The Harmful Algal Blooms and Hypoxia Research and Control Amendments Act of 2011

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Figure 1: A harmful algal bloom outbreak hits Florida's Gulf Coast.
P. Schmidt, *Charlotte Sun*/NOAA

Executive Summary

Algal blooms are transient increases or accumulations of typically microscopic algae in freshwater and marine environments. Algal blooms are harmful if they are toxic, hypoxic, or both, which are also known as harmful algal blooms (HABs). Some species of HABs produce toxins which bioaccumulate in marine systems, resulting in the death of fish and other organisms and transferring those toxins to consumers, including humans. Hypoxia, a condition of depleted dissolved oxygen in aquatic systems, can also result from large algal blooms. Areas affected by hypoxia, also referred to as "dead zones," can experience extensive fish mortality at the point of exposure and can lead to the death of marine mammals, birds, and reptiles.

The ecological and public health impacts of HABs and hypoxia cost local economies throughout the United States millions of dollars in damages each year. The tourism, public health, restaurant, and fishing industries of an affected area can suffer greatly once an HAB outbreak occurs. The increasing frequency and severity of HAB outbreaks in both freshwater and marine environments require a comprehensive response from aquatic resource managers.

The Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2011 (S. 1701) addresses the need for a national strategy to prevent, control, and mitigate HABs. Because the causes and consequences of HABs vary across the United States, the bill establishes the importance of regional research and action plans. Conducting further scientific research is also an overarching goal of the bill.

This report outlines a program designed to implement the requirements of the legislation. The main goals of the program are to better understand HABs and hypoxia in order to prevent future outbreaks from occurring, to improve the forecasting of HABs, and to effectively intervene once an outbreak does occur through control and response measures. The program proposed here focuses on research, monitoring, and response to more effectively manage HAB outbreaks and to prevent further ecological, human health, and economic damages to the country. Additionally, a strong planning component of the program coordinates actions moved to enact the research, monitoring, and response.

This report details the goals, the organization, the budget, the timeline, and the performance management of the proposed program. The solutions proposed are not quick-fix remedies for this extensive, multi-faceted problem. However, the Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2011 and the recommended actions in this report provide strategies that could potentially decrease the frequency of outbreaks in the long-run, ameliorating the heavy ecological, public health, and economic impacts caused by HABs. Although HABs and hypoxia are complex environmental problems, the program designed here would be a positive step towards improving the health of freshwater and marine habitats, humans, and local economies.

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Acronyms and Abbreviations

ASP: Amnesic Shellfish Poisoning

CSCOR: Center for Sponsored Coastal Ocean Research

ECOHAB: Ecology and Oceanography of Harmful Algal Blooms

EPA: Environmental Protection Agency

HAB(s): Harmful Algal Bloom(s)

MERHAB: Monitoring and Event Response for Harmful Algal Blooms

NGOMEX: Northern Gulf of Mexico

NOAA: National Oceanic and Atmospheric Administration

NSP: Neurotoxic Shellfish Poisoning

PCMHAB: Prevention, Control, and Mitigation of Harmful Algal Blooms

PSP: Paralytic Shellfish Poisoning

USDA: United States Department of Agriculture

Introduction

Figure 2: The Caloosahatchee River in Florida experiences a harmful algal bloom outbreak.
Sanibel-Captiva Conservation Foundation

Introduction

Harmful algal blooms are proliferations of algae that produce toxins or otherwise alter aquatic environments and which cause harm to humans and aquatic organisms. Hypoxia, the low levels of dissolved oxygen that affect aquatic life, is frequently associated with large algal blooms. Both environmental problems are a consequence of nitrogen and phosphorous nutrient loads, and are aggravated by agricultural and urban run-off to both freshwater and marine water bodies (Larsson et al. 1985).

With increasingly frequent and severe harmful algal bloom outbreaks in both freshwater and marine environments throughout the United States, Congress introduced the Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2011. This bill develops a comprehensive national program to address HABs and hypoxia, assesses associated environmental, socioeconomic, and human health impacts both regionally and nationally, and facilitates the regional, state, tribal, and local development and implementation of event response strategies. This bill amends the original Harmful Algal Bloom and Hypoxia Research and Control Act of 1998 and the Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2004. The programs resulting from these earlier Acts produced the basic scientific and social framework for understanding the causes of HABs and the ecological, public health, and economic consequences of such outbreaks.

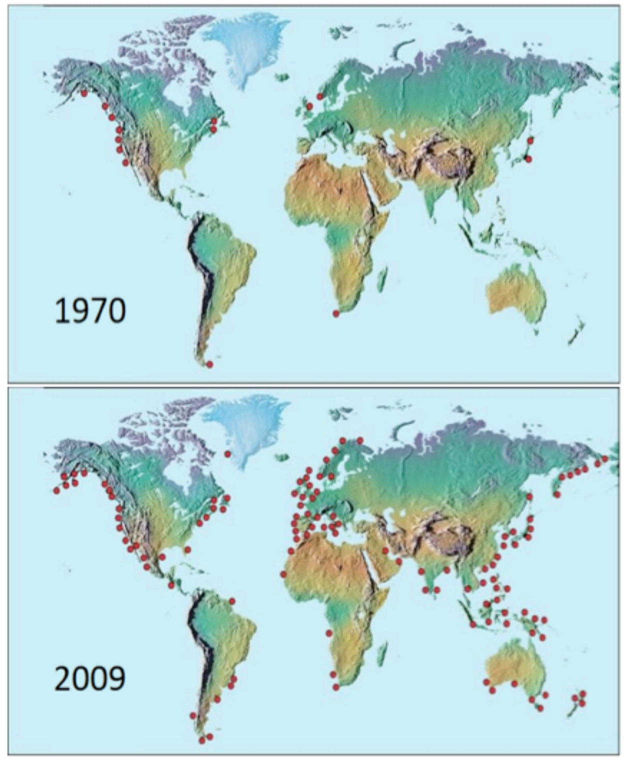


Figure 3: Algal bloom outbreaks reported in 1970 and in 2009 show the increasing instances of HABs worldwide. U.S. National Office for Harmful Algal Blooms, Woods Hole Oceanographic Institution

Research comprises the majority of the bill's financial investment. It reauthorizes financing for the Ecology of Harmful Algal Blooms Program (ECOHAB), which focuses on developing extensive, scientific research in order to better understand the causes and effects of harmful algal blooms (NOAA 2011). Specifically, ECOHAB aims to gain deeper comprehension of the transfer, biosynthesis, and metabolism of toxins and how they affect higher trophic levels (NOAA 2011). The development of new technologies and existing research programs will improve the understanding of the biology behind HABs in order to more effectively manage outbreaks.

The Monitoring and Event Response for Harmful Algal Blooms Program

(MERHAB) is another NOAA sponsored program created from these pieces of legislation. It uses technology to improve water and shellfish monitoring programs (NOAA 2011). MERHAB is increasing the number of regions that will benefit from NOAA's identification, detection, and prediction strategies. Federal agencies, as well as state, academic, tribal, and local programs form partnerships to manage MERHAB (NOAA 2011).

