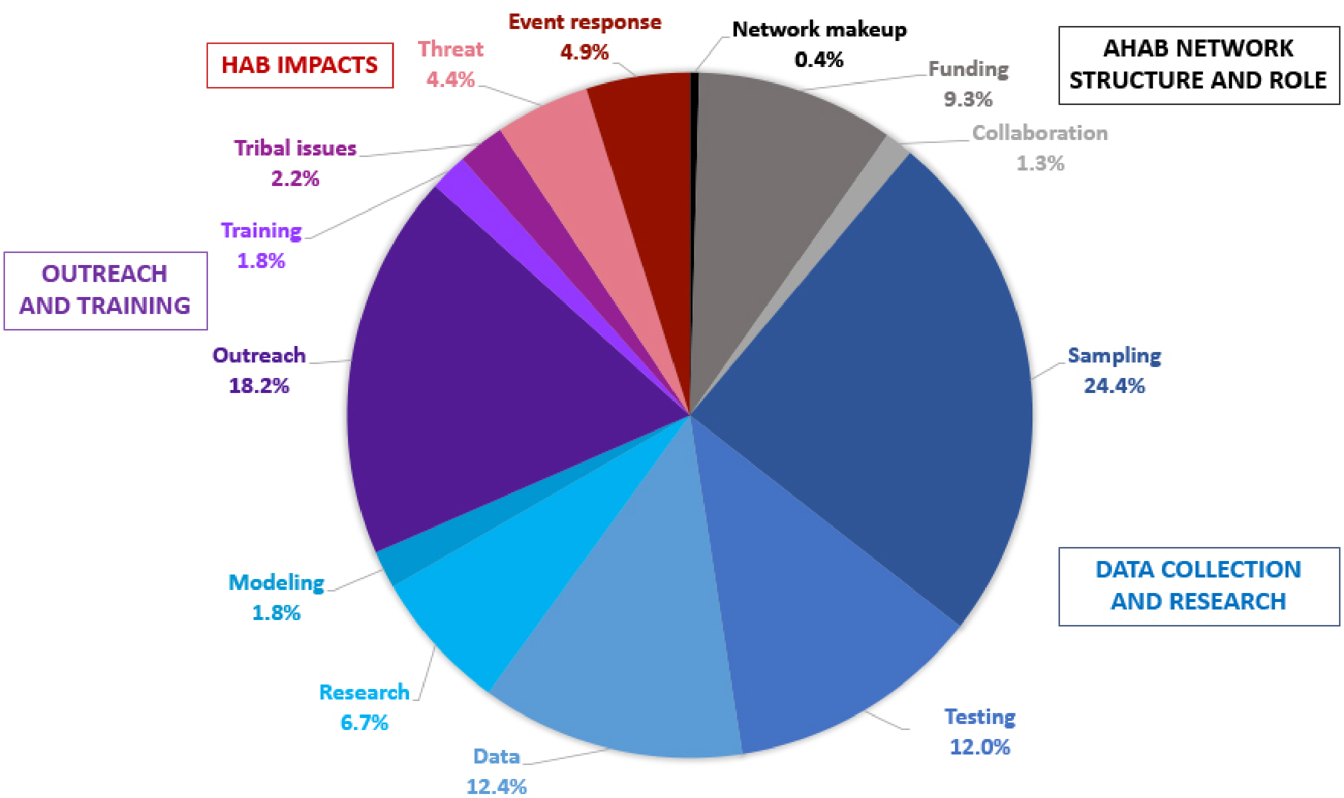

FIGURE A3. Distribution of the 225 comments collected during the AHAB Network informal listening sessions within broad themes (boxes) and categories (pie slices). Categories include: Network makeup (how the AHAB Network should be structured), Funding, Collaboration, Sampling, Testing, Data (how the data should be managed and disseminated), Research (knowledge gaps that should be filled), Modeling, Outreach, Training, Tribal issues, Threat (how HABs are perceived as a danger), and Event response coordination (the role of AHAB during a HAB event). If comments could have been attributed to more than one category, the main overarching theme of a comment was used to categorize it.

Alaska
Harmful Algal Bloom Network

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