SECOORA
Southeast Coastal Ocean Observing Regional Association

Harmful Algal Bloom Plan

This document is an addendum to the Southeast Coastal Ocean Observing Regional Association (SECOORA) Regional Coastal Ocean Observing System Strategic Operational (RCOOS) plan, which establishes priorities for contributing to our improved understanding, management, and stewardship of valued coastal ocean resources. This document will serve as a guide for future investments in harmful algal bloom (HAB) observing and monitoring in the SECOORA region.

Version 1.0 - April 2022

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1. Overview

1.1 Document Description

This Harmful Algal Bloom Plan is an addendum to the Southeast Coastal Ocean Observing Regional Association (SECOORA) Regional Coastal Ocean Observing System Strategic Operational (RCOOS) plan, which establishes priorities for contributing to our improved understanding, management, and stewardship of valued coastal ocean resources. This document expands upon the Harmful Algal Bloom section of the RCOOS plan to provide sub-regional information for algal species negatively impacting the region and serves as a guide for future investments in regional harmful algal bloom (HAB) observing and monitoring. This plan will be reviewed and updated periodically, but no less than every two years, by the SECOORA Science Committee.

The SECOORA Harmful Algal Bloom Plan is intended to inform:

1. SECOORA staff and Board of Directors to establish priorities for funding decisions;
2. SECOORA members to articulate priorities and provide guideposts for future activities;
3. Regional stakeholders and potential members to demonstrate capabilities and describe connections to regional needs and priorities.

1.2 SECOORA Background

The SECOORA footprint spans the four-state region of North Carolina (NC), South Carolina (SC), Georgia (GA), and Florida (FL). Our ocean and coastal waters reach from the eastern side of the Gulf of Mexico to the South Atlantic Bight and are connected by the Loop Current-Florida Current-Gulf Stream continuum.

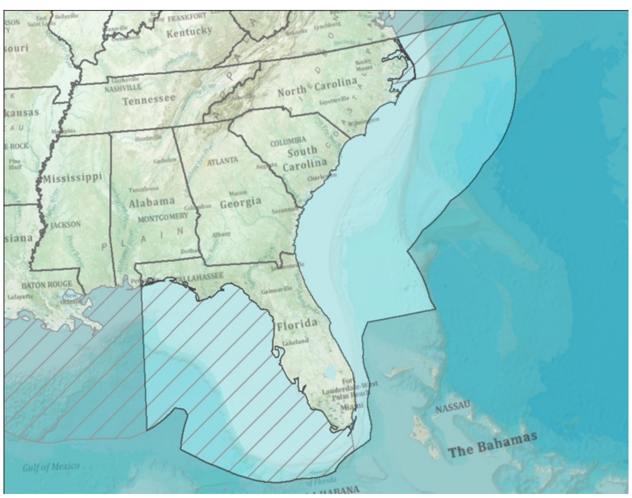

Figure 1 - Map of the SECOORA Region.

SECOORA is organized to provide ocean data, tools, and services in the following focus areas, which correspond with U.S. Integrated Ocean Observing System (IOOS®) societal goals and are important to southeast stakeholders: Ecosystems, including Water Quality and Living Marine Resources; Marine Operations; and, Coastal Hazards and Climate Variability. As outlined in SECOORA's RCOOS Plan, HABs have been identified as a novel area of investment for SECOORA's resources.

2. Harmful Algal Blooms (HABs)

2.1 Harmful Algal Bloom Background

Harmful Algal Blooms (HABs) occur when algae — photosynthetic eukaryotic organisms and macroalgae that live in marine and freshwater environments — experience increased growth while producing toxic or harmful effects to people, fish, shellfish, marine mammals, birds, and submerged habitats. HABs can be caused by a multitude of organisms including phytoplankton, macroalgae, and benthic microalgae (NOAA 2021). The HABs in fresh and marine waters are usually very different, but they overlap in low salinity estuaries (NOAA 2019b).

Overall, HABs can have harmful effects on the economics, environmental health, and human health of coastal communities. Exposure to HAB-related toxins can lead to a multitude of illnesses including respiratory illness, liver illness, neurological damage, and in severe exposure cases can lead to death (Paerl et al. 2016). HABs are continually becoming a more persistent and widespread issue throughout the Southeast. There are multiple challenges associated with monitoring HABs, as tracking HABs requires assets, multi-agency coordination, and investment in development and implementation of hands-on and autonomous data collection methods. The fundamental challenge with HABs is the pace and severity of outbreaks is not matched by science, monitoring, and support for communities to identify and implement solutions (Elko et al., in press). Overall, prevention, control, and mitigation of HABs is critical for management and requires multi-institutional efforts and coordinated investment in research to develop viable strategies and technologies as well as cooperation among agencies for implementation.

