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Health Communication Blindspot: A Case Study of Harmful Algal Blooms in the South (HABITS)

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HEALTH COMMUNICATION BLINDSPOT: A CASE STUDY OF HARMFUL ALGAL BLOOMS IN THE SOUTH (HABITS)

by

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DEDICATION

Dedicated to my incredible wife Jessa and my amazing mom Debbi, who have supported me throughout my life. I will never deserve their endless help and encouragement. I also dedicate this work to anyone looking to improve the health of all people through thorough research and honest dialogue.

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ABSTRACT

A Harmful Algal Bloom (HAB) is a complex natural event that occurs when algae is in its growth stage and creates a harmful toxin as waste. HABs create both ecologic and public health challenges. The hypothesis of this thesis is that state and federal governments have different readability scores when compared side-by-side as measured by Simple Measures of Gobbledygook (SMOG). Because governments are the entity that most often claims responsibility for shared resources, this case study represents a snapshot of current governmental messaging about HABs in the South Atlantic states. These states have a long history of HAB events in both fresh and marine water environments. Intense urbanization, nutrient loading, increasing water temperatures, and ocean acidification have all contributed to increased recorded HAB events in recent years. As this region continues to face booming population growth, the issue of HABs will continue to play a role in the development and exploitation of coastal communities.

The scientific community often grapples with the difficulties of disseminating evidence-based messaging to a lay public audience. One emerging field in environmental health sciences is environmental health literacy (EHL). As a discipline, EHL rests between environmental science and health communication. Sources for this online content analysis were obtained using a targeted search of both South Atlantic state websites and federal agencies concerned with HABs and their effects on human health. 90 webpages were identified from state (n=38) and federal agencies (n=42), as well as non-governmental organizations (n=10). The average SMOG score of all 90 sources is an 11th grade reading level (10.7) with a standard deviation of 2.78. This content analysis reflects the complexity of scientific communication. However, as evaluation and improvement are the final steps in any public health programming, evaluation needs to be undertaken in all EHL programming in order to properly protect the public from known toxicologic and environmental health risks.

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CHAPTER 1: INTRODUCTION

The term Harmful Algal Bloom (HAB) represents a broad spectrum of environmental occurrences that result in water quality degradation. A commonality among all HABs is the rapid proliferation of toxin-producing phytoplankton which have the potential to cause harm to nearby organisms (Maso & Garcés, 2006). Although the review here focuses primarily on human health outcomes, it should not be dismissed that there are certain environmental concerns associated with HABs that do not necessarily register among those encompassed by human health effects. Although algal blooms are naturally occurring events described by the uncontrolled growth of algae or cyanobacteria, these organisms can create deadly toxins that further classify them as HABs.

HABs pose an interesting public policy dilemma due in large part to the ways water resources are regulated and which agencies in the United States are responsible to respond to them. The Environmental Protection Agency (EPA) maintains and is primarily responsible for freshwater (inland) while the National Oceanic and Atmospheric Administration (NOAA) is responsible for marine waters (coastal). The Centers for Disease Control and Prevention (CDC) acts as a sort of human health focused bridge between these agencies as it responds to concerns about HABs through a public health lens. While federal entities maintain various programs for the detection of HABs, most of these events are maintained and/or prevented by local environmental managers.

The Clean Water Act (CWA) of 1972 gave the EPA sweeping authority to enact pollution control measures for U.S. waterways. The basis of this legislation is to maintain surface waters within the country as fishable, drinkable, and swimmable. The Safe Drinking Water Act (SDWA) of 1974 gave the EPA further regulatory powers to enforce issues related to drinking water contaminants, with increasing scrutiny of HAB toxins within the last couple decades. These two pieces of major legislation are not the only or first attempts by governing agencies to address water pollution concerns, however they do illustrate the rapid federalization of water quality regulation (Hudnell, 2010). Within a couple of years the federal government successfully gained regulatory access to essentially all "waters of the United States," a term that has received increasing political scrutiny under the Obama and Trump administrations.

This case study represents a snap-shot of current governmental messaging about HABs. Geographic justifications are given, but the general structure of what follows is introductory and background information, public health implications, health communication overview, and finally the content analysis, respectively. Chapters and headings are used to signal new sections of this work, and although no chapter stands alone, each may individually provide the reader with different context surrounding this issue.

1.1 HAB Classification

Two of the most common categories of HABs in the United States are colloquially termed CyanoHABs and red tides. CyanoHABs are formed from cyanobacteria, also called blue-green algae, which can occur in fresh and brackish water. Red tides, however, occur mainly in marine environments when algae grow in excess. Often the term CyanoHAB is used to describe all freshwater HABs while red tide is used to describe all saltwater HABs, however this is overly simplistic and causes several communication miscues and misunderstandings (Saqrane & Oudra, 2009). While the causative organisms behind HABs vary, all are a form a phytoplankton which form the basis of most aquatic food webs. The health of phytoplankton plays an integral role in the health of the ecosystem, but when these phytoplankton produce toxins they can be dangerous to organisms at all trophic levels. Because phytoplankton photosynthesize and use energy from the sun for basic life functions they tend to accumulate and reproduce best on the surface of water, creating dense mats. Using the dissolved oxygen (DO) in the water and the sunlight from above these algae can create hypoxic conditions that can kill organisms living at all depths in the water column through the cyclic natural phenomena of upwelling and downwelling (Cusack et al., 2016).

Not only do algal bloom toxins cause harm to human and ecosystem health, but the mere presence of algal blooms can cause ecologic disruptions. High density algal mats block sunlight and use inordinate amounts of dissolved oxygen (DO) resulting in fish kills and harm to other aquatic life where sunlight is blocked by the bloom itself. Some algal species also tend to clump and can coat the gills of fish causing them to suffocate. The photosynthetic processes of phytoplankton raise pH as phytoplankton use DO to create hydroxide as a byproduct in the aquatic system. Temperature is also used as a metric for monitoring blooms as most HAB-inducing species prefer warmer waters, hence the seasonal endemic increase in HAB activity during the summer months in the United States.

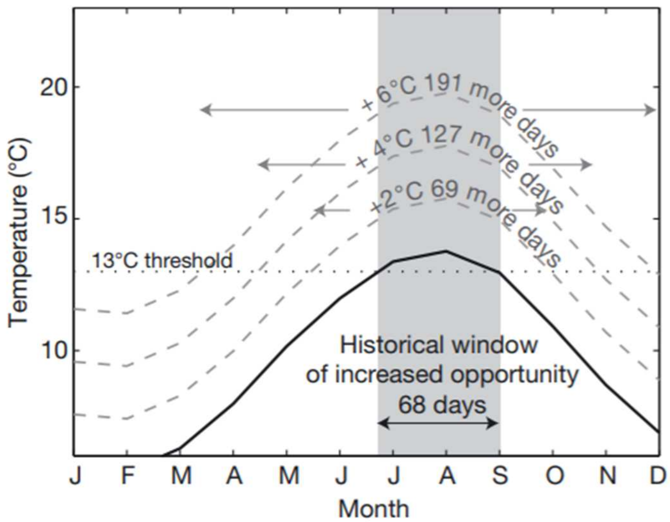

Figure 1.1 Primary HAB Occurrence Window in Northern Hemisphere (Fu, Tatters, & Hutchins, 2012)

Figure 1.1 describes the modeled increased HAB season that mirrors increased temperatures. As global climate variation affects regions differently, increased temperature alone cannot account for the rapid increase in HAB events (Townhill et al., 2018). But the model noted in the figure does project the significance of increased regional ambient water temperatures on HAB seasonality. It should also be noted that the anthropogenic effects of thermal pollution, weather events, and even geophysical alterations can cause variances in water temperature (Fu, Tatters, & Hutchins, 2012).

Cyanobacteria thrive in eutrophic conditions (excess nitrogen and phosphorus), warm water, and high levels of carbon dioxide (CO_2). All three of these conditions are met with increasing speed by the dangers of global climate change. As Paerl and Paul describe, Cyanobacteria are extremely adaptive and can survive through changing environmental conditions. As such, CyanoHABs will likely increase in the future due to the coupled issues of nutrient loading and anthropogenic climate change (Paerl & Paul, 2012). Their research also shows that more frequent precipitation in some areas results in increased runoff and higher nutrient loading and thus results in a greater propensity for future CyanoHABs. CyanoHABs are the most common HAB in freshwater and have been identified in waters in all 50 states (Lopez et al., 2008).

The most common genera of bloom-forming cyanobacteria are *Aphanizomenon, Cylindrospermopsis, Dolichospermum* (*Anabaena*), *Microcystis, Nodularia, Planktothrix* and *Trichodesmium*. Because many of these cyanobacteria are able to perform nitrogen-fixation, they maintain a competitive advantage over eukaryotic plant organisms in the same aquatic ecosystem. Although *Microcystis*, the predominant cyanobacteria in the Great Lakes region of the United States, are not able to perform nitrogen-fixation, they benefit greatly from the increased nitrogen levels accumulated through eutrophication (Huisman et al., 2018).

The science surrounding algal blooms indicates that eutrophication and nutrient loading affect both the intensity and frequency of HABs (Heisler et al., 2008). HABs potentially pose an even greater risk in the future than the damage they have previously caused due to population growth and aquatic habitat encroachment and destruction. The apparent increase in HABs over the last few decades has been displayed in climate models. HABs in both fresh and marine waters increase when CO_2 increases and pH lowers. Both of these facets are affected by the phenomenon known as global climate change (Moore et al., 2008). The global phenomenon of lowering pH in aquatic systems is termed ocean acidification. Ocean acidification takes place over a series of chemical reactions in which ambient deposits of CO_2 actually cause aquatic systems to become more acidic over time.

With over 5,000 known species of marine phytoplankton with the potential to cause discoloration in water, less than 100 species have been shown to produce potent toxins harmful to human health (Hallegraeff, 1993). The most common human health concerns are: Paralytic Shellfish Poisoning (PSP), Diarrhetic Shellfish Poisoning (DSP), Amnesic Shellfish Poisoning (ASP), Ciguatera Fish Poisoning (CFP), Neurotoxic Shellfish Poisoning (NSP), and Cyanobacterial Toxin Poisoning (CTP). As their names imply, many of these conditions arise from the bioaccumulation of the algae-produced toxins in fish and shellfish. This is why the immediate response to blooms is often a closure of certain commercial activities, such as shellfish harvesting, so as to reduce the amount of adulterated shellfish consumption.

While each of these syndromes will be discussed in detail later, it is important to note the diverse ailments resulting from HABs. The primary toxin classes produced from the associated syndromes listed above are: saxitoxins (PSP), okadaic acid/dinophysistoxins (DSP), domoic acid (ASP), ciguatoxins (CFP), brevetoxins (NSP), and cylindrospermopsin (CTP). Due to trophic transfer the toxins produced by algae biomagnify as organisms consume other toxinladen organisms (Sellner, Doucette, & Kirkpatrick, 2003). To qualify the health effects of these toxins researchers have elucidated the use of these biotoxins in biological warfare (Anderson, 2012). In 2020 Sierra & Martínez-Álvarez described the use of saxitoxin in war efforts and the even the possibility of weaponizing HAB toxins in the future.

1.2 Economic Impacts

Economic losses due to HABs have been estimated at over a billion dollars of lost revenue due to poisonings, loss of commercial fishing activity, and loss of recreation and tourism (Hoagland et al., 2002). In 2000 costs of monitoring and management across just 12 states was estimated at $2 million (Anderson et al, 2000). It should be noted that due to the rising number of HABs reported each year, these numbers have likely skyrocketed in the two decades since the publication of the cited reports. HABs also pose undefined economic impacts by killing the natural organisms that compete for resources within these aquatic habitats and cause long-term downstream economic difficulty. Regional beach closures also have large economic impacts. In Washington state it was estimated that a full season beach closure would result in the loss of $20.4 million for the regional economy (Dyson & Huppert, 2010).

In Florida alone the red tide event between September 2012 and early 2013 was estimated to cost over $500 million (2018 $) in health-related expenses alone. These expenses include morbidity costs, treatment costs, and lost wages (Limaye et al., 2019). As these costs only reflect short-term exposures, it should be remembered that chronic exposure to HAB toxins can result in continued economic downturn. As these events continue along the Florida coast, the mounting costs of treatment and monitoring could prove devastating to local economies. Both direct and indirect costs of HABs result in economic difficulty. The rising costs of healthcare, calculated at 15.3 percent of the national GDP (Anderson & Frogner, 2008), also results in the rising cost of HABs.

Florida red tides are caused by *Karenia brevis*, a microscopic algae that thrives in marine waters. *K. brevis* produce neurotoxins which have been linked to both NSP and PSP. Although these events are endemic to certain areas along the Florida coast, many residents of the area report receiving information on these HABs in a piecemeal fashion rather than receiving all relevant information at once. Because of the apparent disconnect between discrete pieces of information surrounding these HABs many avoid seafood altogether when an event receives media attention, despite the fact that commercial seafood is often harvested far from the infected water. Economists call this the “halo effect,” as consumers avoid the risk of any seafood contamination by avoiding seafood rather than avoiding only those species known to cause human health effects (Kuhar et al., 2009). In regions like Florida that rely on aquaculture as a primary economic driver these losses can be devastating to local communities.

1.3 Communication Issues

Perhaps unsurprisingly, Florida residents were twice as likely to be aware of the dangers of *K. brevis* HABs than tourists (Nierenberg et al., 2010). These same Florida HABs resulted in a number of calls to the statewide toll-free Aquatic Toxins Hotline. Only 8% of calls to the hotline reported obtaining the number from a beach sign, while the majority of callers reported obtaining the number from an online resource (39%, with 18% receiving the number from a newspaper or magazine, and 15% receiving the number from a friend). Although 80% of respondents to a survey requested more beach signage with information regarding HABs, only a small portion actually request information as indicated on the signs themselves. This finding means that online resources are the primary source of HAB information for this geographic region, thus bolstering online resources has the potential to greatly enhance public awareness of the dangers of HABs.