Previous legislation has also prompted NOAA to create the Prevention, Control, and Mitigation (PCMHAB) program to reduce the frequency of outbreaks and the damages resulting from them. Prevention efforts include regulating freshwater flow, modification of water circulation, restricting introductions, and nutrient management (Anderson 2001). Control techniques include chemical solutions that manage harmful algal blooms, ideally without damaging non-target organisms. These techniques must be evaluated to determine the environmental impacts of chemical agents used to remove HAB cells (Anderson 2001). Mitigation is used not only to restore affected areas but also to forecast and monitor zones at-risk for HABs before damage to human health and ecosystems occur (Anderson 2001).

The Science Behind HABs and Hypoxia

Algal blooms are transient increases or accumulations of algae or phytoplankton in freshwater and marine environments. Some algal blooms are harmless, while others can damage aquatic organisms chemically and physically (Glibert et al. 2005). Various species of algae are directly harmful because they have the ability to produce toxins (Backer and McGillicuddy 2006).

Red tides are a particular kind of harmful bloom, which occur when a type of red-pigmented dinoflagellate accumulates and tints the water red (Anderson et al. 2002). However, algal blooms can also be green, brown, or yellow, depending on the type of algae (Glibert et al. 2005).

Figure 4: The deep red algae, *Lingulodinium polyedrum*, causes water discoloration and can negatively impact aquatic organisms and potentially human health.
Kai Schumann, California Department of Public Health volunteer/NOAA

Hypoxia, a condition of low levels of oxygen in the water, is often a result of excess nutrients, namely nitrogen and phosphorous, entering an aquatic system. Although nutrient transfer into waters occurs naturally, these excess nutrients typically originate from areas of animal agriculture and urban development. As a result of these nutrient loads, algae rapidly reproduce in a process called eutrophication. Once the algae die, bacteria consume the dead algal biomass. As the bacteria decompose this biomass, they simultaneously respire, consuming the dissolved oxygen in the water. This process creates conditions of low levels of dissolved oxygen, leading to hypoxic water (Anderson et al. 2002).

Bioaccumulation is the process by which compounds accumulate or build up in an organism at a rate faster than they can be broken down (Bigelow 2012). Toxins are produced by some algae and move though the trophic system, leading to bioaccumulation in consumers at higher positions in the food web. Many marine invertebrates, including shellfish, and fish consume these toxic algae. The toxins they consume may or may not affect them directly, but toxins in their tissues will move up the food chain to top consumers, such as large fish, and marine mammals, such as whales. Toxins can be transported through the food web to humans, often through consumption of contaminated shellfish. The toxins can impact humans in different ways leading to mild symptoms or even death (Bigelow 2009).

Scientific research is ongoing and vital to the management of the problems associated with algal blooms. Several species of algae and their associated toxins remain unidentified (Anderson 2007). HABS have complex cycles and succession patterns rendering it difficult to predict the frequency and extent of HAB outbreaks (Anderson 2007). This uncertainty prevents effective mitigation of and rapid response to HABs and their negative consequences. Thus, further scientific research is essential in addressing HAB impacts to the aquatic ecosystem, human health, and the various industries that depend on the health of surrounding water bodies.

Impacts of HABs and Hypoxia

Globally, algal blooms occur primarily in Europe, eastern Asia, and North America. Occurrences of HABs and hypoxia have increased in frequency over the past forty years in the United States, including on the southeastern and northwestern coastlines and the Gulfs of Maine and Alaska (Anderson et al. 2012). Particularly alarming, the northern Gulf of Mexico has suffered from a 7,000 square mile stretch of hypoxia. The impacts of HABs and hypoxia vary greatly between regions and negatively affect the ecosystem, human health, and local economies.

Ecosystem Effects from Hypoxia

Both toxic and non-toxic algal blooms have the potential to cause negative consequences for aquatic organisms. Algal bloom outbreaks can block sunlight from penetrating the water and can also obstruct the gills of aquatic organisms (Glibert et al. 2005). As algal blooms decompose and cause areas of depleted oxygen, mobile invertebrates and fish may migrate away from these hypoxic zones to areas with sufficient oxygen levels. However, slow-moving organisms cannot escape these conditions and thus die from exposure. Extensive hypoxic zones, otherwise known as dead zones, can prevent even fast moving organisms and fish from finding sufficient oxygen levels resulting in extensive fish kills. HABs are usually short-lived, from days or up to months; however, their effects on water quality and habitat-degradation can last for years. (Paerl et al. 2001).

Human Health

Humans can be negatively affected by consuming shellfish or fish contaminated with algal toxins, or accidentally consuming contaminated water during recreational activities (Graham 2007). Eye irritation, diarrhea, amnesia, paralysis, nerve damage, and even death are among some of the negative consequences of human contact with harmful algae. Toxic shellfish may also lead to the mortality of marine mammals, birds, and reptiles as a result of bioaccumulation infiltrating the food web (Graham 2007).

There are several types of shellfish poisoning worldwide, but there are three types that are of major concern in the United States. The algal blooms that trigger paralytic shellfish poisoning are created by several species of dinoflagellates that belong to the genus *Alexandrium* (Zingone et al., 2000). These dinoflagellates occur in northern California, the Pacific Northwest, Alaska, and New England. The dinoflagellate, *Gymnodinium breve,* produces brevetoxins that cause neurotoxic shellfish poisoning. Continuous exposure to airborne brevetoxins can lead to severe respiratory symptoms (Backer and McGillicuddy 2006). These dinoflagellates predominantly occur on the coastline of the Gulf of Mexico. Amnesic shellfish poisoning is caused by domoic acid generated by certain diatoms from the genus *Pseudo-nitzschia*. They are usually found on the coasts of the northwest, east and Gulf of Mexico (Boesch et al. 1997). In 1987, amnesic shellfish poisoning triggered over a hundred cases of human infection and several deaths due to the consumption of affected mussels from the North Atlantic (Bates et al. 1989; Anderson et al. 2012). The news about massive HAB outbreaks motivated people to become aware of shellfish poisoning and avoid seafood during HAB events (Anderson et al. 2000; Anderson 2007).

Table 1: The most prevalent types of shellfish poisoning, their associated toxins and plankton, as well as their affects on human health.

Human Illness	Toxin	Plankton	Process
Amnesic Shellfish Poisoning	Domoic Acids	Diatom	Acts on calcium channels; Gastrointestinal Short-term memory loss
Diarrheic Shellfish Poisoning	Okadaic Acids, Pectenotoxin, Yessotoxin, Dinophysistoxin	Dinoflagellate	Inhibit proteins; Gastrointestinal
Neurotoxic Shellfish Poisoning	Brevetoxin	Dinoflagellate	Acts on calcium channels; Gastrointestinal, tingling
Paralytic Shellfish Poisoning	Saxitoxin	Dinoflagellate	Acts on ion channels; Respiratory failure, death

Economic Impacts
Potential health risks from toxic algae can have immense economic impacts to local communities across a wide variety of industries such as fisheries, tourism, and restaurants. A *Karenia brevis* outbreak off the coast of Galveston, Texas in the summer of 2000 led to extensive fish kills through November. Shellfish fisheries were closed as a precautionary measure to avoid neurotoxic shellfish poisoning. Many of these areas were closed until January 2001, contributing to $10 million in economic loss from fishery closures, beach clean ups, and lost tourism (Evans and Jones 2001). Similarly, a 2005 outbreak of *Alexandrium fundyense* blooms closed shellfish harvests to prevent paralytic shellfish poisoning in humans in the Northeast. Massachusetts suffered $18 million in lost shellfish sales while Maine bore $4.9 million in damages (Jin et al. 2008; Athearn 2007).

