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Health Communication Blindspot: A Case Study of Harmful Algal Blooms in the South Atlantic States

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Abstract. A Harmful Algal Bloom (HAB) is a complex natural event that occurs when algae reach a critical biomass and create one or more toxins harmful to biological life or the environment. By definition, HABs create both ecological and public health challenges. Because governments are the entities most often tasked with the responsibility for shared resources, this case study represents a snapshot of current governmental messaging about HABs in the South Atlantic states. The objective of this online content analysis is to determine the readability of both state and federal government online communications regarding HABs using the Simple Measures of Gobbledygook (SMOG) test. Sources for this study were obtained using a targeted search of both South Atlantic state websites and federal agencies concerned with HABs and their effects on human health. In total, 90 webpages were identified from state (n=38) and federal agencies (n=42), as well as nongovernmental organizations (n=10). The average SMOG score of all 90 sources is an 11th grade reading level (10.7). 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 environmental health communications in order to properly inform the public about known toxicological and environmental health risks.

INTRODUCTION

The purpose of this study was to determine the readability of online content related to Harmful Algal Blooms (HABs) and to contribute to the knowledge of public-facing environmental health communications. Not only are HABs common to the state of South Carolina, but they are also increasing in frequency and intensity (Gobler 2020). Health communicators and water resource managers will be able to use the principles in this analysis to better relay information relevant to the protection of public health and the health of the environment. This content analysis allows those charged with informing the public to better understand the current landscape of publicly available HAB information and potential areas of improvement.

BACKGROUND AND RELATED WORK

A Harmful Algal Bloom (HAB) is a complex natural event that occurs when algae reach a critical biomass and create one or more toxins harmful to biological life or the environment (Maso and Garcés 2006). By definition, HABs create both ecological and public health challenges. To best protect both public health and the ecosystem, communication principles and practices are crucial to provide water users with accurate information regarding HABs. Because governments are the entities most often responsible for shared resources like water, 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 (Lewitus and Holland 2003; Lopez et al. 2008; Greenfield et al. 2017). Intense urbanization, nutrient loading, increasing water temperatures, and ocean acidification have all contributed to increased recorded HAB events in recent years (Wells et al. 2020; Paerl and Paul 2012). HAB increases worldwide require a public health response reciprocal in magnitude (Brooks et al. 2016). 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 Plain Writing Act of 2010 mandates plain language design in federal communications "to enhance citizen access to Government information and services by establishing that Government documents issued to the public must be written clearly." Following suit, many states have adopted similar policies to ensure that citizens have access to information that is understandable and digestible to the nonexpert public. 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.

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, 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, and (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 (Strekalova 2017). 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, HAB-specific information consistent with current health communication science will provide a tool for mass media, social media, or in-person communicators necessary to properly communicate environmental risks to the public (Stellefson et al. 2020).

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 gain additional data for analysis (Sullivan et al. 2018). 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 scientists and citizesn and allows researchers to better disclose their findings to the general public.

Finn and O'Fallon (2017) 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 and 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 et al. 1998).

Especially in terms of water-related issues, the technique of online content analysis around environmental hazards is not without precedent. A 2016 study of online resources related to the risks of seafood consumption was published by researchers from the University of South Carolina (Henderson et al. 2016). While the risks of HAB exposure do not have a compensatory benefit as is seen in seafood consumption, the overlapping audiences provided a pattern for this study to follow in discussing issues relevant to both online health communicators and environmental resource managers. However, no known study relates American public perception to HAB 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.

PROJECT OBJECTIVES/GOAL

The goal of this study was to evaluate the current readability of HAB webpages maintained by government entities inclusive of public-facing resources.

MATERIALS AND METHOD

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 both health and environmental departments, which in some cases are combined but in many are separate government entities. 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 those of both health department sites and 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 nonexpert audience (Treise et al. 2003). Websites were evaluated as a whole but were specific to each individual web address or URL. The use of the terms *webpage* and *website* is not interchangeable, but for the purposes of this study, these terms are most often used to define a specific web address. The logic behind this methodological approach is based on the idea that information seekers are unlikely to follow multiple links to find the information they are looking for (Pang et al. 2015).