Cases of HABs in the Great Lakes region have been reported since the 1960s. Since the Great Lakes are used as a primary source for multiple public water systems, toxins like microcystin can cause immediate public health concerns when they accumulate to levels that cause entire communities to temporarily close municipal water systems as was the case in 2014 for Toledo, Ohio. Modeling reports from NOAA indicated that the HAB conditions on Lake Erie would worsen over the coming weeks without direct intervention. The city issued a drinking water advisory that limited 500,000 residents water access the day following the initial report. The number of people directly affected by this bloom caused news outlets to report it at higher rates than other HAB events although the 2013 bloom on Lake Erie that affected Carrol Township, Ohio was actually a larger bloom than the 2014 bloom affecting Toledo (Wynne et al., 2015).

For decades, limiting phosphorus inputs was held up as the gold standard for reducing the risk of HABs. However, the synergistic effect of nitrogen enrichment has proven to be one of the most important factors in HAB creation and proliferation. Phosphorus tends to increase algal biomass and thus causes problems deeper in the water column as sunlight is not able to penetrate the algal mat. Both nitrogen and phosphorus are components in fertilizers, and thus concern over agricultural practices has long been tied to HABs research and management. While removal of either nutrient tends to decrease the viability of a HAB, both nutrients need to be addressed in order for HABs to be properly managed (Paerl et al., 2016).

Anderson and others establish that eutrophication leads to more intense algal blooms. As anthropogenic fertilizers are washed into waterways by rain and human activity, the overnutrified environment provides ideal conditions for HABs to flourish. Some species are more prone to the effects of eutrophication than others. To support this idea researchers point to *Alexandrium* species which cause blooms in the Gulf of Maine. (Anderson, Glibert, & Burkholder, 2002). *Alexandrium* species - responsible for paralytic shellfish poisoning (PSP) - appear to be affected by nutrient loading as a secondary factor to their growth because of their ability to form cysts and transport through natural storm systems.

Because eutrophication and nutrient loading stem from the overuse of chemicals in agriculture and habitat encroachment, communication practices can curb HABs through audience segmentation and tailoring messages for the agricultural and construction communities. Audience segmentation is a communication technique that groups audiences by need and specific defining criteria. The process of creating unique messages for specific audiences to meet the different audience's needs is known as tailoring (Hawkins et al., 2008).

1.4 Technological Barriers

Response to HABs is both costly and complicated. As not all blooms produce the same toxins, rapid lab response cannot always be obtained. On-site microcystin test kits in the Great Lake region allowed researchers to establish the general efficacy of qualitative analysis, but these rapid tests also produced a 32% false-positive rate when microcystin levels were between 1 and 5 µg/L (Watson et al., 2017). These results emphasize the need for further development of rapid response testing for HABs as the proliferation of algae can cause rapid degradation of water quality. Without reliable quantitative field tests, the management and response to HABs is significantly hindered. Due to the economic impacts discussed earlier, resource managers should carefully take into account both historical and modeling data before final decisions regarding a certain body of water can be made.

Forecast models for HABs range from days to decades. These models can represent simple variables such as DO and pH or complex variables such as wind patterns and land use. Many of these models attempt to account for increasing coastal populations as well as changes in land use and increased imperviousness of the landscape at large. Special nutrient loading causes its own challenges to forecast models because of the variability in non-point sources of pollution from year to year. In general, higher confidence models tend to represent more proximal dates and thus the forecasting function of such models is notably inhibited (Glibert et al., 2010). Higher confidence models are also costly to produce in terms of research and development as well as the high cost of emerging technologies.

The two predominant monitoring approaches for HABs in use today are *in-situ* and remote sensing technologies. *In-situ* sampling and surveying can be extremely cost-prohibitive because of the inputs involved in taking various samples at the water site and then analyzing each individual sample. Remote sensing allows those monitoring for HABs to use satellite-generated images that have been trained to distinguish the color of HABs from other naturally-occurring colors in waterways. Remote sensing can be difficult due to local factors such as cloud cover, so both monitoring approaches have been observed to reflect some characterization discrepancies (Bertani et al., 2017).

The use of Environmental Sample Processors (ESPs) has increased since their original creation in the early 2000s. An ESP autonomously samples water and communicates that data back to scientists on land. Originally deployed to detect *Alexandrium fundyense* in the Gulf of Maine, ESPs can now detect a range of species and have been deployed across the United States (Seltenrich, 2014). By providing real-time web application support, scientists are able to sample water at any time and thus better detect when a bloom occurs as well as when it ends so normal water activities can resume. ESPs are even able to perform classification functions, thus allowing for quicker identification of toxins.

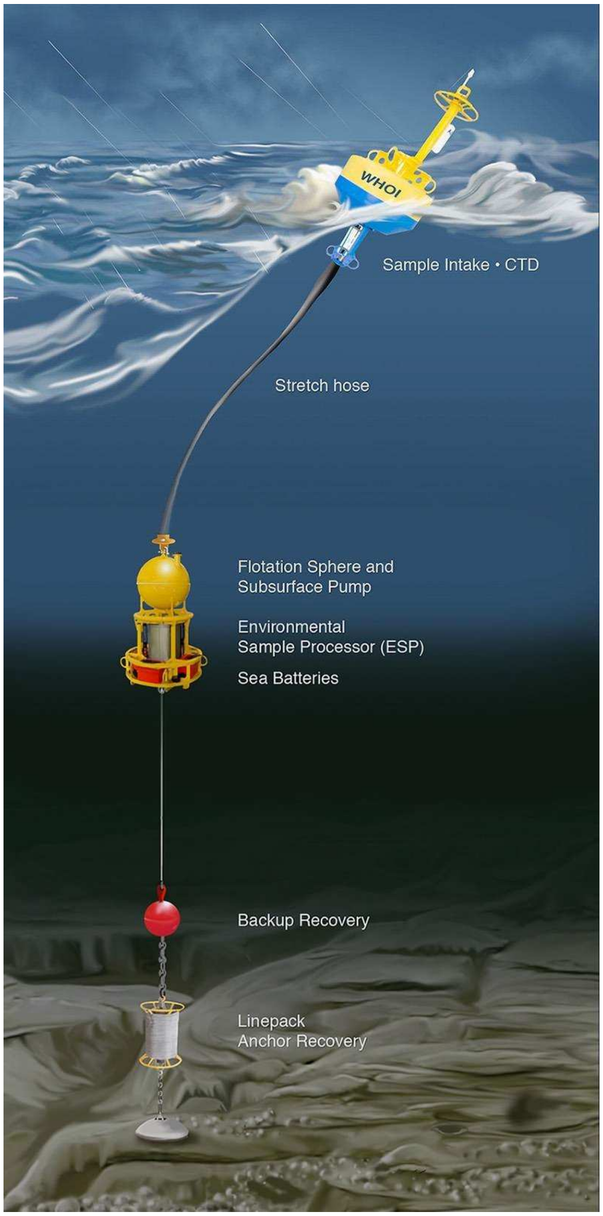

Figure 1.2 ESP Surface to Floor Diagram
(Seltenrich, 2014)

Because newer generations of ESPs are able to fit in tighter locations than previous models, they can now be used in freshwater environments like the Great Lakes and could prove a viable option for monitoring in recreational waters across the country. The diagram above shows not only the complexity of the sampling device, but also illustrates potential health communication needs. The public using the water for recreation needs to understand the importance of the instrumentation as well as the physical structure as the device could be damaged or cause physical harm to people if boats collide with the intake mechanism. The data transmitted to water managers also involves scientific readings with which the public are not necessarily familiar. The need for health communication exists from data collection to data interpretation in water sampling. As HAB data is translated to the general public, technological advancements will continue to allow more rapid results to be directly communicated to the public. Smart devices could alert water users as soon as a HAB has been detected (Alasmari & Anwar, 2016).

1.5 Geographic Justification

The state of South Carolina represents a useful model for HABs research over time. Due to a large population increase coupled with extensive water resources, HABs researchers have been able to see how land use changes and urbanization have combined to create potential HAB areas of concern. The ingredients needed for HABs to proliferate were noted in a population boom around the year 2000 in which golf courses were evaluated for their potential as sites for future HABs and HAB contributors. The results of this study showed that golf course nutrient loading combined with rapid urbanization could cause HABs at an alarming rate. The researchers here encourage the continued use of buffer zones to distance nutrient-rich environments from centers of aquatic life (Lewitus et al., 2003).

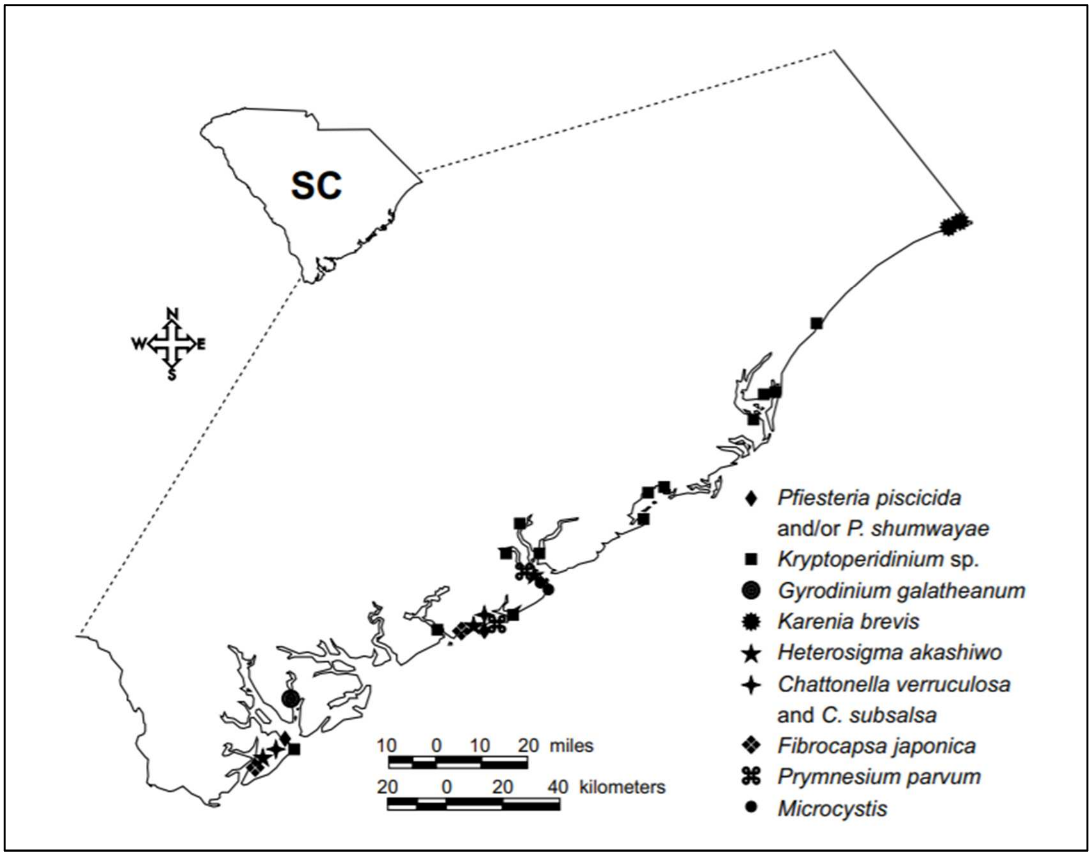

Figure 1.3 HAB Species in SC Through May 2001 (Lewitus & Holland, 2003)

The figure above shows the HAB-forming species identified along the coast of South Carolina through May 2001. Similar figures can be found for the entire eastern seaboard from Maine to Florida and the Gulf Coast from Texas to Florida. This figure was selected to represent a snapshot of just how many distinct species and locations are implicated in HAB formation in one state. Resultant from continued concerns over HABs, South Carolina implemented the South Carolina Harmful Algal Bloom Program to expand monitoring and surveillance within the state. By the use of citizen-led programs the state relies heavily on increased reporting of HAB indicators as defined by State Water Quality Standards per the CWA.

The South Atlantic states are of particular concern for HABs research because of their high propensity to HAB-related events coupled with their geographic proximity to population centers. The Southeast Coastal Ocean Observing Regional Association (SECOORA) consists of the South Atlantic states and includes over 42 million coastal residents. Coordinating coastal observations, SECOORA focuses on resiliency, which plays a role in HAB proliferation and remediation (SECOORA, 2020). While no single composite for the region's freshwater resources exists, state agencies publish regular reports on issues related to water quality. Individual state agencies in the South Atlantic region are also supported by the U.S. Fish and Wildlife Service (FWS) and the U.S. Geological Survey (USGS). Many states also maintain governor-sponsored task forces that evaluate the state's response to HABs and make recommendations for future management of such events.

In general, the coastal waters of the South Atlantic states have been broken down into three distinct parts: the large ocean inlets of North Carolina, the brackish estuaries of South Carolina, and the subtropical waters of Florida (Dame, 2000). Intense urbanization and nutrient loading have once again been cited as possible causative agents for these frequent blooms, but the physical landscape along the middle region of the South Atlantic should not be discounted as a possible protective force against coastal HABs. As this region continues to face booming population growth, the issue of HABs will continue to play a role in the development and exploitation of coastal communities.

CHAPTER 2: PUBLIC HEALTH EFFECTS

As coastal communities continue to grow exponentially due to natural migration, HABs pose particular concern to public health officials in part because of their toxin-producing designation as a contaminant of emerging concern (CEC). No federal aquatic criteria exists for CECs, and as such there is no single water quality standard that is required to be maintained as it relates to the toxins produced by HABs. As HABs increase worldwide, the public health response will need to be reciprocal in magnitude (Brooks et al., 2016). Through the discipline of health communication the effects of HABs can be mitigated so as to pose a smaller impact on human health than is currently observed.

