An Annotated Bibliography of *Karenia brevis* Red Tide Communications Literature

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Introduction

Red tide blooms of the dinoflagellate *Karenia brevis* (formerly *Gymnodinium breve*, *Ptychodiscus brevis*, and *Gymnodinium brevis*) occur on a near-annual basis along the southwest Florida coast. Red tides have been observed in Florida since the 1840s although records describing red tide-like conditions date back to the 1500s. Blooms can last weeks to months and rare severe blooms can persist more than a year.

Karenia brevis produces a suite of neurotoxic brevetoxins which can have adverse impacts on marine wildlife including fish kills and mortality events for marine mammals and sea birds, render shellfish unsafe for human consumption, and cause acute respiratory irritation in humans. Severe red tide events can also have adverse effects on local communities impacting human health, business and tourism, commercial seafood harvest, and quality of life (e.g., outdoor recreation). These events can extend northwest to the Florida Panhandle and beyond, and less frequently along the southeast Atlantic coast.

Despite the long-term historic trends and impacts associated with red tides in Florida, there was a dearth of scientific literature pertaining to red tide communication prior to 2005. This shift in focus was concurrent to an intense 2005 red tide bloom event and the publication of the 2006 *Harmful Algal Research and Response: A Human Dimensions Strategy* [1] report that resulted in the notable (re)acknowledgment of communication as an important component of harmful algal bloom (HAB) mitigation. Effective communication with the public can minimize the potential acute human health risks associated with red tide and prevent adverse economic impacts associated with risk perceptions. Transparent communication with the public can also build trust and confidence in government agencies. Finally, successful interagency communication can streamline response and management efforts through cooperation and coordination while maximizing efficient use of resources. For these reasons, an assessment of the existing red tide communication literature can be used to develop more effective and targeted communication efforts, identify gaps and areas of opportunity.

The purpose of this bibliography is to provide a comprehensive summary of the recent published literature addressing red tide communication in Florida. Communications can broadly be defined as the process of information exchange, the technique for expressing information, or the technology for transmitting the information. For this reason, this literature review includes papers that focus on content, process, and technology for red tide communication efforts.

The review includes both peer-reviewed and “grey” literature sources including technical and industry reports, conference and symposium proceedings and abstracts, and non-

[1] Bauer, M. (Ed.). (2006). *Harmful algal research and response: A human dimensions strategy* (p. 58). National Office for Marine Biotoxins and Harmful Algal Blooms, Woods Hole Oceanographic Institution.

published theses. When possible, the final product is presented and intermediate papers are included in footnotes.

The concept of communication is ubiquitous within the red tide literature. This bibliography includes only those sources where red tide communication, as described above, is a primary focus of the article. Every effort was made to provide a complete bibliography of the existing literature although it is possible that some relevant studies were inadvertently omitted. While this literature review was not constrained to a specific time frame, the bibliography reflects the growth of literature in the field following the 2005 bloom event.

Format

Papers are divided into five categories:

- Public knowledge and perceptions – studies that examine public knowledge and/or perceptions of red tide events and risk;
- Communication, outreach and education – papers that describe various outreach and education programs or projects;
- Social and mass media – studies that analyze the role of social and mass media during red tide events;
- Technology and tools – studies that describe communication tools and technologies; and
- Reviews– articles that present a compilation of communication, outreach and education organizations and efforts.

Within each category, papers are subdivided by literature type and listed in reverse chronologic order beginning with the most recent paper proceeded alphabetically by author for each year. Each paper includes a bibliography (American Psychological Association 7th edition) with DOI or weblink when available, a brief description of the purpose (message) of the research study or outreach/education effort, a brief description of the methods, and the geographic scope or audience of the research study or outreach/education effort.

A short summary highlighting just the communications component of the paper is presented. Although the literature pertaining to red tide communication is relatively young, communications as a field is constantly changing and adapting. Public knowledge and perceptions are expected to change over time in response to on-going education and outreach efforts or personal experiences. Communication techniques and technologies are also continuously evolving. As such, an assessment of the paper and its current application to the field is also provided when appropriate.

In total, summaries for twenty-six research papers, ten reports, one thesis and one symposium proceeding are provided. Nine intermediate works are additionally cited. A compiled bibliography can also be accessed at:
https://zbib.org/e7dca73573e74be9bef6960b48124920

Public knowledge and perceptions

Peer-reviewed publications

Liu-Lastres, B. & Cahyanto, I. P. (2021). Exploring the host-Guest interaction in tourism crisis communication. *Current Issues in Tourism*, 24(15), 2097–2109.[2] https://doi.org/10.1080/13683500.2020.1817876

Purpose or Message: Examine the role of tourism encounters in red tide crisis communication.

Methods: Surveys designed in the context of the practice-based theory approach

Audience/Geographic Scope: Florida residents and visitors

This study used the 2018 red tide event in Florida as the context to explore guest-host interactions in tourism crisis communication. The authors used a practice-based approach to examine visitors' information-acquiring and residents' information-sharing behaviors. Two surveys were distributed to an online panel of visitors and residents and analyzed for individual characteristics, subjective knowledge, and information (receiving or sharing) behavior, respectively. The study results indicate that red tide related information-searching and information-sharing behaviors are linked. Most visitors (86%) responded that they would seek information about red tide for their upcoming trip to Florida and thirty-two percent of those would rely on residents as the source for red tide information. Fifty-six percent of residents indicated that they had shared information about the 2018 red tide to visitors, primarily by word-of-mouth (77%). Residents' likeliness to share information was predicted by their subjective knowledge and social identity as a Florida resident.

Cahyanto, I. & Liu-Lastres, B. (2020). Risk perception, media exposure, and visitor's behavior responses to Florida Red Tide. *Journal of Travel & Tourism Marketing*, 37(4), 447–459. https://doi.org/10.1080/10548408.2020.1783426

Purpose or Message: Mitigate adverse health and societal impacts associated with red tide in Florida by encouraging approaches that promote protective behaviors.

Methods: Social Amplification of Risk Framework surveys

Audience/Geographic Scope: Visitors to Florida, in-state and out-of-state

This study examined the relationship between media exposure, perceptions of risk, and subsequent protective behaviors associated with the 2018 red tide event in Florida. The Social Amplification of Risk Framework was used to compare these attributes for in-state and out-of-state visitors to Florida. Residency, access to the

[2] Intermediate paper: Liu-Lastres, Bingjie and Cahyanto, Ignatius P. (2019). Exploring Residents' Roles as Risk Insiders in Tourism Crisis Management. *Travel and Tourism Research Association: Advancing Tourism Research Globally* (10). https://scholarworks.umass.edu/ttra/2019/research_papers/10/

local community, and media exposure influenced perceived risk and visitor behavior. In-state visitors and visitors that were highly exposed to media demonstrated a greater level of concern and perceived negative impacts to both their travel experience and public health. Floridians and visitors with access to the community or media were also more likely to alter their travel plans due to concerns about red tide. This study suggests that geographic proximity to red tide and media exposure about red tides are risk amplifiers that increase perceived risk and engagement in protective behaviors, regardless of knowledge about red tide.

Kirkpatrick, B., Kohler, K., Byrne, M., Fleming, L. E., Scheller, K., Reich, A., Hitchcock, G., Kirkpatrick, G., Ullmann, S., & Hoagland, P. (2014). Human responses to Florida red tides: Policy awareness and adherence to local fertilizer ordinances. *Science of the Total Environment*, 493, 898–909. https://doi.org/10.1016/j.scitotenv.2014.06.083

Purpose or Message: Evaluate the relative efficacy of water pollution control policies by assessing residents' knowledge and understanding of local fertilizer ordinances.