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 and Hoffman-Goetz 2006). The SMOG test has been the standard in evaluating text complexity since its creation by clinical psychologist Harry McLaughlin (Fitzsimmons et al. 2010), and although originally used in the field of education, SMOG has become the primary measure used to evaluate health-related information. The SMOG test is a measure of readability that assesses sentence structure by counting every word of three or more syllables (Grabeel et al. 2018). The basic rationale behind this test comes from speech and cognitive developmental processes that indicate that words of two or fewer syllables tend to be more frequently used and easily understood by a general audience. As words become more technical, and as sentences include more field-specific jargon, the SMOG score in a sample of text will increase. For the SMOG test to be valid, the text to be evaluated needs to contain at least 10 sentences; thus, some of the excluded sites simply did not have enough content for inclusion using this method. Sentences were scored by an online readability calculator (http://www.readability-formulas.com/free-readability-formula-tests.php) to obtain a score that correlates to a US school grade level. This grade level estimate is often used in many fields—and is prevalent in health care—to provide a normalized metric to text on diverse health topics (Kim and Xie 2017). Given the scientific density and complex vocabulary of both health care and environmental science, the SMOG test with its accompanying grade level scoring system provides a logical evaluation tool for the field of environmental health science.

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 HAB 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 like stand-alone health departments similar to the Florida Department of Health or the CDC, or (2) managers of water resources like the South Carolina Department of Health and Environmental Control (SCDHEC) or the US EPA. This distinction was made based on the known gaps in scientific literacy among the two target communities (Guidotti 2013). 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.

Since governments are not the only organizations with an interest in the management of water resources, nongovernmental organizations (NGOs) were included as a referent group. However, these organizations do not always maintain websites. In an effort to provide statistical power, "news" posts were selected from NGOs to have a large enough sample to draw intergroup comparisons relating NGOs to state and federal sources. The NGOs selected for this study were waterkeeper organizations such as the Congaree Riverkeeper and the Charleston Waterkeeper. The Riverkeeper and Waterkeeper alliance is a nonprofit 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. These organizations are a grassroots effort to protect water resources and are typically composed of a limited staff of one or two individuals and multiple volunteers. Beyond geographic exclusion to the South Atlantic states for NGO, state agencies, and federal agencies of the United States, no other exclusion criteria were followed outside the ".gov" stipulation for inclusion. Sources were gathered in December 2019 and again in February 2020. 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 specific terms. A source qualified as an HAB communication if it contained the words "toxic algal bloom," "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 the Health Belief Model (Rosenstock 1974) and has been applied to health education as a means of evaluating the quality of online health information (Friedman et al. 2008). Mobilizing information relies on preexisting attitudes, such as information seeking, which is manifested 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. Although not an explicit construct of the Health Belief Model, cues to action are also used in environmental science, as is seen in the various advocacy groups around the globe. The aspects related to mobilizing information are 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 such as charts and tables was recorded and reported in the final analysis as comprehension aids. Further, carefully created maps have been shown to enhance community perception on environmental risk (Severtson and Vatovec 2012). The inclusion of a map or a link to a map was recorded as a measure of comprehension aids provided on each site. Other measures identified in the results section are defined there, but the broad terms here are supplied for context. Relevant measures and their definitions may also be found in health communication literature.

A codebook was modified from the codebook used in a previous study by Henderson et al. (2016), described above, for analysis of the targeted search. 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 can be found in Appendix B. Sources for necessary codebook amendments and adaptations for this study are noted at the end of the codebook itself for reference.

The data analysis for this study was generated using SAS University Edition software for Windows (SAS). Statistical tests included preliminary Chi-square or Fisher's exact tests as appropriate, followed by a simple linear regression model with the SMOG score acting as the outcome variable.

RESULTS

Table 1 enumerates all sources by their class affiliation: state, federal, and NGO (Riverkeepers). In total, 90 sources were identified, which consisted of 38 state sources, 42 federal sources, and 10 NGO webpages. Table 1 lists state and federal sites. State sites are grouped together by state, and federal agency sites are identified by the number of sources identified that are 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 comparisons showed a statistically significant intraclass relationship ($p=0.0217$) using the Chi-squared test: $\chi2$ (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 cutoff point of 9, and it 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. NGOs undertake different missions and indeed have different stakeholders than governments. As such, 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 webpages, 59% (n=53), were written in paragraph form, and 60% (n=32) of paragraph pages utilized chunking. Overall, 3% (n=3) of sites required clicking next to see all content, including two Florida webpages and one NOAA page. Some sort of glossary or term definition was included in 29% (n=26) of webpages, with 2 of the 42 federal sources (4.76%) meeting these 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). Out of all sources, 4% (n=4) were written in the second person, with the F-pattern of web design used on 69% (n=62) of all pages with 42% (n=38) using typographic cues.