One of the earliest public health alerts from the occurrence of HABs in the United States was the regional scare surrounding *Pfiesteria* in the Chesapeake Bay in Maryland in the late 1990s. Fish were discovered with skin lesions associated with the microorganism *Pfiesteria*. Human exposure to the associated toxins included neurological symptoms including suppressed cognitive function (Grattan et al., 1998). Although *Pfiesteria* had previously been linked to fish kills, this was a considerable public health scare in the nation's capital because of the rapid health effects of even moderate exposure (Fleming et al., 1999). Toxicologists have since identified multiple exposure pathways leading to illness in humans. While various organisms will produce different toxins, it is interesting from a public health perspective to note the relatively similar symptomatic appearance of exposure including headache, nausea, and neurological symptoms.

Cyanobacterial Toxin Poisoning (CTP) occurs most frequently in freshwater HABs. Carmichael suggests that there are over 40 genera of cyanotoxin-producing cyanobacteria, but highlights *Anabaena, Aphanizomenon, Cylindrospermopsis, Lyngbya, Microcystis, Nostoc,* and *Oscillatoria (Planktothrix)* as the primary culprits of deleterious human health effects (Carmichael, 2001). Humans can be exposed to these cyanotoxins by ingestion or inhalation of aerosolized toxins. These toxins pose significant health concerns such as gastroenteritis and nausea as well as respiratory distress. As with many environmental toxicants, the most vulnerable populations to these effects are the very young, the very old, and those with preexisting health conditions.

Certain cyanotoxins have been linked to specific neurological diseases and syndromes such as sporadic amyotrophic lateral sclerosis (sALS), commonly known as Lou Gehrig's disease. Researchers connected sALS with the neurotoxin beta-N-methylamino-l-alanine (BMAA) using epidemiologic data from Guam in the 1940s and 1950s. BMAA is produced by cyanobacteria and was likely consumed incidentally in the largely pescatarian diet of the natives of the island (Stommel, Field, & Caller, 2013). As fish represent one of the largest imports in the United States it remains incredibly important to test fish consumed around the world for known toxins to reduce the risk of human consumption.

Under the Hazard Analysis and Critical Control Points (HACCP) program, the Food and Drug Administration (FDA) tests seafood for dozens of toxins and physical contaminants either upon its importation from other nations or prior to its sale as a domestic product. NOAA also maintains a voluntary inspection program as outlined by the Agricultural Marketing Act of 1946. While these efforts are undoubtedly necessary, recent oceanic events, such as the Deepwater Horizon oil spill, have brought the seafood industry under further scrutiny (Gohlke et al., 2011). Because the voluntary inspection program remains voluntary, and the FDA is only able to screen a limited portion of seafood consumed in the United States due to limited funding and the rapid transactions in the seafood industry, the risk of American consumption of adulterated seafood remains remarkably high.

Routes of transmission for cyanotoxins have been proposed for both aerosolized toxins and ingested toxins (Facciponte et al., 2018). Since the mechanisms of respirable particulate matter are relatively well understood, researchers have been able to identify algal toxins in the nasal and respiratory passages of humans and other land mammals. Although previous research has associated spatial clustering of epidemiologic data with distance to a HAB (Caller et al., 2009), more current research finds no such relationship to either geography or time of year. These findings relate the chronic nature of exposure to HABs resulting in cyanotoxin-related ailments beyond sporadic HABs due to an accumulation of toxins over days, weeks, or years.

Aerosolized toxins are of particular concern to public health. Because these toxins do not require the ingestion of tainted water or seafood, the potential scope of the effects of these toxins spans entire communities. As mentioned previously, *K. brevis*, is the culprit of Florida red tides. These algae produce toxic aerosols that have been documented to affect asthmatic individuals along the Florida coast. The effects of just 1 hour of beach exposure for these individuals did not subside for the following 5 days (Kirkpatrick et al., 2011). Respiratory distress was identified in beach goers who were more than a mile from the water, but the aerosolized toxins know no boundaries. As the potential for red tides migrates north into waters in Georgia and the Carolinas public health officials will need to be diligent to advise vulnerable populations to avoid affected areas.

Some of the toxins associated with marine HABs are acutely lethal such as ciguatera fish poisoning which has a total body toxic dose of just 70 ng (Fleming et al., 2006). Many of these toxins are heat and acid stable meaning normal food preparation techniques will not neutralize the toxic effects. Public health interventions in this case must prevent the harvesting of organisms from waters known to be contaminated by a HAB. Many HABs target the nervous system and as such cause intense and rapid neurological conditions, hence the naming of Amnesic Shellfish Poisoning (ASP) and Neurotoxic Shellfish Poisoning (NSP).

Ciguatera Fish Poisoning (CFP) occurs when fish with ciguatoxins are consumed. Ciguatoxins are primarily produced by *Gambierdiscus* species of microalgae and cause gastrointestinal distress quickly followed by peripheral neurologic symptoms within 12 hours of consumption. Ciguatoxin profiles also vary by region and thus the potency of any one poisoning could significantly vary from one to another. (Dickey & Plakas, 2010). Detection techniques for ciguatoxins in fish are still quite cumbersome, and thus the most efficient public health intervention continues to be avoiding consumption of any fish that may have been exposed to ciguatoxins or HABs in general.

Lyngbya is another cyanotoxin producing organism that thrives in tropic and subtropic climates. Rashes and other dermatologic effects have been observed from exposure to *Lyngbya*-associated toxins dating back to at least 1980 when an outbreak of “seaweed itch” struck the island of Oahu, Hawaii. Symptoms began within 24 hours and continued for as long as 12 days (Osborne, Webb, & Shaw, 2001). As these toxins affect the use of recreational waters, the physical and commercial activity impacts of such blooms can cause increased public panic and distress. Although the cited study was performed in Hawaii, lower salinity systems have been associated with these HABs as well including Lake Wateree in South Carolina (Ferry et al., 2020).

HABs can affect municipal drinking water systems in a variety of ways. Some of the most common HABs-related effects on drinking water are changes to taste and odor. Consumers of drinking water associated with any algal bloom, not just HABs, may report changes in their water to local water managers. When cyanotoxins are detected in water it can result in the same deleterious health effects as described through the route of inhalation. Chronic exposures to cyanotoxins in drinking water have not been extensively explored, but as a CEC researchers will likely consider this long-term exposure in the coming years.

In an effort to better understand the public health impacts of HABs the CDC developed the Harmful Algal Bloom-related Illness Surveillance System

(HABISS) in 2008. Although the program ended in 2012, the state partnerships and lessons learned from the data collected remain invaluable. Hundreds of cases of canine poisonings throughout the U.S. were identified. In total, 11 states participated in HABISS with North Carolina, South Carolina, and Florida all contributing data. During the years 2007-2011 Backer and others identified 584 case reports of human illnesses associated with cyanobacteria or algae with 219 meeting the criteria for a confirmed case (Backer et al., 2015). More than 4,500 bloom events were reported to HABISS by the 11 participating states.

Since the discontinuation of HABISS, the CDC and EPA created the One Health Harmful Algal Bloom System (OHHABS) in 2014. Similar to HABISS, the intent of this program was to create a framework where state and federal partners can collaborate to ensure the CDC's National Outbreak Reporting System (NORS) receives the most accurate data about HABs possible. OHHABS consists of the One Health framework and thus focuses on the combined health effects of HABs on the environment, animals, and humans. The One Health model links human health and animal health in order to create a holistic view of environmental risks. NORS contains foodborne and waterborne outbreaks, thus the two platforms overlap when HABs cause human disease outbreaks.

One of the primary concerns with the data collected in any HAB dataset is the under-reporting as symptoms of HAB-related illnesses may be falsely diagnosed as an acute case of gastroenteritis or respiratory distress. Unless a patient knows to inform a healthcare provider that they were recently recreating around contaminated water, the symptoms of illness can often be dismissed as some sort of general unidentified gastric discomfort. Especially because symptoms of illnesses correlated with HABs tend to subside on their own within 48 hours, the vast majority of infected individuals will never seek healthcare treatment. These effects of incomplete medical diagnoses undermine the data integrity of any repository of HABs events, however if the public was made aware of the symptoms of HAB-related illnesses then they would be more likely to seek care as well as more likely to avoid exposure to HABs altogether.

The success of statewide public health surveillance efforts surrounding HABs has been mixed. In New York State there were 139 HABs identified in 2015. Of those 139, 51 HAB-associated illnesses were reported with 32 cases that met the CDC case definition for human HAB-associated illness. Among patients identified the median age was 24 years old with dermatologic symptoms reported in 22 (69%) of the patients. According to researchers the HAB-associated illness reports in New York had never been more than 10 in any given year (Figgatt et al., 2017). The increase in reporting could result from a number of factors including increased public awareness and a longer period of warm waters when compared to previous years. The New York State Department of Health was able to rely heavily on the New York State Department of Environmental Conservation to identify locations of HABs.

Detecting HAB exposure in human populations remains difficult, especially when compared to the relative ease of detection to other toxins such as lead or mercury. This is due to the widespread use of rapid and technically simple laboratory tests for the confirmation and quantification of heavy metals. Although more than 250 unique toxins have been identified as harmful to human health under the umbrella of microcystins, no widespread assays exist to confirm human exposure to cyanobacteria. In 2019 Wharton et al., produced a study describing the creation of a urine-based assay designed to detect a common microcystin toxin known as MC-LR in quantities as low as 0.050–0.500 ng/mL (Wharton et al., 2019).

Modeling and forecasting for HABs remains incredibly important as water resource managers attempt to more quickly identify when a bloom is occurring in order to properly advise the public and mitigate the situation. While there are various tests and assays to describe various toxins, enhanced modeling allows resource managers to better predict where certain organisms will arise and influence HABs. Since HABs in the Gulf of Mexico tend to vary widely from HABs off the west coast of the United States or even HABs in the Gulf of Maine, predictive models specific to traditionally geographic HABs play an important role in preventing exposure to toxins themselves.

One of the most exciting applications of computer-based modeling for freshwater HABs involves the Sentinel-3 satellite from the European Space Agency. This process involves using baseline images of freshwater sources using NASA color data. The color baseline color of large bodies of water is recorded and then a computer is trained to recognize deviations from the normal color. Because algal species rely on chlorophyll-a, which has a distinct color, near real-time evaluations of water based on color can allow managers to use satellite images to determine the probability of a bloom. This technique does have a tendency to produce a high false positive rate because chlorophyll-a can accumulate on the surface of a body of water for reasons other than HAB formation.

Researchers implemented this technology across an app known as the Cyanobacteria Assessment Network (CyAN) which allows users of the mobile application to access Sentinel-3 data. This app was designed to bring managers more accurate and reliable data and to create an instant feedback loop to the science of HABs. A mobile application was developed as mobile technology is already more widely available than traditional desktop computing. The software design was split 70/30 between scientists and resource managers. The design dictates 70% of data processing, from development to delivery, is the responsibility of scientists, and 30% of the data comes directly from managers with metrics for various thresholds and the responsibility of site location. Through the use of specific algorithms previously developed, the tool is able to convert images to cyanoHAB abundance measured in cells/mL.

As various states maintain different thresholds for public advisories, end-users (managers) are able to set their own thresholds for receiving alerts from the system. The app allows the end-user to overlay images so as to see the baseline map as well as the satellite imagery. Images are able to be viewed up to one (1) year previous which allows managers to see changes to blooms over time. The effectiveness of the app data was used by comparing CyAN app sites with additional sampling performed at bodies of water across the United States. In June, 2017 a HAB on Utah Lake was discovered between monthly sampling periods. After an alert via CyAN water managers obtained additional sampling and discovered a HAB and were able to issue a corresponding public advisory.

Some of the primary limitations to current HAB modeling and forecasting are issues related to cybersecurity. Because these apps relate data from an international satellite to both state and federal end-users certain limitations are in place in order to maintain data integrity. These limitations serve to protect the data, but also tend to slow the transmission from the source to the end-user. Another limitation of the CyAN app is the requirement that relatively large bodies of water be used for analysis. As the satellite used obtains pixel resolution of 300 meters, some bodies of water that may be of particular concern to local water managers may not represent a usable datapoint (Schaeffer et al., 2018).

Recently these same satellite images were used to prioritize areas of concern based on the frequency of blooms. Utilizing the U.S. public water surface intake locations as well as recreational water sources researchers ranked HAB-associated waters that exceeded the WHO threshold of 100,000 cells/mL (Clark et al., 2017). This and other quantitative measures can help water managers and public health officials prioritize precious monitoring resources as well as focus on areas of highest concern for further analysis. These prioritization efforts allow funds to go to areas with more frequent blooms and allow the research that comes from these areas to reach new areas of concern as they arise.

Coastal HAB monitoring represents difficulties due to the topography and intricacies of the coastline itself. Public health monitoring programs have become increasingly important to certain coastal communities (Franks, 2018). Hu and others developed a user-friendly web-based service to track the intensity and forecast the duration of *K. brevis* blooms along the Florida Gulf Coast (Hu et al., 2015). Although endemic to the region, this open source platform allows managers to use Google Earth products to evaluate HABs. Because this data is quickly adapted to the needs of a broad user base, this modeling can be used in a near-real time fashion to inform public health decisions. The underlying algorithms behind the user-friendly data however require the input of satellite imagery, sampling data, and numerical modeling. When any one of these features is not accurate, the entire model can produce inaccurate models and result in unnecessary concern or perceived safety.

Because surveillance represents one of the foundational practices and principles of public health, a combination of efforts for data collection is necessary. Patients seeking healthcare after exposure, water quality monitoring programs, and post-bloom evaluation are all crucial pieces of a holistic public health program designed to address the human health impacts of HABs. As surveillance methods and the descriptive epidemiology of HAB-related illnesses become increasingly complex the need to properly communicate risk characterization to the public remains paramount. The public health response to harmful algal blooms requires a strong health communication piece to alleviate unnecessary exposures in the general population.