Methods: Self-administered survey

Audience/Geographic Scope: Full time and seasonal residents in Sarasota County, Florida

This study examined residents' knowledge and understanding of the role of fertilizers in red tide blooms in Florida and the rationales for local fertilizer ordinances, a policy tool implemented as a red tide prevention and mitigation strategy. Fertilizer ordinances are a water pollution control policy the purpose of which is to reduce non-point sources of pollution, primarily nitrogen and phosphorus. An opt-in survey design was implemented in Sarasota County, a coastal community impacted by red tides. Survey respondents were highly educated and self-identified as having high levels of concern about red tides in Florida, however this did not correspond to accurate knowledge about the local fertilizer ordinance, appropriate fertilizer application recommendations, or the potential impacts on red tide frequency, duration, or size. This lack of knowledge and confusion was consistent across the various subpopulations identified. The effectiveness of fertilizer ordinances is contingent upon compliance which is not possible without robust knowledge and understanding of the policy. Based on the survey results, the authors suggest that intensive and targeted education should be a component of any water pollution control policy that relies on public understanding and adherence for it to be effective.

Kirkpatrick, B., Kohler, K., Byrne, M. M., & Studts, J. (2014). Florida red tide knowledge and risk perception: Is there a need for tailored messaging? *Harmful Algae*, 32, 27–32. https://doi.org/10.1016/j.hal.2013.09.008

Purpose or Message: Assess the potential need for tailored messaging about red tide for specific groups and evaluate changes in red tide knowledge and perceptions over time.

Methods: Self-administered survey

Audience/Geographic Scope: Full time and seasonal residents in Sarasota County, Florida

This study examined residents' knowledge and perceptions of red tide in Florida using a self-administered survey instrument. To evaluate the need for tailored messaging, data were compared across four different populations: healthy (non-asthmatic) residents, healthy seasonal "snowbirds", asthmatic residents, and asthmatic seasonal "snowbirds". Results were also compared to those of two previous studies in 2005 and 2007 to examine changes over time. The results suggest that knowledge level was consistent across all populations and demographics, whereas differences in risk perception were exhibited, particularly among individuals with asthma and snowbirds. Differences in knowledge did exist over time, although results were less conclusive as differences occurred in both directions. Based on these results the authors suggest that tailored messaging is not needed for these specific user groups, but more effective outreach efforts are necessary, especially those that pertain to seafood consumption and swimming safety.

Larkin, S. L., Lucas, K. M., Adams, C. M., & Stevely, J. (2011). *Strategies to address red tide events in Florida: Results of a 2010 survey of coastal residents* (Electronic Data Information Source No. FE891). University of Florida.[3]

Purpose or Message: Evaluate the public's concern for, experience with, and knowledge of red tides as well as mitigation, control, and prevention preferences.

Methods: Stratified random mail survey

Audience/Geographic Scope: Residents of twelve coastal counties in Florida.

This study presents the results of a survey used to assess public opinion and knowledge regarding red tides in Florida. The survey instrument also evaluated preference for specific red tide mitigation, control, and prevention strategies. Surveys were mailed to residents in twelve Florida coastal counties divided by geographic region: Northeast (St. Johns, Flagler, Volusia, and Brevard); Southwest (Manatee, Sarasota, Lee, and Charlotte); and Northwest (Bay, Okaloosa, Franklin, and Gulf). The number of surveys were stratified by population and red tide strategies were randomized by order. Results of the study suggest that the majority

[3] Intermediate paper. Lucas, K. M. (2010). *Willingness-to-pay for red tide mitigation, control and prevention strategies: A case study of Florida coastal residents* [Master of Science]. University of Florida.

of participants reported experiencing negative effects during a red tide event and indicated some level of concern about red tide (76%). However, misperceptions and misinformation about the causes and effects of red tide were widespread, especially with respect to the safety of seafood consumption. Television and newspapers were identified as the primary sources of information (89% and 82%, respectively). Using the "stated preference" methodology the authors show that respondents were most willing to pay for prevention programs, followed by control and then mitigation programs.

Nierenberg, K., Byrne, M. M., Fleming, L. E., Stephan, W., Reich, A., Backer, L. C., Tanga, E., Dalpra, D. R., & Kirkpatrick, B. (2010). Florida red tide perception: Residents versus tourists. *Harmful Algae*, 9(6), 600–606. https://doi.org/10.1016/j.hal.2010.04.010

Purpose or Message: Evaluate public knowledge and preferences about red tide information to aid in the development of outreach materials.

Methods: Intercept survey

Audience/Geographic Scope: Tourists and residents of Sarasota County, Florida

This study sought to identify knowledge gaps and preferred sources of information among tourists and residents in Sarasota County, Florida. Survey results suggest inaccurate and inconsistent knowledge for both populations. As with more recent survey studies, the greatest misperceptions were regarding the safety of seafood consumption. The misperceptions about red tides, especially the human health implications, may cause individuals to participate in either harmful activities that are deemed safe or to forego safe activities that are mistakenly deemed as unsafe.

The authors found minor differences in how tourists and residents get their information. The Internet, local TV news, and Mote Marine Laboratory and Aquarium, the local science organization and site location for surveys, were all cited as the primary sources where individuals would go to learn more about red tide. Tourists, however, were much more likely to go to the Internet. Both populations were highly likely to read beach signs, although toll free numbers, especially among tourists, were unlikely to be used. The authors highlight the importance of ensuring currency, consistency, and accuracy among the various information sources, especially when communicating about uncertainty.

Morgan, K. L., Larkin, S. L., & Adams, C. M. (2010). Red tides and participation in marine-based activities: Estimating the response of Southwest Florida residents. *Harmful Algae*, *9*(3), 333–341. https://doi.org/10.1016/j.hal.2009.12.004

Purpose or Message: Analyze the behavioral response to marine-recreation activities during a red tide and identify the factors that affect those decisions.

Methods: Participant choice models

Audience/Geographic Scope: Residents in Sarasota and Manatee Counties, Florida

This paper used a multinomal model to analyze the behavioral responses of southwest Florida residents to red tides for four marine-based activities: beach going, boat saltwater fishing, pier saltwater fishing, and restaurant patronage. The authors analyzed the specific behavioral response for each of the activities (i.e., did the respondent cut short, delay, or relocate) and the factors that affected that decision. This study was not a direct assessment of red tide communication, however, three of the explanatory variables were associated with individual knowledge level with respect to red tide events. These variables included the modes of information that respondents used for red tide information, perceived knowledge, and actual knowledge about red tide events. Of the 15 variables analyzed the only statistically significant variables were those that indicated the number of activities the respondent participated in, perceived knowledge, and actual knowledge. There was a correlation between greater knowledge and the likelihood that a resident would engage in a behavioral response. Based on these results the authors recommend that red tide-related educational materials should be available in a time- and location-sensitive manner to minimize probable economic losses. They further suggest that materials should target recreationists and include recommendations for alternative marine-based activities or locations to retain consumer spending in the area.

Kuhar, S. E., Nierenberg, K., Kirkpatrick, B., & Tobin, G. A. (2009). Public perceptions of Florida red tide risks. *Risk Analysis*, 29(7), 963–969.[4] https://doi.org/10.1111/j.1539-6924.2009.01228.x

Purpose or Message: Understand the perception of risk of red tide events between different social groups in Florida.

Methods: Questionnaire surveys and semi-structured interviews

Audience/Geographic Scope: Beachgoers in Sarasota and Pinellas Counties, Florida

This study utilized a convenience sample of beachgoers at two beaches in Sarasota and Pinellas Counties, Florida. Surveys and semi-structured interviews were conducted to assess perceptions of red tide causes and impacts as well as risk perceptions in different social groups. Results show that females and older individuals perceived higher levels of health impacts than other respondents, as did those respondents who had experience with red tide events. Residents and experienced respondents were also more likely to think that red tides were increasing in frequency and duration. Health professionals and visitors were more likely to perceive risks in eating seafood. This study shows that there are several

[4] Intermediate paper. Allen, S. E. (2007). *Florida red tides: Public perceptions of risk* [Master of Arts]. University of South Florida.

social characteristics that act as explanatory variables for risk perception and amplification of risk may occur regarding the consumption of seafood during red tide events.

Larkin, S. L. & Adams, C. M. (2008). Public awareness and knowledge of red tide blooms. *Journal of Extension*, *46*(2).[5,6] https://www.joe.org/joe/2008april/a8.php

Purpose or Message: Understand the level of awareness and knowledge of red tide events among southwest Florida residents to improve communications to the public to mitigate the economic impacts of red tide on local communities.