Webpage focus was determined by a review of the content with a 75% threshold that best aligned with 1 of 3 classifications with a relatively even distribution: Biochemistry (31%), Ecological (40%), and 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. Of the sites, 19% (n=17) mentioned specific toxins with the common freshwater toxins of Microcystin (13), Cylindrospermopsin (9), Anatoxins (7), and Saxitoxins (7)—the last of which can be produced in both fresh and saltwater conditions—being enumerated most frequently. Further, 8% (n=7) mention specific diseases and syndromes resulting from human HAB exposure. With the science showing that the naked eye cannot reliably identify an HAB, 39% (n=35) list at least one way to identify an HAB without laboratory techniques, and 30% (n=27) list activities to avoid when an HAB is suspected.

Unprompted pop-ups were only observed on federal sites; these asked consumers if they were willing to take a survey to improve the site. Over half of the sources, 58% (n=52), contained links to outside sources and information, with an average of 5 sources per page (4.70 links). The 2 sites with the 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

Table 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
	Federal Total		42
	State & Federal Total		80
NGO	Riverkeepers	RVKP	10
	TOTAL		**90**

of other organizations, indicative of collaborative activities. All 5 pages with other organizational logos were academic presentations hosted on government sites. Because multiple federal agencies were represented by only 1 webpage, most analyses were performed using statistics grouped by class.

Figures 1 and 2 show median SMOG scores among state and federal agencies, respectively. Ultimately, 10% error bars were used for two main reasons: (1) using only one coder, or website reviewer, 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. These two figures illustrate the intraclass variation in SMOG scores. The maximum median SMOG score is the US EPA score of 14.68 represented by 9 different webpages. The minimum agency SMOG score of 7.0 represented by a single webpage was another federal agency, the US Fish and Wildlife Service (FWS). 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.

A simple linear regression model fits SMOG score data in Figure 3. The y-axis in this linear regression shows SMOG scores from 5 to 20 to more clearly display the positive slope of the linear regression between the state and federal sources. 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. This model contains 80 observations with 2 parameters (state and federal). Despite the relatively large mean square error (MSE) of this model of 7.469, with an R2 value of 0.0565 there is almost no statistically significant correlation in the relationship between state and federal agency distinction and associated webpage SMOG scores, using logistic regression. Both of these results could be partially explained by the small sample size. As more webpages are added around this issue, the model could improve.

Each webpage's focus was coded with 75% threshold criteria with 3 classifications, with an ecological focus representing the plurality in the identified sources: Biochemistry 31% (n=28), Ecological 40% (n=36), and Public Health 29% (n=26). All 90 observed webpages are indicated in the radar chart in Figure 4, which is 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.

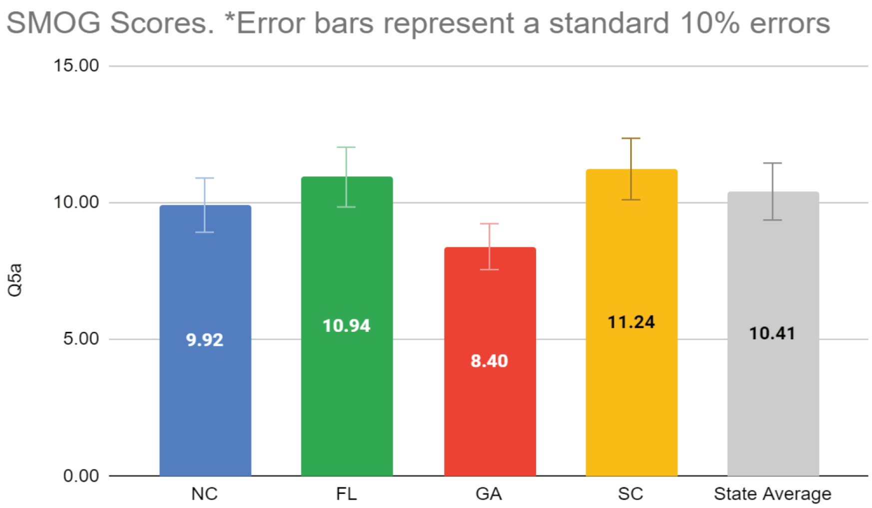

Figure 1. State SMOG scores.