Health communication embraces a wide field of interdisciplinary specialist to improve the health status of populations. The National Communication

Association defines health communication as, “How people communicate in different health care contexts” (National Communication Association, 2020). Health care here can be interpreted as anything from general public health primary prevention to medical tertiary and quaternary prevention. As health communicators, public health professionals are responsible for delivering information to the general public that is both accurate and easily understood. A subfield of health communication is risk communication, which involves communicating a health risk to a particular population. For the purposes of this study the terms risk communication and risk communicators are used interchangeably with health communication and health communicators who are all identified as public health professionals.

As a construct of public health, risk can be understood as the magnitude of a hazard multiplied by the probability of the hazard’s occurrence. Risk communication is applied in a precautionary context to address public health concerns like sexually transmitted infections and major cardiac events with the understanding that avoiding certain risky behaviors will lower individual risk of harm by eliminating a hazard or lowering the probability of the hazard’s occurrence. The recent COVID-19 pandemic involved risk communicators recommending physical distancing and mask wearing to curb the effects of an infectious disease. In environmental health the risk formula can become more difficult as entire populations are exposed to a hazard. To understand the cross-section of what can be done about exposure to hazards, risk communicators attempt to translate the quantifiable magnitude of a hazard to the population at-large.

Risk perception of HABs in coastal communities in Ecuador has been established. In 2018 Borbor-Córdova et al. described a survey effort to ascertain the risk perception of HABs among fishermen, restaurant owners, and government officials in Ecuador. Of 181 respondents from the fishermen and restaurant owners 34% said they should avoid eating seafood from a red tide, 27% said they should not avoid eating seafood from a red tide, and 39% said they did not know. Comparing this cohort with the government officials we see that 50% of the government officials said they should avoid eating seafood from a red tide and the other 50% said they should not avoid eating seafood from a red tide. The two pieces of this study that stand out are the fact that government officials do not know themselves what to recommend, and that a plurality of fishermen and restaurant owners responded that they were unsure. (Borbor-Córdova et al, 2018). This wide variety in responses lends credence to a centralized risk communication tool for describing HABs and their effects on human health.

As an environmental occurrence, HABs encompass a nearly ideal situation for risk communication. Because HABs tend to be geographically endemic and confined to sources of water, the target population for risk communications can be easily assessed. These target populations tend to fall into two broad categories as either 1) users of water affected by HABs or, 2) resource managers of waters affected by HABs. These populations have different needs, but communicating accurate information allows health communicators to maintain a toolbox to meet the needs of the growing populations affected by HABs.

Below are various examples of health communications produced by government agencies designed to inform the public and advise against known HAB exposure. One common practice in U.S. health communication is for the federal government to produce materials that can be customized by state governments. The Ohio advisories in Figure 2.1 are different degrees of advisories with the red sign reading “DANGER” (left) being posted where HAB toxins are present, and the orange sign reading “WARNING” (right) posted where any algal bloom has been identified. Figure 2.2 is an example of an Illinois-customized infographic with simple instructions to avoid HAB exposure that was originally created by the U.S. EPA. Figure 2.3 is one of a series of 4 posters designed by health communicators at the CDC to be used in places of business and schools to encourage risk avoidance among recreational water users.

Figure 2.1 Ohio Public Health Advisories Posted at Water Sites (Ohio EPA, 2020)

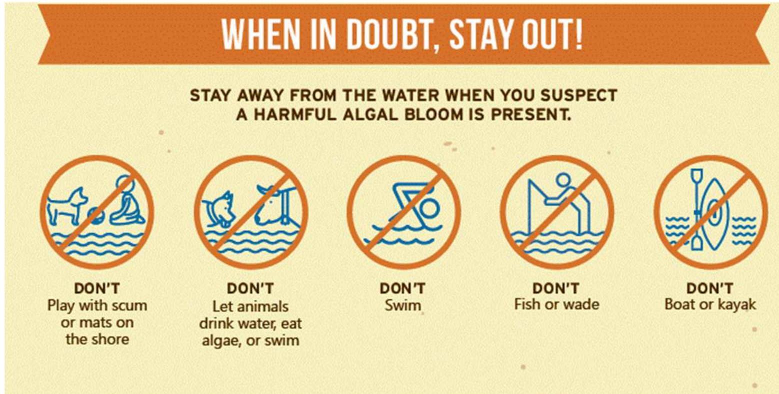

Figure 2.2 Illinois Infographic for HAB Avoidance
(Illinois EPA, 2020)

Figure 2.3 CDC Poster for Schools
and Businesses (CDC, 2020)

The need for appropriate health communication and education tools in environmental health has increased as the prevalence of known environmental hazards has increased. In 2010 Fitzpatrick-Lewis et al., performed an analysis of environmental health advisories. All 24 identified records were scored as weak communication tools and highlighted the personal nature of risk perception and susceptibility (Fitzpatrick-Lewis et al., 2010). Given the researchers' results and recommendations, it remains apparent that health communicators continue to address environmental hazards with varying degrees of success.

CHAPTER 3: GOVERNMENTAL PLAIN LANGUAGE DESIGN

Of all scientific suggestions, only a few make their way to the federal register. Plain language reached this milestone when President Barack Obama signed the Plain Writing Act of 2010. The brief statute's purpose is, "to enhance citizen access to Government information and services by establishing that Government documents issued to the public must be written clearly (Plain Writing Act, 2010)." Following suit, many states have adopted similar policies to ensure citizens have access to information that is understandable and digestible. The strategies employed by health communicators to create communications that meet these simple criteria are collectively referred to as plain language design (PLAIN, 2020). However, as will be shown, not all public-facing scientific communication is written in a manner that is easily understood by the populations who most need the information.

In 2017, Shriver composed a timeline of the most significant gains in plain language design from 1940-2015. An upward trend in the phrase "plain English" using Google Book's visual analytics shows a doubling of the use of the phrase from the mid-1940s to the mid-2000s. The tool used in this study searches the published text of books compiled into the Google Books database and thus creates a raw count of the queried term. As plain language design becomes increasingly normalized a complete history of communication practices becomes more important in understanding the direction to take the field of health communication. Some of the major accomplishments in plain language design have come from technological advancements like the advent of television and the invention and mass adoption of personal computers (Shriver, 2017). Shriver highlights an increase of plain language use in private and public sectors. Health communication in the sciences, especially in risk communication and quantification, are more important now than ever as more and more data is aggregated daily.

An interesting example of a new trend in plain language design is how medical doctors are now being trained across the country. Not only are medical students now trained in health literacy - an important development over the last decade - but they are now trained in plain language design (Warde et al., 2018). Being trained in these design principles helps young scientists to understand the plain language that will be presented to them from pharmaceutical companies, professional organizations, and government agencies. Plain language will also help these young professionals to better communicate with their patients through written communications in the form of patient handouts, web communications, and more. By receiving this training medical doctors will be able to better understand and communicate toxicologic risks.

The relationship between health communication and toxicology is not a new one. Some of the biggest public health achievements have resulted from the overlap of these two fields. From curbing tobacco smoke to public perceptions of air pollution, the findings in laboratory sciences of environmental health have a history of changing public opinion and eventually public policy. One recent study in Germany relates public perceptions of nanotechnology to the toxicological tests performed on substances (Laux et al., 2018). This study highlights the necessity for scientific rigor surrounding health communication as many members of the public were unable to distinguish between nanomaterials, nanotechnologies, and nanoparticles. No known study relates American public perception to HABs risk communication, and as such, health communication examples from other public health risks will play a significant role in the establishment of environmental health communication norms for HABs and similar events.

The scientific community often grapples with the difficulties of disseminating evidence-based messaging to a lay public audience. One emerging field in environmental health sciences is environmental health literacy (EHL). As a discipline, EHL rests between environmental scientists concerned with environmental exposures and their effects on human health and health communicators who inform the public on proper risk characterization and classification so as to mitigate or eliminate the risk altogether. EHL has far reaching implications as the backbone to many community-based participatory research (CBPR) projects. Due to the nature of environmental sampling, many scientists are turning to citizen-science in order to create meaningful data for analysis. Citizen-led data collection efforts allow scientists to gather wide swaths of data by increasing the volume of participation. EHL helps to bridge the gap between scientist and citizen and allows researchers to better disclose their findings to the general public.

Finn & O'Fallon describe the history of EHL as a blend of health communication and deeper understanding of the corollaries between exposure and human health impacts. The researchers connect iconography with health communications such as a skull and crossbones to symbolize potential danger, or the ever-growing symbols currently used by militaries around the world to denote specific dangers like nuclear radiation or toxic chemicals (Finn & O'Fallon, 2017). One successful example of EHL is the implementation of environmental sensitivity index mapping for use by emergency responders to an oil spill. While the hazards of oil spills in aquatic areas were well known, emergency responders often failed to understand just how to protect specific habitats from the devastation of a spill. Iconographers created simple designations so as to direct responders to environmentally sensitive areas and the best practices for protecting those areas. (Jensen, Halls, & Michel, 1998). One of the leading texts on environmental health communication comes from a study performed by a team from the Center for Risk Communication of Columbia University. Peters, Covello, and McCallum analyzed trust and credibility based on survey data from random digit dialing. Survey respondents were adults eighteen years of age or older living in six different communities located in New Mexico, Ohio, New Jersey, Wisconsin, North Carolina, and Virginia. Over 1,000 respondents (n=1,181) were asked to evaluate the same passage of environmental information for trust and credibility where the source of the information was described as 1) industry, 2) government, or 3) a citizen group. Researchers found that across all respondents the information from industry was perceived to have the least credibility where industry was noted as the group with the lowest perceived care toward public health and safety. This same study found government and citizen groups to have varying credibility based on respondent scores. (Peters, Covello, & McCallum, 1997).

An additional study aimed at evaluating source credibility in environmental health combined 5 case studies from environmental health issues with survey data to evaluate the consistency of a credibility index across various exposure related events. Using the Meyer's Credibility Index the case studies included cancer rates related to a Kodak photography development industrial park, health concerns surrounding an inactive hazardous waste disposal site previously owned by DuPont chemical company, New York's largest solid waste landfill, and a possible link between brain cancers and three additional hazardous waste sites. All case studies were located in the state of New York, and thus the New York State Department of Health (NYSDOH) played a role in both health assessments and risk communication. Across all sites news and state agencies were perceived to be more trustworthy and accurate than information provided by industry (McComas & Trumbo, 2001).

Although news outlets and private companies are responsible to their shareholders, government agencies are sometimes under less public scrutiny. Beyond the importance of transparency in business dealings in the name of public trust, government agencies are under legal mandate to take measures to create communications that are understandable to everyday Americans. As mentioned before, the Plain Writing Act of 2010 outlines simple practices to be used by federal agencies to better communicate with the country. By July 13, 2011, agencies were required to 1) designate an official for "plain writing," 2) educate staff on plain writing principles, 3) create a quality assurance process for compliance to the act, among other requirements. It should be noted that the American Bar Association, of which a plurality of policy makers at all levels of government are members, also urges its members to use plain language in all communications (PLAIN, 2020). If the public cannot understand the information presented to them from their own government, it is illogical to assume that the public will be capable of making an informed risk characterization.

When the public is receiving risk information from various outlets, it becomes difficult to accurately qualify public risk assessment capacity. Households within communities may also differ in their preferred communication channels. With the rise of social media, it is increasingly important that succinct and accurate risk information is widely available to perform a built-in check on new information arising following an environmental event. In localized emergency settings, such as HABs, word-of-mouth has been cited as the most common and effective communication strategy (Wolkin et al., 2019). Given the rapid pace of technological advancement and the social isolation of a digital age, a hybrid communication strategy that implements multiple communication channels will become increasingly important as relying upon word-of-mouth communication may be insufficient. Thus, an updated online briefer regarding HABs will provide health communicators on television, social media, or in-person the tools necessary to properly communicate environmental risks to the public.

Proper risk management in environmental health requires proper risk communication. Impacts on health and the environment must be properly understood before mitigation or avoidance efforts can be responsibly implemented. The balance between human health and ecological health in risk communication is expressed in Figure 3.1 (EPA, 2018). While health communication plays a role in each step of the risk management process, the most prominent feature of health communication is the risk characterization step listed in both the ecological risk assessment and the human health assessment.

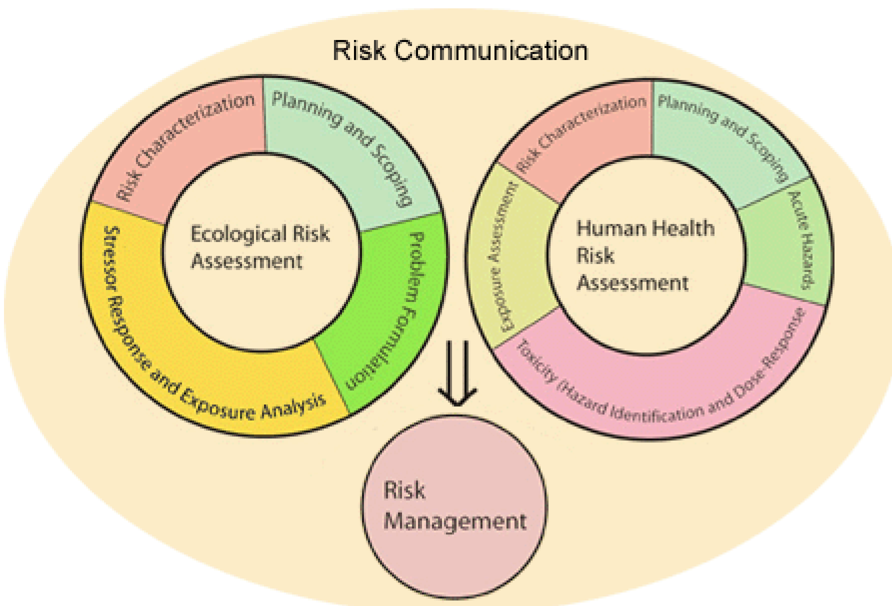

Figure 3.1 EPA Risk Communication Schema (EPA, 2018)

In an effort to better address the balance between public outrage and public apathy given any number of scientific topics the EPA published *Seven Cardinal Rules of Risk Communication* as a sort of guiding policy with its first iteration published in 1988. The document outlines the metaphorical rules of engagement as: 1) Accept and involve the public as a legitimate partner; 2) Listen to the audience; 3) Be honest, frank, and open; 4) Coordinate and collaborate with other credible sources; 5) Meet the needs of the media; 6) Speak clearly and with compassion; 7) Plan carefully and evaluate performance (Covello & Sandman, 2001). Each of these rules stands on its own merits, but a further evaluation of these combined principles serves as legitimate guidance from the nation's leading environmental agency. Over the years the EPA's original rules have been used by the CDC and WHO independently to establish proper uses of risk communication.