Methods: Random digit dialing telephone survey

Audience/Geographic Scope: Manatee and Sarasota Counties, Florida

This paper presents the results of a 2001 telephone study of Manatee and Sarasota county residents to evaluate public awareness and understanding of red tide events in Florida. Knowledge assessment questions indicate that respondents were reasonably knowledgeable about *Karenia brevis* biology. Respondents had an overall lower understanding of the human and environmental health impacts of red tide especially those questions associated with the safety of seafood consumption and swimming during red tide events. Mass media (newspapers and television) were identified as the most common sources for red tide information. Based on their results, the authors indicate a need for outreach and education programs in southwest Florida and recommend that these programs should engage the media, especially in providing real-time, location-specific information to allow the general public to make informed decisions. Specifically, the authors propose collaborations with local environmental reporters or the use of local cable television stations for public service announcements to reach tourists and short-term residents. They also note the role of education in informed decision making by residents and tourists and the reduction of adverse economic impacts to the business community impacted by red tides.

This article is part of the growing arena of literature regarding public perceptions of red tide. The paper's results are no longer current and should not be interpreted as such. However, the results remain useful in helping to understand how perceptions and preferences may have changed over time and the recommendations regarding the importance of real-time, location-specific information are still relevant.

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[5] Intermediate paper. Adams, C. M., Larkin, S. L., Mulkey, D., Hodges, A., & Ballyram. (2002). *Measuring the economic consequences and public awareness of red tide events in Florida* (p. 155) [Final report submitted to the Harmful Algal Task Force Florida Marine Research Institute Florida Fish and Wildlife Conservation Commission]. Food and Resource Economics Department, University of Florida.

[6] Intermediate paper. Stevely, J., Larkin, S., & Adams, C. (2008). Red Tide: Sources of information, public perceptions, and future actions. *American Fisheries Society Symposium, 64*, 245–252.

Reports

Turley, B., Karnauskas, M., McPherson, M., Sagarese, S., Rios, A., Jepson, M., Stoltz, A., & Blake, S. (2021). *Local ecological knowledge outlining severe red tide events between 2000—2019 on the West Florida Shelf.* (No. SEDAR72-WP-09; SEDAR, p. 19).[7] http://sedarweb.org/sedar-72-wp-09-local-ecological-knowledge-outlining-severe-red-tide-events-between-2000-%E2%80%93-2019-west

Purpose or Message: Investigate individual fishermen's local ecological knowledge (LEK) of red tides in Florida

Methods: Oral histories and participatory mapping.

Audience/Geographic Scope: Current or retired commercial and for-hire fishermen with experience in state and federal waters along the Florida Gulf Coast.

This study utilized oral history interviews to discuss major red tide events and the impact of these events on their fishing careers, the marine environment, and local economies. A total of 214 events were describe and 73% of these had accounts of species-specific fish kills. Interviewees consistently identified 2005, 2014, and 2018 as exceptional red tide events. The intensity of the 2018 event was ranked higher than the 2014 and 2005 events with 85% of interviewees categorizing the event as "major" or "devastating" as compared to 60% for the prior red tides. Regional differences were seen in the interviewees reporting of location of bloom impacts. Offshore regions were more likely to be reported as affecting the Big Bend area through Tampa Bay whereas inshore areas were reported from Tampa Bay south. The 2018 event was perceived to have lasted longer than previous red tides and 89% of interviewees reported that they believed the ecosystem was still recovering from that event.

Theses

Pree, K. (2017). *Understanding possible factors involved in recreational fishers' exposure to red tides* (Karenia brevis) *in Lee County, FL* [Doctor of Philosophy]. The Florida Agricultural and Mechanical University.

Purpose or Message: Evaluate the relationships between the awareness, knowledge, behaviors and beliefs of red tides and demographics of licensed recreational fishers in Lee County, FL.

Methods: Interviews and random sample electronic surveys.

Audience/Geographic Scope: Licensed recreational fishers in Lee County, Florida

[7] Intermediate paper. Karnauskas, M., McPherson, M., Sagarese, S., Rios, A., Jepson, M., Stoltz, A., & Blake, S. (2019). *Timeline of severe red tide events on the West Florida Shelf: insights from oral histories.* (No. SEDAR61-WP-20; SEDAR, p. 16). https://sedarweb.org/sedar-61-wp-20-timeline-severe-red-tide-events-west-florida-shelf-insights-oral-histories

This thesis presents the results of a mixed-method research project designed to evaluate trends in red tide knowledge, behaviors and beliefs of recreational-licensed fishers in Lee County, Florida. Interviews with local and state officials (n=9) provided information to guide the development of electronic surveys administered via email. 431 completed surveys were received. Approximately 11-28% of the recreational fishers surveyed reported that they participated in recreational shellfish harvesting although no fishers claimed to be solely shellfish harvesters. Results indicate that licensed recreational fishers are relatively knowledgeable about red tides, the notable exception being their lack of understanding that red tides are natural. Respondents were less knowledgeable about red tide safety and shellfish harvesting management. Half (49.9%) of respondents were not aware that red tide blooms caused shellfish harvesting area closures. 13.7% of respondents *moderately* or strongly *disagreed* with the statement “I do not harvest shellfish if I see indications of red tide blooms in the water” and a small percentage of respondents (3.2%) indicated that it was safe to eat shellfish harvested from areas where there are red tide blooms. However, 70.4% of respondents disagreed with statements regarding the safety of consuming finfish.

Respondents indicated that email was the preferred method to receive information about red tides, followed by TV news, and phone alerts. The author notes that many recreational shellfish harvesters are unaware that it was illegal to harvest shellfish onshore along beaches, but also that harvesting at legal shellfish harvesting areas may be limited for those who have no means of transportation to reach those sites. The results highlight the challenges associated with recreational harvester knowledge including awareness of regulated shellfish harvesting areas and finding and interpreting shellfish harvest status reports and maps. This was especially relevant for non-English-speaking populations. Interviews revealed that there is confusion and uncertainty as to which agency is responsible for promoting education and notification of red tides for recreational shellfish harvesters. To mitigate potential health impacts, the author suggests that agencies work together to distribute emails to licensed fishers with registered email addresses to communicate when red tides are present and when shellfish harvesting areas are closed. Signs or posts at boat launching sites may bridge the gap of notifications for non-English-speaking audiences or those without registered email addresses.

Communication, outreach, and education

Peer-reviewed publications

Hoagland, P., Kirkpatrick, B., Jin, D., Kirkpatrick, G., Fleming, L. E., Ullmann, S. G., Beet, A., Hitchcock, G., Harrison, K. K., Li, Z. C., Garrison, B., Diaz, R. E., & Lovko, V. (2020). Lessening the hazards of Florida red tides: A common sense approach. *Frontiers in Marine Science*, *7*, 538. https://doi.org/10.3389/fmars.2020.00538

Purpose or Message: Suggests a simplified approach to red tide risk communication on a mobile website.

Format: Prototype mobile website

Audience/Geographic Scope: Florida

The authors argue that risk communication policies that improve the public's ability to understand the dynamic spatial and temporal aspects of red tides are preferred over physical, chemical, or biological controls to mitigate *Karenia brevis* bloom impacts. They suggest that the recommendations of the World Meteorological Organization of alerts, watches, and warnings for hazards with short lead times and durations should be applied to *Karenia brevis* blooms due to their dynamic characteristics as a natural hazard. Forecasting and preparedness planning policies could be adopted as hazard lead times and durations increase.

Public notification of timing and location of blooms could reduce public health and economic impacts. The article includes a table of various public notification services with their intended audience and perceived ease of use. These services include Mote Marine Laboratory's Beach Condition Reporting System, NOAA's Harmful Algal Bloom Operational Forecast System and Harmful Algal Blooms Observing System, FWC's Red Tide Current Status, FDACS's Shellfish Harvesting Area Status, FDEP's Algal Bloom Sampling Status, and the University of South Florida Ocean Circulation Group's Red Tide Prediction and Tracking tool. The authors present a prototype mobile website to distribute the multi-institutional *Karenia brevis* services across a single platform, streamlining the existing complex navigational process.

