S. HRG. 115–846

HARMFUL ALGAL BLOOMS: THE IMPACT ON OUR NATION'S WATERS

HEARING

BEFORE THE

SUBCOMMITTEE ON OCEANS, ATMOSPHERE, FISHERIES, AND COAST GUARD

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED FIFTEENTH CONGRESS

SECOND SESSION

AUGUST 28, 2018

Printed for the use of the Committee on Commerce, Science, and Transportation

Available online: http://www.govinfo.gov

U.S. GOVERNMENT PUBLISHING OFFICE
57–491 PDF WASHINGTON : 2025

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED FIFTEENTH CONGRESS

SECOND SESSION

JOHN THUNE, South Dakota, *Chairman*

ROGER F. WICKER, Mississippi
ROY BLUNT, Missouri
TED CRUZ, Texas
DEB FISCHER, Nebraska
JERRY MORAN, Kansas
DAN SULLIVAN, Alaska
DEAN HELLER, Nevada
JAMES INHOFE, Oklahoma
MIKE LEE, Utah
RON JOHNSON, Wisconsin
SHELLEY MOORE CAPITO, West Virginia
CORY GARDNER, Colorado
TODD YOUNG, Indiana

BILL NELSON, Florida, *Ranking*
MARIA CANTWELL, Washington
AMY KLOBUCHAR, Minnesota
RICHARD BLUMENTHAL, Connecticut
BRIAN SCHATZ, Hawaii
EDWARD MARKEY, Massachusetts
TOM UDALL, New Mexico
GARY PETERS, Michigan
TAMMY BALDWIN, Wisconsin
TAMMY DUCKWORTH, Illinois
MAGGIE HASSAN, New Hampshire
CATHERINE CORTEZ MASTO, Nevada
JON TESTER, Montana

NICK ROSSI, *Staff Director*
ADRIAN ARNAKIS, *Deputy Staff Director*
JASON VAN BEEK, *General Counsel*
KIM LIPSKY, *Democratic Staff Director*
CHRIS DAY, *Democratic Deputy Staff Director*
RENAE BLACK, *Senior Counsel*

SUBCOMMITTEE ON OCEANS, ATMOSPHERE, FISHERIES, AND COAST GUARD

DAN SULLIVAN, Alaska, *Chairman*
ROGER F. WICKER, Mississippi
DEB FISCHER, Nebraska
JAMES INHOFE, Oklahoma
MIKE LEE, Utah
RON JOHNSON, Wisconsin
CORY GARDNER, Colorado
TODD YOUNG, Indiana

TAMMY BALDWIN, Wisconsin, *Ranking*
MARIA CANTWELL, Washington
RICHARD BLUMENTHAL, Connecticut
BRIAN SCHATZ, Hawaii
EDWARD MARKEY, Massachusetts
GARY PETERS, Michigan

CONTENTS

WITNESSES

HARMFUL ALGAL BLOOMS: THE IMPACT ON OUR NATION'S WATERS

TUESDAY, AUGUST 28, 2018

U.S. SENATE,
SUBCOMMITTEE ON OCEANS, ATMOSPHERE, FISHERIES, AND COAST GUARD,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Subcommittee met, pursuant to notice, at 2:35 p.m., in room SR–253, Russell Senate Office Building, Hon. Dan Sullivan, Chairman of the Subcommittee, presiding.

Present: Senators Sullivan [presiding], Wicker, Fischer, Gardner, Young, Baldwin, Markey, and Peters.

Also present: Senator Nelson.

OPENING STATEMENT OF HON. DAN SULLIVAN, U.S. SENATOR FROM ALASKA

Senator SULLIVAN. The Subcommittee on Oceans, Atmospheres, Fisheries, and the Coast Guard will now come to order.

Good afternoon. And I want to welcome everybody.

Today is an important oversight hearing that we are having to discuss harmful algae blooms, or HABs, as they are frequently called, and the impact of HABs across our Nation in coastal resources and coastal communities.

HABs are scientifically complex and economically damaging, and almost every state in the country now experiences some kind of HAB event, including my home state of Alaska. I'll give a couple examples of what's happening in Alaska. And I know that my colleagues here on the Committee are going to talk about some of the things happening in their states.

Over the last 80 years in Alaska, HABs have actually killed 15 people and sickened hundreds. Given that shellfish is a staple in many homes throughout Alaska, particularly for our tribal communities, this is a serious concern. HABs have also imposed serious financial consequences on our valuable seafood industry, not just in Alaska, but throughout the country, and, in recent years, conditions that are triggering HABs are occurring more frequently. There are multiple types of HABs, which create difficulties for monitoring, researching, and responding to them. Paralytic shellfish poisoning, also known as PSP, is a serious illness caused by eating shellfish contaminated with the toxic algae. This is a concern particularly as it can cause serious human illness and even death at very small concentrations. Commercially harvested shellfish is regularly tested, but PSP is a particular hazard for many

shellfish that are harvested for personal use or in subsistence use. For example, in southeast Alaska, many tribal members are particularly concerned with the lack of a PSP testing available for subsistence and recreational shellfish collection, which is very important in my state.

In 2013, the Southeast Alaska Tribal Toxin Network was formed to coordinate efforts to monitor HABs and to develop a deeper understanding of when and where these HABs are likely to occur. With eyes on the water, each week partners from 17 tribes are able to inform their communities about the current risk of harvesting subsistence shellfish.

PSP is a significant danger to our commercial shellfish industry, as well. One example in southeast Alaska, in terms of the Geoduck Clamfish Reef, worth over $5 million annually, is in danger. This fishery has been plagued by unexplained PSP toxicity, resulting in very significant economic losses.

Another growing HAP concern is the neurotoxin domoic acid, which has been a major concern, not just in Alaska, but entire—the entire West Coast, particularly in California, Oregon, in the Washington Dungeness crab industry. This toxin has recently been found in Alaska, in the waters at Kachemak Bay, and is a growing concern for my state's $3-million-per-year Dungeness crab industry. Although HABs have occurred in Alaska's waters as far back as recorded history goes, the increasing frequency of events has far-reaching impacts.

I have long supported HAB and hypoxia research so that we can better understand these events and better prepare to respond to them. This is why I cosponsored the bipartisan Harmful Algae Bloom and Hypoxia Research Control Amendments of 2017, along with my Ranking Member, Senator Baldwin, and other committee members, including Senator Peters and Senator Nelson.

HABs pose significant risks to our fishing community, our economic and tourism community. Given the importance of the ocean and our coastal resources to Alaska's economy, Florida's economy, many other economies, it makes sense that we, as a Nation, coordinate our HABs and hypoxia programs, led by the National Ocean and Atmospheric Administration.

I will now give the floor to Ranking Member Baldwin for her opening remarks. And we are glad to have the Ranking Member of the entire Commerce Committee, Senator Nelson, here. I have also asked, if he has time, Senator Rubio, who I know cares about this issue, to stop by, as well.

Senator Baldwin.

STATEMENT OF HON. TAMMY BALDWIN,
U.S. SENATOR FROM WISCONSIN

Senator BALDWIN. Thank you, Mr. Chairman.

This summer, algae blooms are turning hundreds of Wisconsin's sparkling blue lakes and rivers into green pea soup, closing beaches and upending boating, fishing, and family recreation plans. We're not even in peak bloom season, but already, as of early August, there have been over 160 days of beach closures in Dane County, my home county, alone, mostly due to blue-green algae, more than any summer in over a decade.

Here is—oh, it's up already—here is a satellite, image taken last week, showing algae blooms in Green Bay and in the Lake Winnebago watershed, which would be right there. And Green Bay is up there. Algae blooms are so bad in Green Bay that they've caused a dead zone to persist in the Bay's deep waters for over 20 years, slowly removing oxygen from the waters, killing off fish and other aquatic life. A recent study led by University of Wisconsin-Milwaukee researchers shows that this dead zone is only getting worse. Wisconsin's largest lake is Lake Winnebago, and it's shown on the photo behind me. Lake Winnebago has been plagued with a particularly bad algae bloom this summer. It was so bad, in fact, that one of our witnesses today, Mr. Neu, canceled his plans to attend a fishing tournament on the lake because of the algae. Unfortunately, Mr. Neu is not alone. There are over a million anglers in the state of Wisconsin, and the state attracts the third-most nonresident anglers in the country and generates the second-most nonresident expenditures, only after Florida. From bass, pike, walleye, trout, to musky, Wisconsin is home to over 160 different fish species and is a top destination for fishing. But, algae blooms threaten our freshwater sport-fishing paradise by not only making the fish sick, but by posing risk to anglers, also.

Fishing is just one activity that algae blooms impact. The blooms spoil so much of what defines a great Wisconsin summer: boating, swimming, and beach-going activities. These are activities that define summertime in Wisconsin. But, these activities become dangerous to human health during algae bloom events.

With over 15,000 lakes and rivers, we have a lot to lose from harmful algal blooms in Wisconsin. Many thousands of residents live on or near waterfronts, many businesses rely on healthy waterfronts for their revenue. A case in point, next we have a photo of Lake Menomin, which is at Menominie, Wisconsin. This lake is clogged with algae throughout the warmer months, at a substantial cost to the community. Students at the University of Wisconsin—Stout estimated that a clean lake could provide a $36 million boost to the local economy, a city of 16,000, and could lead to students wanting to stay in the area year-round. These stinky, toxic, persistent blooms are on the rise in Wisconsin and the rest of the United States. They're increasing in frequency, in duration and extent. Climate change is making it worse by creating more favorable conditions for algae blooms.

Recently, an unprecedented harmful algal bloom greened the shorelines of Lake Superior, which has waters that are famous for being cold and crisp and clear. These harmful algal blooms stretched 50 miles from Superior to the Apostle Islands, which is a popular destination for kayakers, canoers, and hikers, and me. As waters warm, unprecedented events like this may become the new normal. Scientists are trying to figure out exactly what is driving this new pattern in blooms, and they've linked it to periods of heavy rainfall, which increases nutrient-rich runoff. Climate change will only make things worse.

The National Harmful Algae Bloom and Hypoxia Program expires in just over one month, on September 30. I want to voice my support for the Harmful Algal Bloom and Hypoxia Research and Control Act, which would reauthorize this crucial program. I

worked with my colleagues to include amendments to this bill to ensure that we're not only studying these harmful events, but we are arming local communities with the tools to address their water quality challenges. The Senate has taken action and passed this bill, and now we need to get it across the finish line. We need to acknowledge and act on the urgency of our national harmful algae bloom crisis.

I look forward to hearing from our expert witnesses about the increasing challenges of harmful algal blooms and what we can do to best respond, from the local to the national level.

Thank you, Mr. Chairman.

Senator SULLIVAN. Thank you, Senator Baldwin.

And we have the Ranking Member of the entire Commerce Committee, Senator Nelson. I know this is an issue that he cares about.

So, Senator Nelson, if you would like to make an opening statement, as well, the floor is yours.

STATEMENT OF HON. BILL NELSON, U.S. SENATOR FROM FLORIDA

Senator NELSON. Thank you, Mr. Chairman.

And may we insert into the Committee record letters that we have received from Floridians, which will document the extent that the harmful algae blooms have suddenly enveloped Florida into a green slime that then, when it goes down some of the freshwater streams and rivers, meets with a phenomenon that occurs of bacteria out in the Gulf of Mexico, called red tide, which appears periodically in the Gulf, but, when it moves close to shore, as the red tide has this year, and then is fueled by the extra nutrients in the water, causing the algae growth of the freshwater river, that supercharges the bacteria into what we are now experiencing, and that most people have seen, the dead fish and the dead mammals, which has been an additional plague on Florida this year.

Senator SULLIVAN. Without objection, with regard to the letters.

[The information referred to follows:]

HARBOR BRANCH—FLORIDA ATLANTIC UNIVERSITY

U.S. Senate,
Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard,
U.S. Sen. DAN SULLIVAN (Chairman).

Regarding: Hearing on Harmful Algal Blooms (HABs)

Dear Chairman and Honorably Committee members,

I would like to state for the record that I firmly believe the state of Florida is likely the most HAB impacted region in the United States in terms of 1) the variety of harmful algal species that routinely occur in Florida waters; 2) the number of major HAB events that occur on a yearly basis (with many different HAB species blooming in different areas of the state simultaneously); 3) both the areal size and duration of the different HAB events; and 4) the resultant range of different algal toxins (*e.g.,* brevetoxin, microcystin, saxitoxin, etc.) and other negative effects that occur with the blooms (*e.g.,* hypoxia/anoxia, massive fish/wildlife kills, seagrass and habitat loss, fisheries and recreational water closures, economic losses, etc.). And whiie the environmental and economic damage from these reoccurring HABs in Florida are both massive and devasting, and have garnered national media attention, I also believe there is a hidden (and likely major) public health crisis associated with these HABs that we are not close to understanding: *we do not fundamentally understand how the many different toxins produced by the many different HABs in Florida waters are directly affecting the short and long term health of our local human populations.* Exposure routes to toxins can come through the air, water and the food supply, and many people who live and work in active HAB regions may

have added exposure through occupational or recreational routes. In my opinion, in addition to increasing the technological capabilities and scientific research into a better understanding of the environmental drivers and monitoring of HABs, for the state of Florida, State and Federal agencies need to provide much greater resources into understanding the direct threat to public health with human epidemiology studies linked to our basic HAB research. My Institute and University (FAU–HBOI) is on the front line of what we believe is the first of such an effort in the state. We have founded the *Florida Center of Coastal and Human Health* to address the direct link between HAB exposure and human health. However, this is only the start, and without adequate resources, we will not be able to adequately protect and warn our populations about the potential risks to their health.

Sincerely,

JAMES M. SULLIVAN, PH.D.,
Executive Director,
Florida Atlantic University—Harbor Branch Oceanographic Institute.

NORTH SWELL MEDIA & CONSULTING
Jensen Beach, FL

Dear Senators,

Thank you for the opportunity to provide written testimony before the Senate Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard hearing entitled "Harmful Algal Blooms: The Impact on Our Nation's Waters."

My home state of Florida is currently ground zero for all things algae, and as a Floridian I believe this hearing presents a chance to bring to light this environmentally harmful event currently plaguing the state of Florida, while also discussing solutions that will provide relief to our businesses suffering financially, our aquatic life that is dying in record numbers, and Floridians and visitors experiencing health issues due to this environmental crisis.

This is neither the first nor the last occurrence of harmful algal blooms in Florida. In 2016, Florida had record rainfall that triggered the U.S. Army Corps of Engineers to release tons of polluted water East and West into the St. Lucie and Caloosahatchee estuaries. The Federal Government is considering a WRDA bill that includes authorization for a reservoir south of Lake Okeechobee, which will eventually clean and send much of this water south, reducing the size and frequency of polluted discharges into our rivers. However, it will not solve the underlying issue of the water being polluted in the first place.