Rules 1-3 involve including communities in communications. Without properly understanding the community in question, the overall direction of communication can be misaligned by not actually addressing a root concern but rather focusing on an ancillary symptom. Rule 4 speaks to the need to collaborate. This can build interagency credibility as populations maintain differing levels of trust toward individual agencies as a result of media coverage, structural changes within the agency, political pressures, et cetera. Rules 5 and 6 encourage bidirectional communication between risk communicators and the media, recognizing the media's important role in any public communications. By clearly communicating with the media and those affected by environmental hazards, risk communicators are able to affect behavior change through emotional connection rather than only relying on simple facts and figures. The final rule to plan and evaluate is of particular concern for HABs risk communicators because of the recurrence of events. When proper evaluation tools are in place, risk communicators can improve upon previous efforts rather than beginning anew for each separate event.

These risk communication rules proposed by the EPA came on the heels of the Chernobyl nuclear disaster and the Bhopal tragedy. Both incidents shook the world and awakened many to the silent dangers of radiation and chemical exposure. Trust is at the center of any risk management strategy, and while governments cannot protect citizens from all risks, they can properly manage risks by properly communicating risk characterization to the public. But regardless of how effective the content of the messaging may be, when there is not trust in the relationship between institutions and the public then their communications effectively fall on deaf ears.

Saar Alon-Barkat (2020) used the Elaboration Likelihood Model to illustrate how complex messaging is less likely to lead to public understanding than simple messaging. This may seem like a logical assumption, but it is often contrary to the way governments choose to communicate risk. As evidenced by the ecological measurements prominent in many HAB communications, it is clear that the initial reaction of some risk communicators is to overwhelm the public with data. Alon-Barkat shows how images and icons tend to encourage trust at a higher rate than messages full of numbers and words. Institutional trust can take a long time to build, but by simplifying risk messaging governments agencies can more responsibly communicate risks to vulnerable populations.

Beyond health literacy - the term used to describe an individual's ability to comprehend information related to their health - issues of poor numeracy also plague modern society. Oxford Dictionary defines numeracy as the "ability to understand and work with numbers" (Numeracy, 2020). While anecdotal evidence at any high school would tell you that the average American does not consider themselves to be a mathematician, it is interesting how often governments produce statistics and present raw data to a public that is ill equipped to draw any reliable conclusions from said data. As long as health illiteracy and poor numeracy plague the American populace it will remain the responsibility of health communicators to properly characterize risk for the general public.

Although risk communication and health communication have been used interchangeably here, they are both facets of the larger discipline of risk management. Messaging for risk communicators has evolved over the years from spoken warnings and pictograms to videos and billboards. Social media represents the new frontier of risk communication. Facebook, Instagram, and Twitter pose a challenge for risk management because of the possibility of important messages being drowned out and needing to compete for an audience (Park & Lee, 2018). Regardless of the medium, proper risk management and proper public health begins with messaging that can be easily understood and acted upon.

In the content analysis that follows, a major assumption is that public health officers - whose job it is to inform the public on public health risks - are intrinsically concerned with presenting data in a form that will be as easily comprehended and thus acted upon. Bias afflicts all people and is particularly apparent in communications. However, with proper quality assurance and quality compliance plain language can be used by all levels of government to properly communicate risk. Just as evaluation and improvement are the final steps in any public health programming, evaluation needs to rule environmental health programming in order to properly protect the public from known toxicologic and environmental health risks.

CHAPTER 4: CONTENT ANALYSIS

A simple Google search for the term “harmful algal bloom” using the news filter in late August 2020 returned a result of about 56,100 results. Of the first page, the top 10 results, there were 8 articles published within the last week. The 2 remaining articles were published within the last 2 weeks. At the time of the search the most recent article identified among these 10 links was a piece from a local newspaper from Utah published 10 hours earlier. This article describes a potential HAB treatment on Utah Lake and contains direct quotes from both county and state health department leaders. The HAB treatment described is a complex solution that uses chemical pH manipulation to create a habitat that is nonviable for the rapid proliferation of the endemic HAB-causing organism. The article also described an appropriation bill recently passed by the Utah state legislature that directs half a million dollars to HAB research and treatment (Richards, 2020).

The above brief analysis represents a sample content analysis of a single article. Many facets of the analysis are omitted, but the purpose is to highlight the insights that can be gleaned from this type of analysis. In the midst of a pandemic that has resulted in over 50,000 laboratory confirmed COVID-19 cases in the state and over 400 deaths since January (Imlay, 2020), a local newspaper decided to run a story about non-COVID directed funds by the state legislature as another example of a pressing public health issue. Hours after the piece above was analyzed, a separate outlet reported that the very same marina being studied for this new treatment was being closed by a county health department because of a detected HAB. The Utah Department of Health (UDOH) website that reads, “Harmful algal blooms contain cyanobacteria that can cause skin irritation, gastrointestinal illnesses, and in some cases, produce toxins that cause serious health impacts to people, livestock, and pets.” This piece illuminates the ever-growing science and need for public attention and understanding to lead to public compliance in the name of public health (Curtis, 2020).

Just as responsible science calls for the accumulation of evidence to draw reliable conclusions, there are hundreds of news articles each year about HABs across the country. Yet the public appears largely unaware of the science and consequences of HABs. The above example is a simple descriptive analysis, but it illustrates what a content analysis is while at the same time drawing attention to the imminent public health concern about HABs and their impacts.

4.1 Background

Content analyses are one of the most widely used and helpful tools in developing effective health communications aimed at health behavior change. Content analyses began with physical communications such as newspapers and tangible advertisements, but as the digital age swept across the globe the frequency of online content analyses grew exponentially (Tian & Robinson, 2014). Content analyses are frequently used in the business world by advertisers and marketers to establish a framework for a service or product within an industry (Macnamara, 2005). The process of a content analysis can follow the general scientific method of hypothesis testing but can also represent a simple qualitative or quantitative examination of a topic, similar to an academic literature review. This online content analysis involved quantitative measures to explore health communications surrounding HABs given their rapid rise as a public health concern.

Environmental health topics are often overlooked as public health concerns. This gap is illustrated in part by the fact that less than 6% of all state and territorial health departments in the United States have a joint mission for the environment: Colorado, Kansas, and South Carolina. The Council on Education for Public Health (CEPH) even removed the requirement for explicit environmental health education in schools of public health (CEPH, 2018). The removal of this criteria has led to multiple schools and departments of public health to completely divest from their environmental health concentrations and degree programs. These two examples represent an incomplete public health field that does not fully address the environmental health concerns of the American population. When public health professionals are not trained in environmental health and do not have opportunities to practice environmental health within a state public health agency, we cannot be surprised when environmental health concerns begin to take an outsized toll on the public.

The One Health approach, endorsed by the CDC, EPA, and WHO encourages public health officials to address health concerns in a holistic fashion. One Health emphasizes the health of humans, animals, and the environment with the logic that health for one group is reliant on the proper health of the others. Although public health officials are not necessarily trained in environmental health needs in the United States, environmental health agencies continue to hire public health professionals just as public health agencies hire environmental scientists. The compatibility and critical nature of environmental health sciences within the overall umbrella of public health is displayed by the collaborative partnership between the WHO and the National Institute of Environmental Health Sciences (NIEHS) over the past nearly 40 years (WHO, 2011).

As one of the remaining environmental health programs within a CEPH-accredited school of public health – and with direct access to one of the three state health departments with this One Health focus – The Arnold School of Public Health at the University of South Carolina is uniquely qualified to address the direct links between environmental health and health communication. As blindspots in public health include environmental health and issues related to environmental sciences, the research performed at this university and those with similar parameters becomes increasingly relevant and needed. Through the fields of health communication and environmental sciences, environmental public health concerns are characterized and disseminated to the general public. Proper risk assessment of environmental hazards in public health is a major need in preventing and control disease in the general population.

This content analysis is primarily quantitative using descriptive statistics. This study was designed to analyze the quality of HAB information maintained by State and Federal agencies and to determine if these sources meet common standards of health communication. The primary aims of this study were to identify the current state of online governmental publications in regard to HABs in the American Southeast. In aggregate there are dozens, if not hundreds, of reputable websites and webpages containing reliable information about HABs. However, the webpages included in this analysis were selected because of their propensity to be read by residents of the geographic region of the South. Selection criteria of sources is included below.

4.2 Methods

Sources for this online content analysis were obtained using a targeted search of both South Atlantic state websites and federal agencies concerned with HABs and their effects on human health. These agencies include health and environmental departments. The South Atlantic states, inclusive of North Carolina, South Carolina, Georgia, and Florida were selected as states of interest due to their increasing frequency of HABs as well as their geographic similarities and proximity. State website searches included searches of both health department sites as well as environmental resource management sites such as the North Carolina Department of Environmental Quality (NCDEQ). Searches were limited to ".gov" web addresses due to significant increases in credibility scores when compared to ".com" sites among a non-expert audience (Treise et al., 2003).

As discussed previously, management of water resources falls under the purview of various state and federal agencies depending on the location of waters and the legal context of a given situation. As such, federal agencies that were likely to have HABs information that would affect residents of the South Atlantic states were included in this analysis. Websites were grouped into two broad categories as either related to 1) users of water resources, or 2) managers of water resources. This distinction was made based on the known gaps in scientific literacy among the two target communities (Guidotti, 2013).

To establish a readability score the text from each webpage was evaluated using the Simple Measure of Gobbledygook (SMOG) test, a validated tool for the assessment of readability (Friedman & Hoffman-Goetz, 2006). For readability purposes sources needed to contain at least 10 sentences of text, and thus some of the excluded sites simply did not have enough content for inclusion here. Sentences were assessed by an online readability calculator (http://www.readabilityformulas.com/free-readability-formula-tests.php) to obtain a score that correlates to a U.S. school grade level.

Because this study was designed to assign median scores to multiple webpages from permanent agencies, blog posts such as “news” updates that are frequently posted on sites were excluded from governmental agencies. However, “news” posts were selected from NGOs in an effort to maintain statistical power in drawing intergroup comparisons relating NGOs to state and federal sources. Beyond geographic exclusion to the South Atlantic States for NGO and State agencies, and Federal agencies of the United States, no other exclusion criteria were followed. Sources were gathered in December 2019 and again in February 2020. A source qualified as a HAB communication if it contained the words “toxic algal bloom” or “harmful algal bloom” or “HAB.”

Mobilizing information in health communication is information that leads to further action on the part of the receiver. The theoretical backing of mobilizing information is Health Belief Model (Rosenstock, 1974) and has been applied to health education as a means of evaluating the quality of online health information (Friedman, Tanwar, & Richter, 2008). Mobilizing information relies on pre-existing attitudes, such as information seeking, which is manifest by visitation of a site regarding HABs. These cues to action are an indicator of health behavior and can include contact information, checklists, or links to further information. The aspects related to mobilizing information will be documented as an additional layer of analysis.

Health numeracy, defined as the ability of a person to understand quantitative health information, is also a necessary component for evaluation. As a means of conveying risk information, numeric data has been shown to complicate comprehension for a public audience (Peters, 2008). Sites containing numeric information including charts and tables will be recorded and reported in the final analysis. Carefully created maps have been shown to enhance community perception on environmental risk (Severtson & Vatovec, 2012). The inclusion of a map or link to map will be recorded as a measure of comprehension aids provided on each site.

A codebook was modified from a previous study for analysis of the targeted search described above. SMOG readability scores were analyzed and individual agencies were given a composite score of the median readability grade-level based on the sites the agencies produced and maintained. The complete codebook is found in Appendix B.

The data analysis for this study was generated using SAS software for Windows. Statistical analysis was performed using SAS University Edition inclusive of SAS Studio 3.8, SAS 9.4M6, the 15.1 release of SAS Analytical. Copyright © 2018 SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA (SAS).

4.3 Results

Because most people seeking health information today use online resources (Morahan-Martin, 2004), an internet search was conducted to establish health communication practices using the terms 'toxic algae,' 'harmful algae,' and 'algal bloom.' In all 90 sources were identified with 38 State sources, 42 Federal sources, and 10 NGO webpages represented respectively. Table 4.1 lists each agency identified along with the number of sources identified maintained by each individual organization. A complete list of all webpages identified can be found in Appendix A.

The mean SMOG score of all 90 sources was 10.7, equivalent to an 11th grade reading level in the United States education system. State and Federal webpage comparison showed a statistically significant intraclass relationship (p=0.0217) using the Chi-squared test χ^2 (df 2, n=90) = 7.6601. Fisher's exact test of independence was also used due to a relatively low expected value for sources with a SMOG score less than the cut-off point of 9, and signaled significance (p=0.0025). States were more likely to have a reading level under 9th grade than Federal pages by a ratio of 12:5. NGO sources were not compared for independence to State and Federal sources.