2.2 Harmful Algal Blooms in the Southeast

This plan will address coastal HABs as defined within the National Harmful Algal Bloom Observing Network (NHABON) Framework. The geographic extent of HABs addressed in SECOORA's plan will be constrained to coastal regions of NC, SC, GA, and FL. These coastal regions will include the area from the head of tide to the edge of the U.S. Exclusive Economic Zone. This plan does not include an exhaustive list of all HABs within the Southeast, rather it highlights the species of concern and areas to improve observing and monitoring. Each HAB is formed from a different algal species and presents unique challenges in terms of monitoring and evaluating environmental impacts.

2.2.1 Blue-Green Algae or Cyanobacteria (CyanoHABs)

Studies have shown that some harmful blue-green algae or cyanobacteria (CyanoHABs) can be salt-tolerant and able to live in estuarine environments. Eutrophication of fresh and brackish waters, largely due to nutrient run-off from anthropogenic sources (e.g. development, agriculture), has increased the number of CyanoHAB events in coastal areas of the Southeast U.S. (Paerl and Huisman 2009). Studies have found that freshwater HAB events are linked to coastal or estuarine HAB events, as

HABs are transported to the coast via water management actions (Heil and Muni Morgan, 2021; Oehrle et al., 2017; Metcalf et al., 2021; Tatters et al., 2021).

CyanoHABs can contain harmful toxins known as cyanotoxins, the most common in the US include microcystins, cylindrospermopsin, anatoxins and saxitoxins (EPA, 2021). Cyanotoxin exposure to humans can lead to gastrointestinal illness, respiratory illness, muscle weakness, dermatitis, and death. Saxitoxins are responsible elsewhere for paralytic shellfish poisoning, which occurs when shellfish consume toxic algae, concentrating the toxins and posing a threat for human consumption (EPA, 2021).

2.2.2 Florida Red Tide

One of the most well-known HABs in the Southeastern region is the Florida Red Tide caused by *Karenia brevis,* a species of dinoflagellate that produces potent neurotoxins. Red tide blooms have been documented to have deleterious impacts to marine ecosystems including mass fish die-offs and marine mammal deaths. Toxins can accumulate in shellfish and when eaten can cause Neurotoxic Shellfish Poisoning in humans (WHOI 2018). Additionally, toxins from *Karenia brevis* can become aerosolized and cause human respiratory illness. Red tide is currently the most prolific HAB in the state of Florida and has the farthest-reaching impacts affecting the most people and biota (Heil and Morgan, 2021; Heil and Steidinger, 2009; Steidinger, 2009).

2.2.3 *Sargassum* (macroalgae)

Sargassum, or brown macroalgae, has grown in the Atlantic Ocean for centuries supported by natural nutrient sources. Data has shown that increased nitrogen from anthropogenic sources is supporting excess growth of *Sargassum* leading to toxic blooms that have harmful impacts (Lapointe et al. 2021). Unlike other species of HABs, the algae itself is not toxic; however, once large blooms of *Sargassum* wash onshore, it can negatively impact critical coastal habitats and ecosystems as well as have economic and human health impacts. Decomposing *Sargassum* on beaches releases hydrogen sulfide gas. The inhalation of hydrogen sulfide gas can cause respiratory issues for humans (Miami-Dade County, 2021). In 2019, Miami-Dade County officials estimated it would cost $45 million to remove *Sargassum* from a 15-mile stretch of beach (FIU News, 2021). Beyond the economic cost of clean-up, *Sargassum* blooms can also result in a reduction in tourism and recreation at impacted beaches. Within ecosystems, *Sargassum* can also have deleterious effects; blooms can impact seagrasses, coral reefs, and many other marine animals including sea turtles (Lapointe et al. 2021).

Figure 2 - Image of Sargassum in Palm Beach County, Florida. Image Credit: Brian Lapointe, FAU

2.2.4 Texas Brown Tide in Florida

Figure 3 - Image of Texas Brown Tide in the Indian River Lagoon, Florida. Image Credit: Florian Koch, NOAA NCCOS

Brown tide, *Aureoumbra lagunensis,* has been observed in the Indian River Lagoon (IRL). There are multiple sources and factors of anthropogenic nutrients that influence brown tide growth in the IRL. Large amounts of anthropogenic nutrients discharging from Lake Okeechobee and the St. Lucie Basin have contributed to outbreaks (Florida Audubon Society, 2013). Additional factors contributing to brown ride growth include nutrient input from septic systems, nutrient laden-stormwater runoff, an organic muck layer, and limited water flow within the IRL (St. Johns River Management District, 2022 and Marine Resources Council, 2018). Similar to Sargassum, the algae itself is non-toxic but can cause damage to ecosystems, fisheries resources, and recreational facilities, often due to the sheer biomass of the accumulated algae, which blocks sunlight from reaching submerged vegetation. When this biomass decays as the bloom terminates, oxygen is consumed, leading to widespread mortalities of plants and animals in the affected area due to low levels of dissolved oxygen (Anderson 2009; Gobler et al. 2013; Hall et al. 2018).