One legislative solution would be to reauthorize the Harmful Algal Bloom and Hypoxia Research Control Act. Originally signed into law by President Clinton (P.L. 105–383) in 1998, HABHRCA and its subsequent reauthorizations have "reaffirmed and expanded the mandate for the National Oceanic and Atmospheric Administration *(NOAA)* to advance the scientific understanding and ability to detect, monitor, assess, and predict HAB and hypoxia events."[1]

While the Senate unanimously passed its version of reauthorizing legislation in September 2017, I implore each of you at the hearing today to have conversations with your respective delegations and to quickly take up and pass this legislation in the House of Representatives.

But while legislative solutions can bring about the necessary policy changes that will ultimately save our public's health, our fisheries, and Florida's unique tourism industry, overall funding levels for these programs must not be continuously debated and put on the chopping block.

As citizens concerned with the future of our environment and constantly running defense on environmental attacks by the current administration, we are counting on our Federal Government to protect our bedrock environmental laws and those agencies responsible for carrying out these laws. This year, President Trump's Fiscal Year 2018 Budget Proposal proposed a 25 percent cut to the Environmental Protection Agency (EPA), and over a billion dollars in cuts to NOAA.

Agencies like the EPA and NOAA provide science-based actions to protect our waterways, and decreased funding only undercuts preparedness and resilience. Thankfully, the President's budget proposal is just that-a proposal. House and Senate champions must continue to plus up agencies like the EPA and NOAA in order to continue our ability to actively defend against events such as harmful algal blooms

[1] NOAA National Centers for Coastal Ocean Science, Harmful Algal Bloom and Hypoxia Research and Control Act *Legislative History.*

and red tide. When the science isn't there, neither are the solutions to effectively get the region to "ounce back."

Sincerely,

TERRY GIBSON,
Principal.

August 10, 2018

To whom it may concern,

I am writing you this letter in concern for my family business, Snook Hut Bait & Tackle in Cape Coral, FL. My husband and I just bought our bait and tackle shop back in February of this year. We made this decision because up until then, he worked for a very large restaurant chain and the days/hours were very long tothe point we hardly ever saw him. We have 3 amazing children and they want and need their father around. So we decided to take what little we had saved up and buy the shop. Our family loves to fish, we wanted to have our family work together and to teach our children life values along with responsibility, dedication, loyalty and to show them bard work pays off. These days. kids think they are entitled to everything, nope, not in my house! We felt buying the shop was a win, win for us. We would get to be together working hard for a passion that we all have, fishing!

Our business was originally established back in 2014 and since then, there has been a continuous growth in revenue each year. Looking back through the books we are now at $30K+ LESS than that of the previous years (for the months of May through present). The red tide and algae bloom is destroying our business and has been for the past few months. If our business is not making money neither are we. This is a double edge sword for us.

It was mid season when we opened the store so things were going fairly well. We knew that summer time was coming and business would slow down so we knew that we would need to budget accordingly. However, we did not see or prepare to be where we are today. Today, I am panicking. We have lost so much money due tothe water quality and the fish die oft: We have had days not a sing1e customer to walk through our doors. This is heartbreaking and terrifying at the same time. We don't even have the money to pay our rent for the shop, let alone all the other monthly bills that are due every month. This shop is my family's livelihood and these past few months we have not been able to bring any money home. We are not only on the verge of losing our business but we are now facing possibly loosing our home. The business money i, not there and we used what litt1e we had of our personal money to help with the businesses bills but now we are drained, both personal and business. We need help!!!! Please help us!

On days that we do get a customer in, they are here on vacation and they tell us how they will never come back down here. This is devastating to hear. It's this time of the year where you rely on your loyal customers. But none of them are out fishing because of the conditions of the water, so the only people that occasionally come in are people visiting. So to hear them talk about how horrible our area is, and how they will never be back is disturbing. If things remain the way that they are, we wont be open for them to come back even if they decided to give our area a second chance.

All those hundreds and thousands of dead fish due to the red tide and algae bloom decided not to go alone, they have taken all my business along with them along with many other businesses in the area. I am really hoping and begging for relief down here. This is drastically affecting so many small businesses and families in so many ways. Our bait and tack1e shop is all my family has.

Every bit of what has taken place here ALL stems from the Okeechobbee release water. That water being released has caused a MAJOR CRISIS, to small businesses like mine and we all need your help. Please help as!

Truly,

CHRISTINE MILLER,
Snook Hut Bait & Tackle.

TREASURE COAST DEMOCRATIC ENVIRONMENTAL CAUCUS OF FLORIDA
Stuart, FL, August 22, 2018

Senate Commerce Subcommittee,
Oceans, Atmosphere, Fisheries and Coast Guard,
Washington, DC.

Senators,

I am writing to you in an effort to address the current algae bloom occurring on both Florida's East and West Coast due to discharges from Lake Okeechobee. The bloom species on both coasts are toxic. More than 300mt of marine fish, dolphins, manatees, turtles have died.

We have yet to fully understand the short and long term effects of these toxic algal blooms to human health but the increase in emergency room patients during this timeline is discerning. The toxic algae has been linked to hepatic cancer and neurological diseases as Alzheimer and Lou Gehrig's disease.

The lost of tourism and fishing has been devastating. We do not yet know of the long term loss to fishing & tourism which are ranked Nr. 1 and 2 in the state as people look to alternate vacation plans in the future.

We do not expect the current bloom to subside until November 2018, when the dry season begins. This means that full time residents will have been exposed to the algal toxins for approx ½ year.

We are asking the Senate for:

1. Pass the Bill to provide funds as part of the Federal Government's 50:50 partnership to build Southern Reservoir, south of Lake Okeechobee.
2. To include in the directive to the Army Corps of Engineers, that a component of their decision should be the health of citizens who are exposed to polluted water when discharges to the East and West occur. It cannot only be the safety for the citizens living near the Lake Okeechobee dike from a breech.
3. Additional funding for monitoring nutrient runoff a main source of food for the algae to local communities.

Thank you for your consideration of this request.

Sincerely,

PAUL LAURA,
Chair,
Treasure Coast Democratic Environmental Caucus.

BREVARD COUNTY BOARD OF COUNTY COMMISSIONERS
Viera, FL, August 23, 2018

Re: Impact of Harmful Algal Blooms on the Indian River Lagoon, Brevard County, Florida

Dear Senate Commerce Subcommittee on Oceans, Atmosphere, Fisheries and Coast Guard,

Thank you for holding this hearing on the impacts of Harmful Algal Blooms (HABs) to our Nation's precious water resources and the citizens, businesses, communities and who depend on clean water for healthy living and prosperous economies.

Brevard County has experienced direct impacts of HABs over the past several years resulting in the rapid decline in health of the Indian River Lagoon (IRL), an estuary of national significance and local ecological treasure. Algal blooms, fueled by excessive levels of nutrients in the IRL, appear to be increasing in frequency and magnitude and have manifested in expansive seagrass loss, increased occurrence of fish kills, and greater potential for toxin exposure in the aquatic environment. A suite of HAB species in the IRL have contributed to the detrimental impacts endured by Brevard County in recent years, including a "superbloom" of green algae and cyanobacteria in 2011, a recurring brown tide *(Aureoumbra lagunensis)* that has bloomed six of the last eight years in Brevard waters, and interspersed major blooms of the potential toxin-producing red tide species *Pyrodinium bahamense.*

Prolonged blooms of these harmful algal species have severely impacted light penetration in the IRL, resulting in the loss of tens of thousands of acres of vital seagrass. As the "lifeblood of the lagoon", the reduction in seagrass habitat represents an estimated $235 to $470 million in commercial and recreational fisheries losses in the IRL since 2011. Additionally, elevated biomass of algal blooms has increased the occurrence of hypoxic and anoxic events in the IRL as oxygen in the

water column is consumed during algal die-offs. In 2016, Brevard experienced a record breaking fish kill and has endured numerous localized fish kills and other marine species mortalities during the past 8 years. Brevard also faces the increased potential for toxin exposure in the IRL as saxitoxin-production by the dinoflagellate species *Pyrodinium bahamense* poses a potential threat to human health. There is currently an IRL-wide ban on the taking of pufferfish due to human ingestion of toxins from pufferfish caught in Brevard waters in 2002.

HABs in Brevard have also affected public perception regarding quality of water in the IRL, potentially affecting tourism and property values. The IRL is an important economic resource to the state, providing an annual economic value of $7.6 billion, supporting over 71,000 IRL-related jobs and providing recreational opportunities for 7.4 million people annually, according to a 2016 economic valuation update.

The ecological crisis facing the IRL spurred Brevard County voters in 2016 to impose upon themselves a half-cent sales tax to raise funds to implement projects identified as critical to IRL restoration. While the half-cent sale tax for the lagoon is expected to generate nearly $500M over the next decade, State and Federal matching funds are essential to fully fight this problem and restore the health of the IRL. The longer it takes to raise funds and implement projects, the greater the risk of surpassing the ecological tipping point where-after HAB impacts may be unstoppable or significantly more difficult to mitigate.

We greatly appreciate the renewed interest in researching HABs. We need to better understand their causes, their impacts, and how to stop them. We need better tools to monitor HABs, more research on the harmful epidemiological impacts to humans and wildlife, better communication for informing people of human health concerns, and better technologies for preventing and mitigating blooms current and future blooms.

Thank you again for the opportunity to provide input on this topic of high interest and importance to our community. We will do our best to answer any questions you may have regarding local impacts of HABs on Brevard County.

Sincerely,

VIRGINIA BARKER,
Director,
Brevard County Natural Resources Management Department.

Cocoa Beach, FL, August 23, 2018

Thank you for allowing me the opportunity present my concerns to the Senate Commerce Subcommittee on Oceans; Atmosphere, Fisheries and Coast Guard about Harmful Algae Blooms (HABs).

I live in Brevard County, one of the areas effected by harmful algae blooms. I am co-leader of the Space Coast Chapter of Citizens' Climate Lobby. I am a concerned environmental voter.

When deciding where to retire, my husband and I chose Cocoa Beach in Brevard County because of its natural beauty. We wake up to the sunrise over the Atlantic and in the evening we can see the sunset over the Banana River lagoon. Regrettably, more than the beauty of nature is threatened by HABs. The invasion by HABs into the Indian River Lagoon (IRL) has reached a point of ecological crisis, threatening marine life, human health and drinking water.

The situation can be seen easily in the following photos:

Fish Kill March 25, 2016.*(CNN)*
https://www.cnn.com/2016/03/25/us/florida-fish-kill/index.html

"In the preceding January, parts of central Florida received triple the amount of rain they normally do for the month. All that rainwater eventually made its way into estuaries via urbanized neighborhoods, picking up fertilizer and other pollutants along the way. But that's not all.

Temperatures were warmer than usual during the winter, allowing a toxic algae bloom and brown tide to deplete the water of oxygen."

A second smaller fish kill occurred in April 2018. Current levels of bacteria are comparable to the levels that accompanied the 2016 fish kill.

The next photo was published in Florida Today on March 2, 2018.

The third picture from Florida Today 5/7/2018 shows red algae that turned the lagoon the color of tomato soup.

Unfortunately, these pictures are typical of the color of the lagoon in recent years. HABs are much worse now than ever previously recorded. NOAA, *http://www.noaa.gov/what-is-harmful-algal-bloom,* gives us explanations as to the ways human activity has set the stage for HABs.

"HABs occur naturally, but human activities that disturb ecosystems seem to play a role in their more frequent occurrence and intensity. Increased nutrient loadings and pollution, food web alterations, introduced species, water flow modifications and *climate change* all play a role. Studies show that many algal species flourish when wind and water currents are favorable. In other cases, HABs may be linked to "overfeeding." This occurs when nutrients (mainly phosphorus and nitrogen) from sources such as lawns and agriculture flow into bays, rivers, and the sea, and build up at a rate that "overfeeds" the algae that exist normally in the environment. Some HABs appear in the aftermath of natural phenomena like sluggish water circulation, unusually high water temperatures, and extreme weather events like hurricanes, floods, and drought."

My request is that when you look into what needs to be done to restore the IRL to health that you consider the role climate change has on the lagoons' and oceans' ability to sustain life.

Not only do we need to restrict overfeeding of nutrients and upgrade our aging sewage infrastructure, but we have to lessen the effects of climate change. The science is simple. Climate change causes droughts which change the flow of water in the lagoons. Additionally climate change causes short intense periods of deluges. These sudden intense periods of rain stress sewer systems and exacerbate nutrient runoff.

Atmospheric levels of CO_2 need to be brought down to 350 ppm. Laws need to be passed that would make fossil fuel consumption more expensive. The best way to achieve this would be to put a revenue neutral price on carbon.

I thank you for your efforts to study and find solutions that will repair our endangered waterways.

JOYCE WASSERMAN,
Space Coast Chapter of Citizens' Climate Lobby.

August 24, 2018

Subject: Comments from START (Solutions to Avoid Red Tide)

Dear Senator Nelson

As the Chairman/CEO of START (Solutions To Avoid Red Tide), I am very concerned about the prolonged toxic red tide bloom that has plagued the west coast of Florida since February. It now stretches from Sanibel Sound to Tampa Bay. In its wake the beaches are piled with dead sea life from fish to sea turtles and manatees. Beach goers are a rare sight as people stay away to avoid the chronic coughing and running eyes from the airborne toxins. Local restaurants and hotels are reporting a 40 percent drop in business. Red tide now an environmental, social and economic disaster.

Many environmentalists and others involved with the marine environment attribute the longevity and severity of this bloom to the release of nutrient rich water from Lake Okeechobee. This obvious major source of unwanted nutrients is especially suspicious this year because the west coast is now also getting slimy green algae, a fresh water variety that is a signature of Lake Okeechobee.

For years, environmentalists and scientists have advocated for a "Water South" policy that ends the dumping of Lake Okeechobee's polluted water into our rivers. The current crisis requires the initiation of an integrated water system that runs future Lake releases through Stormwater Treatment Areas (STAs) on purchased sugar land that will filter it so it can be effectively used as a much needed water source for the drying portions of the Everglades.

It's time for our Federal and state policy makers to work with the sugar industry to create the necessary land access that can support the water management system that will end these perennial disasters.

SANDY GILBERT,
Chairman/CEO,
START.

FLORIDA REALTORS®
Tallahassee, FL, August 24, 2018

ATTN: Honorable BILL NELSON,
United States Senate,
Washington, DC.

Dear Senator Nelson,

On behalf of more than 185,000 REALTORS in Florida, represented by local REALTOR boards, we write to lend our strong support for this year's Water Resources and Development Act (WRDA) package, S. 2800, America's Water Infrastructure Act of 2018. This legislation includes funding authorization for critical pieces of the Central Everglades Restoration Plan (CERP) which will help address the blue green algae blooms contaminating Florida's waterways and beaches.

The algae blooms are creating an environmental disaster that is causing difficulties for constituents in our great state. These blooms are hurting local economies, impacting housing markets, and causing health concern for numerous Floridians. The crisis is real, and we need your help to prevent it from growing.