Reich, A., Lazensky, R., Faris, J., Fleming, L. E., Kirkpatrick, B., Watkins, S., Ullmann, S., Kohler, K., & Hoagland, P. (2015). Assessing the impact of shellfish harvesting area closures on neurotoxic shellfish poisoning (NSP) incidence during red tide (*Karenia brevis*) blooms. *Harmful Algae*, *43*, 13–19. https://doi.org/10.1016/j.hal.2014.12.003

Purpose or Message: Assess the link between confirmed Neurotoxic Shellfish Poisoning cases and red tide shellfish harvesting area management.

Audience/Geographic Scope: Florida

Method: Analysis of Florida Department of Health (FDOH) electronic data repository for reportable diseases in Florida and Florida Department of Agriculture and Consumer Services (FDACS) Division of Aquacultures shellfish harvesting area dataset.

This paper sought to determine the linkage between confirmed cases of Neurotoxic Shellfish Poisoning (NSP) with the management of shellfish harvesting area (SHA) closures due to red tide events. The authors compared the reported cases of NSP within the FDOH reportable diseases databases with the closing and opening status of SHA between 2004 and 2009. A total of 24 confirmed NSP cases were associated with the consumption of shellfish harvesting during a red tide event, the majority of which (78%) involved non-residents. The authors conclude that the management of SHA closures is effective for commercial harvesting but suggest that the existing outreach and education programs may not be effective for recreational harvesting, especially by Florida's visiting and non-English speaking populations. Local and state governments should improve their communication about the risks of recreational harvesting and consumption of shellfish during a red tide bloom. These efforts may be aided by the posting of physical signage, particularly in tourist areas.

Hall, E. R., Nierenberg, K., Boyes, A. J., Heil, C. A., Flewelling, L. J., & Kirkpatrick, B. (2012). The art of red tide science. *Harmful Algae*, 17, 1–5. https://doi.org/10.1016/j.hal.2012.02.002

Purpose or Message: Develop innovative outreach products to explain the ecologically complex topic of red tide events in Florida.

Format: Various outreach mediums

Audience/Geographic Scope: Visitors to Mote Marine Aquarium, Sarasota, FL and project Facebook page.

Method: Integrated science curriculum

The paper presents the development of an innovative outreach collaboration between red tide researchers at Mote Marine Laboratory and students at the Ringling College of Art and Design in Sarasota, FL titled "The Art of Red Tide Science". The project was integrated into the science curriculum for students and final projects were presented at a gallery event and put on temporary display at the Mote Marine Aquarium. Final projects were judged and used as a project evaluation tool. Evaluative data was not presented although the authors indicate that the projects were successful in presenting nearly accurate (80-90%) information in an engaging format. This paper suggests that interdisciplinary collaborations could be successful in developing outreach products for complex ecological topics but it remains to be determined if these innovative products are more successful in improving knowledge and dispelling misconceptions about red tide compared to traditional mediums.

Nierenberg, K., Hollenbeck, J., Fleming, L. E., Stephan, W., Reich, A., Backer, L. C., Currier, R., & Kirkpatrick, B. (2011). Frontiers in outreach and education: The Florida red tide experience. *Harmful Algae*, 10(4), 374–380. https://doi.org/10.1016/j.hal.2011.01.004

Purpose or Message: Describe the development, implementation and evaluation of outreach and education products developed during the 10-year Florida Red Tide Research Group funding cycle.

Format: Variety of logo branded materials including printed educational materials, promotional products, signage, websites, and social media content.

Audience/Geographic Scope: Florida with targeted implementation in Sarasota and Manatee Counties.

The article presents the development and evolution of an outreach and education program associated with the National Institute of Environmental Health Sciences 10-year funded project conducted by the interdisciplinary Florida Red Tide Research Group. The authors report that dissemination of outreach tools improved over time. Information was distributed more effectively, and content was seemingly more relevant to target and general audiences as research results were documented. As outreach efforts transitioned to more web-based platforms, outreach information needed to be updated more regularly. Specific project personnel should be identified as part of the outreach plan to ensure continuity and timeliness of information to be disseminated and platforms should be assessed for their ease of use, content relevance, and longevity.

Despite improvements to content delivery, evaluation of outreach materials remained stagnant throughout the project duration. Evaluative metrics included numbers of items distributed or the number of users with no discernable measures of impacts. Goals for outreach and education campaigns should be developed at the front end as part of the research project and formal evaluations should be incorporated into outreach and education campaigns.

Fleming, L., Jerez, E., Stephan, W. B., Cassedy, A., Bean, J., Reich, A., Kirkpatrick, B., Backer, L., Nierenberg, K., Watkins, S., Hollenbeck, J., & Weisman, R. (2007). Evaluation of harmful algal bloom outreach activities. *Marine Drugs, 5*(4), 208–219. https://doi.org/10.3390/md504208

Purpose or Message: Evaluate the efficacy of the Florida Aquatic Toxins Hotline

Format: Toll-free automated hotline (1-888-232-8635*) with optional access to a Poison Information Specialist

Audience/Geographic Scope: State of Florida

Method: Scripted phone interview

The pilot evaluation study examined customer use and satisfaction of the Aquatic Toxins Hotline, a jointly funded automated hotline established by the Florida Poison Information Center in Miami, Florida. The results suggest that the automated hotline met the needs of users and provided useful HAB-related information to the caller. The majority (77%) of participants were Florida residents and 73% of callers only used the automated menu with less than one-quarter of callers choosing to speak to a specialist. This data suggests that the hotline was not being used by tourists and the need to speak to a Poison Information Specialist was limited. At the time of this publication, the Aquatic Toxins Hotline is no longer in service*. According to the website, Florida's Poison Control Centers direct individuals with HAB and toxin related questions to call 1-800-222-1222 or to contact the Florida Department of Health's Aquatic Toxin Program at 1-850-245-4250. Though no longer in service, the recommendations provided by the pilot study remain relevant to current HAB outreach tools and require a focus on tourists, not just Florida residents, and providing regularly updated geographic locations for HABs and possible health effects.

Reports

Shafer, J.L. (2020). *Volume 2: 2018 Regional red tide response assessment for Tampa Bay and Sarasota Bay* (Technical Report. No. 02-20; p. 106 p). Science and Environment Council of Southwest Florida. https://www.scienceandenvironment.org/project/redtide/

Purpose or Message: Provide an overview of the regional responses to the 2018 red tide event and a template for a Red Tide Response Operations Plan.

Audience/Geographic Scope: Tampa Bay and Sarasota Bay counties (Pasco, Pinellas, Hillsborough, Manatee and Sarasota), Florida

This report presents a review of the county-level responses to the 2018 red tide event in the five counties within the Tampa Bay and Sarasota Bay region. The report summarizes information gathered from semi-structured interviews conducted with emergency response and natural resource managers, county documents, and media reports. Communication is identified as an essential component within these response operations to coordinate response efforts within and between counties, to help reduce human exposure to hazardous red tide debris, and to provide red tide status updates to partners (i.e., visitor bureaus) and the public.

Based on the successes and lessons learned from the 2018 event, the author presents a draft communication response plan for the region that includes daily (or weekly) Situation Reports and weekly calls with regional cooperating partners. A coordinated multi-media communications plan for public should include: 1) A Red Tide information page on county websites that provides information about red tide tides, human health effects, links and information sources, and daily beaches updates; 2) Daily (or weekly) social media posts on localized conditions and county

response; 3) County Red Tide Hotline with FAQs for operators; 4) Daily (or weekly) Red Tide Media Updates; and 5) Short PSA videos explaining county response efforts. Evaluative metrics for each component are included.

Morgan, K. L., Larkin, S. L., & Adams, C. M. (2008). *Public costs of Florida red tides: A survey of coastal managers* (Industry Report No. 08–1; p. 21). Florida Agricultural Market Research Center, Food and Resource Economics Department, University of Florida. http://fred.ifas.ufl.edu/pdf/agmarketing/pubs/2000s/Public_Costs_FL_Red_Tide_08-1_.pdf

Purpose or Message: Determine the financial and managerial impacts of red tide events on county and city governments charged with the management of public beaches along the Florida Gulf coast.