These outbreaks are not isolated to single events. The western coast of Florida, for example, experiences a *Karenia brevis* outbreak almost every year. Consequences from these outbreaks can cost up to $32 million per outbreak, affecting Florida's famed tourism industry among many other negative impacts to the ecosystem and human health (Steidinger et al. 1999).

Figure 5: The Caloosahatchee River closes in June 2011 due to a harmful algal bloom outbreak shutting down a drinking water plant and preventing recreational and tourism activity. Mike Dove/ Sanibel-Captiva Conservation Foundation

Scientific Solutions

Current systems for predicting and monitoring algal blooms rely mostly upon manual seawater sampling from boats, and often involve visual identification of the phytoplankton (Kulis, personal communication; Laurent 2009). New technologies, such as Surface Plasmon Instrumentation for the Rapid Identification of Toxins (SPIRIT) are capable of identifying toxins and potentially algae in affected areas. Remote sensing systems are also used, as in the Harmful Algal Bloom Operational Forecast System (HAB-OFS) in the Gulf of Mexico. These systems use sea surface temperature, dissolved oxygen, or other oceanographic data to predict when HABs are likely to occur (Anderson 2009). However, the HAB-OFS system in the Gulf uses remote sensing in the form of satellite data and wind monitoring on buoys.

Algal bloom control methods include ozonation, ultrasonics, and various chemical treatments (Sengco 2004). Chemical treatments include copper sulfate, sterol surfactants, sodium hypochlorite, magnesium hydroxide, and others, but they have not been used widely because of concerns about ecosystem effects and the price of these treatments. These methods can have acute ecological side effects, which has prompted the search for less invasive methods (Rey 2011). Control methods must be environmentally friendly, not kill or harm other aquatic organisms, and have no long lasting effects (NOAA 2012). Meeting these criteria may require "softer" methods than aggressive application of chemicals. Clay dispersal has the potential of being a very efficient, rapid, and cost effective control method that has low environmental impacts (Anderson 1997). These methods have been used extensively in countries such as Korea, where algal blooms have high economic costs (Anderson 2009).

Clay treatment involves the application of minute mineral particles, which bind to algal cells, causing them to sink and removing them from the water column within hours (Sengco 2004). This increases water transparency, reduces toxicity, and limits the extent of hypoxic conditions to the sea floor, mitigating the acute effects of algal bloom outbreaks and measurably increasing the survivorship of fish (Shirota 1989). Additionally, clays have the potential of removing not only algal cells but also toxins associated with these blooms, although the effectiveness of this method is dependent upon the addition of a flocculant (Pierce 2003).

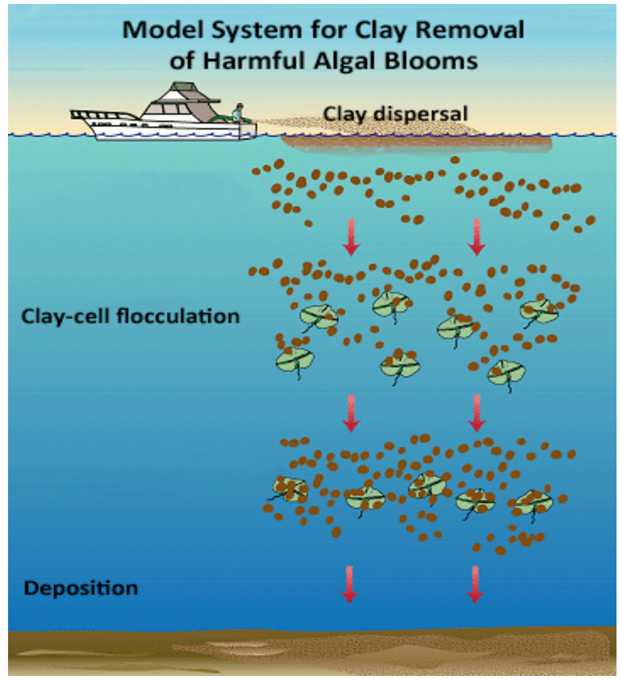


Figure 6 depicts clay flocculation, a method in which clay particles bind to algae and sink to the bottom. Adapted from Smithsonian Environmental Research Center

Figure 7: An individual applies the clay flocculation method to a HAB outbreak. J. Culter, Mote Marine Laboratory

The goal of a new mitigation project called sediment resuspension is to suppress the cysts of *Alexandrium funyense*, a toxic dinogflagellate that occurs in the Gulf of Maine (Anderson 1997). Sediment resuspension involves turning over the top 10 to 20 cm of the sediment on the ocean floor, comparable to how farmers till surface soil on agricultural lands (Anderson and

Ralston 2011; Figure 8). This redistributes and buries most cysts under the sediments in an anoxic layer that discourages germination and growth (Anderson and Ralston 2011). Therefore, sediment resuspension has the potential to greatly reduce the density of cysts in the surface sediment before the occurrences of algal blooms, which may decrease algal bloom duration and intensity and reduce the quantity of toxins produced (Anderson and Ralston 2011).

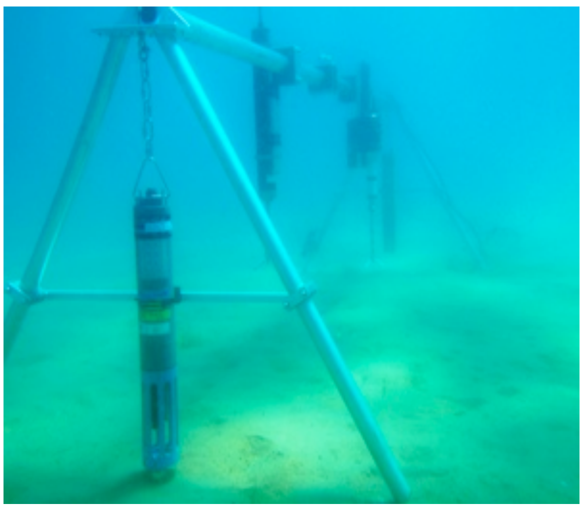


Figure 8: Sediment resuspension device. UC Davis

This method only applies to the types of algae that produce cysts and spores (Anderson and Ralston 2011). It is important to determine what proportion of *Alexandrium* cysts, as well as other cyst forming dinoflagellates, are buried through sediment resuspension. In addition, scientists are quantifying the rate at which the cysts are sinking, what nutrients are released during the process, and how this affects the benthic community (Anderson and Ralston 2011).

Legislative History

Senator Olympia Snowe [R-ME] introduced The Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2011 (S. 1701) on October 13, 2011. The bill proposes a national strategy with a focus on regional action plans, and if passed, would allot $30 million to these efforts every year through 2015.

S. 1701 is preceded by two additional pieces of legislation. The Harmful Algal Bloom and Hypoxia Research and Control Act of 1998 established the underlying foundations for the current legislation requirements. It created the Inter-Agency Task Force on Harmful Algal Blooms and Hypoxia to complete assessments on the economic and ecological impacts of HABs and hypoxia and to develop strategies for reducing, mitigating, and controlling outbreaks. In addition, the Act required the Task Force to complete an assessment specifically on the Northern Gulf of Mexico Hypoxic Zone. This report examined the ecological and economic impacts, distribution dynamics, causes, sources and loads of nutrients transported by the Mississippi River to the Gulf, effects of reducing nutrient loads, methods for nutrient load reduction, and the social and economic costs and benefits of such methods. The Task Force was required to develop a plan to reduce, mitigate, and control hypoxia in the Northern Gulf of Mexico based on the assessment. $52 million was appropriated over three years for research, education, and monitoring activities related to the prevention, reduction, and control of HABs and hypoxia.

The Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2004 changed the Task Force to a permanent body. After the 1998 legislation prompted investigation into the general causes and consequences of HABs and hypoxia, the 2004 Amendments sought to further research the scientific nuances behind the increasing number of outbreaks throughout the country. Although scientific research is integral to all three pieces of HAB legislation, the primary purpose of the 2004 Amendments was to provide the means for more scientific research.

The Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2011 reauthorizes the 1998 Act until the year 2015 and establishes the National Harmful Algal Bloom and Hypoxia Program. The Program will develop a national action strategy to prevent, control, and mitigate HABs, produce regional research and action plans, and continue coordinating the research, planning, and implementation work of various agencies, tribal, regional, state, and local officials, experts, and stakeholders. The National Oceanic and Atmospheric Administration (NOAA) will be responsible for overseeing the development of the program, national strategy development, and regional research and planning. The legislation aims to use these tools to control the human and environmental costs of HABs and hypoxia, including protecting coastal economies, improving human health, and supporting fisheries.

Issue and Political Background

As the damages associated with HABs increase, the question of who should implement research, control, and mitigation programs inevitably arises. If the government does not take full responsibility for funding and implementing these programs, no individual or entity will. There are two approaches the government could take in combating the problem of HABs and hypoxia, preventive management and reactive management.

Generally, preventive management is a method used in minimizing the occurrence of change or crisis. Preventive management would reduce nutrient loads through different methods such as redesigning sewage infrastructure, regulating fertilizer usage, and imposing a total maximum daily load requirement for discharges to waterways. Stakeholders in favor of preventive management of HABs include the fishing industry, conservationists, and the tourism and recreation industries. Their motivations in supporting this style of management focus on long-term sustainability of coastal habitats that can lead to sustainable fish stocks and other ecosystem services, promoting healthy ecosystems and their services, as well as human benefits ranging from recreation and clean drinking water to the prevention of shellfish-borne poisoning and other negative public health consequences caused by HABs.

Conversely, reactive management involves responding to a change or a crisis after it occurs. Reactive management attempts to control and mitigate HABs through closing beaches and shellfish beds as well as direct interventions such as clay flocculation. Proponents of reactive management efforts include both farmers and private industries who are motivated by the economic benefit of reducing management costs associated with fertilizer and sewage runoff into waterways, fertilizer producers as well as taxpayers who may claim that the funds appropriated towards preventing this problem should be allocated towards different social or economic issues.

The preventive approach is potentially less expensive over time, minimizing the risk for stakeholders affected by expensive damages to their industries. This approach also minimizes ecological damage while promoting recreation such as activities associated with healthy beaches and lakes. However, initial costs for preventive approaches are greater than the initial costs for the reactive approach and prevention funding may deprive financial resources for other programs. In addition, intensive regulations are required in order to effectively carry out preventive measures.

Immediate cleanup costs for a reactive approach will be less expensive. This approach inherently generates short-term response, which may suffice, while research simultaneously conducted may inform the need for long-term action. However, the reactive approach does not address the underlying causes for the increasing frequency of HABs. Reactive approaches would likely generate greater damages to aquatic ecosystems and biodiversity, negatively affect local industries and interfere with recreation. Furthermore, scientists are uncertain of the ecological consequences of using various treatments to control outbreaks after they occur.

Agriculture

Agriculture has a profound effect on the prevalence of HABs. Experts have emphasized that nutrient loading associated with agricultural runoff can cause HAB and hypoxia outbreaks (Beman 2005). The specific nutrients, including nitrogen, phosphorous and iron, are introduced into the water column through the use of fertilizer in agricultural areas (Spatharsis 2007). Although indirectly implied, the Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2011 fails to explicitly address agriculture as an unquestionable cause of HAB outbreaks and hypoxia.

"Excessive nutrients in coastal waters have been linked to the increased intensity and frequency of hypoxia and some harmful algal blooms...Increases in nutrient loading from point and nonpoint sources can trigger and exacerbate harmful algal blooms and hypoxia" (US Congress 2011).

This "nutrient loading" is an abnormal pattern for coastal systems, which are often nitrogen poor, and as a result, maintain clear water and diverse ecosystems (Beman 2005). Introducing excess nutrients can lead to eutrophication and hypoxia in water columns that had previously been unaffected by algal blooms (Glibert 2006).

The Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2011 states that "since much of the (nutrient) increases originate in upland areas and are delivered to marine and freshwater bodies via river discharge, integrated and landscape-level research and control strategies are required (US Congress 2011)." As shown above, the necessity of limiting nutrient runoff as a way to mitigate Harmful Algal Blooms is well documented. Under the 1998 version of the bill, the USDA established the Agricultural Drainage Management Systems Charter (ADMS) to minimize the level of nutrient runoff entering coastal ecosystems. These efforts, however, must be complemented with the active participation and support of stakeholders such as the agriculture sector and the local and federal government. The linkages between agriculture and algal blooms are not explicit in the HAB bills, which instead focus on the mitigation and control needed to manage HABs. The exclusion of nutrient loading caused by agriculture from the legislation limits the funding available for the large-scale agricultural shift to less wasteful methods. This omission draws the focus away from preventing the blooms by changing our inputs to the system. Without efforts to control the nutrient inputs into the system, the occurrences of HABs can be expected to increase in extent and severity (Anderson 2008).

Program Design

Figure 9: The HAB outbreak at the Caloosahatchee River was caused by untreated sewage, manure, and fertilizer run-off. Greg Rawl/ Sanibel-Captiva Conservation Foundation

Program Design

The program design presented here aims to achieve three goals: better understanding of HABs and hypoxia in order to prevent future outbreaks, accurate forecasting of upcoming HAB outbreaks, and the effective intervention of such outbreaks through control and mitigation techniques. Strides towards research, monitoring, and response of HABs are the primary components of work necessary to reach these goals. In order to effectively coordinate the legislative requirements associated with research, monitoring, and response, a planning component is essential to establish a strong foundation for our proposed program. Our program design details the goals, organization, and budget of the planning, research, monitoring, and response sections of the program. This will be followed by our timeline for implementing this program design as well as our performance management guidelines.

Planning

The planning portion of the program design can be divided between a national strategy and regional plans. The national strategy, written within a year and revised every two years, must ensure that the legislation's requirements are met. In addition to the national plan, three HAB-specific regional offices will be established to develop regional plans in heavily affected areas: the Pacific, the Northeast, and the Gulf of Mexico.

The regional component of the program design will apply to NOAA's six priority regions, namely the Pacific Coast, the Northeast, the Mid-Atlantic Coast, the Gulf of Mexico, the Great Lakes, and Hawaii and Puerto Rico operating as one region. Regional offices will manage the three of these regions with the greatest need (the Pacific, Northeast, and Gulf of Mexico), while the national office will manage the remaining three regions. The regional offices will be located in existing NOAA offices in Seattle, Washington, Boston, Massachusetts, and Starkville, Mississippi. The regional offices must submit a plan every two years outlining the timeframes in which tasks will be completed and identifying research, monitoring, and response priorities as well as stakeholder involvement.