If the WRDA legislation is brought to the U.S. Senate floor, and ultimately passed, it would assist with the algae crisis by advancing the planning, design, and construction of the Everglades Agricultural Area Storage Reservoir project. This project will significantly increase water manager's capacity to divert damaging discharges away from the coasts for storage, treatment, and release into the Everglades.

As you and many of your colleagues know, the solution to America's largest environmental restoration plan does not hinge on one specific project. However, the passage ofWRDA is a key piece of a larger initiative to bring normalcy to Florida's citizens and the businesses that line the impacted waters. The WRDA bill needs to be brought to a vote in the U.S. Senate to provide Florida with access to the additional Federal resources needed to help solve this crisis. We stand ready to assist you in any way possible to make this happen.

The State of Florida has recently established a dedicated funding source to pay its portion of CERP. Now we need your help to spur Congress into action on WRDA

bill. This bill has the capacity to provide relief for millions of Floridians and their communities, and we look forward to your support in achieving its passage.

Sincerely,

CHRISTINE HANSEN, CIPS, CRB, GRI,
President,
2018 Florida Realtors®

CH:ds

Eric Sain, CIPS, GRI, 2018 Florida Realtors® President-Elect
Barry Grooms, 2018 Florida Realtors® Vice President
Cheryl Lambert, SFR, 2018 Florida Realtors® Treasurer
Christina Pappas, 2018 Florida Realtors® Secretary
Bill Martin, RCE, 2018 Florida Realtors® CEO

L. Michele Holbrook
Amelia Island-Nassau County Association of REALTORS®

Erin Clements
Bartow Board of REALTORS®

Joseph Pavich Sr.
Bonita Springs-Estero REALTORS®

Marvin Puryear
Central Florida Commercial Association of REALTORS®

John McCrory
Central Panhandle Association of REALTORS®

Lars Kier
Central Pasco Association of REALTORS®

Debra Callahan
Daytona Beach Area Association of REALTORS®

Robin Schwartz
Dixie-Gil-Levy County Board of REALTORS®

Adam Grenville
East Pasco Association of REALTORS®

Manuel Quiros
East Polk County Association of REALTORS®

Liz McMaster
Emerald Coast Association of REALTORS®

Kathi Obendorfer
Englewood Area Board of REALTORS®

Steven Klein
Fla Gulfcoast Commercial Association of REALTORS®

G. Martin Brabham
Flagler County Association of REALTORS®

Rhonda Brewer
Florida Keys Board of REALTORS®

Susan McQuillan
Gainesville-Alachua County Association of REALTORS®

Mari Colgan
Greater Tampa REALTORS®

Rona Port
Heartland Association of REALTORS®

Edward Hirst
Hernando County Association of REALTORS®

Will Langley
Key West Association of REALTORS®

William Golightly
Lake City Board of REALTORS® Heidi Gravel

Heidi Gravel
Lake Wales Association of REALTORS®

J Kyle Vreeland
Lakeland Association of REALTORS®

David Grego
Marathon & Lower Keys Association of REALTORS®

Gary Elliott
Marco Island Area Association of REALTORS®

H B Warren
Martin County REALTORS® of the Treasure Coast

George Jalil
Miami Association of REALTORS®

Richard Baranski
Naples Area Board of REALTORS®

Lorie Coogle
Navarre Area Board of REALTORS®

John Schmidt
New Smyrna Beach Board of REALTORS®

Ben Bates
Northeast Florida Association of REALTORS®

Steve Rudnianyn
Ocala/Marion County Association of REALTORS®

Cristie Schmidt
Okeechobee County Board of REALTORS®

Louis Nimkoff
Orlando Regional REALTORS® Association

Daniel Hernandez
Osceola County Association of REALTORS®

Suzanne Frisbie
Palm Beach Board of REALTORS®

Deborah Mays
Pensacola Association of REALTORS®

Paul Hendriks
Pinellas Suncoast Association of REALTORS®

Rosemary Mahoney
Punta Gorda/Port Charlotte/North Port Association of REALTORS®

Christopher Dixon
REALTORS® Association of Citrus County

Sabrina Burke
REALTORS® Association of Franklin & Gulf Counties

Hollie Billero Buldo
REALTORS® Association of Indian River County

Abigail Carr
REALTORS® Association of Lake & Sumter Counties

Ronald Lennen
REALTORS® of the Palm Beaches & Greater Fort Lauderdale

Greg Owens
REALTORS® Association of Sarasota and Manatee

Donna Guido
Royal Palm Coast Realtor Association

Dustyn Corace
Sanibel & Captiva Islands Association of REALTORS®

Donald Sarley
South Broward Board of REALTORS®

Michael Artelli
Space Coast Association of REALTORS®

M. Dianne Pittman
St. Augustine & St. Johns County Board of REALTORS®

Will Shepherd
Tallahassee Board of REALTORS®

Steven LaFountain
Venice Area Board of REALTORS®

Kenneth Anderson
West Pasco Board of REALTORS®

Candace Cecil
West Volusia Association of REALTORS®

TO: Senate Commerce Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard

FROM: Kimberly Streiber—Martin County FL Resident & Parent

August 25, 2018

Hello,

I am a fifth generation Native of Florida who has always loved and enjoyed nature and the outdoors. I am approaching my 43rd Birthday. I have watched water conditions deteriorate in my hometown my entire life because of lake Okeechobee discharges. Entire sea grass beds have died, oyster populations have been decimated to nonexistence and fisheries that once flourished have become decimated. The worst impact has been over the last 10 years with the onset of harmful toxic algal blooms, which are in fact Cyanobacteria blooms that contain a toxin called Microcystin. This toxin has been tied to ALS (Lou Gehrig's disease) Alzheimer's disease, liver cancer, and nonalcohol related liver failure. It has also been noted as causing cancer in humans by the International Agency for Research. Our economy is suffering, businesses that rely on the water, especially during the summer no longer have a prosperous season to look forward to each year. The dangers and affects these blooms have had on our own, the health of the residents who live here,. 8nd the economy show more and more each year. We no longer call the time from May to October Summer here, we call it Algae Season!

We pray that the toxic green slime that covers our waterways will not poison us or our children beyond recovery, but have educated ourselves enough to know better. Many people have moved away to avoid it, many who have just moved here and bought water front property for high dollar prices are extremely upset they were not warned about existence and issues that come with fresh water discharges from Lake Okeechobee. We have a higher rate of liver cancer, and several cancers, here on the Treasure Coast than many other places in the country. I myself have suffered with and battled the disease on three separate occasions within the last 5 years. My first experience was with thyroid cancer, then a bone tumor that caused me to require a full hip replacement at the age of 40, and lastly a brain tumor that also required invasive surgery that has left me unable to do the same work and earn the same level of income that I once did. As a single mother, I am left struggling to provide the life that my son was promised and doesn't fully understand why at only 11. Our largest local healthcare provider Martin Health Systems has posted signs in all facilities asking patients if they have been exposed to the water or to the Cyanobacteria and has incorporated in into standard intake questioning for all patients. Our local authorities have placed permanent signage at all public beach and recreational water access points warning people to stay away if algae are visible in the water. Most of our public beaches are closed this weekend due to the issue. You can't go to a park near the water because the toxins are airborne, and you will come home with a raw sore throat, itchy red eyes, stomach issues, and stiff joints, at least those are the symptoms I experience immediately upon breathing air near bodies of water containing the discharges.

These discharges and the toxic cyanobacteria that comes with them have devastated every town they touch, and they are quite literally killing what was once deemed the happiest Seaside town in FL. Please, we beg of you, make it stop! Do whatever you can to help us, it is your civic duty to protect the people of this country. We are desperate for help here!

Sincerely,

KIMBERLY R. STREIBER.

NATIONAL CENTER FOR INTEGRATED COASTAL RESEARCH
UNIVERSITY OF CENTRAL FLORIDA
August 26, 2018

Hon. JOHN THUNE,
Chairman,
Senate Committee on Commerce, Science, and Transportation,
Washington, DC.

Hon. BILL NELSON,
Ranking Member,
Senate Committee on Commerce, Science, and Transportation,
Washington, DC.

Dear Chairman Thune and Ranking Member Nelson,

Coastal and waterfront communities depend on clean water as the foundation of a healthy and growing economy. Tourists from around the world are drawn to clean and pristine beaches, lakes, and other waterways, and local communities benefit from the economic boost that tourists spend in hotels, restaurants, and shops. Similarly, residents of waterfront communities regularly use beaches and other waterways for recreation and community-building. In short, clean water is the thread that ties waterfront communities together, drives their economies, and provides a high quality of life for residents and an unforgettable experience for visitors.

In many waterfront communities across Florida, widespread Harmful Algal Blooms (HABs) are severely impacting water quality and are having a deleterious chain impact on local economies and human health. HABs occur when colonies of photosynthetic microorganisms that live in fresh or saltwater grow out of control and produce toxins that can have harmful effects on people or wildlife. In recent years, the state of Florida has experienced several HABs, most notably outbreaks of red tide *(Karenia brevis),* brown tide *(Aureoumbra lagunensis)* and blue-green algae *(Microcystis spp.* and *Anabaena spp.*).

While our coastal communities have proven resilient to HABs in the past, the current blooms appear to be larger and more devastating than previous events. On Florida's southeast coast, massive blooms of blue-green algae emerged in June and have clogged waterways on and off since then. Satellite imagery from NOAA has shown that the bloom of blue-green algae first emerged on Lake Okeechobee, and locals attribute the emergence of the bloom to discharges from Lake Okeechobee into the St. Lucie River. The latest NOAA satellite image-from August 17-shows that blue-green algae continues to flourish in Lake Okeechobee, with algae visible in nearly 50 percent of the lake's surface, and that in the past few days it has reappeared in the St. Lucie River threatening a repeat of 2016.

The situation on Florida's southwest coast is even worse. Discharges from Lake Okeechobee into the Caloosahatchee River have also taken the blue-green algae to west Florida's beaches and waterways, creating a similar situation as in the southeast coast. However, the situation is compounded by an unprecedented outbreak of red tide that has moved into the region's beaches and waterways from the Gulf of Mexico.

Communities in southwest Florida are experiencing two different types of HABs: blue-green algae originating inland in Lake Okeechobee, and red tide originating offshore in the Gulf of Mexico. Visit Florida, the state's tourism development agency, recently started surveying businesses in affected southwest Florida counties to gauge their levels of economic losses. So far, $8 million in losses attributable to the current HABs have been reported. In addition, local governments and volunteer organizations have cleaned up more than 2,000 tons of sea life-fish, manatees, dolphins, and turtles—that have washed up on the region's beaches.

This year's unprecedented HABs on both coasts have significantly impacted local economies, public health, and the environment. A crisis that our partners on the ground describe as "the hurricane that has stayed with us for months" is likely to have long-lasting impacts on residents' well-being and may also damage Florida's brand as a world-class tourism destination. The crisis is already taxing local governments that are still in recovery mode from last year's hurricane Irma. And the worst part is that we don't know when the blooms will end. Furthermore, members of our group, and others, have recently shown that there is a direct relationship between blue-green algae and marine pathogenic bacteria from a family that includes the bacterium that causes cholera and another flesh-eating bacterium native to coastal Florida. We are legitimately concerned that these algal blooms might subsequently lead to the proliferation and dispersal of these pathogenic bacteria in our coasts or potentially contaminate our water supply during hurricane season.

The mission of the National Center for Integrated Coastal Research, located at the University of Central Florida, is to assess natural and human-related impacts to the health, restoration, and sustainability of our coastal systems and to conduct long-term, integrated, interdisciplinary research and we stand ready to assist in any way we can. The Center brings together over 40 faculty in 12 Departments and 7 Colleges including biologists, chemists, engineers, and biomedical researchers working together with anthropologists, sociologists, political scientists, planners, emergency managers, and economists. Our ultimate goal is to integrate science with societal needs and thereby guide more effective economic development and planning, environmental stewardship, hazard mitigation planning, and public policy development. In the end we aim to ensure the economic and ecological health of coastal communities.

We applaud the Committee's willingness to take on this important issue, and ask Congress to provide assistance to our state agencies and local governments in their clean-up and recovery efforts.

Sincerely,

GRAHAM A.J. WORTHY,
Department Chair and Pegasus Professor, Director,
National Center for Integrated Coastal Research,
Provost's Distinguished Research Professor of Biology, and
Hubbs-Sea World Endowed Professor of Marine Mammalogy,
University of Central Florida.

TAMPA BAY REGIONAL PLANNING COUNCIL
Pinellas Park, FL, August 26, 2018

Senator BILL NELSON,
Senate Office Building,
Washington, DC.

RE: Harmful Algal Blooms

Dear Senator Nelson,

The Tampa Bay Regional Planning Council remains concerned about Harmful Algal Blooms in the Gulf of Mexico along Florida's west coast. We have conducted research indicating that the Tampa Bay regional economy would be significantly impacted by such an event and that prolonged exposure of such blooms would negatively impact the competitiveness of the region's economy.

Harmful Algal Blooms (HABs), otherwise known as Florida Red Tide, have direct impacts on the Tampa Bay regional economy. While direct impacts occur primarily In Gulf coast areas, there are also indirect impacts on the region's economy, the second largest in the State Florida at 157 billion dollars.

According to a Florida Department of Health summary *report.* HABs impact Floridian's through respiratory illnesses, pneumonia and gastrointestinal Illnesses that often times require hospital stays. These hospital stays also result in loss of work that is exacerbated by losses to tourism due to beach closures and recreational marine activity. Fish kills reduce fishery sales and require clean up by local government. Together, these impacts result in millions of dollars of losses. The report's findings are based on collected survey data. We used the report's estimates to extrapolate an inflation adjusted estimate of HAB's economic impacts to the Tampa Bay region. Each week HAB's are present they inflict an estimated $1 million dollars of direct and indirect damage to the Tampa Bay economy, especially the economies of Pinellas and Manatee counties.

Sincerely,

SEAN T. SULLIVAN,
Executive Director.

SAVE THE MANATEE® CLUB
Maitland, FL, August 26, 2018

Senate Commerce Subcommittee on Oceans, Atmosphere, Fisheries and Coast Guard

Honorable Senators,

I write to you today on behalf of Save the Manatee Club's 33,000 nationwide members who are gravely concerned about the impacts of harmful algal blooms on Florida's threatened manatees.

As of August 20th, 103 manatees are believed to have died from the red tide that continues to threaten roughly 145 miles of shoreline along the coasts of Manatee, Sarasota, Charlotte, Lee, and Collier counties in Southwest Florida. Still more manatees are victims of the toxic cyanobacterial bloom associated with discharges from Lake Okeechobee. Together, these algae blooms consume oxygen from the water, cause respiratory and neurological distress, and kill acres of aquatic vegetation essential to manatee survival. A third harmful algal bloom periodically occurs and contributes to unusual manatee mortality events in the Indian River Lagoon.