Audience/Geographic Scope: Nine county (Okaloosa, Franklin, Gulf, Pinellas, Manatee, Sarasota, Charlotte, Lee and Collier) and 18 city governments within the nine sample counties along Florida's Gulf coast.

Method: Telephone interviews of city and county managers to assess beach and red tide management activities, actual or estimated costs of red tide management, funding sources and allocations, and the existence and types of public relations efforts.

This study surveyed city and county managers to evaluate information on costs associated with red tide management. Included is a discussion pertaining to red tide public relations and activity efforts. Five of the nine counties surveyed followed various public relations protocols. The other four counties do not manage their beaches (Okaloosa), do not have municipalities exposed to the Gulf (Franklin), or did not engage in any public notification efforts. Sarasota and Manatee County lifeguards sent twice-daily reports of red tide conditions for their beaches. These plus Charlotte and Collier Counties utilized red tide signage on public beaches. Gulf, Sarasota, Charlotte, and Collier Counties issued communications to media, hotels, Tourism Development Councils, Chambers of Commerce, health care agencies, and county websites either by press releases or email. Manatee County's Chief Lifeguard would conduct red tide education. Sarasota was the only county with formal guidelines and procedures for red tide events. Typically, red tide actions were triggered by public complaints (odor or dead fish) received by the city. Cities directly responsible for beach cleaning would investigate the complaint and begin their cleaning process following local, state, and federal guidelines. Cities not responsible would notify their host county.

Social and mass media

Peer-reviewed publications

Skripnikov, A., Wagner, N., Shafer, J., Beck, M., Sherwood, E., & Burke, M. (In press). Using localized twitter activity for red tide impact assessment. *Harmful Algae*. http://arxiv.org/abs/2107.02677 (pre-print)

Purpose or Message: Evaluate the spatial and temporal accuracy of Twitter red tide activity.

Methods: Twitter keyword and sentiment analysis and spatio-temporal correlations

Audience/Geographic Scope: Florida Gulf coast counties (Pasco, Hillsborough, Pinellas, Manatee and Sarasota).

This study evaluated the use of Twitter, a social media microblogging service, as a complementary real-time data source for red tide conditions. The authors analyzed cleaned and geo-profiled tweets posted for one year between May 2018 and 2019. Tweets were analyzed using sentiment analysis and compared with red tide conditions for the georeferenced location. Correlations between Twitter activity, tweet sentiments and red tide conditions were strong at large spatial (regional and county-level) and temporal (weekly) scales but declined at finer scales (i.e., city and zip code level and daily). Geo-tagged tweets provided stronger correlations and a more reliable data source. Keyword analysis indicates that most red tide related tweets were negative. When categorized, these tweets predominately corresponded to environmental concerns followed by health and economic concerns.

Li, Z., Garrison, B., Ullmann, S. G., Kirkpatrick, B., Fleming, L. E., & Hoagland, P. (2015). Risk in daily newspaper coverage of red tide blooms in southwest Florida. *Applied Environmental Education & Communication*, 14(3), 167–177.[8] https://doi.org/10.1080/1533015X.2015.1067579

Purpose or Message: Evaluate how local newspapers are framing risk in news stories about red tide blooms in Southwest Florida.

Methods: Quantitative content analysis to evaluate print media in the context of human health risk, environmental risk, or economic risk.

Audience/Geographic Scope: Southwest Florida newspapers covering Naples, Sarasota, and Tampa areas.

This study evaluated the print media coverage of local newspapers and the Associated Press in Southwest Florida from 1987-2012 for stories related to red tide.

[8] Intermediate paper. Li, Z., Garrison, B., Ullman, S., Kirkpatrick, B., Hoagland, P. & Fleming, L. E. (2013, November). *Telling the red tide story: Framing and news media coverage in Florida*. 141st American Public Health Association Annual Meeting and Expo, Boston, MA. https://www.researchgate.net/publication/266788310_Telling_the_red_tide_story_Framing_and_news_media_coverage_in_Florida

811 items were coded for story content related to health effects, environmental risk, or economic impacts. The majority (80%) of stories focused on environmental risk associated with red tides, primarily fish kills. Nearly half of the stories addressed human health impacts associated with red tide with 90% of those addressing respiratory irritation. 30% of the stories focused on economic impacts such as tourism and recreation. Lastly, a considerable number of news stories also focused on red tide intervention topics, especially red tide research. Most stories had a neutral tone (56-62%) with 37-41% of stories classified as having a negative tone.

Morgan, K. L., Larkin, S. L., & Adams, C. M. (2011). Empirical analysis of media versus environmental impacts on park attendance. *Tourism Management*, 32(4), 852–859. https://doi.org/10.1016/j.tourman.2010.07.010

Purpose or Message: Understand the decision-making response of nature recreationists to environmental conditions and local media coverage.

Methods: Multivariate model with park attendance as the dependent variable and environmental conditions, seasonality, and media coverage as explanatory variables.

Audience/Geographic Scope: Park attendance at Lovers Key State Park, Lee County, Florida

This study evaluated the relationship between changes in daily attendance at Lovers Key State Park, a Southwest Florida coastal state park, with the occurrence of red tide events. While the purpose of this study was to evaluate economic impacts associated with these relationships, the study provides insights into how recreationists make their decisions. Multiple regression analysis was used to evaluate daily attendance as a function of environmental factors (including red tide cell counts), seasonality, and local newspaper coverage of red tides. The results indicate that red tide variables were not associated with fluctuations in park attendance. However, newspaper coverage of red tide events did have a significant negative impact on park attendance with a daily reduction in visitors when an article was published with the keyword “red tide”. This study highlights that recreationists are more responsive to news coverage about red tides than they are to actual red tide cell counts thereby necessitating the need for timely and accurate media coverage. The authors confirm that a tourism-media partnership should be developed to deliver information to the public and prevent negative economic impacts.

Kusek, K. M., Vargo, G., & Steidinger, K. (1999). *Gymnodinium breve* in the field, in the lab, and in the newspaper – A scientific and journalistic analysis of Florida red tides. *Contributions in Marine Science*, 34, 1–229.

Purpose or Message: Analyze Florida red tide from the public information perspective.

Audience/Geographic Scope: Articles published within the *St. Petersburg Times*

Method: Comprehensive analysis of Florida red tide newspaper coverage in the St. Petersburg Times from 1953 to 1997.

This paper evaluated public understanding of Florida red tides as well as the communication link between scientists and the public and the reliability of that newspaper coverage. Newspaper analysis was conducted for about 500 red tide articles written in the *St. Petersburg Times* between 1953 and 1997. The analysis identified a discernable set of trends in red tide coverage by decade. Of note, apart from the 1960's, newspaper coverage failed to report the end of a red tide. The 1970s experienced more criticism in red tide coverage than any other decade due to the sensationalist coverage and the use of blanket statements regarding red tide-affected areas; both of which were perceived to have substantial economic impacts to area businesses. News briefs became a common practice in red tide reporting; however, accuracy may have been sacrificed due to their lack of content.

This analysis noted that red tide was not part of an assigned beat and, due to the complexities associated with red tide, this can lead to inconsistent reporting. Descriptions of red tide generally improved with time. A consistent critique of red tide coverage throughout the decades was the use of dramatic, general, or scientifically inaccurate language. These inaccuracies were amplified by the use of lifted quotes (verbatim descriptions from previous news stories that were either originally inaccurate or were not updated to stay current with the changing science), misleading or alarmist headlines, and use of unofficial sources for information. It is noted that these criticisms may add tension to strained relationships between scientists and journalists.

The paper provides a list of recommendations that are relevant to the complex and daily news coverage associated with red tides. These include, but are not limited to providing proper context, providing maps specifying bloom location, ensuring accurate captions and headlines, using reliable and credible sources, reporting the end of a red tide bloom, and generally improving communication between scientists and journalists.