Figure 10: Three regional offices will be operating in Seattle, WA, Boston, MA, and Starkville, MS.

Appendix I outlines a staffing plan to meet the program's goals. The program will be housed under the Center for Sponsored Coastal Ocean Research of NOAA. The national strategy will be managed primarily by a National Director and a National Program Coordinator. As the face of the program, the National Director is responsible for ensuring that the legislation's requirements are met and that the members of the Task Force, as mandated in the legislation, are effectively coordinated. The National Program Coordinator undertakes the daily work of creating, writing, and implementing the national strategy, which will be submitted to the National Director. The plan is renewed every two years which means that once the first plan is completed, the National Program Coordinator must begin writing and implementing the second plan shortly thereafter. A temporary Strategy Consultant will be contracted for a year to work with the National Program Coordinator to design and write the national strategy.

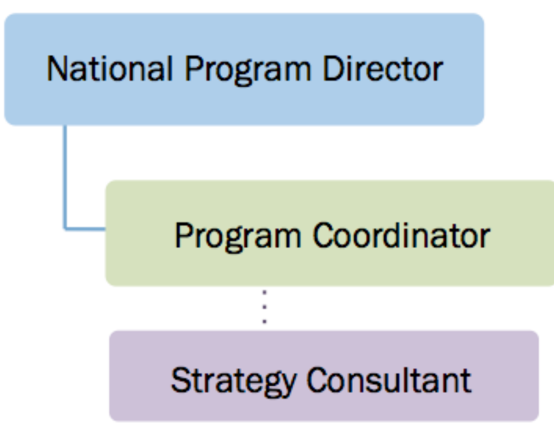


Figure 11: The national office will consist of a National Program Director, a Program Coordinator, and a temporary Strategy Consultant, who will create a national strategy to ensure that the program will satisfy the legislation requirements.

The national strategy goes through a rigorous vetting process. The National Director along with the National Program Coordinator will draft the plan with the input from the interagency task force. Public meetings and a formal comment period are to follow before further revision by the Taskforce. Changes may be made in response to public comments before the final plan is submitted to Congress.

The budget is outlined in Appendix II. Although the bill allocates $30 million each fiscal year through 2015, the program proposed here increases the budget to $54 million each year, considering the addition of three regional offices. Planning receives 5% of the budget, research accounts for 53%, monitoring comprises 24%, and response covers 18% of our proposed budget.

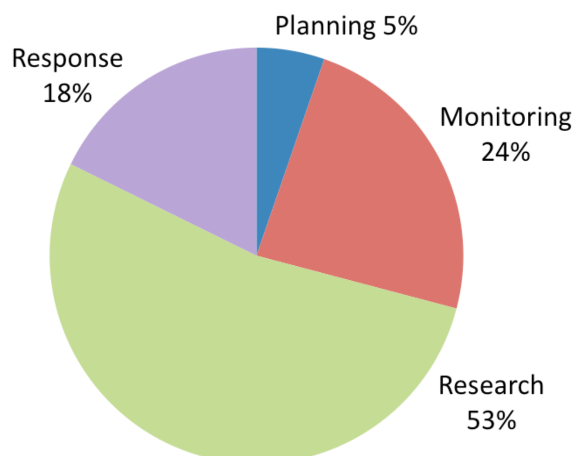


Figure 12: The budget funds planning, research, monitoring, and response strategies.

The planning component of the program will be allotted $2.93 million. Funding for the national-level planning will total $360,000 per year. This amount covers the salaries for the National Program Director, the National Program Coordinator, and the Temporary Strategy Consultant. The regional portion of the planning program will cost $768,000 annually as a result of $648,000 for salaries, $40,000 to hold conferences with regional stakeholders, and administration costs.

The Master Calendar (Appendix III) establishes a timeline for activities within the first year of implementation. Specifically, it establishes a timeframe for hiring the necessary staff and for implementing the program design strategies developed to improve research, control, and mitigation of HABs and hypoxia. By the end of the first year, the program should have established the necessary framework to implement all aspects of the program once the national strategy is finalized and published.

Developing the National Strategy

The first priority is to hire the staff who will oversee the drafting and ultimate implementation of the national strategy. Hiring will be managed in phases, beginning with the National Director in January 2013. The job search for the National Program Coordinator and Temporary Strategy Consultant will begin in late February so that the new National Director has the opportunity to interview final prospects for the deputy positions. All positions will be hired into CSCOR.

With the new hires in place, the interagency task force will assemble in April to establish an outline of necessary outputs and expected outcomes for the national strategy. This outline will then be processed and compiled by staff and synthesized into a draft, which will be completed by the end of June.

Revising, Revising, and Publishing the National Strategy

Once the draft of the national strategy is completed, the next step is to hold public meetings and webcasts to allow interested parties to engage in discussion about the strategy. The comment period will be open for 60 days, from July through August, to allow stakeholders ample time to respond before the strategy is revised.

During the public comment period, the National Director, National Program Coordinator, and the Temporary Strategy Consultant will form interagency task force work groups and reach out to scientists engaged in HAB research as well as local and regional governments in high-bloom regions to better understand how the strategy will affect their work.

After comments from the public and industry stakeholders are incorporated, the revised draft will be published for comment for another 30-day period to allow for further scrutiny.

In December, NOAA staff will incorporate final revisions and will publish the national strategy in the Federal Register and submit the plan to Congress.

Establishing Regional Offices

The regional HAB offices will be established in existing NOAA offices and will require additional staff. The process of hiring staff will begin in April, after the National Director and the National Program Coordinator have been hired. The regional HAB offices will ultimately contain four permanent employees: a Regional Director, a Regional Plan Coordinator, a Monitoring Coordinator, and a Response Coordinator. In April, only the Regional Director and Regional Plan Coordinator positions will be hired for each of the three regions.

Once in place, they will begin to engage with local stakeholders through visits with state and academic research groups, interviews with coastal resource managers, and holding public meetings. The staff will use that knowledge and those relationships to develop a regional action strategy. The regional strategy must be completed by December.

Research

Our research goals aim to expand research that is currently conducted under NOAA's Prevention, Control, and Mitigation of Harmful Algal Blooms (PCMHAB), Ecology and Oceanography of Harmful Algal Blooms (ECOHAB), and Monitoring and Event Response of Harmful Algal Blooms (MERHAB) programs. Finally, research incorporates developing technology that will be used to monitor and respond to HABs and hypoxia.

CSCOR already has a research department including a Monitoring Research Manager, an Ecology Research Manager, and a Response Research Manager. Our proposed program creates a Deputy Manager position to support each existing research manager. The Managers and Deputy Managers are the intermediaries between the government and the researchers through their responsibilities in allocating grant money to research institutions. These duties include soliciting proposals, awarding grants, managing agency and stakeholder participation, and synthesizing project findings to create tools to prevent and respond to harmful algal blooms.