3. HABs in the SECOORA Region by State

The following describes HAB related activities in the SECOORA region by state and identifies some of the common coastal HAB species. This includes the associated environmental and human health concerns that can result from HABs, HAB monitoring and sampling within the state, and state-specific HAB hotspots. These regional hotspots include areas where 1) HABs are an emerging concern and 2) HABs are causing significant harm. This is not an exhaustive list of HABs, rather an identification of high-priority species and regions to focus on for potential future investment in monitoring and observing. SECOORA recognizes that states

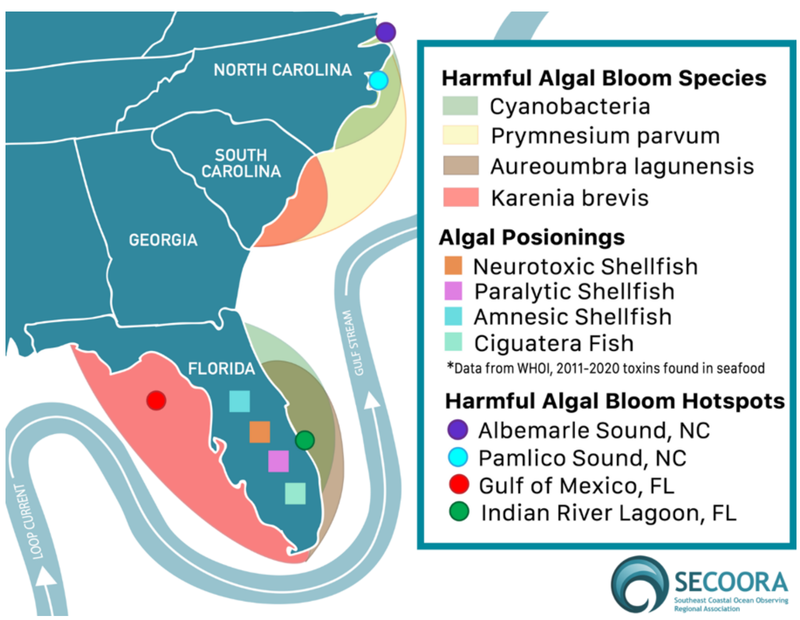

Figure 4 - Map of HABs, algal poisonings, and HAB hotspots in the SECOORA region.

within the region have limited information surrounding coastal HABs. SECOORA would like to highlight the need to fill in HAB monitoring and sampling gaps within these geographic areas.

3.1 North Carolina

3.1.1 Species of HABs in North Carolina

- CyanoHABs: *Dolichospermum, Microcystis,* and *Cylindrospermopsis*, Anatoxins and Saxitoxins (EPA, 2021).
  - Blooms can result in hypoxic conditions leading to fish and submerged aquatic vegetation die-offs.
  - Ingesting or recreating in contaminated water can kill pets, livestock, and other animals.
  - Exposure to humans can lead to gastrointestinal illness, respiratory illness, muscle weakness, dermatitis, and more.
- *Pfiesteria* sp.
  - Blooms can result in wildlife deaths (i.e., fish kills)
- *Prymnesium parvum* (Golden Algae)
  - Blooms can result in wildlife deaths (i.e., fish kills)
- *Pseudo-nitzschia* spp.
  - Presence can cause Amnesic Shelling poisoning
- *Karenia brevis* (Red Tide)
  - Presence can cause Neurotoxic Shellfish poisoning. A major event occurred in 1987, when a large bloom was transported from the west Florida shelf, around the FL Keys and up the coast in the Gulf Stream, which impinged on the coast (Tester et al., 1988).
  - Blooms can result in wildlife deaths (i.e., fish kills)
- *Karlodinium veneficum*
  - Bloom can result in wildlife deaths (i.e., fish kills)
- Raphidophytes
  - Several genera including Heterosigma, Chattonella, and Fibrocapsa
  - Mode of toxicity is still debated but are linked to fish kills and harm to shellfish

3.1.2 HAB Hotspots in North Carolina

CyanoHAB blooms are a continual issue for the North Carolina sounds. Albemarle Sound has persistent CyanoHAB blooms which kill fish and present a threat to recreation. The Albemarle-Pamlico estuarine complex provides half the nursery ground area used by fish from Maine to Florida and is extremely important for fish populations along the Atlantic seaboard (Burkholder et al. 2001; Mallin et al. 2002). Over the past decade visible CyanoHAB blooms have been reported across varying freshwater systems, most prominently since 2013 in the Chowan River which empties into western Albemarle Sound. In 2019, record microcystin levels (>400 micrograms per Liter) were repeatedly detected during these events; Schnetzer in prep). Reports of waters of the Pamlico River and the Chowan River turning green due to a large CyanoHAB bloom has been a recurrent phenomenon.

Figure 5 – Image of a CyanoHAB bloom an HAB of concern in NC. Image credit: NOAA

In addition to CyanoHAB blooms, North Carolina has also had dinoflagellate blooms. Historically, North Carolina waters have had over 40 *Pfiesteria* blooms resulting in the death of over a billion fish (Burkholder et al. 2001).