It is imperative to acknowledge that while red tides do occur naturally, the frequency a, intensity of recent events are firmly attributable to human activity. Land-based nutrients feed red tides, which are further exacerbated by the deluge released from Lake Okeechobee. The sources of these nutrients are many. Septic systems, agricultural fertilizer, animal waste, and urban runoff are poorly managed throughout the state and end up in our lakes, springs, rivers, and coastal systems where they fuel the toxic bloomers that threaten both natural and economic resources.

These blooms have been brewing for years. The root cause of both is poor management of water resources. It is essential that robust nutrient management schemes be implemented alongside measures to conserve water to maintain the integrity of natural systems. Clean water and the protection of our Nation's wildlife are non-partisan issues, and we need leaders who understand the importance of preserving these resources.

Please accept our sincere thanks for your attention to this matter, with particular gratitude to Senator Nelson for seeking the public's input for this hearing.

Regards,

ANNE HARVEY HOLBROOK,
Staff Attorney,
Save the Manatee Club.

ASSOCIATION OF NATIONAL ESTUARY PROGRAMS
Washington, DC, August 27, 2018

Senator JOHN THUNE,
Chairman,
Committee on Commerce, Science, and Transportation,
United States Senate.

Senator BILL NELSON,
Ranking Member,
Committee on Commerce, Science, and Transportation,
United States Senate.

Senator DAN SULLIVAN,
Chairman,
Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard,
Committee on Commerce, Science, and Transportation,
United States Senate.

Senator TAMMY BALDWIN,
Ranking Member.
Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard,
Committee on Commerce, Science, and Transportation,
United States Senate.

Dear Chairmen Thune and Sullivan, and Ranking Members Nelson and Baldwin,

On behalf of the Association of National Estuary Programs we write to strongly commend your efforts to better understand and address the crippling impacts of harmful algal blooms (HABs) on coastal waters and coastal communities along all of our coasts, including the Great Lakes.

By convening a panel of renowned experts on this topic for your August 28th hearing, you are underscoring the serious nature of HABs and their potentially devastating impacts on coastal economies as well as wildlife. Reported human health impacts include coughing and irritation, and can pose a particular problem among those with asthma or other respiratory ailments.

We are attaching a fact sheet that we hope you find helpful as you examine the underlying causes of HABs, especially the red tide impacting the Florida coasts, and most importantly what steps must be taken to prevent the most serious impacts of these phenomena.

The Association of National Estuary Programs coordinates efforts of the 28 National Estuary Programs, a unique, voluntary, non-regulatory program established in 1987 and reauthorized in 2016 through the Clean Water Act and administered by the Environmental Protection Agency to protect and restore water quality and ecological integrity of estuaries of national significance.

In the 2016 reauthorization of the NEP, Congress directed EPA to establish a competitive fund to, among other things, specifically address recurring HABs. In 2018 Congress provided $1 million for this competitive fund.

Several NEPs have played a pivotal role in helping communities, states, and private citizens address the impact of HABs. Currently two NEPs in particular, the Sarasota Bay National Estuary Program and the Charlotte Harbor National Estuary Program, find themselves on the front lines in confronting this complex phenomena. Both are in the stretch of Florida coast that is experiencing one of the longest and most serious red tide events, a type of harmful algal bloom (HAB), resulting from the proliferation of Karenia brevis, an algal species typically found in low concentrations in off-shore coastal waters.

It is widely accepted that human activities can exacerbate most harmful algal blooms, including red tides. Habitat degradation and loss, nutrient pollution in runoff from developed landscapes (urban, residential, and agricultural), and other factors may stimulate and worsen HABs.

As noted in the attached fact sheet, when we invest in America's estuaries through the National Estuary Programs, we get cleaner water and thus minimize nutrient pollution that can worsen the frequency, duration, and extent of red tides and other harmful algal blooms in the future. These investments include:

1. Reducing nutrient pollution entering our waters from all sources: runoff from urban, suburban, and agricultural landscapes, point-source discharges; & atmospheric deposition on land & water (*i.e.,* air pollution that falls, often in rain, snow, and dusts).
2. Conserving and creating natural coastal habitats like oyster reefs, mangroves, marshes, and fresh-water wetlands that remove nutrient pollution and provide other valuable ecosystem services.
3. Investing in water infrastructure such as sewage treatment, and engineering stormwater facilities that mimic the ecosystem services provided by natural habitats to remove nutrient pollution from runoff before it can reach our coastal waters.

Again, we applaud your focus on HABs as a major environmental problem found in all 50 states across the Nation. HABs are taking their place alongside global coral bleaching, ocean acidification, rising sea levels and extreme weather events as having severe impacts on human health, fresh and salt water ecosystems, and the economies that depend on them.

ANEP and its 28 programs stand ready to assist you and your committee as you confront this daunting challenge.

RICH INNES,
Association of National Estuary Programs.

ANEP Update: Winter 2018

THE ASSOCIATION OF National Estuary Programs

America's Estuaries of National Significance - Looking to the Future

Innovative Leadership

The National Estuary Program (NEP) was created by Congress in 1987 as a non-regulatory, core program of the Clean Water Act (Section 320) to address complex environmental and economic threats facing estuaries of national significance. Estuaries support natural resources, built infrastructure, and tourism that provide a foundation for the U.S. coastal economy.

Strategic Partnerships

Trusted by private- and public-sector partners and local and state governments, the NEP has established a 30-year track record of success to protect and restore our national estuaries using strategic and innovative approaches to build consensus and solve problems.

Productive, Effective & Efficient

NEPs implement specific actions based on the best available science and a *Comprehensive Conservation and Management Plan* to improve water quality, manage public lands and waters, update critical coastal infrastructure, and reduce the risks, impacts, and costs of coastal flooding and storm events. For every dollar EPA provides, NEPs leverage $19 in local funds to protect and improve coastal environments, communities, and economies.

The NEP: Recognized for its Value to the Nation

With bipartisan leadership in 2016, the U.S. Congress reauthorized the NEP, strengthened the commitment to on-the-ground activities while cutting administrative costs, and established a new competitive grants program to address emerging issues that threaten the ecological and economic well-being of coastal areas.

100% of NEPs implement CWA core water programs.

The coastal population (more than 52% of the U.S. total) is growing, increasing future risks and costs.

Estuaries are economic centers in coastal states, which help deliver more than 80% of U.S. employment and GDP (NOEP, 2016).

Nutrient pollution is one of the most widespread, costly, and challenging environmental problems in the U.S.

Harmful algal blooms are a major environmental and economic problem in all coastal states.

Despite their environmental and economic importance, East Coast wetlands are being lost at twice the rate they are being restored.

Critical infrastructure is at risk along coastlines from storm surge, sea level rise, erosion, and flooding.

NOEP, 2016. State of the U.S. Ocean and Coastal Economies 2016 Update. www.oceaneconomics.org/download/

Representing 28 NEPs nationwide, the Association of National Estuary Programs thanks our Congressional leaders, EPA, and our state and local partners for their continued support of the National Estuary Program!

ANEP coordinates information exchange among NEPs and works to enhance program effectiveness nationwide. Each year, ANEP convenes a national tech-transfer meeting with the 28 NEP directors, NEP support staff, EPA representatives, and key partners. This year, discussion focused on the destructive 2017 hurricane season and NEP actions that could provide enhanced benefits, risk reduction and resilience to our NEP communities, estuaries, and watersheds.

Four Priority Issues and Actions were Identified.

1: **Healthy Estuaries Fuel the Nation's Economy**
The continued prosperity that coastal communities and the nation reap from coastal industries like transportation, construction, fishing, and tourism is clearly linked to estuary health, clean water and sustainable natural resources. **NEP ACTION: Coordinate and update economic value and return-on-investment assessments for all NEP estuaries pursuant to CCMP guidance.**

2: **Resilient Infrastructure Protects Community Prosperity, Public Safety, and Estuary Health**
Prosperous 21st century coastal communities *must* plan for and build resilience in their natural and human-built infrastructure. NEP estuaries are home to some of America's critical infrastructure assets: Deep-water ports and their global transportation networks; Energy, water and wastewater infrastructure; Military bases; and even NASA's public-private partnership for commercial space exploration. Many U.S. coastal infrastructure assets are aging, inadequate to support projected coastal population growth, and at risk to damage from storms, flooding, and sea level rise. **NEP ACTIONS: Implement and update risk-based community vulnerability assessments, and integrate green and gray infrastructure into community planning.**

3: **Expanding NEP Connections to Innovation, Industry, and Other Partners**
Private-sector industry is an important partner to NEPs to drive technological innovation, create jobs, and solve complex problems. From resilient coastal construction techniques to smart sensor technologies for water quality monitoring, the NEP plays an important leadership role in expanding private-sector participation in technology research, development, and commercialization. **NEP ACTION: Expand and diversify industry participation in NEP activities with a focus on innovation, new technology development, and market-based solutions to complex problems.**

4: **Sharing the Successful NEP Management Conference Model**
NEPs support and convene partners through a unique Management Conference model that builds consensus and collaboration between all levels of government, the scientific community, private industry, and citizens. **NEP ACTION: Continue to be a science-based information resource to communities nationwide, including those exploring how to apply the NEP model in other estuaries and elsewhere.**

See *Nationalestuaries.org* for more information.

Florida Red Tide (*Karenia brevis*) Impacts and How the National Estuary Programs Can Help

What is the current Florida red tide event?

Florida's current red tide event, a type of harmful algal bloom (HAB), results from the proliferation of *Karenia brevis*, an algal species typically found in low concentrations in offshore coastal waters.

Karenia brevis can move toward shore and reach bloom concentrations in response to factors that are physical (*e.g.*, tides, currents, and water temperatures), chemical (*e.g.*, nutrients and salinity), and biological (*e.g.*, outcompeting other algal species).

Human activities can exacerbate most harmful algal blooms, including red tides. Habitat degradation and loss, nutrient pollution in runoff from developed landscapes (urban, residential, and agricultural), and other factors may stimulate and worsen HABs.

Florida red tides are known to:

- Produce a toxin (brevetoxin) that can: 1) make people sick; 2) kill fishes, shellfishes, marine mammals, and birds; and 3) make shellfish unsafe to eat.
- Create low-oxygen "dead zones" that worsen already adverse conditions; and
- Hurt local economies through lost commerce, recreation, and tourism.

Image: Florida FWC, myfwc.com/redtide

What is being done to combat harmful algal blooms, including red tides, in Florida and throughout the nation through NEPs?

When we invest in America's estuaries through the National Estuary Programs, we get cleaner water and thus minimize nutrient pollution that can worsen the frequency, duration, and extent of red tides and other harmful algal blooms in the future. These investments include:

1. **Reducing nutrient pollution entering our waters from all sources**: runoff from urban, suburban, and agricultural landscapes, point-source discharges; & atmospheric deposition on land & water (*i.e.*, air pollution that falls, often in rain, snow, and dusts).
2. **Conserving and creating natural coastal habitats** like oyster reefs, mangroves, marshes, and freshwater wetlands that remove nutrient pollution and provide other valuable ecosystem services.
3. **Engineering stormwater facilities that mimic the ecosystem services provided by natural habitats** to remove nutrient pollution from runoff before it can reach our coastal waters.

Image: Charlotte Harbor National Estuary Program, www.chnep.org

To learn how the Association of National Estuary Programs assists these efforts, visit nationalestuaries.org.

Florida Red Tide (*Karenia brevis*) Impacts and How the National Estuary Programs Can Help

Where can I find reliable sources of information about Florida red tide and other harmful algal blooms?

Status updates (Florida Fish & Wildlife Conservation Commission): http://www.myfwc.com/research/redtide/statewide/

Shoreline and Beach observations (Mote Marine Lab): http://www.visitbeaches.org/

Forecasting tools: NOAA, https://tidesandcurrents.noaa.gov/hab/gomx.html; USF Collaboration for Prediction of Red Tides, http://cprweb.marine.usf.edu/

Human health concerns (Florida Department of Health): http://www.floridahealth.gov/environmental-health/aquatic-toxins/index.html

Additional background information:
Gulf of Mexico Alliance: A Primer on Gulf of Mexico HABs.
http://myfwc.com/media/2668161/habprimer.pdf

US Environmental Protection Agency: What is nutrient pollution?
https://www.epa.gov/nutrientpollution/infographic-what-nutrient-pollution

Mote Marine Lab: Florida Red Tide FAQs https://mote.org/news/florida-red-tide

Additional scholarly articles:

Brand, L.E. and A. Compton. 2007. Long-term increase in *Karenia brevis* abundance along the Southwest Florida Coast. Harmful Algae 6:232–252.

Dixon, L.K, P.J. Murphy, N.M. Becker, and C.M. Charniga. 2014. The potential role of benthic nutrient flux in sup-port of Karenia blooms in west Florida (USA) estuaries and the nearshore Gulf of Mexico. Harmful Algae 38:30–39.

Heil, C.A., L.K. Dixon, E. Hall, M. Garrett, J.M. Lenes, J.M O'Neil, B.M. Walsh, D.A. Bronk, L. Killberg-Thoreson, G.L. Hitchcock, K.A. Meyer, M.R. Mulholland, L. Procise, G.J. Kirkpatrick, J.J. Walsh, and R.W. Weisberg. 2014. Blooms of *Karenia brevis* (Davis) G. Hansen & Ø. Moestrup on the west Florida shelf: nutrient sources and potential management strategies based on a multi-year regional study. Harmful Algae 38:127–140.

Glibert, P.M., J.M. Burkholder, T.M. Kana1, J. Alexander, H. Skelton, and C. Shilling. 2009. Grazing by *Karenia brevis* on *Synechococcus* enhances its growth rate and may help to sustain blooms. Aquatic Microbial Ecology 55:17–30.

James, K.J., B. Carey, J. O'Halloran, F.N.A.M. Van Pelt and Z. Škrabáková. 2010. Shellfish toxicity: human health implications of marine algal toxins. Epidemiology and Infection 138:927-940.

Kimm-Brinson, K.L. and J.S. Ramsdel. 2001. The red tide toxin, brevetoxin, induces embryo toxicity and developmental abnormalities. Environmental Health Perspectives 109:377–381.

van Deventer, M., K. Atwood, G.A. Vargo, L.J. Flewelling, J.H. Landsberg, J.P. Naar, and D. Stanek. 2011. Karenia brevis red tides and brevetoxin-contaminated fish: a high risk factor for Florida's scavenging shorebirds? Botanica Marina 55:31-38.

To get involved with the National Estuary Program in your state to help reduce nutrient pollution and protect your community and its economy, visit nationalestuaries.org.

CONSERVANCY OF SOUTHWEST FLORIDA
August 27, 2018

Senate Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard,
Washington, DC.