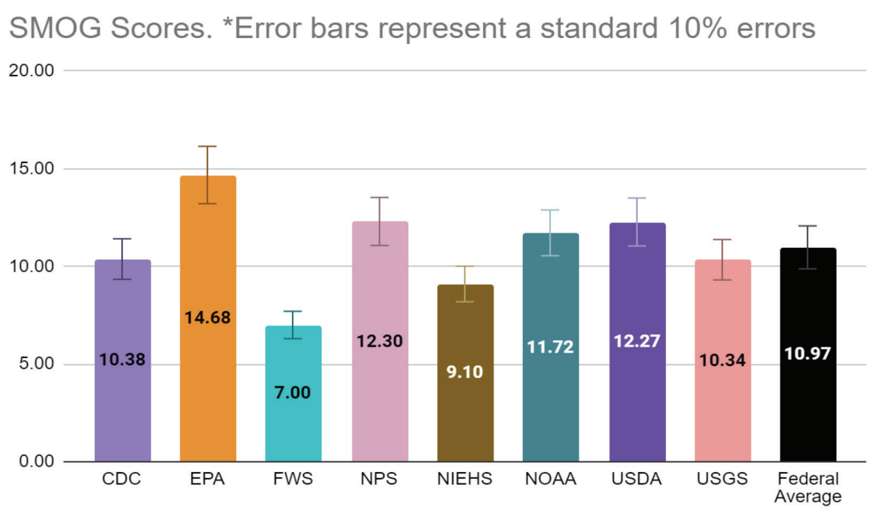

Figure 2. Federal SMOG scores.

DISCUSSION

This analysis indicates the potential for the development of 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 HAB 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 and Klein 2015). The best strategies in health communication have long been studied in health care settings, and health communicators apply the same logic to the ecological domain (Fitzpatrick-Lewis et al. 2010). As a general guide as noted above, public-facing information should score no higher than 9.0, if not lower. The combined score of 10.7 indicates a grade-level reading score of 11th grade and shows clear room for improvement.

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 due to 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 and

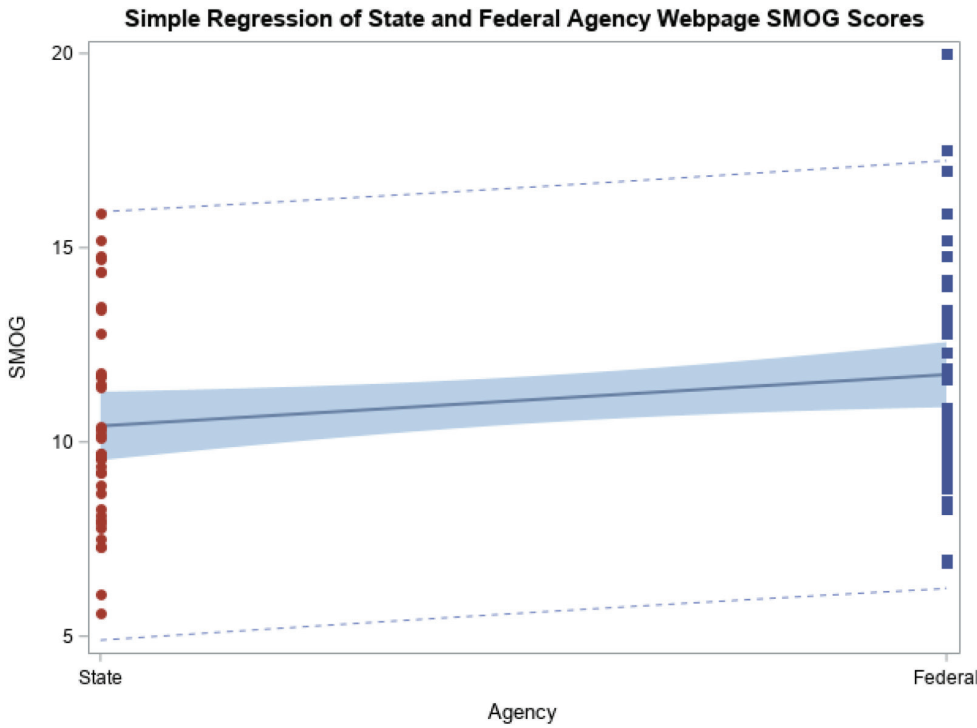

Figure 3. SMOG score simple regression.