3.1.3 Monitoring and Sampling in North Carolina

- NC Department of Environmental Quality (DEQ) has a Fish Kill & Algal Bloom Report Dashboard.
- The University of North Carolina at Chapel Hill Institute of Marine Sciences (UNC IMS) conducts HAB research and monitoring, including examining the respiratory threats of specific HAB species.
  - UNC IMS is leading the effort and has two long-term water quality monitoring programs: ModMon and FerryMon.
    - The Neuse River Estuary Modeling and Monitoring Project (ModMon) is a collaborative effort between the UNC IMS and the NC DEQ to monitor conditions in the southern Pamlico Sound.
    - ModMon data are available on the SECOORA portal.
    - FerryMon uses NC Department of Transportation ferries to collect water quality data in rivers and the Pamlico Sound.
  - In 2020, researchers conducted a Quantitative Evaluation of Changing Nutrient Sources to the Albemarle Sound System.
  - In 2021, a project was initiated on Determining Nutrient Controls on Phytoplankton Production and the Proliferation of Harmful Algal Blooms in Albemarle Sound. This study is using experimental nutrient additions to determine the limiting nutrient for HAB growth in Albemarle Sound and is making direct measurements of nitrogen inputs via biological N_2 fixation

- The NC State University Plankton Ecology Lab, has conducted toxin monitoring studies in several water bodies in coastal NC.
    - In situ HAB tracking is ongoing in the Chowan River, the Tar River, Lake Mattamuskeet and Bogue Sound (Wiltise et al. 2018, Schnetzer et al. in prep.). Overall studies indicate the presence of multiple toxins (mainly microcystin, cylindrospermopsin, and anatoxin) at low levels year-round in each of these water bodies. This raises concerns about potential chronic long-term exposures and human health risks.
    - A study conducted in collaboration with the NC Division of Marine Fisheries found both microcystin and cylindrospermopsin accumulation in several commonly-caught fishes and blue crab. These algal species were found in varying parts of the animals (gut, viscera and muscle).
    - The NC State's Center for Marine Sciences and Technology team is monitoring the accumulation of microcystin and domoic acid in several marine sounds in the wider Albemarle-Pamlico Sound region. Preliminary results indicate that there is a substantial amount of microcystin transported to these coastal sounds from upstream freshwater sources and both toxins are present in oysters within the Sounds.
- The partnership of the Albemarle Resource Conservation and Development Council (ARC&D), Albemarle Commission, Chowan-Edenton Environmental Group (CEEG), Green $aves Green Little River Keepers, Soil and Water Conservation Districts (SWCD), state agencies, local governments, and universities are monitoring water quality in rivers and creeks in the region to determine and address the sources of nutrients.
- The Albemarle-Pamlico National Estuary Partnership (APNEP) has a comprehensive conservation and management plan that outlines goals and objectives for an ecosystem based approach to protect and restore the Albemarle-Pamlico estuary. This plan includes the required monitoring and assessment measures needed to maintain healthy coastal ecosystems and protect human health.
- NOAA's National Centers for Coastal Ocean Science (NCCOS) has developed a HAB monitoring system for both the Pamlico and Albemarle Sounds using satellite imagery to locate, monitor, and quantify HABs in these regions.
- Currently, NOAA's Plankton Monitoring Network (PMN) includes sampling sites in the state of North Carolina.

3.1.3. Educational Resources in North Carolina

- The NC DEQ Division of Water Resources (DWR) has created a HAB Identification Guide.
- The NC Department of Health and Human Services has a guide on the dangers of recreating in waters contaminated with HABs.
- The NC Sea Grant has a two-pager with information about HABs in North Carolina. This information flier was produced in collaboratively by NC Sea Grant, NC DEQ and several of the research labs mentioned above.

3.2 South Carolina

3.2.1 Species of HABs in South Carolina

- Emerging HAB Species of Concern
  - *Microcystis sp.*
    - James Island- stormwater pond but may have saltwater influence
  - *Dolichospermum*
    - Goose Creek Reservoir- fresh water reservoir created by damming Goose Creek, a tidal tributary of the Cooper River.
  - *Aphanizomenon sp.*
    - Identified in outlet that drains into intracoastal waterway
    - Goose Creek Reservoir
- *Prymnesium parvum* (Golden Algae)
  - Bloom can result in wildlife deaths (i.e., fish kills)
- *Kryptoperidinium sp.* (Carolina Red Tide)

3.2.2 Coastal HABs in South Carolina

Records of coastal HABs in South Carolina are fairly limited. A Kryptoperidinium bloom was first discovered in Bulls Bay, South Carolina in 1998 (Wolny et al. 2008). In 1999, *Kryptoperidinium* was identified in estuaries from Georgetown to Hilton Head (Wolny et al. 2008). Monitoring conducted in 2001 found *Kryptoperidinium* (formally Scrippsiella carolinium) present in additional estuaries along South Carolina's coast as early as February during the year.

Figure 6 - Image of a fish kill event as a result of Prymnesium parvum or Golden Algae, an emerging HAB of concern in SC. Image Credit: Mike Hooper, USGS

HABs have been documented near Kiawah Island due to tidal exchange with stormwater ponds. Similar areas of concern exist near the Waccamaw River, which is tidal, extending as far as 40 miles upstream from Winyah Bay. Here, tidal flows can transport estuarine algal species far upstream especially when river discharge is low and storm surge and tidal forcing are high. These drivers are all intensified by climate change.