Of all webpages 47% (n=42) listed a date when content was modified. Over half of the pages, 59% (n=53), were written in paragraph form and 60% (n=32) of paragraph pages utilizing chunking. 3% (n=3) of all sites required clicking next to see all content including two Florida pages and one NOAA page.

Some sort of glossary or term definition was included on 29% (n=26) of pages with 2 of the 42 Federal sources (4.76%) meeting this criteria. Although 18% (n=16) had an electronic mailing list or newsletter these were almost exclusively observed among NGOs (9 out of 10 NGO sources analyzed representing over half of all mailing lists identified). 4% (n=4) of all sources were written in 2nd Person with the F-pattern of web design used on 69% (n=62) of all pages with 42% (n=38) use of typographic cues.

Webpage focus was determined by a 75% threshold that best aligned with 1 of 3 classifications with a relatively even distribution: Biochemistry (31%), Ecological (40%), and 3) Public Health (29%). Importantly 57% (n=51) included a warning about human exposure and 37% (n=33) included an animal-specific warning about exposure (n=33). About a third of sites, 37% (n=33), described specific bodies of water including all 10 NGO pages. Almost half, 44% (n=40), had a call to action, but no webpages contained a summary or takeaway section.

Specific toxins are important in medical diagnostics and water management. 19% (n=17) mentioned specific toxins with the common freshwater toxins of Microcystin (13), Cylindrospermopsin (9), Anatoxins (7) and Saxitoxins (7) being enumerated most frequently although 8% (n=7) mention specific diseases and syndromes resulting from human HAB exposure. With the science showing that the naked eye cannot reliably identify a HAB, 39% (n=35) list at least one way to identify a HAB without laboratory techniques and 30% (n=27) list activities to avoid when a HAB is suspected.

Unprompted pop-ups were only observed on Federal sites which asked consumers if they were willing to take a survey to improve the site. Over half of sources, 58% (n=52), contained links to outside sources and information with an average of 5 sources per page (4.70 links). The two local maximum number of links provided were by the NGO Albemarle Resource Conservation and Development Council (26) and the CDC (17). Only 6% (n=5) contained the logos of other organizations, indicative of collaborative activities. All 5 pages with other organizational logos were academic presentations hosted on government sites.

Table 4.1 enumerates all sources by their class affiliation: State, Federal, and NGO (Riverkeepers). Because multiple Federal agencies were represented by only 1 webpage, most analysis was performed using statistics grouped by class. The Riverkeeper alliance is a non-profit organization dedicated to protecting rivers at a local level. Riverkeepers from each state in the South Atlantic region were identified. The NGO class was primarily included for comparison of descriptive analytics to State and Federal sources. Of the 90 total sources, 38 were State-maintained, 42 were Federally maintained, with the remaining 10 being pages maintained by NGOs.

Table 4.1 Agencies Represented

Class	State/Agency	Abbreviation	Sources
State	North Carolina	NC	12
	Florida	FL	14
	Georgia	GA	4
	South Carolina	SC	8
	State Total		38
Federal	Centers for Disease Control and Prevention	CDC	12
	Environmental Protection Agency	EPA	9
	Fish & Wildlife Service	FWS	1
	National Park Service	NPS	1
	National Institute of Environmental Health Sciences	NIEHS	1
	National Oceanic and Atmospheric Administration	NOAA	6
	US Department of Agriculture	USDA	7
	US Geological Survey	USGS	5
	National Total		42
	National & State Total		80
NGO	Riverkeepers	RVKP	10
	All Total		90

Figure 4.1 shows median SMOG scores among each individual agency. Error bars represent a 10% error used for two main reasons, 1) using only one coder has a greater potential for researcher bias to influence results, and 2) because the SMOG formula involves counting specific words the variation of word counts on each page is not completely comparable across every source.

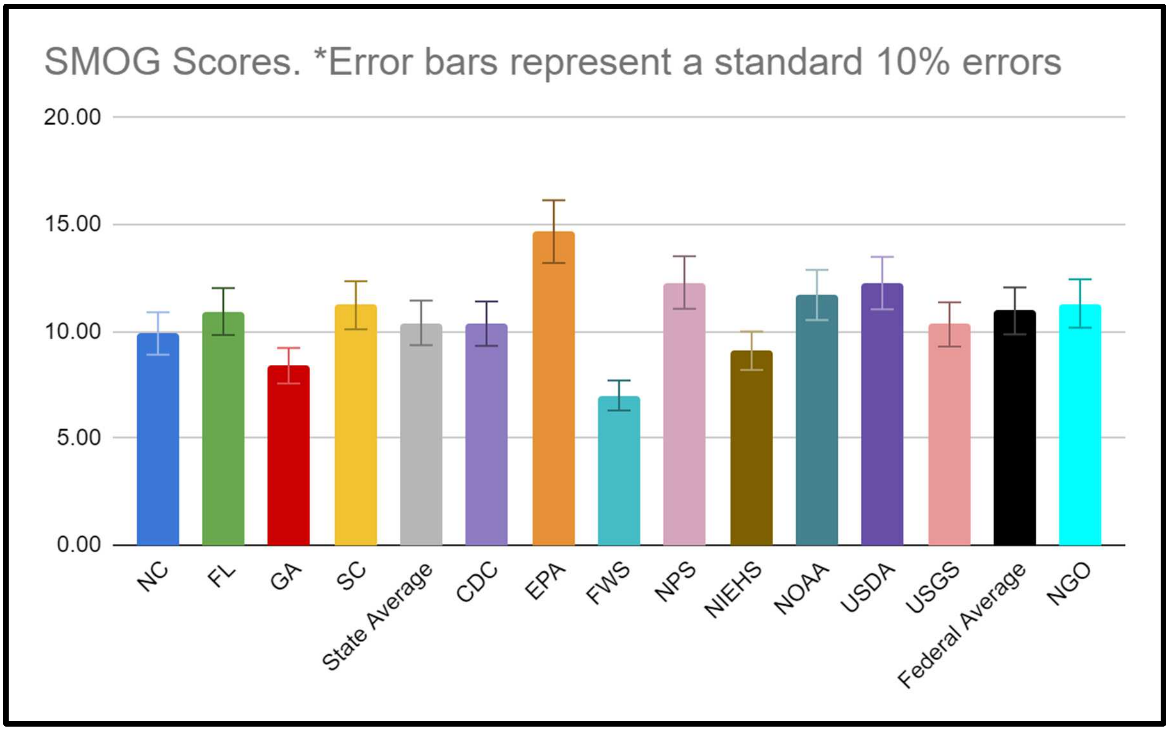

Figure 4.1 All Agency SMOG Scores

Using the same color scheme as represented each agency in Figure 4.1, Figures 4.2 and 4.3 show State and Federal agencies respectively. These two figures illustrate the intraclass variation in SMOG scores. The maximum median SMOG score is the EPA score of 14.68 represented by 9 different webpages. The minimum agency SMOG score was another Federal agency, the U.S. Fish and Wildlife Service (FWS), of 7 represented by a single webpage. Taking an aggregated average of median SMOG scores by State, Federal, and NGO classes yields 10.41, 10.97, and 11.32 respectively. State and Federal classes are represented by 38 and 42 sources respectively while the median NGO score was obtained from 10 sources.

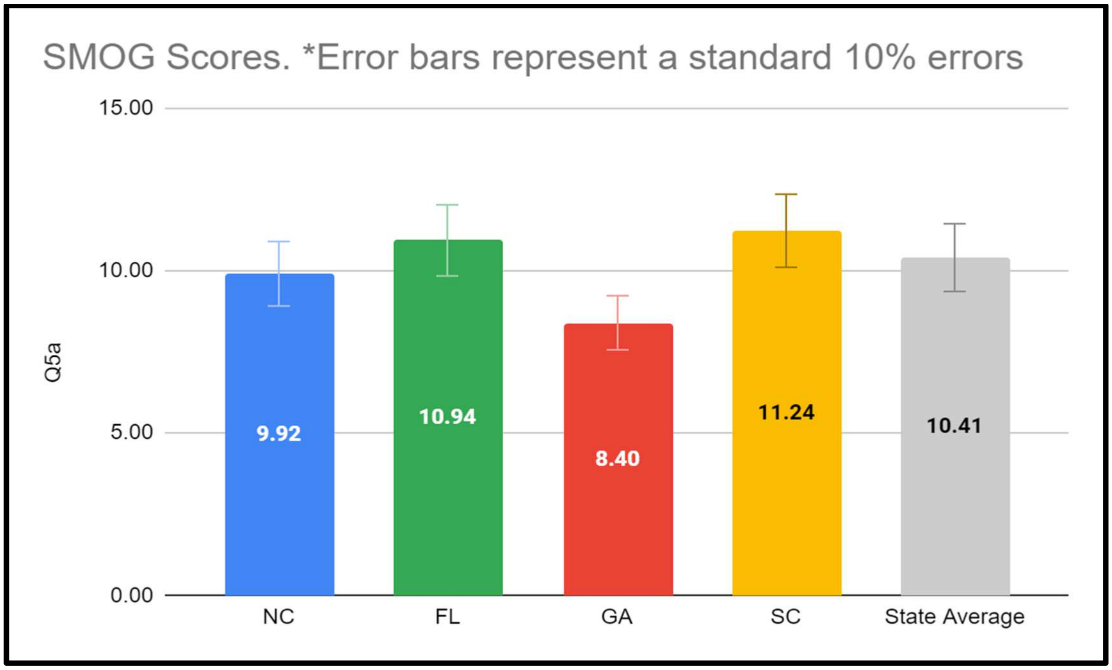

Figure 4.2 State SMOG Scores

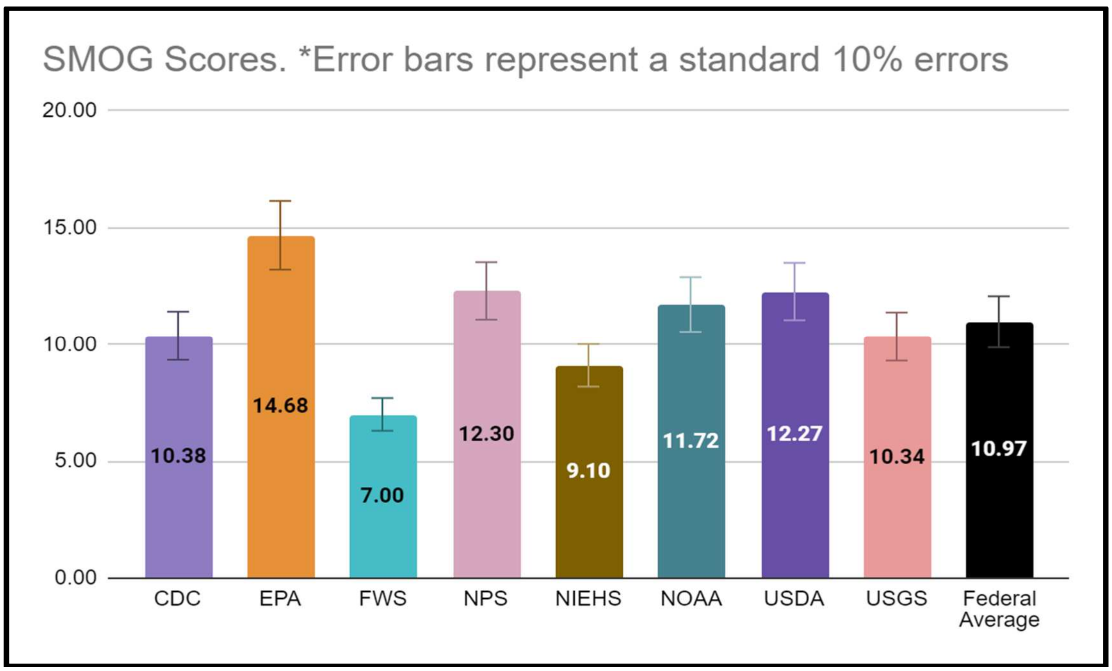

Figure 4.3 Federal SMOG Scores

A simple linear regression model fits SMOG score data in Figure 4.4. The y-axis in Figure 4.4 shows SMOG scores from 5 to 20 to more clearly display the positive slope of the linear regression. This model contains 80 observations with

2 parameters (State and Federal). The mean square error (MSE) of this model is 7.469 with an R^2 value of 0.0565 indicating a correlation in the relationship between State or Federal agency distinction and associated webpage SMOG score. Each State observation is indicated along the left side of the graph by red circles while each Federal observation is indicated along the right side by blue squares. Dotted lines represent 95% prediction limits.