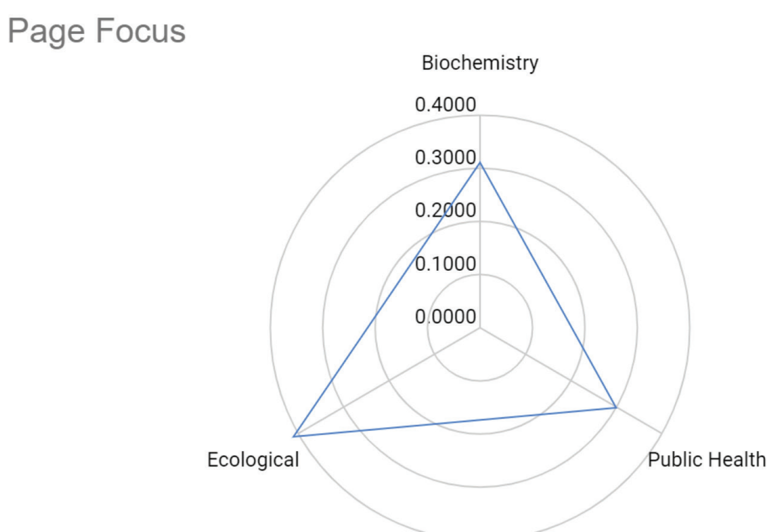

Figure 4. Page-specific focus.

Volsko 2008). This has been a mass communication standard despite the fact that the nationwide high school graduation rate rose to 94% in 2020 from 72% in 1980 (NCES 2020). The median SMOG score of all sources 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. As shown in Figure 3, simple linear regression did not yield a strong correlation between increased SMOG scores based on state or federal classification, despite the noted statistical difference. This was likely due to the wide spread of the data to include outliers, such as the low SMOG scores in Georgia or the relatively high SMOG scores in US EPA communications.

The results of this analysis are troubling on one hand, but on the other, they 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. Consumers of the information found on these sites are often 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 find answers to their questions in an efficient manner without requiring them to scour more information than is applicable to their unique needs. Figure 4 shows how government communicators tend to triangulate information about HABs around the biochemistry or physical processes of HABs and their ecological and public health determinants and consequences. The sites identified are relatively balanced between these three topics, which can generally help information seekers find what they are looking for despite their varied needs and backgrounds.

As noted previously, HAB intensity and causative organisms vary in freshwater and marine water. Given the difference in coastline length between Florida's long coast and Georgia's relatively short 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 that have no coastal waters alongside Alaskan waters with 33,904 mi (54,563 km) of coast as measured by the NOAA method (NOAA 1975). Describing salinity is particularly pertinent to this study because HABs are not just a coastal phenomenon or problem. Sites identified by this study tended to describe salt and brackish water HABs, but freshwater HABs were not excluded from consideration or discussion. Much of what we know about which algal species thrive in certain environments is based on water salinity. 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 toxins are similar to food poisoning, and inhaled HAB exposure typically presents with airway aggravation. Contact dermatitis, or swimmer's rash, is the most common result of dermal HAB toxin exposure. All of these symptoms could responsibly be included on HAB websites. Proper audience segmentation for health care practitioners, researchers, and the general public will allow these sources to maintain various levels of complexity (Paige et al. 2017).

Audience segmentation can be improved with a wide variety of web design tools. 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, 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 much as conflicting messaging can.

The scientific method relies on falsifying 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, thus 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 risky behavior or new exposure, there are moral implications to human experimentation. HABs have produced health outcomes ranging from mild rashes to death and have been observed in multiple species. As we await the advancement of science to improve the detection of thresholds of safe HAB toxin exposure, as well as technological advancements that allow water managers to quickly and accurately assess various water sources, the precautionary principle (Kriebel et al. 2001) should be applied to HABs. 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 that 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.

CONCLUSION

The findings of this study provide at least 2 specific items that can and should be implemented by governments. First, readability standards should be created and standardized prior to any webpages being released on the internet. Making readability a gatekeeper for information to be communicated to the public provides greater operational efficiency as there is less confusion between government communicators and their audience. Readability standards also create a simple way for citizens to keep governments accountable for informing the public regarding shared resources under the respective government's care. Second, regular readability evaluation schedules should be created to evaluate social media and other "news" items or blog posts. These communications tend to be rapid-release and thus may not necessarily be subject to review by an assigned communications officer. Thus, a retrospective analysis can be performed to better facilitate future direct communications by subject matter experts. This will help subject matter experts communicate more clearly to their target population as well as improve public awareness of specific issues as misconceptions are identified and addressed. Given the diverse ways the public interacts with water resources and affects water quality, these simple actions by governments will at the very least create a more responsible framework for communicating risks about HABs.

Although some agencies were shown to have more readable content than others 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. Perhaps the most salient example of future directions would be the creation of a quick reference for what the public needs for an HAB webpage. This tool could be developed rather quickly but would need to involve all stakeholders described in the study at hand. Future researchers should consider ways to evaluate public trust as a means of measuring the ability of institutions to reliably and responsibly influence human behavior for the betterment of public health and the health of the environment.

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APPENDIX A. WEBPAGES IDENTIFIED

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. 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:
1. Title/heading of webpage/PDF:
2. 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?