3.2.3 Monitoring and Sampling in South Carolina

- University of South Carolina's Arnold School of Public Health includes a National Institute of Environmental Health Sciences-funded Center of Excellence for Oceans and Human Health and Climate Change Interactions ($OHHC^2I$). Specifically, $OHHC^2I$ research is focused on development of tools to detect and assess the health risks associated with bacterial and HABs microorganisms.
  - The Arnold School of Public Health has established the Harmful Algal Bloom (HAB) Project as one of four major research projects and a community engagement core.

    - Research has focused on the effects of stoichiometry of nutrients and effects on toxin production of Microcystin, Cylindrospermopsin, and Dolichospermum.
    - The Toxicology Project at OHHC^{2}I has assessed the effects of HAB toxins in mammals and resulting effects on human health.
- SC Department of Natural Resources (SC DNR) collects a broad range of water, sediment and biological resource samples from 30 randomly selected tidal creek and open water sites as part of the South Carolina Estuarine and Coastal Assessment Program (SCECAP) once each summer. The samples provide nutrient and chlorophyll-a levels as indicators for HAB potential.
- SCDHEC also collects monthly sampling for chlorophyll-a and microcystin annually from May through October at 44 permanent estuarine ambient surface water quality monitoring sites.
- SCDHEC recently formed the South Carolina HAB Network (SC HABNet), a multi-institutional collaboration to monitor and study HABs in South Carolina.
- Currently, NOAA's Plankton Monitoring Network (PMN) includes sampling sites throughout the US including the state of South Carolina.
- Coastal Carolina University's Environmental Quality Lab and Waccamaw Watershed Academy conducts HAB monitoring and sampling, and participates in the SCDHEC HABNet working group.
- SCDHEC hosts an Algal Bloom Monitoring mapping site, which provides HAB monitoring, HAB watch, and HAB Advisory notices to the public.
    - There are no sampling sites in the stretch of coastal waters from Hog Inlet to Murrells Inlet, only estuarine sites.
- The Long Bay Hypoxia Monitoring Consortium initiated a plankton monitoring program at ocean piers in the Grand Strand in 2011.

3.2.4 Educational Resources in South Carolina

- SCDHEC has a webpage of HAB Resources and Advisory Warnings and a Harmful Algal Bloom Monitoring App that shows statewide monitoring stations, as well as advisories and watches.
- SCDHEC has created an educational algal bloom identification rack card for public distribution.
- The SC HABNet is developing a data and information portal for access to and dissemination of data and information related to HABs and environmental and human health concerns.
- The OHHC^{2}I Community Engagement Core uses an Education → Alert → Inform → Involve strategy in working with communities affected by HABs (Water Watch and Lake Wateree Property Owners Association) and Climate Change, particularly minority communities (Low Country Alliance for Model Communities and Environmental Justice Strong) and the seafood community (e.g. Interstate Shellfish Sanitation Conference). Tools developed include Internet Content Analysis of Web Sites on HABs, Environmental Report Cards, and development of forecasts (How's My Beach).
- The OHHC^{2}I has completed a study entitled "Health Communication Blindspot: A Case Study of Harmful Algal Blooms in the Southeast (HABITS)". The purpose of this study was to determine the content and readability of online HAB content. Health communicators and water resource managers can use the principles from the study to better communicate HAB threats to communities and the general public.

3.3 Georgia

3.3.1 Species of HABs in Georgia

Figure 7 - Photo of baby oysters at the UGA Skidaway Institute of Oceanography, where there was a die-off event from a HAB exposure. Image Credit: UGA

- Emerging HAB species of concern
    - *Heterosigma akashiwo*
    - *Heterocapsa rotundata*
    - *Akashiwo sanguinea*
- *Pseudo-nitzschia* spp.
    - Presence can cause Amnesic Shelling poisoning.

3.3.2 HABS in Georgia's Coastal Waters

HABs within the coastal and intercoastal regions of Georgia (GA) are largely undocumented; although, this does not suggest that HABs have not occurred, or will not occur in the future (GADPH, 2015). Increases in nutrient runoff are hypothesized to be increasing the number of HAB dinoflagellates in coastal Georgia waters (Verity, 2010).

Few instances of coastal HABs have been reported in the state of Georgia. Historical reports include HABs observed in the coastal estuaries of Sapelo Island in 1956 and 1972 where *Kryptoperidinium* blooms were documented (Young, 2020 and Pomeroy et al. 1956, 1972). More recently in 2017, an Akashiwo bloom occurred in the Skidaway River resulting in an oyster fishery die-off event (Pfeiler, 2020). The Georgia Department of Public Health has created a Coastal Georgia HAB Response Plan to address the potential threat of HABs in the region.

3.3.3 Current Monitoring in Georgia's Coastal Waters

- Currently, NOAA's Plankton Monitoring Network (PMN) includes sampling sites in the state of Georgia.