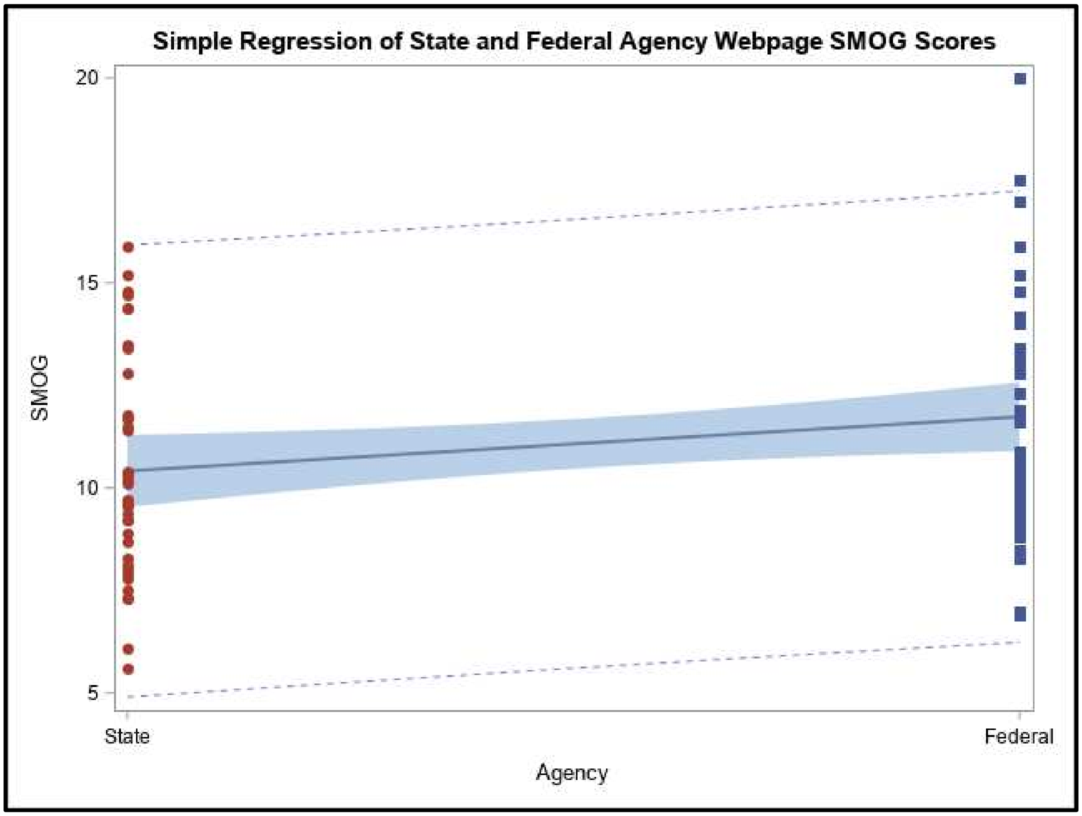

Figure 4.4 SMOG Score Simple Regression

Each webpage's focus was coded with a 75% threshold criteria with 3 classifications, with an ecological focus representing the plurality in identified sources: 1) Biochemistry 31% (n=28), 2) Ecological 40% (n=36), and 3) Public Health 29% (n=26). All 90 observed webpages are indicated in the radar chart in Figure 4.5 designed to show relative frequencies. Each circle, or band, from the center represents an additional 10% frequency. Given the distribution, Biochemistry and Public Health foci fall along the same band, and the Ecological focus lies on the outermost band indicating a 40% frequency.

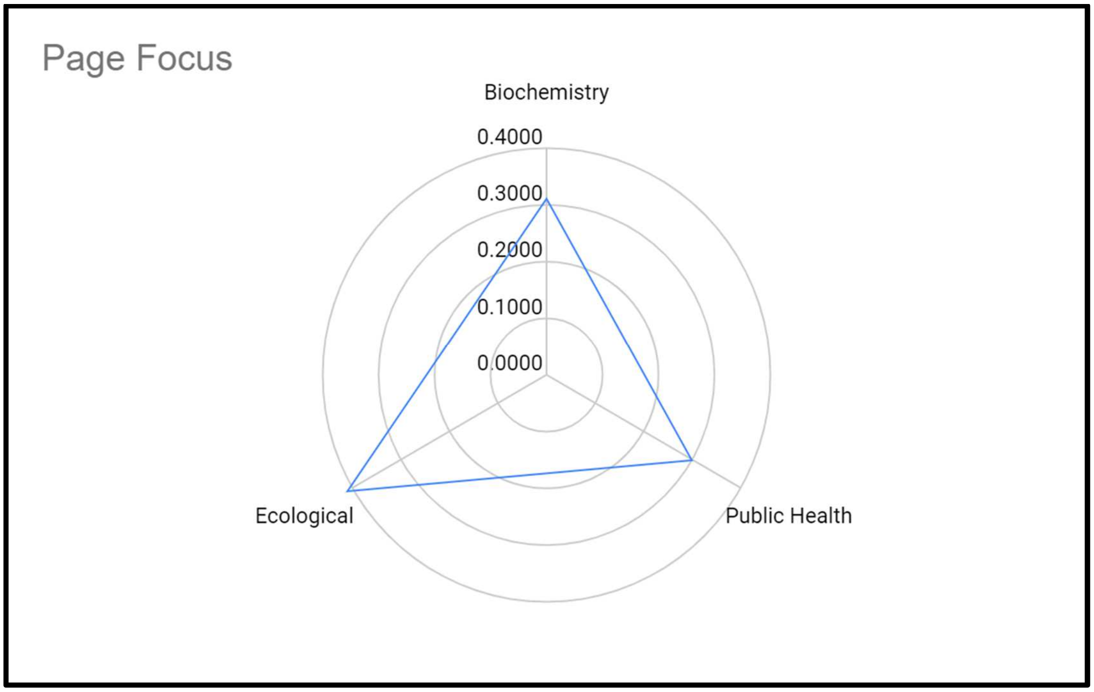

Figure 4.5 Page-Specific Focus

As noted previously, HAB intensity and causative organisms vary in freshwater and marine water. Given the difference in coastline length between Florida's 8,436 mi (13,576 km) and Georgia's 2,344 mi (3,772 km) of coast, Georgia faces a greater ratio of freshwater HABs compared to Florida's propensity for marine HABs. Federal pages also consider inland states like Kansas which have no coastal waters alongside Alaskan waters with 33,904 mi (54,563 km) of coast as measured by the NOAA method (NOAA, 1975).

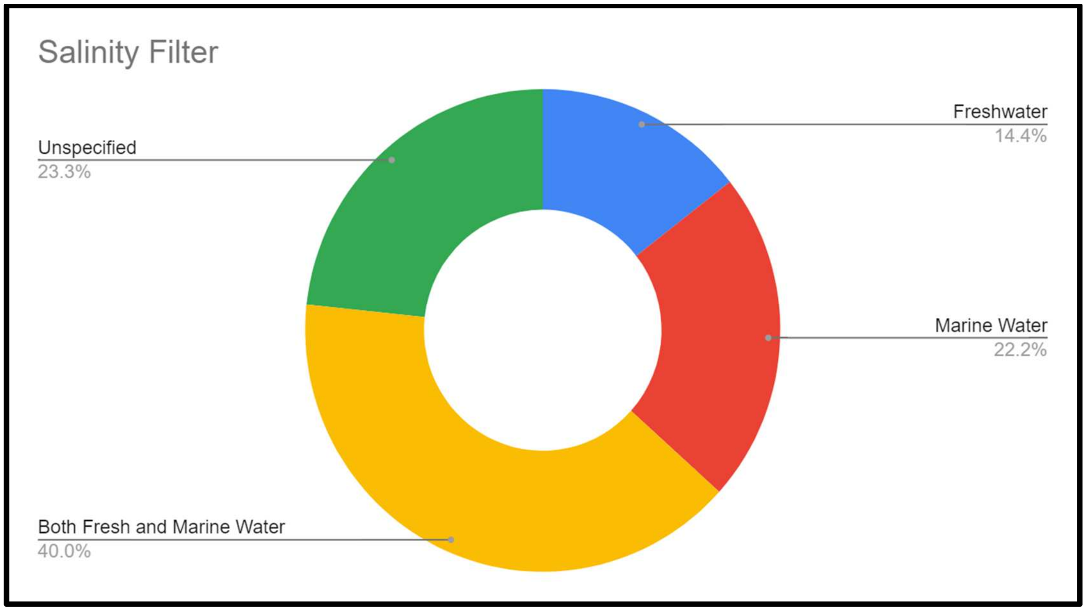

Figure 4.6 Salinity Basis

4.4 Discussion

This analysis indicates prescriptive measures to increase public awareness and compliance with public health recommendations. As Rimer and Kreuter (2006) suggest, tailored health communication is the best route for HABs communications moving forward. Luckily for health communicators, audiences are already geographically segmented and can thus receive communications better tailored to the water quality in their location. Although educational attainment is closely tied to health literacy (Jones et al., 2012), plain language design continues to influence risk perception across demographics and geographies (Ferrer & Klein, 2015). The best strategies in health communication have long been studied in healthcare settings, and as health communicators apply the same logic to the ecological domain (Fitzpatrick-Lewis et al., 2010).

The results of this analysis are troubling on one hand but also show organic means of simple and rapid improvements. Perhaps the simplest solution for all sites to increase their readability is to include summary or takeaway sections. These sections are particularly helpful within an environmental hazard context. Often consumers of the information found on these sites are looking for quick facts to help with their risk characterization and determination. Readability can also be improved with shorter paragraphs, known as chunking, and the use of bullet points. A frequently asked questions (FAQ) page would also be helpful for all sites. These solutions help online information-seekers to find answers to their questions in an efficient manner without requiring the viewer to scour more information than is applicable to their unique needs.

As each of these 4 states, and indeed all 50 states, face a different HAB landscape and environment it is too simplistic to prescribe any specific toxins or diseases that should be included on all webpages. However, common symptoms of all ingested HAB toxin are similar to food poisoning and inhaled HAB exposure typically presents with airway aggravation. Contact dermatitis, or swimmers rash, is the most often result of dermal HAB toxin exposure. All of these symptoms could responsibly be included on HAB websites. Proper audience segmentation for healthcare practitioners, researchers, and the general public will allow these sources to maintain various levels of complexity (Paige, Krieger, & Stellefson, 2017).

All pages had at least one measure of content and subsequent web design that could be improved. Used in this content analysis as a proxy measure, organizational logos can be indicative of interorganizational collaboration. Links were often provided to external organizations and agencies, but if the scientific collaboration ends there then the public suffers from incomplete scientific experimentation. Academic papers are peer reviewed, but one recommendation for government agencies would be to institute agency-wide checklists for an interagency review of all new scientific information. This would likely result in a minor delay in disseminating new information, but this method would allow agencies and organizations to avoid providing the public with conflicting information. Few aspects of public communication can ruin institutional reputation and public perception as conflicting messaging.

SMOG scores were the primary measure of this content analysis. There was an observed statistical difference between States and Federal sources. The NGO class was excluded from regression analysis because of low expected values given the comparatively lower number of identified sources. In SMOG analysis the 9th grade cutoff has long been used as the gold standard for communications to simultaneously maintain necessary topic-specific complexity and simplicity that matches the literacy level of the general public (Walsh & Volsko, 2008). This has been a mass communication standard despite the fact that the nationwide high school graduation rate has risen to 94% in 2020 from 72% in 1980 (NCES, 2020), a boom largely attributed to the Bush-era policy of “No Child Left Behind” and the Obama administration’s implementation of common core curriculum (US News Report, 2020). Median SMOG score of all HABs was 10.7 equating to an 11th grade reading level. An examination of the arbitrary 9th grade cutoff should be considered with all other results presented here.

4.5 Future Research

The implications of the findings of this study are further emphasized by the institutional reputation of the CDC and WHO immediately following the COVID-19 pandemic. The first recommendation in public health is often an education-based program, but when the educator is not trusted or well understood the educational program will likely fail. Official government media outlets like those with the CDC and EPA tend to maintain reliability and scientific integrity. But given the lack of public trust in these agencies and limited scientific literacy among the American populous, complex communications often fail.

A prevalent example of public trust and health communication was the debate around face coverings and cloth masks. Some of the first studies performed in the pandemic were about limiting transmission of SARS-CoV-2 and showed the efficacy of face masks in limiting droplet spread. Quite responsibly, the CDC released these findings with the caveat that protective factors were not studied and thus it would not be responsible to speculate on the effectiveness of such an intervention for the general public to protect themselves against contracting the new respiratory disease.

Roughly 6 months following the initial recommendations to wear masks to protect others, studies began to show a significant protective factor against COVID-19 for wearers of cloth masks. However, some may argue that these communications were too little too late. Even as the science and resultant health communication became more clear, public perception of public health institutions deteriorated.

The scientific method relies on falsifying negative null hypotheses rather than attempting to prove alternative hypotheses. Causation is not correlation primarily because it is difficult to control all external factors in an experiment, creating a dilemma for health communicators. Confounding factors make disseminating and generalizing results extremely difficult. The dietary recommendation for one study population could have the exact opposite effects for another population (e.g. a prescriptive Mediterranean diet for someone with severe seafood allergies). Health communicators must understand the implications of the science while maintaining public perception of transparency.

Even when mounting evidence shows adverse health effects from a risky behavior or new exposure, there are moral implications to human experimentation. HABs have produced health outcomes ranging from mild rashes to death have been observed in multiple species. As we await the advancement of science to determine a threshold of safe HAB toxin exposure, and technological advancements that allow water managers to quickly and accurately assess various water sources, the precautionary principle should be applied to harmful algal blooms. With declining public trust in governments and low scientific literacy among Americans, environmental health communicators have a challenging task to properly characterize the risk of HABs.

This study does contain many of the same limitations common to all content analyses. While every effort was made to sample as many sources as possible within the representative agencies, it is possible that certain pages were not analyzed given the methodological approach which is reliant on search engine algorithms. The single coder dilemma was also a limitation as implicit bias was introduced because only one researcher participated in data collection. Another possible limitation was the study period as some sites were updated during the study. Despite these limitations, this content analysis contains valuable information that can be applied immediately to environmental health sciences in the form of online risk communications.

Although some agencies were shown to have more readable content in this study, these results represent a single moment in time. As web content is refined these pages have the potential to improve. Communication researchers will continue to study information interpretation and processing, resulting in different criteria for measuring the effectiveness of health communications over time. Public input should also be considered in evaluating readability to determine comprehension and the efficacy of environmental health communications. Future researchers should consider ways to evaluate public trust as a means of describing the ability of institutions to reliably and responsibly influence human behavior for the betterment of public health.