Reports

Economic impacts of water quality issues in the Gulf of Mexico (p.36). (2020) [Final Report to the Gulf of Mexico Alliance]. The Balmoral Group. https://dl.dropbox.com/s/qrew0bnjt3mk9al/Economic%20Impacts%20of%20Water%20Quality%20Issues%20in%20the%20Gulf%20of%20Mexico_FinalReport.pdf?dl=0

Purpose or Message: Present the findings of the project funded by the Gulf Star Grant of the Gulf of Mexico Alliance.

Audience/Geographic Scope: Gulf coast counties in Florida.

This report presents the results of a Gulf Star Grant project focused on quantifying the linkages between economic outcomes and Gulf of Mexico coastal health, specifically harmful algal blooms. The primary purpose of the project was to quantify the economic impacts of HABs and develop an online dashboard which allows users to assess the economic impacts across time, geography, and sector. However, a component of the project included an evaluation of social media and scientific data to isolate any economic results linked to these factors. Correlation analysis was conducted to test the relationships between FWC-FWRI cell count data, Google search trends, and economic data for the period of June – November, 2018. Results indicate that digital media data is highly correlated with economic impact changes, whereas there were no to very low correlations found between the actual cell count data and economic variables. In the authors' words "the actual HAB event has less bearing on economic impact than the perceived HAB event", implicating the role of social media as a risk amplifier during red tide events.

Technology and tools

Peer-reviewed publications

Hardison, D. R., Holland, W. C., Currier, R. D., Kirkpatrick, B., Stumpf, R., Fanara, T., Burris, D., Reich, A., Kirkpatrick, G. J., & Litaker, R. W. (2019). HABscope: A tool for use by citizen scientists to facilitate early warning of respiratory irritation caused by toxic blooms of *Karenia brevis*. *PLOS ONE*, *14*(6), e0218489. https://doi.org/10.1371/journal.pone.0218489

Purpose or Message: Provide a respiratory forecast on "Every Beach, Every Day" during *Karenia brevis* blooms.

Format: Web-based communication tool hosted by Gulf of Mexico Coastal Ocean Observing System (https://www.gcoos.org)

Audience/Geographic Scope: Potential beach goers throughout the Gulf of Mexico.

The article describes the citizen science "HABscope" system for estimating *Karenia brevis* cell counts. The integration of cell abundance data and high-resolution wind forecasts allows for the production of daily, beach-specific reports and forecasts. Respiratory risk assessments can be provided at 3-hour intervals for up to 24 hours after a sample has been taken and processed. HABscope enables the public to select a beach and time of day with the lowest risk of respiratory impacts where data has been collected.

Nierenberg, K., Reich, A., Currier, R., Kirkpatrick, B., Backer, L. C., Stumpf, R., Fleming, L., & Kirkpatrick, G. (2009). Beaches and HABs: Successful expansion of the Florida red tide reporting system for protection of public health through community education and outreach. *Florida Journal of Environmental Health, 203*, 18–24.

Purpose or Message: Real-time beach conditions for beaches along the Gulf Coast of Florida.

Format: Website (www.mote.org/beaches) presented as a Google Earth map interface and automated voice system (941-BEACHES) for non-internet capable audiences.

Audience/Geographic Scope: Residents and visitors of nine counties in southwest Florida and the Florida Panhandle

The authors described the implementation and expansion of the Beach Conditions Reporting System. This citizen outreach tool relies on volunteer sentinels who provide subjective current beach conditions reports for local beaches in nine Florida Gulf Coast counties. Information reported can include: 1) Dead Fish, 2) Respiratory Irritation, 3) Water Color, 4) Wind Direction, 5) Surf Condition, 6) Florida Beach Warning Flag flying, 7) Surf Height, 8) Surf Type, 9) Rip Currents, and/or 10) Red Drift Algae. The website provides links to Florida red tide sources of information and other external websites that address potential hazardous beach events. The Beach Conditions Reporting System allows for Gulf Coast beach goers to make informed decisions about beach recreation and health risks.

Kirkpatrick, B., Currier, R., Nierenberg, K., Reich, A., Backer, L. C., Stumpf, R., Fleming, L., & Kirkpatrick, G. (2008). Florida red tide and human health: A pilot beach conditions reporting system to minimize human exposure. *Science of The Total Environment*, 402(1), 1–8. https://doi.org/10.1016/j.scitotenv.2008.03.032

Purpose or Message: Development of a real-time beach conditions reporting system as an Integrated Ocean Observing System Health Pilot Study for harmful algal blooms.

Format: Website presented as a Google Earth map interface and automated voice system for non-internet capable audiences.

Audience/Geographic Scope: Sarasota and Manatee Counties, Florida

Method: Real-time volunteer-based data reporting system

The authors described the development of a beach conditions reporting system in Sarasota and Manatee Counties. This system depends on subjective reports from lifeguards at eight public beaches on: the level of respiratory irritation, the amount of dead fish on the beach, water color, wind direction, surf conditions, and beach warning flag status. Reports were collected on personal digital assistants and automatically transferred to a website (no longer active) or telephone message. Media releases and links on partner website were used to promote the pilot reporting system to the public. A voluntary satisfaction survey was used to evaluate the service with 94% of users stating the site was very helpful.

Conference and Symposium Proceedings

Kirkpatrick, B., Fleming, L. E., Henry, M. S., Clark, R. D., & Backer, L. C. (2004). The use of electronic media to educate and communicate with the public during a harmful algal bloom. In: Steidinger, K.A., J.H. Landsberg, C.R. Tomas, and G.A. Vargo (Eds.). *Harmful Algae 2002*. Florida Fish and Wildlife Conservation Commission, Florida Institute of Oceanography, and Intergovernmental Oceanographic Commission of UNESCO, St. Petersburg, Florida, USA. https://myfwc.com/research/redtide/research/scientific-products/x-international-conference/

Purpose or Message: Evaluate the public's reporting of local conditions to a red tide website.

Format: Mote Marine Laboratory website, www.mote.org

Audience/Geographic Scope: Mote Marine Laboratory website users

The purpose of this paper was to assess how the public uses the Mote Marine Laboratory website to report local conditions or ask questions about *Karenia brevis* red tide. Emails were analyzed during a 2001 red tide bloom. The majority of emails reported about fish kills and respiratory information (62 and 56%, respectively). About one-quarter of all emails requested more information. The authors conclude from their analysis that the public wants more information and educational materials about red tide blooms, especially tourists who may not be familiar with the event and conditions. The reports proved useful to Mote scientists who used the information to identify the location and intensity of respiratory irritation.

This paper also provides a list of websites and resources that provide red tide information. It was noted that Mote Marine Laboratory was the only organization that solicited feedback from the public. While these agencies and institutions are still purveyors of red tide information, only the Mote URL (http://www.mote.org/) remains active.

Reports

Kavanaugh K. E., Derner, K., and Davis, E. (2016) *Assessment of the Eastern Gulf of Mexico Harmful Algal Bloom Operational Forecast System (GOMX HAB-OFS): An analysis of forecast skill and utilization from May 1, 2008 to April 30, 2014.* NOAA Technical Report NOS CO-OPS 082, p. 80. https://repository.library.noaa.gov/view/noaa/14756

Purpose or Message: An evaluation of the NOAA Gulf of Mexico Harmful Algal Bloom Operational Forecast System.

Format: Twice-weekly bulletins

Audience/Geographic Scope: Subscriber list of researchers and public service officials for *K. brevis* blooms in the Gulf of Mexico.

The NOAA GOMX HAB-OFS issues semi-weekly bulletins to serve as decision support tools for a variety of state and federal agencies, health and resource managers, and scientists. The report presents the results of an evaluation of utilization and forecast quality for coastal Florida products produced from May 1, 2008 to April 30, 2014. Reports of product utilization are presented. Overall, 76.6% of all bulletins produced were utilized by an end-user and there was negligible difference in the usability of bulletins based on priority level (low, medium, or high). Product utilization increased after the launch of a HAB-OFS Facebook page in 2012 to disseminate conditions reports to the public.

Kleindinst, J. L., & Anderson, D. M. (n.d.). *Internet-based communication tools for dissemination of information on harmful algal blooms (HABs)*. https://www.researchgate.net/publication/237285680_INTERNET-BASED_COMMUNICATION_TOOLS_FOR_DISSEMINATION_OF_INFORMATION_ON_HARMFUL_ALGAL_BLOOMS_HABS

Purpose or Message: Evaluate the public's reporting of local conditions to a red tide website.