RE: Harmful Algal Blooms: The Impact on Our Nation's Waters

Dear Members of the Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard:

The Conservancy of Southwest Florida, on behalf of our more than 7,000 supporting families, appreciates the opportunity to provide the following comments for the record during the Senate Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard hearing on "Harmful Algal Blooms: The Impact on Our Nation's Waters" on August 28th, 2018. We have reached a critical juncture for the health and wellbeing of our waterways. Harmful algal blooms are on the rise, and do not show any indication of ending without drastically changing the way we control pollution, restore our waterways, and manage water resources.

Harmful algal blooms (HABs) cause a number of significant negative impacts which include damage to the overall health of the environment that has a ripple effect on other sectors, including the economy and our quality of life. These blooms harm the natural ecosystem, our tourism-based economy in southwest Florida, and can cause detrimental short and long-term health impacts to humans.

Southwest Florida is currently suffering from the impacts of two major harmful algal bloom events: a nearly year-long bloom of the marine dinoflagellate *karenia brevis* (red tide) and an over two-month long freshwater cyanobacteria (blue-green algae) bloom that began in Lake Okeechobee, and then made its way to the coast via the discharges from the lake into the Caloosahatchee River and Estuary.

Economic Impacts

Coastal communities depend on the health of the local rivers, estuaries, and ocean to supply food, preserve quality of life, and support our tourism-based economy. Without this tourism industry, many local businesses and people suffer. Recreational fishermen, the hotel industry, the restaurant industry, and home owners alike all suffer economically as a result of the unfavorable effects harmful algal blooms have on the economy. Those that have homes or businesses along the coastal waterways experience a significant decrease in property value when water quality is diminished, as documented by a 2015 Florida Realtors Report. The economic impacts of the 2018 blooms are still being collected and quantified but the preliminary numbers indicate this will be a disastrous event for southwest Florida's economy.

Environmental Impacts

As colonies of algae grow out of control and produce toxins, the toxins can cause direct mortality to aquatic life. Proliferation of algae can also cause the water to become depleted of dissolved oxygen. As a result of both direct toxicity and/or lack of oxygen, massive fish kills occur, piling up in local waterways and beaches. HABs create imbalances in the aquatic ecosystem by smothering and killing submerged aquatic vegetation, which are a vital habitat to countless other plant and animal species. Not only have thousands of pounds of dead fish washed ashore during these southwest Florida HAB events, so have larger marine animals such as manatees and sea turtles-many of these species are listed as threatened or endangered under the Endangered Species Act.

Human Health Impacts

Not only is the smell of dead animal carcasses washed ashore and floating in nearby water nauseating, exposure to the HABs from both the red tide and the blue-green algae also cause serious health issues for humans. The toxins released from red tide into the air cause severe respiratory problems, including trouble breathing, burning eyes, and coughing/wheezing. Ingesting shellfish contaminated by red tide can also cause severe illness. Long term effects from the blue-green algae blooms are still being studied but include heightened risks for liver cancer and gastrointestinal illnesses, as well as neurological diseases like ALS and Alzheimer's. Both the red tide and the blue-green algae HABs produce unsafe conditions for people.

Conclusion

HABs can be caused or exacerbated by nutrient pollution (nitrogen and phosphorus) from agricultural, urban stormwater, and wastewater sources. Although red tide occurs on a regular basis in the Gulf of Mexico, once the bloom moves closer to the coast it can utilize anthropogenic sources that can prolong the bloom and

strengthen its severity. Blue-green algae blooms are strongly correlated with increasing levels of nutrient pollution in our watersheds and waterways.

In order to secure a better future for generations to come, it is crucial to have a regulatory framework to enforce solutions to Jimit the reoccurrence of these HABs.

Strong, enforceable fertilizer ordinances and restricting or eliminating the use of fertilizer can greatly reduce nutrient pollution—as can stricter laws on compliance and enforcement of agricultural best management practices, and on untreated sewage and leaking septic tanks. It is imperative that the standards for water quality are met and are at levels that keep waterways safe for drinking water supplies, recreational use, and for aquatic life to thrive.

To better prepare for future blooms and instill as many preventative measures as possible, it is vital to have the research, the monitoring, and funding resources in place in order to address these escalating HAB events.

Thank you for your time and consideration in addressing this critically important issue.

Sincerely,

MARISA CARROZZO,
Senior Environmental Policy Specialist.

Stuart, FL, August 27, 2018

Senate Commerce Subcommittee on Oceans, Atmosphere, Fisheries and Coast Guard

Subject: Hearing on Harmful Algal Blooms

Honorable Subcommittee Members:

Thank you for addressing the critical public health, economic and environmental impacts of the toxic blue-green algae blooms affecting the St. Lucie Estuary, the Caloosahatchee Estuary and Lake Okeechobee. I am an environmental engineer with over 30 years of experience, and have dedicated my professional career to the improvement of the environment in Florida. I've been honored to work on the Kissimmee River Restoration, Everglades Restoration and numerous projects in the Lake Okeechobee and estuary watersheds.

For more than 90 years, the economy, environment and public health of the estuarine regions have been sacrificed as polluted overflow from Lake Okeechobee has been diverted away from its natural southerly course and discharged to the estuaries. These discharges contain toxic algae, as well as millions of pounds of nutrients and sediment.

It is essential that discussions of the harmful algae blooms affecting the Lake and estuaries fully recognize that the source of the algae this year and in prior years is a very polluted Lake Okeechobee. Scientists have known about the source of this pollution for almost 50 years: excessive levels of nutrient loads in stormwater from the surrounding watershed. The Lake Okeechobee watershed consists of approximately 3.5 million acres. The water quality of the lake is at an all-time crisis level, and human health is suffering as polluted lake water is discharged to the estuaries. For calendar year 2017, the phosphorus loading to the lake was the highest ever recorded, and the 5-yr average phosphorus loading to the lake was more than 5 times the pollution allocation established for the watershed (the "Total Maximum Daily Load" or "TMDL.") The result: an algae bloom covered 90 percent of the lake this summer. While the estuaries' watersheds also contribute excessive nutrients in stormwater runoff, the source of the toxic algae is Lake Okeechobee.

I have recently drafted a paper describing the pollution of Lake Okeechobee and this is attached for your information. Please contact me if I can be of assistance.

Sincerely,

GARY F. GOFORTH, P.E., PH.D.

ATTACHMENT

A BRIEF DISCUSSION OF LAKE OKEECHOBEE POLLUTION

G. Goforth—8/27/2018

The source of the toxic blue green algae currently damaging estuarine ecosystems, regional economies and human health is a very polluted Lake Okeechobee[1] (TCPalm 2018a). As a result of this pollution, on July 2, 2018, NOAA satellite image indicated that 90 percent of the surface of Lake Okeechobee was covered with a blue green algae bloom *(Figure 1).* Members of every branch of Florida government, state agencies and others have known about the source of this pollution for almost SO years: excessive levels of nutrient loads in stormwater from the surrounding watershed. Lake Okeechobee is one of the largest lakes in the United States, with a surface area of approximately 730 square miles. The lake is approximately 9 ft deep. The watershed that contributes flow and nutrients to Lake Okeechobee is approximately 3.5 million acres in size and consists of nine hydrologic sub-watersheds *(Figure 2).* Only 12 percent of the watershed is residential or built-up, while fifty-six percent is agricultural and rangeland, with the rest in wetlands and other water bodies (SFWMD 2018). The lake is almost completely enclosed by a 143-mile earthen dam (the Herbert Hoover Dike) with 36 major water structures that control flow into and out of the lake. Fisheating Creek is the only remaining unregulated natural connection to the lake.

For more than 4 decades state and Federal agencies have implemented activities designed to reduce the pollution entering the lake, including conducted research, monitored water flow and water quality, established regulatory (*i.e.,* permitting) programs, constructed regional storage and treatment systems, offered extensive dairy buyouts, and assisted agricultural landowners with best management practices (BMPs). However, the state continues to allow landowners to discharge high levels of nutrients with little to no enforcement, and the pollution of Lake Okeechobee and the estuaries continues. The water quality of the lake is at an all-time crisis level, and human health is suffering as polluted lake water is discharged to the estuaries. For calendar year 2017, the phosphorus loading to the lake was the highest ever recorded, and the 5-yr average phosphorus loading to the lake was more than 5 times the pollution allocation established for the watershed. This pollution target is called the "Total Maximum Daily Load" or "TMDL." The result: an algae bloom covered 90 percent of the lake this summer (NOAA 2018). In addition, the state's annual "progress report" on efforts to reduce pollution of the lake underestimates the actual loading to the lake. For the last two years the FDEP has published reports indicating phosphorus loading to the lake has decreased -yet these claims conflict with the measured loads to the lake, *e.g.,* the average load measured in 2017 was almost 61 percent higher than reported by FDEP.

[1] Nutrient loading to the estuaries from local stormwater runoff is also excessive, however toxic algae blooms occur almost exclusively in association with large discharges from Lake Okeechobee (LaPointe *et al.,* 2015, TCPalm 2016, TCPalm 2018b).

Figure 1. On July 2, 2018, 90 Percent of Lake Okeechobee Was Covered with blue-green algae Bloom (from NOAA)

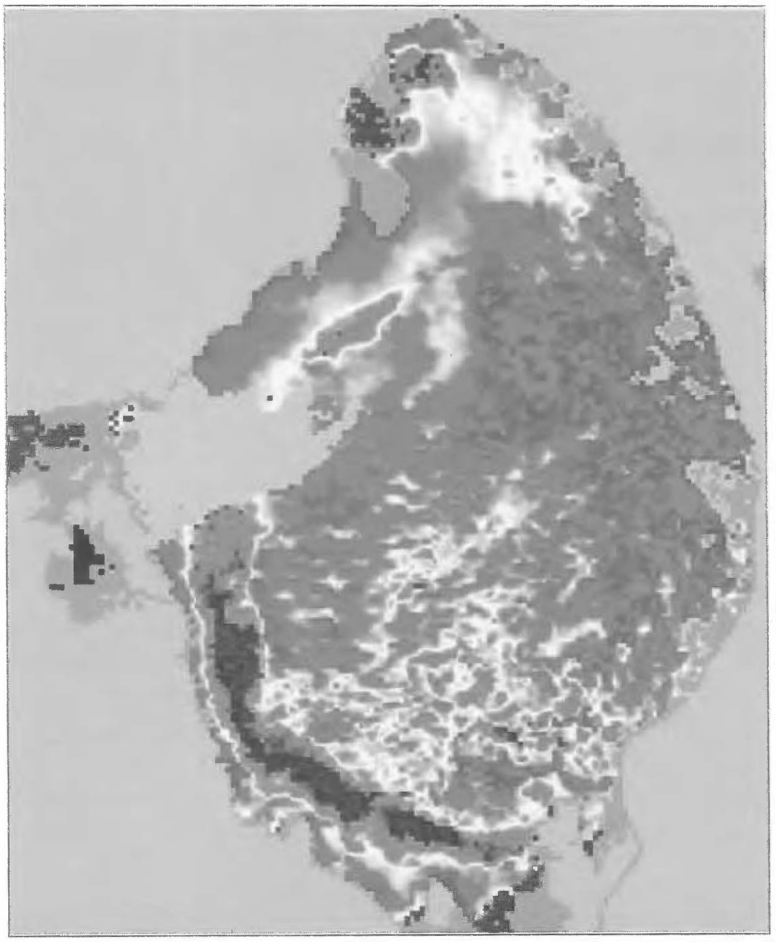


Figure 2. The Lake Okeechobee Watershed (from SFWMD 2018)

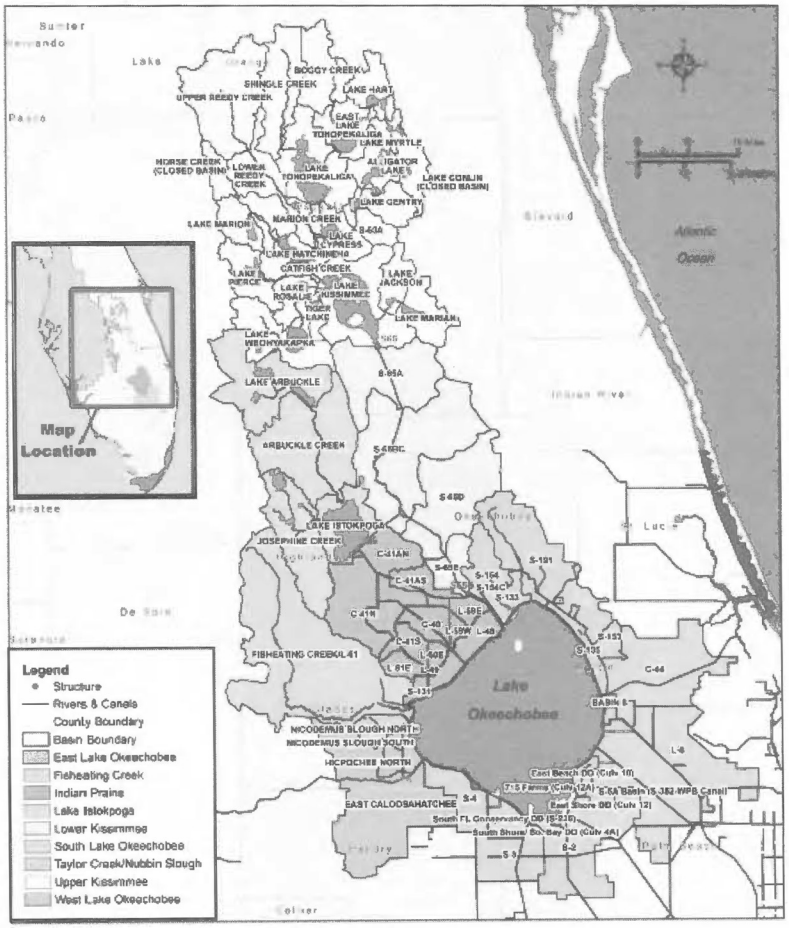


Figure 8B-1. LOW detailing major hydrologic features, subwatersheds, drainage basins (black labels indicate basins).

Historical Inflows to Lake Okeechobee (1963–2017)

Historical surface[2] inflows to the lake can be separated into two timeframes:

1. Prior to 1983
2. From 1983 to the present

Prior to 1983, stormwater runoff containing excessive levels of phosphorus and nitrogen from the Everglades Agricultural Area (EAA) was routinely discharged into the lake. During that period, flows from the EAA and the remainder of the South Sub-watershed[3] made up approximately 16 percent of the total lake inflow *(Figure 3).* However, due to the elevated nutrient concentrations of this runoff, nitrogen loads from the South Sub—watershed made up 43 percent of the total nitrogen entering the lake *(Figure 4).* With 49 active dairies, the Taylor Creek/Nubbin Slough Sub-watershed was the single largest source of phosphorus with 34 percent of the total lake inflow loads for the period 1973–1982 *(Figure 5).*

Flows entering the lake from the Upper Kissimmee Sub-watershed (*i.e.,* that area from Lake Kissimmee north to Orlando) and the Lower Kissimmee Sub-watershed (Kissimmee River valley) during this time period comprised 45 percent of the inflows to the lake, 21 percent of the nitrogen loads and 22 percent of the phosphorus loads.