3.3.4 Educational Resources in Georgia

- The Georgia Department of Environmental Protection has created an educational HAB Story Map.
- The Georgia Department of Public Health has a HAB webpage, with general educational information.

3.4 Florida

3.4.1 Species of HABs in Florida

- CyanoHABs: *Dolichospermum, Microcystis,* and *Cylindrospermopsis*, Anatoxins and Saxitoxins (EPA, 2021).
    - Blooms can result in hypoxic conditions leading to fish and submerged aquatic vegetation die-offs.
    - Ingesting or recreating in contaminated water can kill pets, livestock, and other animals.
    - Exposure to humans can lead to gastrointestinal illness, respiratory illness, muscle weakness, dermatitis, and more.
    - In some instances, presence can cause Paralytic Shellfish poisoning.
- *Karenia brevis* (Florida Red Tide)
    - Blooms can result in wildlife deaths (i.e., fish kills)
    - Presence can cause Neurotoxic Shellfish poisoning
    - Oyster and scallop harvesting closures in the Apalachicola area due to domoic acid.
- *Aureoumbra lagunensis* (Texas Brown Tide)
- *Pseudo-nitzschia* spp.
    - Presence can cause Amnesic Shelling poisoning
- *Gambierdiscus toxicus*
    - Presence can cause Ciguatera Fish Poisoning
- *Pyrodinium bahamense*
    - Presence can cause Paralytic shellfish poisoning
- Macroalgae
    - *Sargassum* spp.

3.4.2 Coastal HAB Hotspots in Florida

Florida Red Tide – Gulf of Mexico (GOM)

When aerosolized, brevetoxins produced by *Karenia brevis,* also referred to as Florida Red Tide, have the potential to cause respiratory illness in humans, and when found in shellfish can lead to Neurotoxic Shellfish Poisoning in humans (WHOI 2018). Red tide has become a nearly annual event in the Gulf of Mexico (GOM). Red tide has resulted in widespread reports of fish, sea turtle, marine mammal, and other wildlife mortalities (HAB Task Force, 2022). Within the GOM, red tide is most common between Clearwater and Sanibel Island, Florida (FWC 2021). Red tide blooms generally last 3-5 months, affecting hundreds of miles of beach; however, there have been multiple red tide events that have persisted anywhere from 16-30 months (FWC 2021).

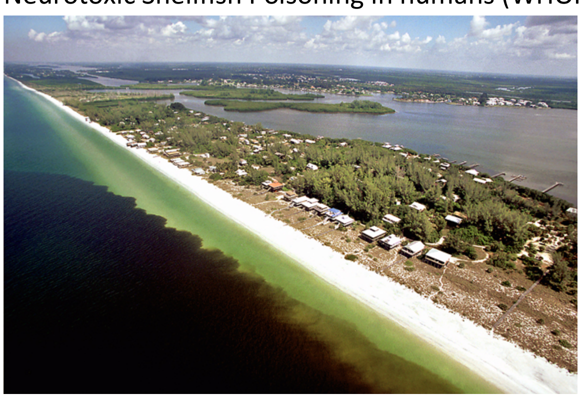

Figure 8 - Image of Florida Red Tide along the coastline. Image Credit: NOAA

As red tide is persistent in the GOM, many resources have been allocated to help mitigate the problem. In 2019, the Florida Red Tide Mitigation & Technology Development Initiative was formed between Mote Marine Lab and Florida Fish Wildlife Conservation Commission (FWC). Signed in 2019 by Governor Desantis, the law provided an annual $3 million allocation for six years to support the Florida Red Tide Mitigation & Technology Development Initiative. In January of 2020, the Harmful Algal Bloom Task Force created Initial Recommendations Regarding Red Tide (Karenia brevis) Blooms. More recently, the HAB Task Force released Progress and Recommendations Regarding Red Tide, which includes a series of recommended monitoring actions.

Currently, there is extensive coastal red tide monitoring in the GOM (e.g., satellite remote sensing, glider deployments) but limited offshore water quality sampling. The Florida HAB Task Force (HAB Task Force, 2020, 2022) identified the need for updates to existing monitoring activities, as well as identification of technologies that can be scaled to incorporate automated monitoring, emphasizing the importance of early warning.

HABs in the Indian River Lagoon (IRL)

From 2009 to 2011 HABs have devastated the Indian River Lagoon's (IRL) seagrass population killing over 47,000 acres of seagrass (Waymer, 2020). A shift in the IRL began in 2011 as a major CyanoHAB outbreak was observed. This was followed in 2012, by a major *Aureoumbra lagunensis* or brown tide event. Since 2012, brown tide has occurred almost every year within the IRL. In 2016, the HABs in the IRL resulted in the death of thousands of fish. The continued issue of excess nutrient pollution in the waterways of the IRL have contributed to an ecological disaster. Most recently, in 2021, the effects of a HAB-induced seagrass die-off has led to the deaths of hundreds of manatees. In total over the last year, indirect impacts of the loss of seagrass in the IRL has contributed to the starvation and ultimate death of over 1,000 of Florida's manatees. In the past, cases of *Pyrodinium bahamense* have also been reported in the IRL. Consumers of recreationally caught puffer fish in the IRL alerted the State of Florida to the problem of toxic *Pyrodinium bahamense* (Badylak et al. 2004). *Pyrodinium bahamense*, a bioluminescent bloom-forming dinoflagellate, produces a variety of saxitoxin. Since that time, the State of Florida has had to institute routine monitoring for PSP toxins in clams in the IRL, Tampa Bay, and other Florida bays to protect public health.