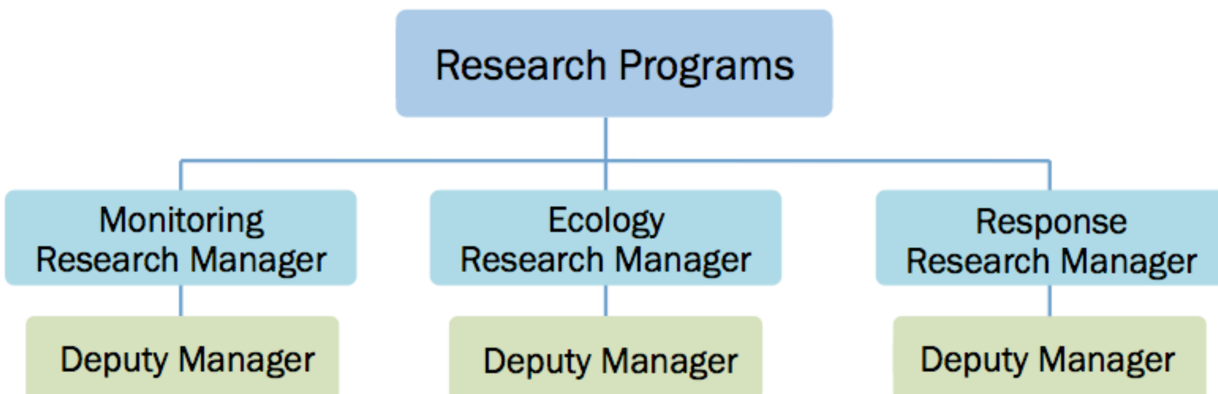


Figure 13: Existing research managers will be assisted by new Deputy Managers for monitoring, ecology, and response research.

Our program dedicates the majority of our budget, $30 million, to research. Almost all of the money will go directly towards the research projects selected. These grants will be allocated through specific programs, including prevention, forecast, control, hypoxia, and regional research grants. The remaining $265,000 in the research budget will finance the salaries of the three new Deputy Managers as well as travel and conference expenses.

The process of selecting these six new staff will begin in June, as the draft of the national action plan is released; the selection process could take as long as four months. Once the staff is in place, they will begin revising the existing grant proposals to facilitate new research priorities, such as freshwater HAB research and nutrient loading prevention.

Grants will not be announced until after the national action plan is published in

December 2013 to ensure that the grant programs are consistent with the priorities of the national strategy. Once the action plan is published, the grant managers will announce the grants, evaluate research proposals and award the grants in 2014.

Monitoring

The regional offices will build networks to expand monitoring efforts. Consistent monitoring on water quality conditions such as temperature and salinity in a network of locations will facilitate prediction for future outbreaks. Developing and deploying new technologies will also improve monitoring measures. The development, execution, and maintenance of this monitoring network will be contracted out to various local partners, potentially including state fishery managers, municipal coastal managers, academic researchers, and various government entities.

At the regional level, a Regional Director will manage his or her assigned office in Seattle, Boston, or Starkville. The responsibilities of the Regional Directors are similar to those of the National Director as each position coordinates their region's office staff and ensures that a regional plan is submitted every two years. The three Regional Plan Coordinators, each working in one of the three offices, develop a regional plan for the office of their region and will submit that report to their respective Regional Director. Additionally, each regional office will house a Monitoring Coordinator who is responsible for managing the tasks of conducting water quality testing or implementing monitoring technology, using contracted local partners.

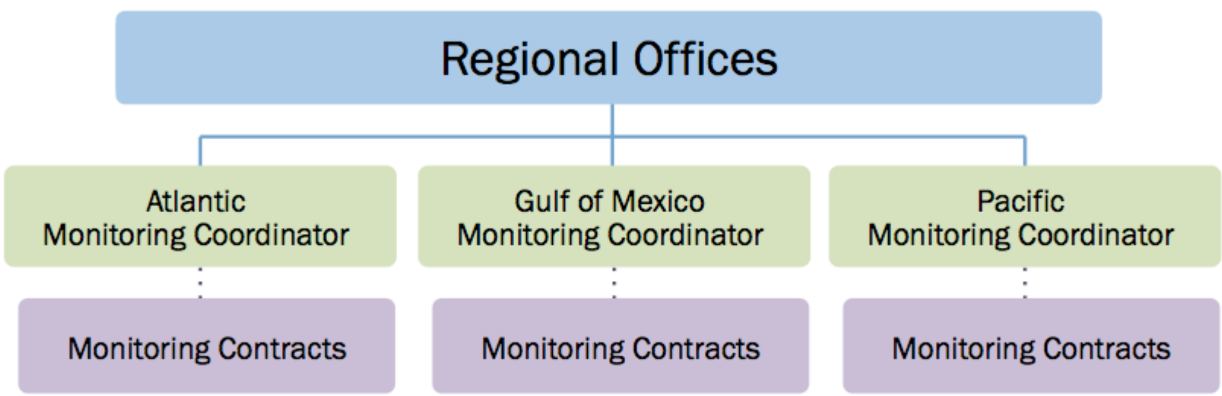


Figure 14: Each regional office will be staffed with a monitoring coordinator who is contracted from the local community.

Monitoring efforts will be allotted $13.09 million. Salaries compensating Monitoring Coordinators of each region will comprise $270,000 of the monitoring budget, and the equipment necessary to conduct monitoring and sampling efforts, such as buoys and submersibles, will cost $4.82 million. Monitoring contracts will award $8 million to local teams of government officials, which delegate water sampling duties to resource managers, lifeguards, or other partners to collect water quality data and monitor coastal conditions in order to better prepare for HABs.

In December 2013, each Regional Director will hire a Monitoring Coordinator. Because HAB monitoring will be outsourced to local and regional partners with existing infrastructure and personnel, in the second year, the Monitoring Coordinator will be responsible for helping those local and regional partners to develop and implement monitoring programs. The Monitoring Coordinator will also purchase and distribute monitoring equipment specific to the region.

Response

Our program will build a response network through local event response teams. Teams that are contracted will serve as the agents that implement technologies such as clay flocculation and sediment re-suspension on the outbreak itself, while other teams may alert suppliers of tainted seafood, close fisheries, and notify tourism agencies to mitigate damages.

An Event Response Coordinator in each regional office is responsible for implementing event response actions. This includes hiring people who can apply technology such as clay flocculation directly to current outbreaks as well as coordinating local stakeholders and political support.

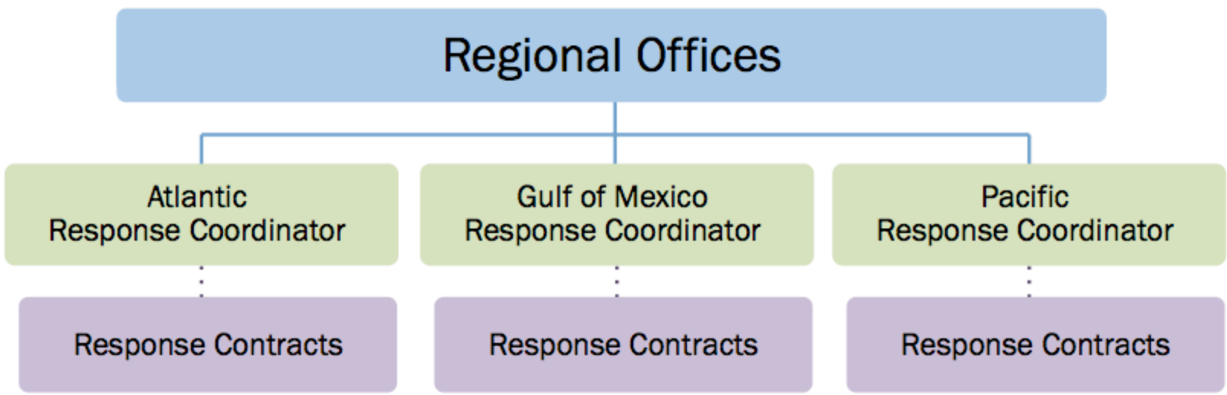


Figure 15: A Response Coordinator will be contracted from the community of each regional office in order to appropriately respond to a harmful algal bloom outbreak.