As a way to reduce the nutrient pollution entering the lake, beginning in 1979 the operations of the major structures (pump stations S–2 and S–3 and hurricane gate structure no. 5) were changed to divert nutrient laden runoff from the EAA to the Everglades. By the end of 1982 these operations, referred to as the interim Action Plan, were complete. Although currently the EAA discharges are less than 3 percent of the total inflows to the lake, historical discharges from the EAA contributed significant nutrient loads. A cursory estimate of these loads can be approximated by assuming the runoff from the EAA began in 1960, and further assuming that flows and loads from the EAA from 1960 to 1973 occurred at the 1973–1982 average annual levels. Using these rough assumptions, it can be approximated that between 1960 and 1982, the EAA contributed approximately 140 million pounds (63,350 metric tons) of total nitrogen to the lake, and approximately 2.9 million pounds (1,300 metric tons) of total phosphorus. Some of those loads may still be present in the lake sediment.

From 1983 to the present, the flow to the lake from the EAA has been reduced by approximately 82 percent compared to pre-1983. Between 1983 and 2017, flows from the South Sub-watershed made up approximately 5 percent of the total lake inflow, 15 percent of the total nitrogen entering the lake and 7 percent of the total phosphorus entering the lake. Despite the diversion of most of the EAA runoff away from the lake, the average annual inflow to the lake from all basins has increased by about 9 percent since 1982. Approximately SO percent of the flow entering the lake comes from the Upper Kissimmee and Lower Kissimmee Sub-watersheds, along with 35 percent of the nitrogen loads and 31 percent of the phosphorus loads.

A wide range of state and Federal nutrient control programs have been implemented in the Lake Okeechobee Watershed *(Table 1).* In August 2001, the State developed a total maximum daily load (TMDL) of phosphorus for the lake's watershed, established specifically to reduce the frequency of algal blooms in the lake. State legislation (the 2000 Lake Okeechobee Protection Act 373.4595, F.S.) established a January 2015 deadline for achieving compliance with the TMDL. In December 2014, the Department adopted the Lake Okeechobee Basin Management Action Plan (BMAP) for total phosphorus. Hundreds of millions in public funds have been spent on dairy buyouts, agricultural best management practices, regional water quality treatment projects, and other efforts. However, the state continues to allow landowners to discharge high levels of nutrients with little to no enforcement or accountability, and the pollution of Lake Okeechobee and the estuaries continues. The water quality of the lake is at an all-time crisis level, and human health is suffering as polluted lake water is discharged to the estuaries. The 2016 Florida Water Law deleted the January 2015 deadline to achieve compliance with the TMDL, and replaced it with a 20-yr time-frame tied to the BMAP. In addition, the 2016 law replaced the regulatory program that would have held individual landowners accountable for pollution from their land (*i.e.,* the Works of the District permitting program) with the BMAP process, a process that does not hold individual landowners accountable for pollution from their land.

---

[2] Surface inflows exclude direct rainfall on the lake.

[3] The South Sub-watershed includes the EAA, the S–4/Industrial Canal basin and discharges from Ch. 298 Districts along the southern shore of the lake.

While 5-yr flow-weighted mean nitrogen concentrations into the lake have decreased since the diversion of the EAA runoff, the average annual loads have steadily increased since 2010 *(Figures 6–8).* The 5-yr average annual phosphorus load has steadily increased since 2010. During calendar year 2017 the phosphorus loading was the highest ever recorded, while the 5-year average annual phosphorus loading to the lake was more than 5 times the TMDL allocation for the watershed. In addition, during 2017 the concentration rose to almost 250 parts per billion, the highest observed in 35 years. The result: an algae bloom covered 90 percent of the lake this summer (2018).

In addition, the state's annual BMAP " progress report" describing efforts to reduce pollution of the lake significantly underestimates the actual loading to the lake *(Figures 9–10).* For the last two years the FDEP has published reports indicating phosphorus loading to the lake has decreased—yet these claims conflict with the measured loads to the lake, *e.g.,* the measured 5-yr average annual load in 2017 was almost 60 percent higher than reported by FDEP.

SFWMD reports that perhaps 30,000 metric tons of total phosphorus may reside in the top 10 cm of sediments of Lake Okeechobee, which creates an internal loading source that may equal or exceed the external loading source.

Summary: The water quality of the lake is at an all-time crisis level, and human health, the environment and the regional economy is suffering as polluted lake water is discharged to the estuaries. During calendar year 2017 the phosphorus loading was the highest ever recorded, while the 5-year average annual phosphorus loading to the lake was more than 5 times the TMDL allocation for the watershed. The result: an algae bloom covered 90 percent of the lake this summer.

The nutrient concentrations and loads vary significantly among the nine sub-watersheds. For the period since 1982, approximately 45–55 percent of the nutrient loads came from those sub watersheds directly north of the Lake (Upper Kissimmee, Lower Kissimmee and Taylor Creek/Nubbin Slough). Approximately 35 percent of the nutrient load came from the sub watersheds located northwest of the Lake (Lake lstokpoga, Indian Prairie and Fisheating Creek/Nicodemus Slough). The remaining sub-watersheds east, south and west of the Lake contributed approximately 10–20 percent of the nutrient loads.

Note: Some parties have stated that 90–95 percent of the water entering the lake comes from the "north", with some parties specifically indicating the Upper and Lower Kissimmee Sub watersheds. This is incorrect. The confusion stems from the FDEP permit which defines the "North Region" as containing multiple sub-watersheds, including the Upper Kissimmee, Lower Kissimmee, Taylor. Creek/Nubbin Slough, Lake lstokpoga, Indian Prairie and the Fisheating Creek/Nicodemus Slough sub-watersheds. As shown in *Figure 3,* during 1983–2017 just 50 percent of the water entering the lake comes from the Upper and Lower Kissimmee Sub watersheds.

Figure 3. Distribution of Inflows to Lake Okeechobee.

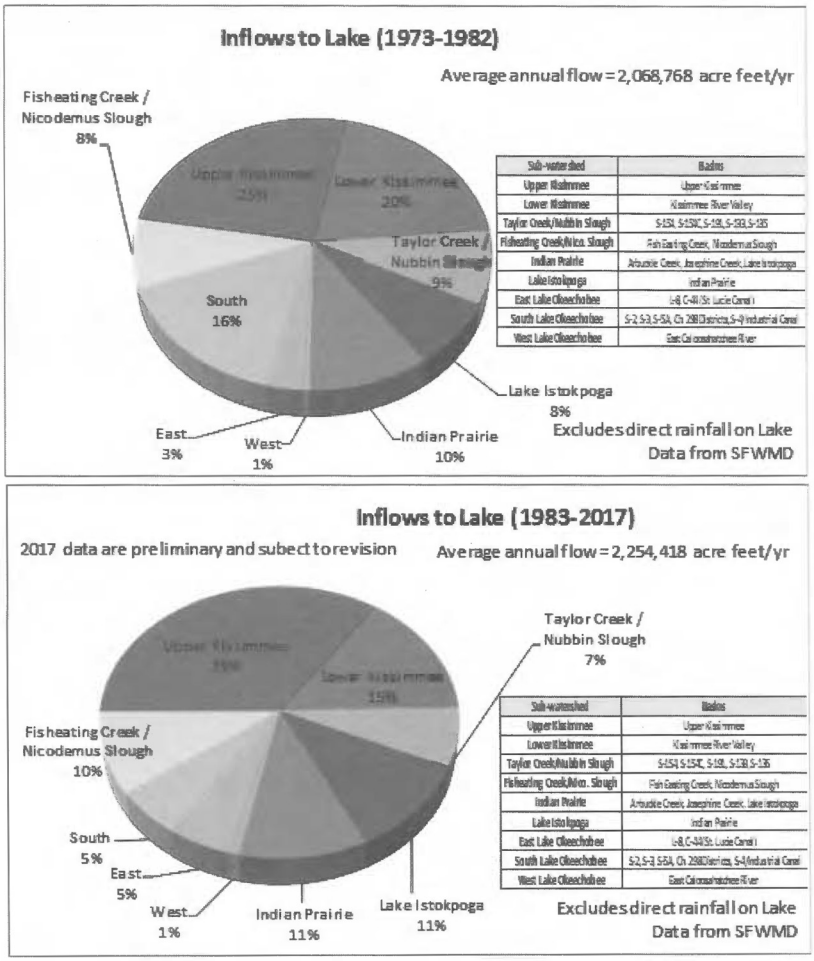


Figure 4. Distribution of Inflow Nitrogen Loads to Lake Okeechobee.

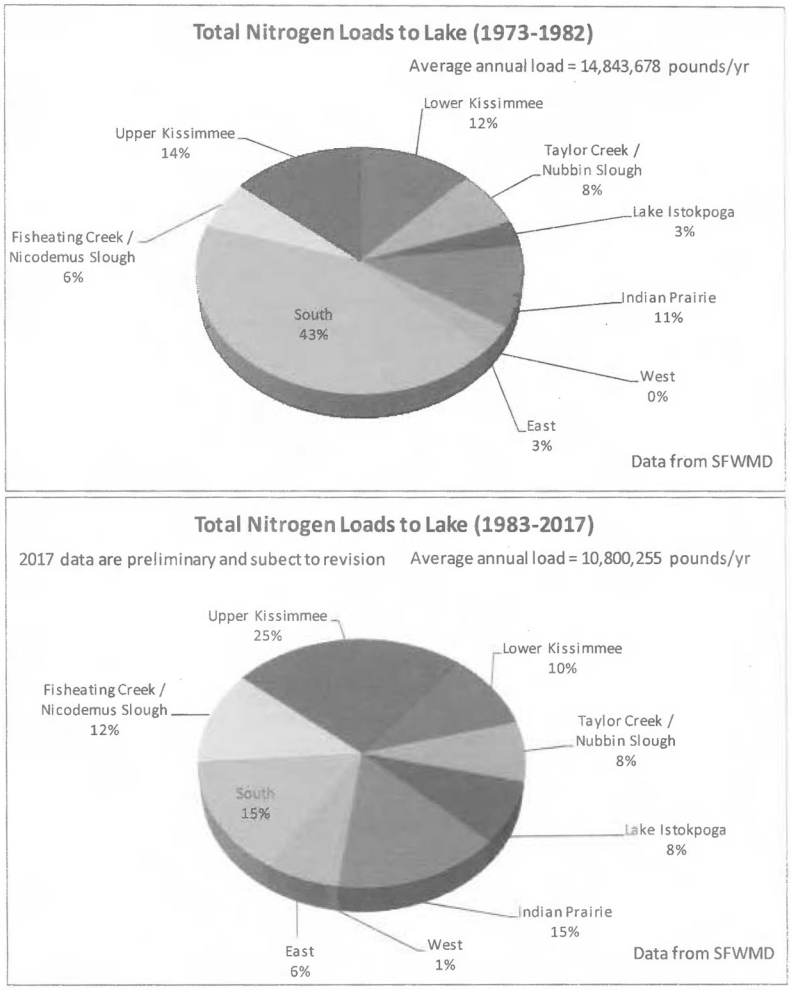


Figure 5. Distribution of Inflow Phosphorus Loads to Lake Okeechobee.

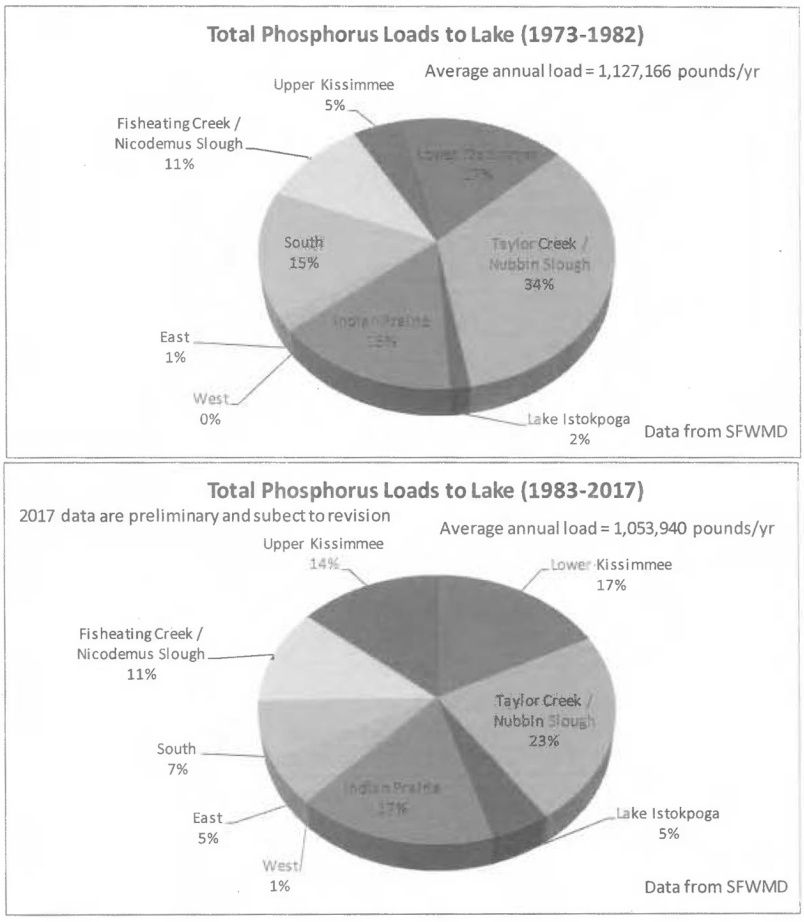
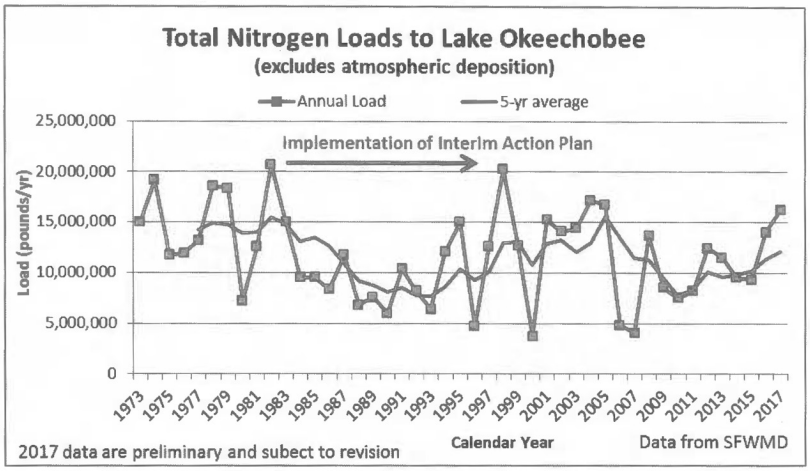


Table 1. Summary of Nutrient Control Programs in the Lake Okeechobee Watershed (from Goforth et al. 2013).

Table 2-3. Summary of the source control implementation time frame for the Lake Okeechobee Watershed.