Figure 9 - Image of a CyanoHAB bloom in the IRL from 2020. Image Credit: Malcolm Denemark - Florida Today

As a form of HAB source control, in 2021 the State of Florida committed $53 million to restore water quality in the IRL. This funding will be used to remediate nutrient pollution by upgrading wastewater treatment and converting septic systems to sewer systems. The University of Florida and Florida Atlantic University - Harbor Branch Oceanographic Institute are supporting long-term HAB monitoring with the IRL. The IRL National Estuary Program (NEP) is developing a comprehensive HAB monitoring plan, the One Lagoon Monitoring Plan. The IRL NEP will use Geocollaborate, a communication platform, to create a geospatial platform to integrate IRL HAB data. This project will help support HAB monitoring, tracking, data sharing, and emergency response. IRL NEP is also working with St. Johns River Water Management District and Florida Fish and Wildlife Conservation Commission (FL FWC) to evaluate analytical techniques and develop new tools to enhance HAB detection (FWC 2021).

3.4.3 HAB Monitoring and Sampling in Florida's Coastal Waters

- NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML) is using subsurface automated dual samplers (SAS) to capture water quality data to evaluate the nutrients entering Biscayne Bay, which contribute to regional HABs.
- USF College of Marine Science is using NASA satellite imagery to track *Sargassum* and post weekly bulletins on the *Sargassum* forecast.
- NOAA National Centers for Coastal Ocean Science provides a GOM HAB Forecast.
- The FL DEP has created an Algal Bloom Dashboard that lists HAB observations within the last 30-days statewide.
- FL FWC established the Harmful Algal Bloom Task Force in 1999 and it was reactivated in 2019, with the top priority being red tide.
- The Florida Red Tide Mitigation & Technology Development Initiative is a partnership between Mote Marine Laboratory (MML) and FL FWC to develop prevention, control, and mitigation technologies for Florida red tide.
- NOAA's National Center for Environmental Information has created the Harmful Algal BloomS Observing System (HABSOS), which maps state-wide HAB sampling.
- The Gulf of Mexico Ocean Observing System (GCOOS) developed a Red Tide Respiratory Forecast that is based on the location of *Karenia brevis* and wind forecasts (speed, direction) to determine locations impacted by airborne red tide toxins.
- Mote Marine Lab has designed a user-friendly app that provides beach condition reports including locations where dead fish are present, locations of respiratory irritation among beachgoers, water color, wind direction, and what flags are currently flying at lifeguard-monitored beaches.
- FL FWC provides the current status of *Karenia brevis* blooms using tables, static maps, and interactive Google Earth maps. The statewide *Karenia brevis* map breaks down coastal areas by highlighting when HAB concentrations are not present, very low, low, medium, and high.
- FWC/FWRI-MML Cooperative Red Tide Program conducts periodic offshore transects to assess offshore blooms of *Karenia brevis* that can initiate and feed the coastal blooms.
- FL FWC collects and analyzes semi-weekly, shore-based water samples to determine the presence and concentration of harmful algal cells, which is used to inform *Karenia brevis* forecasts. These semi-weekly updates are posted on FWC's website.
- USF, with funding from SECOORA and in coordination with FL FWC, provides seasonal *Karenia brevis* outlooks and short-term (4.5 day) trajectory forecasts for the West Florida Shelf and Tampa Bay.

NOAA's Plankton Monitoring Network (PMN) includes sampling sites in the state of Florida.

- MERHAB and the GCOOS are funding HABSCOPE which provides data on *Karenia brevis* abundance, and informs models which provide *Karenia brevis* forecasts at the beach level.
- MML, with funding from NOAA Ecology and Oceanography of HABs (ECOHAB) is working to determine factors that end *Karenia brevis* blooms.

3.4.4 Educational Resources in Florida

- SECOORA's Florida Red Tide Resources page provides information on *Karenia brevis* monitoring, modeling, and forecasting.
- NOAA NCCOS has a website with a multitude of Gulf of Mexico: HAB Forecasting Resources.
- FL DEP has created a HABs FAQs educational document for public distribution.
- FL FWC provides red tide status updates and maps.
- A red tide communications strategy is being developed by University of Florida and Florida Sea Grant. This strategy highlights the value of signs on beaches as a primary source of information for the public.
- The FL Department of Health has a webpage about the hazards of HABs.
- Mote Marine Lab maintains the Florida Red Tide FAQs Page.