The Response budget will account for $9.77 million of the entire budget including $270,000 in Response Coordinator salaries and $500,000 for response technology, including clay flocculation equipment among other technologies. Educating communities, restaurants, and tourism agencies during the event of an outbreak will cost $3 million in outreach. However, contracts will comprise the majority of the Response budget, $6 million, awarded to institutions to develop region-specific event response plans. Eventually, these response plans will implement training and salary support for a group of professional response teams that are on-call to control HAB outbreaks and notify local stakeholders to mitigate damage to the community.

In December, each Regional Director will hire a Monitoring Coordinator. Because HAB monitoring will be outsourced to local and regional partners with existing infrastructure and personnel, in the second year, the Monitoring Coordinator will be responsible for helping those local and regional partners to develop and implement monitoring programs. The Monitoring Coordinator will also purchase monitoring equipment specific to the region.

Additionally, in the second year the Response Coordinator will be hired. Like the monitoring program, event response will be outsourced to local research institutions. The Response Coordinator will develop a grant program specific to local event response, will evaluate the proposals, and will award grants with the goal of establishing event response action teams by year three.

Continued Implementation: 2014-2015

Most first year activities are focused on establishing a foundation for the following years. Beginning in 2014, once the national action plan has been finalized and published, the real work can begin.

Moving beyond 2013, the national director and strategy administrator will continue to coordinate research and action among federal agencies and the regional directors. The temporary strategy consultant's position will terminate. The research grants will be awarded from the national office, and the regional monitoring and event response plans will be developed and implemented.

With both the research and regional action plans moving forward, it is NOAA's expectation that the new national strategy will aid scientists to coordinate their research efforts and learn how to more effectively respond to and control harmful algal blooms.

Performance Management and Program Improvement

Performance management systems are laid out with a number of specific goals as a way to measure success of specific programs and management relationships. They can be "an ongoing process of communication between a supervisor and an employee that occurs throughout the year, in support of accomplishing the strategic objectives of the organization" (UC Berkeley 2007).

NOAA will develop measurement systems in line with the regional office initiatives. Regional coordinators will collect information indicated through measurements of performance as well as on an ongoing basis, creating reports for the regional directors to share with and present to each other and NOAA to facilitate uniform results across offices. While coordinators will create regional reports on a 12-month cycle, with all agencies reporting in the beginning of the financial year, regional directors will compile findings and communicate them to the national office on a quarterly basis at the beginning stages of strategy implementation and reduce these to a bi-annual basis as the programs within those offices becomes better established.

At those meeting times, information feedback using the performance management system will modify strategies by region to create a system of yearly reporting and review on a national scale, making corrections after the completion of the reviews. Changes will be overseen by the office involved and implemented depending on urgency.

It is a tenet of a good management system that what gets measured gets accomplished. For this reason, it is important to understand the program design's specific sections. The performance measurement system that NOAA will use to measure the progress of the program design and implementation measures the input, or the resources committed to begin a project. The output of that goal is assessed next, for the actual product produced as well as whether or not the desired outcome of the program was achieved.

A number of indicators will be utilized to assess the progress of each program. For example, under research, if the initial goal is, "Further research of marine and freshwater HABs, and nutrient loading prevention," the measurable output would be

"Increase basic ecology and oceanography research," following with the impact, "Improved understanding of HABs through relevant research programs." For this specific example, a key indicator is whether or not there are better resources to interpret, understand and apply data to HAB programs resulting from the work of the program. Further examples are below:

Planning

- Input: Hire staff and assemble offices for each of the 3 regions: Pacific Coast, Atlantic Coast, and Gulf of Mexico
- Output: A more structured and streamlined approach to managing HAB programs at the national and regional level
- Impact: A more efficient and effective national implementation of the program design

Monitoring

- Input: Enhance regional HAB monitoring and forecasting by adding additional equipment and research projects
- Output: Establish regional monitoring networks for monitoring and forecasting
- Impact: Better forecasting and monitoring of outbreaks, which could lead to reduced environmental degradation and hypoxic zones

Response

- Input: Increase HAB prevention, control and mitigation research; and improve event response time and mitigation technologies
- Output: Develop and implement response strategies
- Impact: Greater capacity to prevent, control, mitigate and respond to outbreaks; and reduce environmental degradation

The last step of the review process is to determine if the impact of the program is in line with the program design goals and should be continued, or needs to be altered in order to improve efficiency or effectiveness. After this process has been completed feedback will go to the management staff of the offices and departments concerned will be required to apply necessary changes to the structure of the programs. Throughout the implementation of the performance management system, it is important to consider that the local culture at regional office locations may vary, so that program design must be structurally flexible. Depending on the needs of the region, this can take the form of allowing more time for the review process, or varying face-to-face meetings with reports from each department. This will allow regional offices the ability to change the review process depending on local organizational structure, resources and overall management.

Continual auditing and evaluation will allow the program to adapt over time and continually reassess for efficacy and efficiency. Once this process has begun, it is recommended that it be repeated at regular intervals of 6 months initially, increasing to yearly after the first two years. This will allow the regions and national offices to consistently assess the progress of the program as well as whether the goals stated within the program design are being accomplished and understood.