Format: Internet-based communication tools

Audience/Geographic Scope: State, National and International HAB community

This paper describes the different Internet-based communication tools available to the HAB community, including the benefits and challenges associated with the various tools. This paper is not specific to *Karenia brevis* but does include Florida red tide communication tools; these will be discussed. Websites should be designed with consideration of their key audience(s). HAB websites can serve as a comprehensive resource for multiple audiences, a technical website for specific exchange between scientists and managers, or project-based websites designed and used for project researchers and managers. The Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) Florida program was used as an example. Since publication of this paper, the ECOHAB – Florida website URL has changed as has the website purpose since the research program is now complete. Select websites with HAB-related information are provided. Many of these sites are relevant to or specifically focused on red tides in Florida. This list includes the Interstate Shellfish Sanitation Conference, Florida Fish and Wildlife Conservation Commission site (old URL), Mote Marine Laboratory (old URL), Solutions to Avoid Red Tide (START), and the now defunct (as of 2007) University of Miami Marine and Freshwater Biomedical Sciences Center. National and International sites of relevance include the U.S. National Office for Harmful Algal Blooms, Intergovernmental Oceanographic Commission and the International Society for the Study of Harmful Algae. Internet LISTSERVs were recommended as a rapid and useful communication tool for subscribers about a particular topic though none were specific to *Karenia brevis*.

Review articles

Peer-reviewed publications

Fleming, L. E., Kirkpatrick, B., Backer, L. C., Walsh, C. J., Nierenberg, K., Clark, J., Reich, A., Hollenbeck, J., Benson, J., Cheng, Y. S., Naar, J., Pierce, R., Bourdelais, A. J., Abraham, W. M., Kirkpatrick, G., Zaias, J., Wanner, A., Mendes, E., Shalat, S., … Baden, D. G. (2011). Review of Florida red tide and human health effects. *Harmful Algae*, 10(2), 224–233. https://doi.org/10.1016/j.hal.2010.08.006

Purpose or Message: A review of economic, health, social and cultural effects as well as education and outreach efforts for *Karenia brevis* red tide.

Audience/Geographic Scope: Florida

This paper presents a review of the literature from 2000-2010 on the known and potential exposures and health effects associated with *Karenia brevis* red tides on humans and animals. Though not the primary purpose of the review, the authors present recommendations for communication needs and present a list of existing outreach and education efforts. According to a 2008 review of neurotoxic shellfish poisoning (NSP) (Watkins et al.), the authors disclose that the incidence of NSP may be more prevalent than diagnoses data suggest and that visitors and certain subpopulations may not be receiving information regarding shellfish harvesting bans. The authors recommend preliminary public health messaging intended to minimize exposure to active red tides such that “asthmatics and others with underlying respiratory diseases should consider staying inland (at least 1-2 miles from the coast) or indoors with the windows shut and air conditioner on”, especially if blooms are close to the coast with a strong onshore wind. Public health messages could also promote the use of paper surgical masks to reduce particle inhalation, although there were unknowns associated with the efficacy of masks over time and in compromised subpopulations.

Numerous extant and now-defunct public information sources were provided. Of the programs that are still active, all weblinks or phone numbers were non-functioning. These include the Beach Conditions Reporting System, the Florida Poison Information Center aquatic toxins hotline, Florida Fish and Wildlife Commission red tide website, NOAA Gulf of Mexico HAB Bulletin, and the Centers for Disease Control and Prevention Harmful Algal Bloom-related Illness Surveillance System (updated to present-day One Health Harmful Algal Bloom System).

Backer, L. C. (2009). Impacts of Florida red tides on coastal communities. *Harmful Algae*, *8*(4), 618–622. https://doi.org/10.1016/j.hal.2008.11.008

Purpose or Message: A review of economic, health, social and cultural effects as well as education and outreach efforts for *Karenia brevis* red tide.

Audience/Geographic Scope: Florida

As it relates to red tide communication, this paper summarizes several Florida red tide outreach and education efforts at the national, state, and local level. Institutional coordination was improved through the formation of the Florida Harmful Algal Bloom Task Force in 1997 and the National HAB Committee. Nationally, the National Center for Environmental Health, the Center for Disease Control (CDC), and the National Institutes for Environmental Health Sciences were identified as agencies that historically have had a HAB focus and thereby support Florida's red tide education and outreach program. Agency-specific websites were identified for the FDOH, FWC, CDC, Mote Marine Laboratory, and the NOAA HAB Bulletin. However, embedded weblinks have changed or are no longer active. Locally, the community advocacy group solutions to avoid red tide (START) was identified as promoting education about Florida red tide. Presently, numerous local organizations exist and fulfill the education and advocacy role initiated by START. The article provides an overview of organizations involved in HAB outreach and education, however the specific information presented may no longer be current.

Heil, C. A., & Steidinger, K. A. (2009). Monitoring, management, and mitigation of *Karenia blooms* in the eastern Gulf of Mexico. *Harmful Algae*, 8(4), 611–617. https://doi.org/10.1016/j.hal.2008.11.006

Purpose or Message: A review of the current (2009) state of monitoring, management, and mitigation of *Karenia* in the Gulf of Mexico, with a focus on Florida.

Audience/Geographic Scope: Gulf of Mexico and Florida

This review focuses on monitoring, management, and mitigation efforts for *Karenia* in the Gulf of Mexico and Florida. This summary addresses the role of communication and education in those areas. Florida's red tide monitoring program has four major components, two of which involve indirect or direct communication efforts: 1) a functional HAB database comprised of historic and current monitoring information; and 2) dissemination methods to provide monitoring data to the public and other stakeholders in a timely and readily accessible manor.

In this review, the authors present the role of communication and education throughout Florida's monitoring, management, and mitigation program. Monitoring of *Karenia* blooms is done through data dissemination methods, including the creation of a HAB database that incorporates georeferenced cell concentration data. Monitoring is also accomplished via public reports through a toll-free fish kill hotline and an associated fish kill database.

Mitigation efforts are focused on precautionary strategies that may reduce the potential health or environmental risks associated with *Karenia* blooms. *Karenia* blooms can occur over a broad range of cell concentrations over which different impacts can occur. To facilitate interpretation of this information to the public, the

state of Florida issues weekly monitoring reports that are associated with potential impacts rather than absolute cell concentrations.

Management is limited to the regulation of the shellfish harvesting areas, removal of dead fish, and public education. Coordination between counties and cities could improve the process by which dead fish are removed thereby enhancing bloom management at local levels. This process could be incorporated into city and county response plans.

Public education could be improved to target specific at-risk populations. Due to the transient nature of *Karenia* blooms, providing the public with accurate and current monitoring data and information is difficult. Numerical models like the NOAA HAB Bulletin and University of South Florida red tide tool provide short-term forecasts of general bloom impacts and bloom trajectories that help address the timeliness challenge. Programs that include lifeguard beach conditions reporting can further mitigate localized impacts. The current method of disseminating information to the public includes emails and web postings. While effective for some, these mechanisms miss Florida's transient and non-English speaking populations. Targeting these specific audiences remains a challenge; there has been some success with beach signage and education dissemination through hotels and restaurants.

Many of the challenges associated with monitoring, management, and mitigation are still relevant more than ten years after this review. Coordination between counties and states has improved as have monitoring and management technologies. The dissemination of timely and accurate bloom information to specific audiences remains a hurdle to effective *Karenia* management.

Heil, D. C. (2009). *Karenia brevis* monitoring, management, and mitigation for Florida molluscan shellfish harvesting areas. *Harmful Algae*, *8*(4), 608–610. https://doi.org/10.1016/j.hal.2008.11.007

Purpose or Message: Describe Florida's *Karenia brevis* monitoring, management, and mitigation procedures for molluscan shellfish harvesting areas

Audience/Geographic Scope: State of Florida

This paper describes Florida's *Karenia brevis* molluscan shellfish control program. The goals of the program are to provide maximum utilization of the molluscan shellfish resource while reducing the public's risk of Neurotoxic Shellfish Poisoning. Public education and stakeholder involvement were identified as necessary components of the program to ensure public understanding and support.