4. SECOORA Investments in HABs Observing and Monitoring

4.1 Current SECOORA HAB Observing and Monitoring

SECOORA is currently working with partners at the Florida Fish and Wildlife Research Institute (FWRI), NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML), the USF Coastal Ocean Monitoring and Prediction System, and Mote Marine Lab to monitor and model *Karenia brevis* on the West Florida Shelf. Partners are working together to enhance in situ offshore monitoring of HABs using buoys, gliders, and ship-based field surveys targeting key bloom dynamics and they also use satellite remote sensing to observe surface optical properties.

USF leads the physical and ecological modeling efforts to evaluate bloom dynamics and issue red tide forecasts. USF produces 4.5-day (1-day hind cast, 3.5-day forecast) trajectory forecasts for the West Florida Shelf with the West Florida Coastal Ocean Model (WFCOM) and for Tampa Bay with Tampa Bay Circulation Model (TBCOM). These trajectory forecasts are used in FL FWC HAB products are available on the SECOORA Florida red tide resources page.

4.2 SECOORA HAB Investments

The SECOORA Regional Coastal Ocean Observing System (RCOOS) Strategic Operational Plan 2020 – 2025 presents the SECOORA priorities for contributing to our improved understanding, management, and stewardship of valuable coastal ocean resources. The RCOOS plan identifies focus areas that guide our work. SECOORA will invest in data collection, product development, and applied research to better understand the environmental and societal concerns identified within each of the focus areas. HABs are listed as a sub-topic within the "Ecosystems: Living Marine Resources and Water Quality" focus area (pages 20-22). For each sub-topic listed within the focus area, the following information is provided:

- **Challenges**: defines key management challenges in the region
- **Priority Geographic Area(s)**: identifies the most critical geographic areas
- **Partner Activities**: examples of related efforts by state, federal, and NGO partners
- **Core Variables Required**: core variables as defined by IOOS with other data identified as needed
- **Current SECOORA Investments**: funded RCOOS components
- **Additional SECOORA Investment Opportunities**: needs defined by stakeholder engagement, subject matter expert discussion, and previous observing platform gap analyses

IOOS is partnering with NOAA NCCOS to support sustained HAB observing activities by the regional associations. Congress has supported this IOOS initiative, although the total funding via IOOS for all 11 regions is currently limited to $2M - $5M annually. SECOORA anticipates receiving a small annual allocation, initially in the $150,000 range, for investment in HAB monitoring and observing in the Southeast. The HABS section of the RCOOS plan identifies investment opportunities in observing assets, data management and communications, products, emerging technologies, and education and outreach resources; however, the RCOOS plan does not specifically identify where SECOORA can have the greatest return on investment with limited funding available for HAB research and monitoring. Section 4.2.1 identifies near term priorities to advance SECOORA efforts in the region. These efforts build upon many existing SECOORA resources and advance new technologies. With the available funding, SECOORA will target low-cost and leveraging options that enhance observing assets or predicative tools so that communities/states can better monitor HABs. Additionally, due to the limited initial funding, SECOORA will prioritize data management needs associated with expanded HAB monitoring rather than investing in educational resources.

This document will be reviewed every two years. During these reviews, the areas of future investment can be modified based on completed activities, changes in funding levels, availability of new technology or shifts in HAB patterns geographically.

4.2.1 SECOORA - Areas of Future Investment

The SECOORA RCOOS Plan highlights potential areas for investment based on the input from regional stakeholders. The SECOORA Science Committee reviews the RCOOS Plan annually, and updates can be made based on new information. This plan is a living document, that should be used as a guiding tool. The following are the current regional priorities as identified in RCOOS Plan.

Observing Assets

- Add additional biogeochemical and biological sensors to existing SECOORA moorings.
- Increase the number of onshore or nearshore coastal stations that collect meteorological and physical oceanographic core variables.
- Use drones to capture images/video footage at regular intervals for detection and tracking of HABs.
- Increase the number of standard and event driven SECOORA glider missions annually in the SAB and GOM.
- Work with partners to deploy autonomous surface vehicles (ASVs) or profiling gliders to collect physical oceanographic and biogeochemical measurements for HABs.

Data Management and Communications

- Support the analysis of satellite data for HABs detection and tracking.
- Coordinate data and communications with our neighboring regional associations.

Products

- Expand water quality and HAB data products regionally to meet stakeholder needs (e.g. beachgoers, fishermen, aquaculture, and coastal tourism).

Emerging Technologies

- Support development and implementation of emerging technologies to detect HAB species and their toxins.
- Investigate the use of the following technologies in the Southeast: Imaging FlowCytobot (IFCB), Environmental Sample Processor (ESP), and SPATT Bags.

SECOORA’s priority will be to initiate, and then sustain, HAB observing/monitoring in regional hotspots identified in Section 3 of this HAB plan. SECOORA will host a competitive request for proposals to award the available SECOORA HAB funds (initially in the $100,000 range annually) to support investment within the Southeast that meets priority HAB observing needs as identified in this plan. Additionally, SECOORA will consider existing HAB monitoring activity and capacity within each state, as well as other relevant ongoing work. SECOORA will also work with our neighboring RAs to ensure we are collaboratively supporting HAB monitoring.

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