Timeframe	Event
1970s	FDER Dairy regulatory programs begin
1972	Clean Water Act and Florida Water Resources Act
	South Florida Water Management District Stormwater Permitting Begins
1978	Florida Established Non-Point Source Management Programs
1981	Rural Clean Water Program Taylor Creek Headwaters
1984	FDER Biosolids/Domestic Wastewater Residuals Regulations
1985	Florida State stormwater rule adopted, retention ponds became required for new development
1986	New citrus groves were required to include onsite reservoirs for stormwater runoff.
1987	Surface Water Improvement and Management Act for Lake Okeechobee enacted
1987	FDER Dairy Rule for Lake Okeechobee Basin
1989	Chapter 40E-61, the Lake Okeechobee Works of the District Rule adopted by SFWMD
1990	National Pollutant Discharge Elimination System Programs
1992	Chapter 40E-63, the Everglades Agricultural Area Works of the District Rule adopted by SFWMD
1995	SFWMD Environmental Resource Permitting Regulatory Program adopted
1995	Kissimmee River Restoration Project
1999	Florida Watershed Restoration Act
2000	The Lake Okeechobee SWIM Act is revised to become the Lake Okeechobee Protection Act
2003	FDOH Septage Application requires Agricultural Use Plan
2003	FDACS adopts Rule 5M-3, the BMP rule for the priority basins S-191, S-154, S-65 D and S-65E.
2003	FDACS Land Application of Animal Wastes (Rule 5M-3)
2004	FDOH Wastewater Master Plans
2005	The geographic area of the Lake Okeechobee Protection Act is expanded to include the Upper Kissimmee and the Lake Istokpoga Sub-watersheds.
2006	FDACS expands BMP rule 5M-3 to the entire Lake Okeechobee Watershed
2007	The LOPA is revised to become the Northern Everglades and Estuaries Protection Program
2007	FDACS Urban Turf Fertilization Rule (Rule 5E-1.003)
2011	FDACS amends BMP Rule 5M-3 to the entire Northern Everglades
Beyond 2012	Elimination of land application of biosolids
	Proposed FDEP Numeric Nutrient Criteria

Figure 6. Time Series of Inflow Nutrient Loads to Lake Okeechobee.



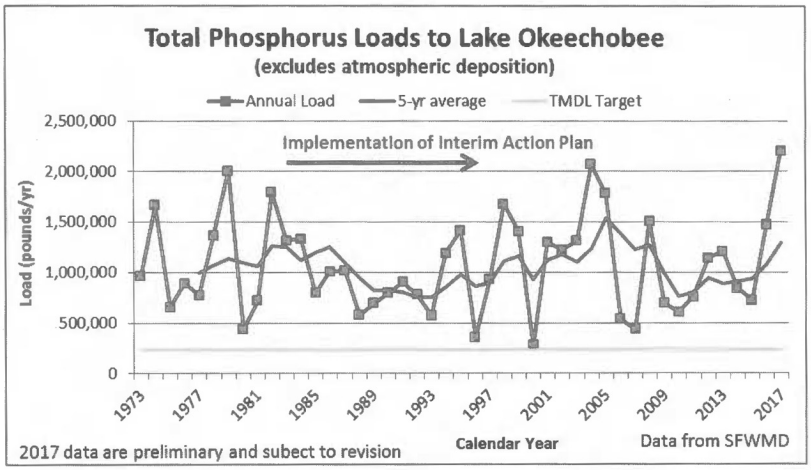
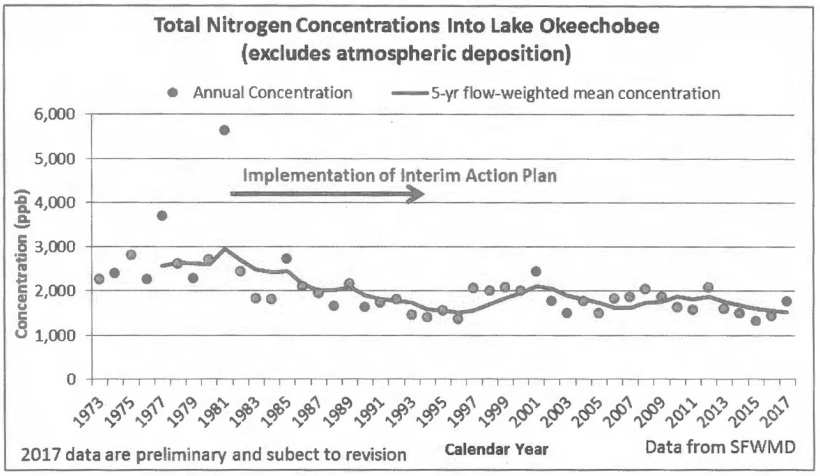


Figure 7. Time Series of Inflow Nutrient Concentrations to Lake Okeechobee.



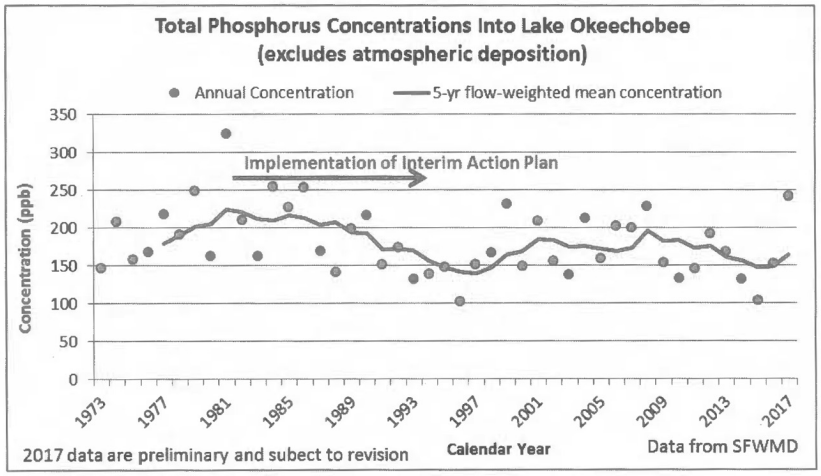


Figure 8. Inflow, outflow and in-lake nutrient concentrations (SFWMD 2018).

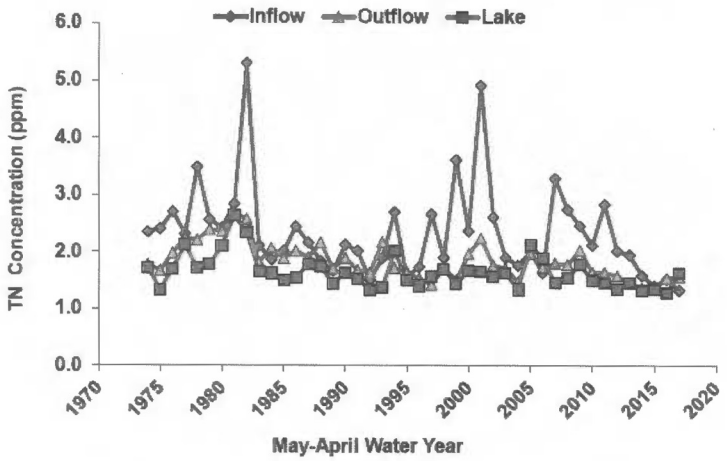


Figure 8B-28. Timelines of inflow, outflow, and lake average TN concentrations calculated from the lake N budget.

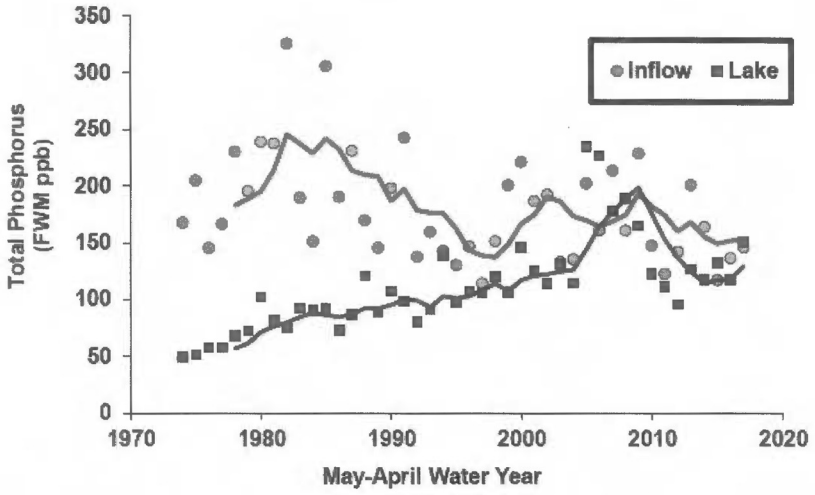


Figure 8B-25. Timelines of inflow and lake average TP concentrations (five-year moving average trend lines) calculated from the P budget of Lake Okeechobee.
(Note: ppb – parts per billion, which is equivalent to µg/L.)

Figure 9. Comparison of 2016 measured phosphorus loads to the lake with FDEP estimate.

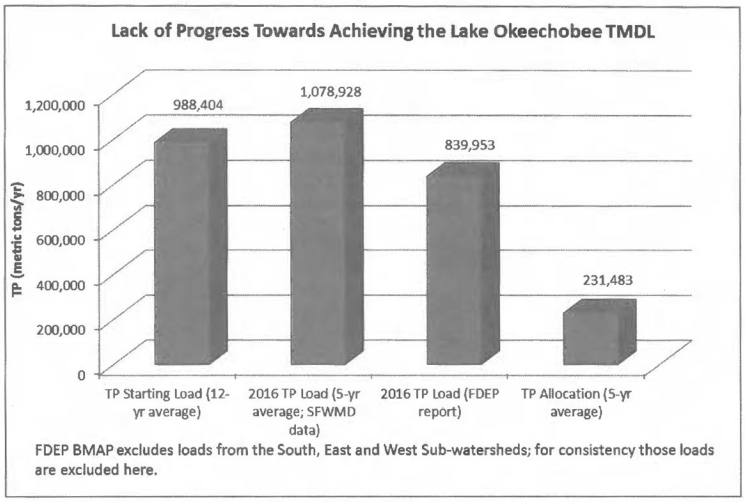
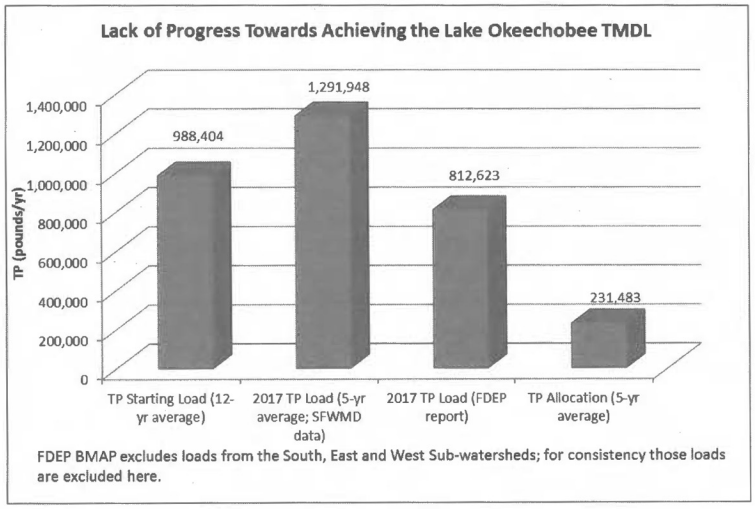


Figure 10. Comparison of 2017 measured phosphorus loads to the lake with FDEP estimate.



Partial 2018 Inflows to Lake Okeechobee

The following is a *preliminary summary* of partial 2018 flows and phosphorus loading for the period January 1–July 31, 2018.

Based on preliminary data, basins showing the greatest percent increase in 2018 inflows compared to 2017 include the Taylor Creek/Nubbin Slough (478 percent), Indian Prairie (330 percent) and Lake lstokpoga (304 percent) *(Figure 12).* The basin with the largest volume increase over last year is the Upper Kissimmee, with approximately 175,000 acre feet more than last year; nevertheless, the Upper and Lower Kissimmee sub-watersheds have contributed less than half of the total inflows so far this year. The basins contributing the largest phosphorus loads are Indian Prairie and Taylor Creek Nubbin Slough, which together account for almost half the phosphorus loading to the lake so far this year *(Figure 13).* Changes in nutrient concentrations between historical averages and 2018 are shown in *Figure 14.* Generally, nitrogen concentrations have been lower than average. The largest increases in phosphorus concentrations occurred in the Fisheating Creek/Nicodemus Slough and South subwatersheds.

Figure 11. Distribution of 2018 Inflows to Lake Okeechobee.

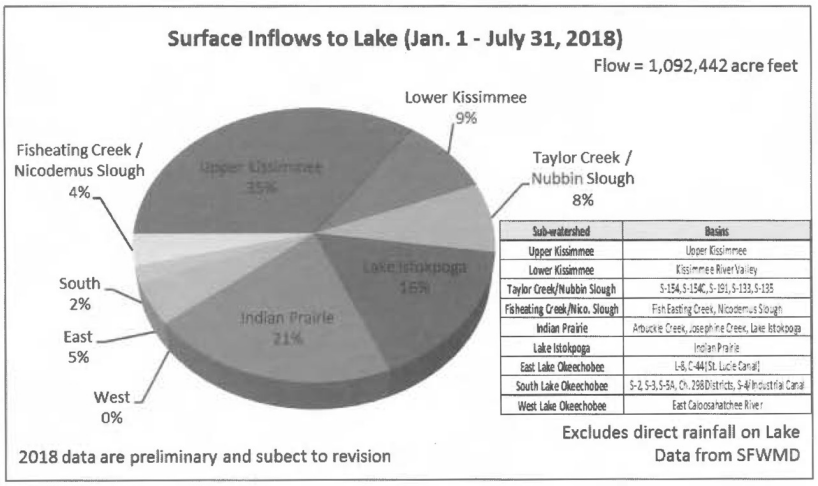


Figure 12. Comparison of Inflows to Lake Okeechobee (Jan. 1 – July 2018).