Watkins, S. M. (2008). Neurotoxic shellfish poisoning. *Marine Drugs*, *6*(3), 430–455. https://doi.org/10.3390/md20080021

Purpose or Message: A review of known epidemiology of Neurotoxic Shellfish Poisoning and recommendations for improved prevention

Audience/Geographic Scope: State of Florida

This paper provides an epidemiological review of Neurotoxic Shellfish Poisoning (NSP) in Florida. Based on their report, the authors provide the following recommendations. NSP surveillance and reporting could be improved through timely alerts to healthcare workers and public health epidemiologists during an outbreak. This includes the development and dissemination of targeted education on the signs, symptoms, and diagnoses of NSP, particularly for high-risk areas. Outreach and education recommendations target recreational harvesters, especially non-English speaking visitors in high-risk areas. The authors suggest a need for improved dissemination of shellfish harvesting area openings and closings, in a user-friendly, readily available website.

Reports

Krimsky, L., Staugler, B., Flewelling, L., Reich, A., Rosen, B., Stumpf, R., & Whiting, D. (2019). *State of the Science for Harmful Algal Blooms in Florida:* Karenia brevis *and* Microcystis *spp.* (Produced from the Florida Harmful Algal Bloom State of the Science Symposium SGR-136; p. 36). University of Florida IFAS, Florida Sea Grant. http://www.flseagrant.org/publications/

Purpose or Message: A report presenting the outcomes of the 2019 Florida Harmful Algal Bloom State of the Science Symposium.

Audience/Geographic Scope: State of Florida

The report presents an overview of the 2019 State of the Science Symposium for *Karenia brevis* and *Microcystis* cyanobacteria blooms in Florida including a communications summary. The report identifies challenges associated with communicating about harmful algal blooms including general misconceptions about HABs, bloom terminology, complexity of HABs, and mixed messages. Recommendations for improvements to HAB communication were provided and include a better social science understanding of what the public wants and needs; determine appropriate communication formats and preferred sources of information; and developing outreach inclusive of values, cultures, and multilingual audiences. Objectives for HAB communication were identified as maintaining and disseminating timely, accurate, and targeted information; developing information in easily accessible forms; avoiding use of controversial terms; focusing on relatable impacts and solutions; and ensuring audiences understand and trust HAB messages and sources. Lastly, the report identifies opportunities for HAB communication which include increased awareness regarding the effects of anthropogenic activities on

HABs; disseminating easily understandable data and forecasting tools; expanded outreach of HAB toxins and risk factors; HAB toxin information for medical practitioners and veterinarians; and realistic messaging regarding bloom control.

The red tide control & mitigation program report to stakeholders (p. 28). (2010). Florida Fish and Wildlife Conservation Commission Fish and Wildlife Research Institute and Solutions to Avoid Red Tide.[9]
https://myfwc.com/media/13102/c_m_stakeholders_lrwcov.pdf

Purpose or Message: A report presenting an overview of the projects funded through the 2007 to 2009 Red Tide Control and Mitigation Program.

Audience/Geographic Scope: State of Florida

This report provides an overview of the twelve projects that were funded through the cooperatively managed FWC-FWRI and START Red Tide Control and Mitigation Program. Four of the twelve projects had a communication, outreach or education component to them and are briefly described here: 1) *Expansion of the Beach Conditions Reporting System to Collier County: Reducing the public health impacts from* Karenia brevis a*erosols* helps to minimize red tide exposure by allowing beach visitors to make informed decisions on which beaches to visit. 2) *Poison control, podcasts, and partnerships* developed and implemented up-to-date red tide training materials for health care professionals, coastal managers, and park workers. The project also included the expansion of the Aquatic Toxins Hotline. 3) *Production of a film documentary on Florida red tides for TV broadcasting* produced a high-quality documentary film on Florida red tide to give the public a better understanding of red tide and act as an educational platform for reducing the social and economic impacts of red tide. 4) *Red tide mitigation through strategic education and outreach* measured the public's knowledge and opinions about red tide control measures and determined the best way to share red tide information with the public to encourage public support of response actions and to meet long-term coastal management goals.

Abbott, G. M., Landsberg, J. H., Reich, A. R., Steidinger, K. A., Ketchen, S., & Blackmore, C. (2009). *Resource guide for public health response to harmful algal blooms in Florida* (Fish and Wildlife Research Institute Technical Report TR-14; p. viii +132).

Purpose or Message: A technical manual for the development of local and public health HAB response plans.

[9] Intermediate paper. Flewelling, L., Heil, C., & Kirkpatrick, B. (2013). One HAB, Many Angles: The Florida Story. In: Pagou, K. A. & Hallegraeff, G. M. (eds). *Proceedings of the 14th International Conference on Harmful Algae*, 251-253.
http://www.whoi.edu/fileserver.do?id=229546&pt=2&p=28787

Audience/Geographic Scope: State of Florida

The technical report was based on recommendations for the Florida Harmful Algal Bloom Task Force Public Health Technical Panel. It provides a thorough review of available resources for public health response to all HABs in Florida, including but not specific to *Karenia brevis* red tides. The introduction on brevetoxins and neurotoxic shellfish poisoning (NSP) recognizes the challenge in reaching foreign and out-of-state tourists regarding potential shellfish and aerosol-related public health risks.

The report provides charts presenting federal, state, and local governmental authority and responsibility for HAB response. Charts are provided for 1) aquatic animal mortality, 2) environmental sampling, 3) shellfish, and 4) human surveillance. The charts remain relevant and a useful tool for collaboration and coordination between entities even if the specific points of contacts may no longer be up to date. The interaction of these agencies is depicted in activity flowcharts (chapter 9) that recommend communication routes and processes during a HAB event.

A comprehensive review of public health surveillance networks and systems is provided and discusses improved coordination and disseminations of HAB-related issues within the public health and response community.

The technical report includes an overview of existing information, education, and communication resources for HABs in Florida. This section presents a list of available print, training, multimedia, and promotional materials available as online resources. The resources provided are still relevant although many of the weblinks are no longer active. Specific guidance is provided on how to respond to the press and public and includes recommendations for 1) preparation and initial response, 2) on-going events, and 3) developing press releases.

Education is recognized as a component of HAB mitigation, including the red tide control and mitigation program. Education is especially important for communicating and encouraging those behaviors that government entities, private sector businesses, and the general public can take to reduce the harmful effects of HABs.

Alcock, F. (2007). *An assessment of Florida red tide: Causes, consequences and management strategies* (Technical Report No. 1190; p. 40). Mote Marine Laboratory.

Purpose or Message: An assessment of and guidance for red tide research, management, and regulatory framework in Florida.

Audience/Geographic Scope: State of Florida

This technical report produced from the Marine Policy Institute at Mote Marine lab provides an assessment of red tide causes, impacts and management in Florida. It includes an assessment of human dimensions research and public outreach and

education as a function of red tide mitigation. The article recognizes the contributions of the *Human Dimensions Research Strategy for Harmful Algal Blooms*[1] report and reiterates the necessity of human dimensions research to effectively influence human behavior and more specifically, the recommended research areas of risk communication including “determinates of organizational trust, risk perceptions, social amplification of risk, media engagement and message development and design.” Numerous state and local efforts were listed as providing public education and outreach including the Red Tide Alliance and Sierra Club chapters although the relative effectiveness of these efforts had not been determined. The Florida Harmful Algal Bloom Task Force was lauded in enhancing communication and collaboration between agency regulators and researchers but the author encourages greater coordination with various stakeholder groups. Further improvements could be made through the implementation of an external review team which would provide oversight of red tide research and management efforts in Florida.

The author recommends that government agencies look to natural disaster and emergency response plans to improve interagency coordination for red tide response in Florida, a challenge because of the various vertical and horizontal layers of government across jurisdictions and sectors. Public education efforts could be improved through greater collaboration among stakeholder groups, notably the Chambers of Commerce and Tourist and Visitors Bureaus. Future efforts should be built upon human dimensions research and include evaluation metrics to assess effectiveness.