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APPENDIX A: WEBPAGES IDENTIFIED

Table A.1 Webpage Index

CDC	https://www.cdc.gov/habs/general.html
CDC	https://www.cdc.gov/habs/index.html
CDC	https://www.cdc.gov/habs/materials/index.html
CDC	https://www.cdc.gov/habs/materials/factsheet-cyanobacterial-habs.html
CDC	https://www.cdc.gov/habs/materials/factsheet-marine-habs.html
CDC	https://www.cdc.gov/habs/pdf/cyanobacteria_faq.pdf
CDC	https://www.cdc.gov/habs/pdf/algal_bloom_poster.pdf
CDC	https://www.cdc.gov/habs/pdf/habsphysician_card.pdf
CDC	https://www.cdc.gov/habs/pdf/habsveterinarian_card.pdf
CDC	https://www.cdc.gov/habs/pdf/ohhabs-fact-sheet.pdf
CDC	https://www.cdc.gov/habs/ohhabs.html
EPA	https://www.epa.gov/cyanohabs/learn-about-cyanobacteria-and-cyanotoxins
EPA	https://www.epa.gov/cyanohabs/causes-cyanohabs
EPA	https://www.epa.gov/cyanohabs/exposure-cyanohabs
EPA	https://www.epa.gov/cyanohabs/health-effects-cyanotoxins
EPA	https://www.epa.gov/ground-water-and-drinking-water/managing-cyanotoxins-public-drinking-water-systems
EPA	https://www.epa.gov/cyanohabs/epa-drinking-water-health-advisories-cyanotoxins
EPA	https://www.epa.gov/ground-water-and-drinking-water/summary-cyanotoxins-treatment-drinking-water

EPA	https://www.epa.gov/cyanohabs/cyanotoxins-and-safe-drinking-water-act-drinking-water-protection-act-contaminant
EPA	https://www.epa.gov/cyanohabs
FL	http://www.floridahealth.gov/environmental-health/aquatic-toxins/harmful-algae-blooms/index.html
FL	https://myfwc.com/research/redtide/taskforce/members/
FL	http://www.floridahealth.gov/environmental-health/aquatic-toxins/updates-report-and-contact/index.html
FL	https://floridadep.gov/AlgalBloom
FL	http://www.floridahealth.gov/environmental-health/aquatic-toxins/blue-green.html
FL	http://www.floridahealth.gov/environmental-health/aquatic-toxins/seafood-safety/index.html
FL	http://www.floridahealth.gov/environmental-health/aquatic-toxins/where-is-red-tide.html
FL	https://myfwc.com/research/redtide/taskforce/history/
FL	https://myfwc.com/research/redtide/taskforce/
FL	https://myfwc.com/research/redtide/general/harmful-algal-bloom/
GA	https://epd.georgia.gov/harmful-algal-blooms
GA	https://www.gachd.org/programs-services/environmental-health-2/harmful_algal_bloom_hab/
GA	https://www.gachd.org/programs-services/environmental-health-2/harmful_algal_bloom_hab/blue-green-algal-blooms/
GA	https://www.gachd.org/programs-services/environmental-health-2/harmful_algal_bloom_hab/red-tide-algal-blooms/
NC	https://deq.nc.gov/about/divisions/water-resources/water-resources-data/water-sciences-home-page/ecosystems-branch/algal-blooms
NC	https://www.ncwildlife.org/Portals/0/Conserving/documents/2015WildlifeActionPlan/NC-WAP_2015_ePDF_052016_chapters1-8.pdf
NC	https://www.ncwildlife.org/Portals/0/Conserving/documents/ActionPlan

	/WAP_Chapter5C.pdf
NC	https://www.ncwildlife.org/Portals/0/Boating/documents/Best%20Management%20Practices%20Manual%20for%20Marinas.pdf
NC	https://www.ncwildlife.org/Portals/0/Fishing/documents/PONDMAN5.PDF
NC	https://www.ncwildlife.org/Portals/0/Conserving/documents/ActionPlan/WAP_Chapter5_5A.pdf
NC	https://epi.dph.ncdhhs.gov/oee/a_z/algae.html
NC	https://epi.dph.ncdhhs.gov/oee/docs/HAB_Events_2005_2012.pdf
NC	https://epi.dph.ncdhhs.gov/oee/algae/protect.html
NC	https://www.fws.gov/nwrs/threecolumn.aspx?id=2147591771
NC	https://www.albemarlercd.org/fighting-algal-blooms.html
NC	https://deq.nc.gov/about/divisions/water-resources/drinking-water
NC	https://www.ncwildlife.org/Portals/0/Fishing/documents/2019FishingDocuments/Pond-Management-Guide.pdf
NC	https://www.ncwildlife.org/Portals/0/Learning/documents/Profiles/mallard.pdf
NIEHS	https://www.niehs.nih.gov/health/topics/agents/algal-blooms/index.cfm
NOAA	https://oceanservice.noaa.gov/hazards/hab/
NOAA	https://www.noaa.gov/what-is-harmful-algal-bloom
NOAA	https://oceanservice.noaa.gov/facts/habharm.html
NOAA	https://oceanservice.noaa.gov/facts/redtide.html
NOAA	https://www.fisheries.noaa.gov/science-blog/phytoplankton-and-habs-sampling-2019-summer-survey
NOAA	https://www.fisheries.noaa.gov/monitoring-seafood-safety-and-coastal-ecosystem-health
NOAA	https://coastalscience.noaa.gov/research/stressor-impacts-mitigation/habhrca/
RVKP	https://www.catawbariverkeeper.org/2019/08/15/algae-update/
RVKP	https://waterkeeper.org/magazines/be-the-change-volume-16/poison-blooms/
RVKP	https://waterkeeper.org/news/waterkeepers-florida-committed-to-

	protecting-sunshine-state/
RVKP	https://waterkeeper.org/news/florida-officials-urged-to-set-standards-to-protect-people-wildlife-from-harmful-algal-blooms/
RVKP	https://waterkeeper.org/news/a-chilling-message-keep-away-from-waters-edge/
RVKP	https://waterkeeper.org/news/suncoast-waterkeepers-sick-of-sewage-campaign-resolves-lawsuit-against-sarasota-county/
RVKP	https://waterkeeper.org/news/everglades-forgotten-northern-estuary/
RVKP	https://waterkeeper.org/news/lawsuit-launched-to-stop-toxic-algae-bloom-releases-from-lake-okeechobee/
RVKP	https://www.congareeriverkeeper.org/what-you-can-do
SC	https://www.scdhec.gov/environment/your-water-coast/harmful-algal-blooms
SC	http://dnr.sc.gov/water/aquaff/plankalgae.html
SC	https://www.dnr.sc.gov/news/2016/sep/sep6_algalblooms.html
SC	https://www.dnr.sc.gov/marine/mrri/environ/pollution.html
SC	https://www.dnr.sc.gov/environmental/reportfishkill.html
SC	https://www.dnr.sc.gov/cwcs/pdf/Hardclam.pdf
SC	http://portal.dnr.sc.gov/marine/NERR/pdf/pondconference5-22-14/Powell_Aeration%20for%20Stormwater%20Ponds.pdf
USDA	https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd518784.pdf
USDA	https://www.ars.usda.gov/research/publications/publication/?seqNo115=93999
USDA	https://www.nal.usda.gov/waic/great-lakes-harmful-algal-blooms-and-hypoxia-agricultural-aspects
USDA	https://reeis.usda.gov/web/crisprojectpages/0209332-harmful-algal-blooms.html
USDA	https://nifa.usda.gov/announcement/mitigating-occurrence-harmful-algal-blooms
USDA	https://agresearchmag.ars.usda.gov/1999/jan/form/
USDA	https://portal.nifa.usda.gov/web/crisprojectpages/1006264-ensuring-food-safety-from-harmful-algal-blooms-and-cyanotoxin-risks.html

USGS	https://www.usgs.gov/centers/glri/science/harmful-algal-blooms-habs?qt-science_center_objects=0#qt-science_center_objects
USGS	https://www.usgs.gov/news/science-harmful-algae-blooms
USGS	https://www.usgs.gov/mission-areas/environmental-health/science/new-guide-help-identify-harmful-algal-blooms?qt-science_center_objects=0#qt-science_center_objects
USGS	https://www.usgs.gov/centers/oki-water/science/harmful-algae-blooms-habs?qt-science_center_objects=0#qt-science_center_objects
USGS	https://www.usgs.gov/centers/glri/science/harmful-algal-blooms-habs?qt-science_center_objects=0#qt-science_center_objects

APPENDIX B: CODEBOOK

HABITS Codebook

BASIC INFORMATION

NOTE: 1=Yes, 0=No

1. Resource code:

2. Web link:

3. Author of webpage/PDF:
1=State Agency
2=National Agency
3=NGO

Publishing organization:
4. Title/heading of webpage/PDF:

5. Is there a date listed on the webpage/PDF?
1=Yes
0=No

    a. If yes, what is the most recent date listed? (yyyy/mm/dd)

    b. If yes, the date listed is the date that the website was:
1=Written
2=Posted
3=Updated
4=Unclear

FORMAT

6. Format:
1=Website
2=PDF
3=Available as both website and PDF

7. Is the webpage/PDF in paragraph form, bullet point form, or both?
1=Paragraph form
2=Bullet point form
3=Both
    a. If webpage/PDF is in paragraph form, are subheadings used to "chunk" information?
1=Yes
0=No

8. Is text written in 2nd person (e.g. "you")?
1=Yes
0=No

9. Is the F pattern utilized in terms of the most important information?
1=Yes
0=No

10. Are typographic cues (color, bold, size, background) used to emphasize key points?
1=Yes
0=No

11. Is type text in a uniform typeface?
1=Yes
0=No

12. Is type size a reasonable readable size?
1=Yes
0=No

13. Do you have to click "next" or scroll through multiple pages in order to view the entire article/all of the information?
1=Yes
0=No

14. Does the page contain a glossary or definition of technical terms?
1=Yes
0=No

15. Are there less than 3 levels of information on the page?
1=Yes
0=No

16. Is there an option to receive a notification when the webpage is updated?
1=Yes
0=No

CONTENT

Focus Area = Minimum of 75% of page devoted to specific topic

17. Is the focus area of the webpage/PDF HAB biology and chemistry (including metrics like water temperature, pH, DO, etc.)?
1=Yes
0=No

18. Is the focus area of the webpage/PDF Public Health (human health impacts of a HAB)?
1=Yes
0=No

19. Is the focus area of the webpage/PDF Ecological (prevention or treatment of water)?
1=Yes
0=No

20. Does the webpage/PDF contain a warning about human exposure?
1=Yes
0=No

21. Does the webpage/PDF contain a warning about animal exposure?
1=Yes
0=No

22. Are freshwater or marine HABs addressed?
1=Freshwater
2=Marine
3=Both
4=None specified

23. Does the webpage/PDF mention temperature as an environmental factor contributing to HABs?
1=Yes
0=No

24. Does the webpage/PDF mention sunlight as an environmental factor contributing to HABs?
1=Yes
0=No

25. Does the webpage/PDF mention pollution as an environmental factor contributing to HABs?
1=Yes
0=No

26. Does the webpage/PDF mention weather conditions as an environmental factor contributing to HABs?
1=Yes
0=No

27. Does the webpage/PDF mention specific toxins?
1=Yes
0=No

a. If yes, what toxins are mentioned?

28. Does the webpage/PDF list ways to identify a HAB?
1=Yes
0=No

29. Does the webpage/PDF list specific activities to avoid if a HAB is suspected?
1=Yes
0=No

30. Does the webpage/PDF mention a specific disease or syndrome?
1=Yes
0=No

a. If yes, what disease(s)/syndrome(s) are mentioned?

31. Does the webpage/PDF mention a specific body of water?
1=Yes
0=No

32. Does the website/PDF contain an explicit call to action (e.g. Don't go in!)?
1=Yes
0=No

33. Does the website/PDF include a summary, review of the key messages, or takeaway points?
1=Yes
0=No

34. Does the webpage/PDF provide a phone number to call for more information?
1=Yes
0=No

35. Does the webpage/PDF provide an email address to contact for more information?
1=Yes
0=No

36. Does the webpage/PDF include the name of a contact person?
1=Yes
0=No

37. Does the webpage/PDF include a mailing address for more information?
1=Yes
0=No

38. Is there a “Contact Us” link on the webpage?
1=Yes
0=No

39. Does the webpage/PDF include an option to “share” the information via social media or email?
1=Yes
0=No

40. Does the webpage/PDF provide any links to additional information that is relevant to our topic?
1=Yes
0=No

    a. If yes, how many links are provided?

41. Is the webpage/PDF offered in other languages?
1=Yes
0=No

    a. If yes, what language(s)?

42. Does the website have any pop-ups or advertisements?
1=Pop-ups
2=Advertisements
3=Both
4=Neither
5=Not applicable (for PDFs)

43. Is there a video and/or sound bite embedded in the website?
1=Yes
0=No

44. Does the website have any embedded links to social media accounts?
1=Yes
0=No

45. Is there a place to leave a comment or view others' comments about the website?
1=A place to leave a comment
2=A place to view others' comments
3=Both
4=Neither

46. SMOG calculation

IMAGES/DESIGN

47. Does the webpage/PDF include photos/illustrations?
1=Yes
0=No

a. If yes, is/are the image(s) of water?

1=Yes
0=No

b. If yes, is/are the image(s) of people?

1=Yes
0=No

c. If yes, is/are the image(s) of animals (fish, birds, aquatic mammals, dogs)?

1=Yes
0=No

48. Does the webpage/PDF include any other organizations' logo(s)?
1=Yes
0=No

a. If yes, which ones?

CODEBOOK REFERENCES*

https://plainlanguage.gov/resources/checklists/web-checklist/

https://digital.gov/resources/checklist-of-requirements-for-federal-digital-services/

https://www.ncbi.nlm.nih.gov/books/NBK82281/

https://ballotpedia.org/Transparency_checklist

https://www.hhs.gov/web/building-and-managing-websites/development-process-and-milestones/website-requirements-checklist/index.html

https://www.municipalone.com/newsview.aspx?nid=6249

https://www.usda.gov/digital-strategy/checklist

https://www.energy.gov/eere/communicationstandards/quality-assurance-checklists-energygov-web-requirements

*At least 3 federal agencies have digital checklists (HHS, USDA, DOE). This should be a recommendation going forward.