Conclusion

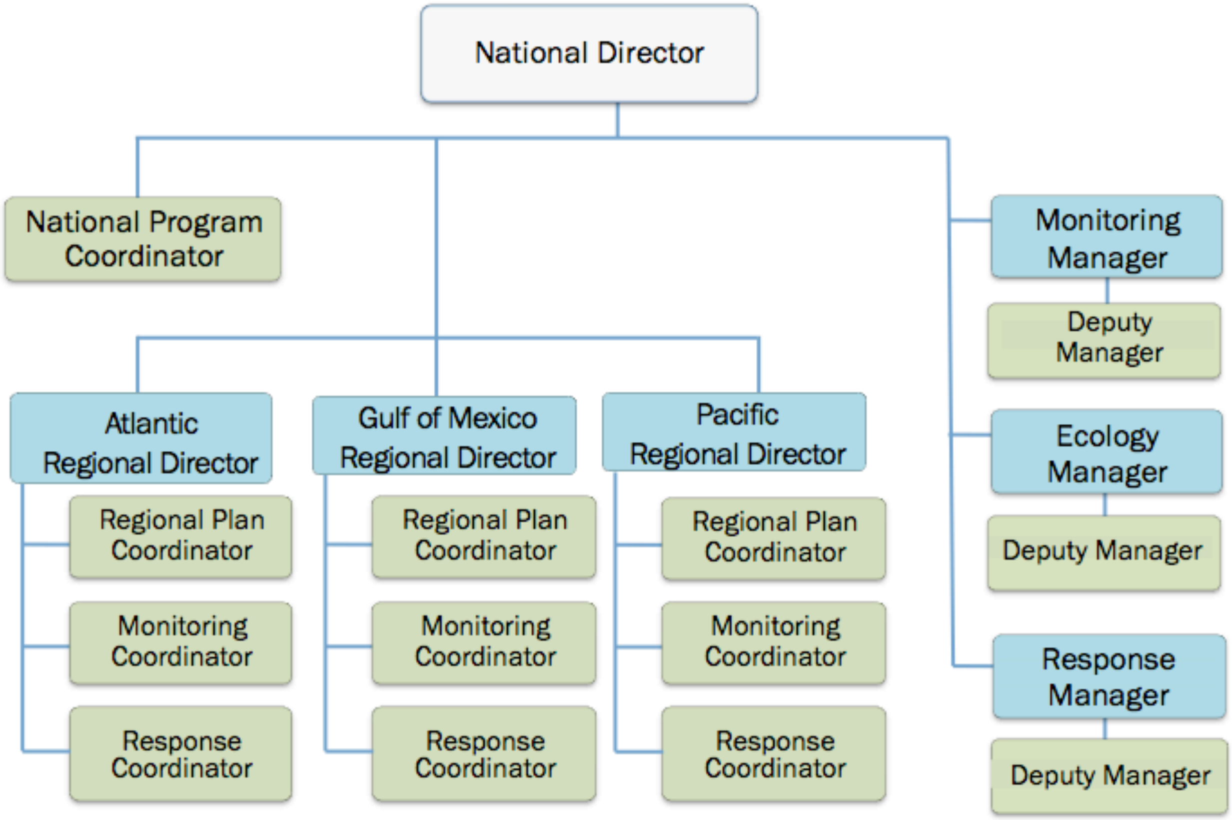
Figure 16: Freshwater harmful algal blooms such as in the case of southwest Florida's Caloosahatchee River can affect human recreation, human health, the freshwater ecosystem, and the local economy.
John Cassani/Sanibel-Captiva Conservation Foundation

Conclusion

Harmful algal blooms and hypoxia are caused by natural conditions in the water as well as agricultural and urban run-off. Both HABs and hypoxia can lead to marine organism mortality, shellfish poisoning, and economic damage to tourism, fisheries, and restaurants, among many other negative impacts. The Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2011 addresses this problem by developing a national strategy that focuses on regional action plans to decrease the negative consequences caused by outbreaks. The program proposed here is designed to implement research, monitoring, and response initiatives to better manage the problems associated with harmful algal blooms.

The program outlined in this report includes many initiatives on both a national and regional level, ranging from scientific research to response teams. Harmful algal blooms and hypoxia are environmental problems with severe ecological, health, and economic consequences; therefore a multi-faceted approach is necessary to prevent, control, and mitigate the problem.

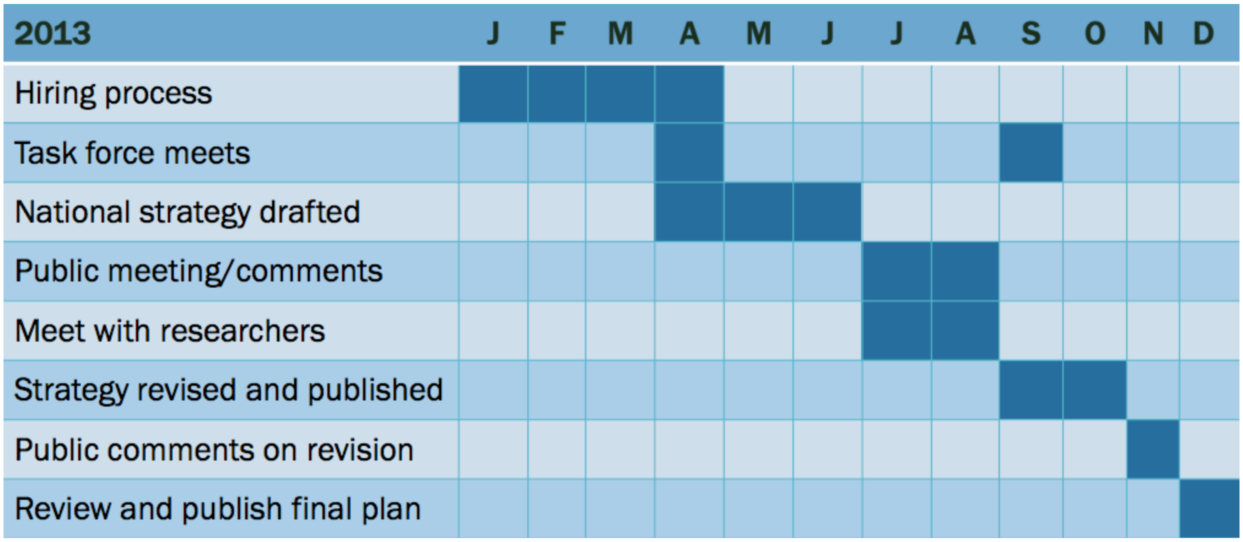
APPENDIX I- FIRST YEAR STAFF ADDITIONS

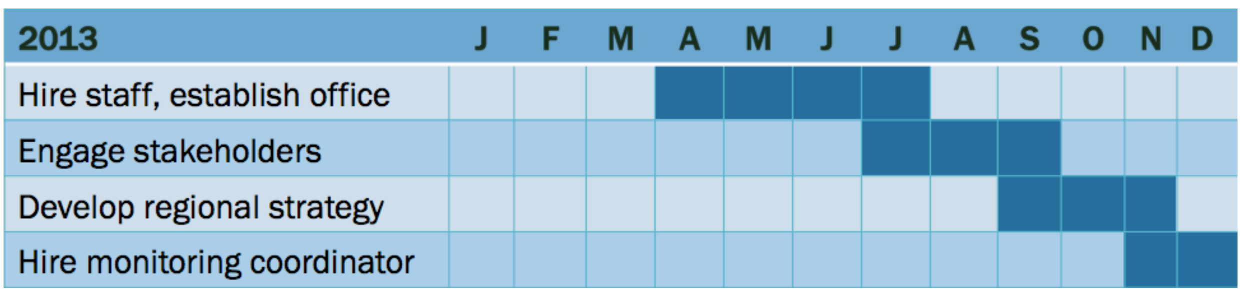


APPENDIX II- FIRST YEAR BUDGET

Planning	
National Office	
Salaries	$235,078
Overhead	included in administration total
Strategy Consultant	$124,872
National Planning Total	$359,950
Regional Offices	
Salaries	$216,038
Administration	included in administration total
Conferences	$40,000
Rent	$0
Regional Office Total	$256,038
Three Regional Offices Total	$768,114
Administration Total	$1,800,000
Planning Total	$2,928,063
Monitoring	
Contracts	$8,000,000
Training	included in contracts
Equipment & Maintenance	$4,820,000
Salaries	$270,000
Monitoring Total	$13,090,000
Research	
Prevention Grants	$8,000,000
Forecast (3m) & Hypoxia (5m) Grants	$8,000,000
Control Grants	$6,000,000
Regional Grants	$7,000,000
Salaries	$265,833
Travel and Conferences	included in administration total
Research Total	$29,265,833
Response	
Response Contracts	$6,000,000
Response Training	included in contracts
Education & Outreach	$3,000,000
Salaries	$270,000
Administration	included in administration total
Equipment/Storage	$500,000
Response Total	$9,770,000
Budget Total	***$55,053,896***

APPENDIX III- FIRST YEAR CALENDAR





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