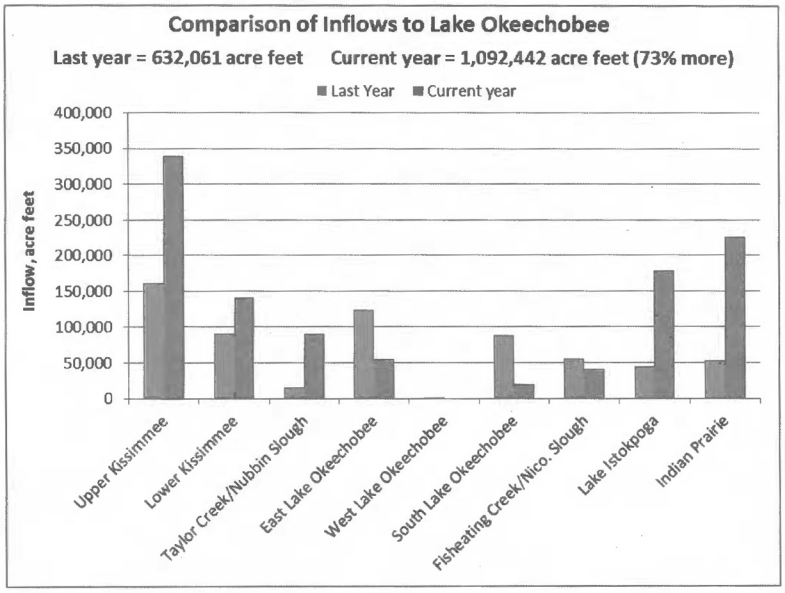


Figure 13. Preliminary Phosphorus Loads to Lake Okeechobee (Jan. 1 – July 2018)

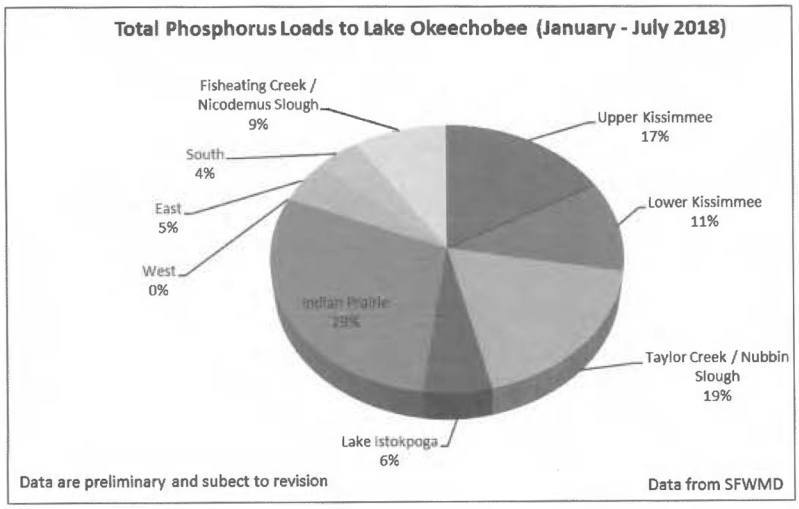
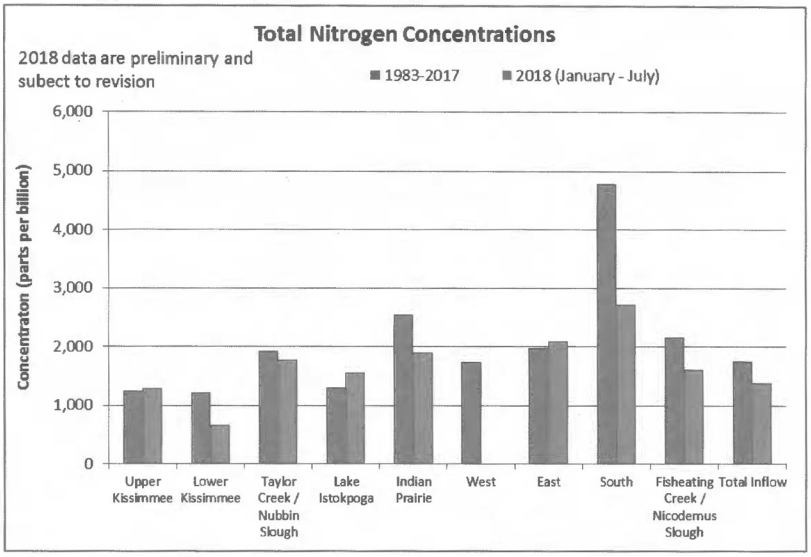
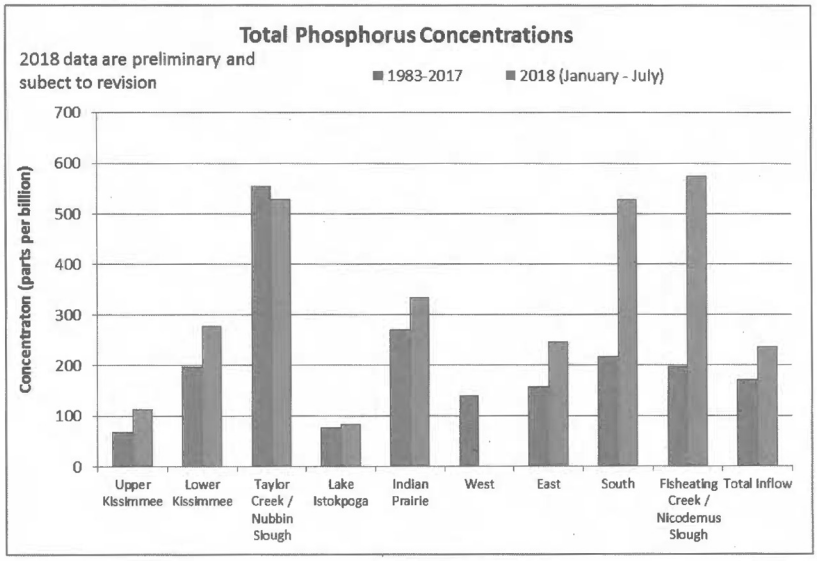


Figure 14. Nutrient Concentrations for the Period 1983-2017 and 2018 (partial).





References

FDEP 2017. Final 2016 Progress Report for the Lake Okeechobee Basin Management Action Plan. June 2017

FDEP 2018. Florida Statewide Annual Report on Total Maximum Daily Loads, Basin Management Action Plans, Minimum Flows or Minimum Water Levels, and Recovery or Prevention Strategies. June 2018.

Goforth et al. 2013. Draft—Technical Support Document: Lake Okeechobee Watershed Performance Measure Methodologies. Gary Goforth, Inc., L. Hornung Consulting, Inc., Soil & Water Engineering Technology, Inc. in association with South Florida Water Management District. February 2013.

Goforth 2017. DRAFT. Watr Quality Assessment of th St. Lucie River Watershed—Water Year 2017. December 2017.

LaPointe et al 2015.

SFWMD 2018. South Florida Environmental Report. March 2018.

TCPalm 2016. "Scientists Agree: Lake Okeechobee Discharges not Septic Systems, Cause Algae Bloms." July 8, 2016.

TCPalm 2018a. "Algae blooms keep popping up in St. Lucie River as Lake Okeechobee discharges continue." June 11, 2018.

TCPalm 2018b. "Again: Go time for green slime." August 22, 2018.

SITKA TRIBE OF ALASKA
Sitka, AK, September 5, 2018

U.S. Senate Committee on Commerce, Science, and Transportation,
Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard,
Washington, DC.

Re: Statement before the United States Senate Commerce Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard Harmful Algal Blooms: The Impact on Our Nation's Waters

Dear Commerce Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard,

Sitka Tribe of Alaska is the federally recognized tribal government for more than 4,400 enrolled tribal citizens in Sitka, Alaska, organized under the Indian Reorganization Act of 1934 as amended. As a tribal government, STA is responsible for the health, welfare, safety, and culture of its citizens. STA respectfully submits the following comments on the Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard hearing on Harmful Algal Blooms: The Impact on Our Nation's Waters.

Thank you for accepting our written testimony. STA has a vested interest in protecting traditional natural resources from harmful algal blooms and the health of local harvesters from biotoxins. STA formed the Southeast Alaska Tribal Ocean Research (SEATOR) partnership in 2013 to unify Tribal governments as the frequency of harmful algal blooms and the risks to Tribal Citizens have increased. The SEATOR partnership now includes 16 Tribal governments in Southeast and Southcentral Alaska, the University of Alaska, State, Federal, and non-profit partners. STA serves as the partnership's regional coordinator and analyzes all partners' samples in its Environmental Research Lab. STA and SEATOR now routinely monitor shellfish biotoxins, shellfish populations, ocean chemistry conditions, and phytoplankton assemblages at more than 30 sites throughout the region.

Paralytic shellfish poisoning (PSP) is a real and recurring risk in rural Alaska. From 2010–2012, there were 26 reported cases of PSP and 2 deaths in Southeast Alaska alone, with potentially more cases going unreported. Alaska is the only state the does not have a consistent state run PSP monitoring program and it is the only state where fatalities still occur from PSP events. STA's marine research program was built on the pressing need to reduce the instances of PSP in harvesters, but many of our findings further underscore the risks harvesters face. Paralytic shellfish toxins are routinely detected in shellfish samples from the SEATOR partnership. In 2017, STA found measurable paralytic shellfish toxins at all of its partner communities and toxin levels above the FDA regulatory limit at 11 of 16 partners sampling sites. During the 2017 summer season, 8 of those communities had active paralytic shellfish toxin producing harmful algal blooms. Fear of PSP and uncertainty around the changing ocean conditions contributing to harmful algal blooms now keep many would-be harvesters from participating in subsistence shellfish gathering. Long coastlines, dispersed populations, and the lack of a State-run recreational shellfish testing program further compound the risks.

All participating SEATOR partners monitor one or more community harvesting sites by collecting and analyzing weekly phytoplankton samples, filtering water samples to test for particulate toxins, and shipping bi-weekly shellfish samples to STA's Environmental Research Lab for paralytic shellfish toxin analysis using the Receptor Binding Assay (RBA, AOAC Method 2011.27). Shellfish toxicity results are sent to partners, State regulators, and researchers immediately after testing, typically within 48 hours of sample harvesting. Any shellfish with toxin levels above the FDA's regulatory limit of 80 µg toxin per 100 grams of shellfish tissue (0.8 ppm) trigger public service announcements on local media stations and on SEATOR web pages. With weekly "eyes on the water" and prompt biotoxin results, SEATOR partners can communicate real time risk assessments to their communities as well as monitor for emerging biotoxin threats such as domoic acid. All SEATOR data is made publicly available by STA on the SEATOR website (seator.org) and the Alaska Harmful Algal Bloom network site (aoos.org/alaska-hab-network) and is used by resource managers and subsistence harvesters.

While the Environmental Research Lab's biotoxin work is most focused on traditional and recreational shellfish harvesters, it is also available to support Alaska's commercial shellfish industry. STA is currently working to become an FDA-certified shellfish testing lab and to validate the RBA as an Interstate Shellfish Sanitation Conference-approved testing method for geoduck. We anticipate full validation of the RBA within 6 months and FDA certification of the lab in the next 18 months. As with subsistence harvesters, Alaska's mariculture and dive industries are threatened by the increase in harmful algal blooms. Increasing Alaska's commercial testing capacity will help Southeast Alaskan divers and oyster growers to reduce their testing costs in the face of rising toxin levels.

STA's Environmental Research Lab is also instrumental in harmful algal bloom research in the region. Currently, STA is partnering with the Southeast Alaska Regional Dive Fisheries Association and the University of Alaska Fairbanks to better understand persistent and recurring winter toxicity in geoducks that have been curtailing fishing opportunities. We have also partnered with the University of Alaska Southeast to develop a predictive model for harmful algal blooms and shellfish toxicity in the region that will be accessible to managers and researchers.

Funded largely by competitive Federal research grants, STA and its SEATOR partners have been successful at reducing the risk of PSP to subsistence harvesters, despite having found shellfish with potentially lethal levels of toxin in Ketchikan in 2017 and in Kake in 2018. We have continued to grow and leverage our monitoring program to better respond to additional marine threats facing traditional harvesters, most notably evidence of domoic acid production in Sitka in July of 2018 and increasing evidence of ocean acidification. Domoic acid and ocean acidification sampling are now integrated into our standard sampling procedures, allowing STA to generate more comprehensive risk assessments for our communities and commercial industries.

STA would like to underscore the importance of Federal funding to Alaska's harmful algal bloom capacity. Without a large population base of other states and access to State funding sources, we cannot currently fund Alaska's necessary harmful algal bloom monitoring efforts without competitive grants. As we increase our lab and environmental monitoring capacity, the SEATOR program's current reliance on soft funds makes it increasingly vulnerable to reductions in funding opportunities. I£ Federal support of Alaska harmful algal bloom monitoring does not continue, the program will suffer while shellfish harvesters in Alaska will again revert to harvesting without phytoplankton or shellfish toxin information, greatly increasing their risk of PSP. If you have any questions, please do not hesitate to reach out to our STA Resource Protection Director, Jeff Feldpausch at 907–747–7469.

Sincerely,

KATHY HOPE ERICKSON,
Tribal Chairman.

Senator NELSON. And so, Florida is facing an environmental and economic harm, where toxic algae is coating—it's coating both coasts. The lifeguards are having to declare that you can stay at the beach on the sand, but you can't go in the water. It's killing all manner of sea life, and it is making people sick, and it is obviously, as a result, hurting businesses.

On the East Coast, a town called Stuart, which is the mouth of the St. Lucie River, I've talked to the parents who have worried about letting their children play outside. I've met with the business

owners, who are worried about the algae and what it will mean for their bottom lines. How about bait and tackle shops? How about anything associated with the beach? How about anything associated with fishing?

The stack of letters that I handed to you, let me just read one line from one of the letters. Christine Miller, the new owner of the Snook Hut Bait and Tackle Shop in Cape Coral, on the west coast, quote, "All those hundreds and thousands of dead fish due to the red tide and algae bloom decided not to go alone. They've taken all my business along with them." That's a bait and tackle shop.

Our storied sugary white beach sands should be, right now, lined with tourists, but, instead, they are lined with dead and rotting sea life, casualties from the massive toxic red tide event that has now lasted 10 months. Over 2,000 tons of dead fish and sea life have been removed from nearly 150 miles of Florida's world-renowned beaches. Dead tarpon, dead manatees, a dead whale shark. The pictures are certainly horrifying enough, but, in person—and I'm a native Floridian, five generations—it breaks my heart to see our beaches and rivers fouled like this.

And it's not a partisan issue. That bill that you talked about, that I introduced a year ago, we passed it. We could never get the House to get off of dead center to pass it. Senator Rubio and I are on that bill together. It's not a partisan issue. We've worked with colleagues, regardless of party, for the good of our states. And we want to secure funding for research on the algae blooms and the projects to restore things like the River of Grass, the Florida Everglades, which sends the water south, as Mother Nature intended, instead of having to dump it to the east and to the west. And when it goes through that River of Grass, it is cleansed, so, when it comes out into Florida Bay, down by the Keys, or when it goes in the Shark River Slough and comes out on the west coast in the Gulf of Mexico, it's clean water. And that's why we're pushing so hard. Let's get the House off the dime to pass exactly what you said, Mr. Chairman. Senator Portman and I introduced that bill last year, and it passed the Senate unanimously. And last week, I joined my colleague, Senator Rubio, in filing a bill to require a coordinated scientific strategy to address the toxic algae in Florida.

These are pieces of a broader puzzle. And, as we act at the Federal level to restore and try to clean up the environment, the state—the states—have to do their part, because states are invested with the responsibility of water quality.

And so, I want to thank the Chairman for convening this hearing today. And I also want to welcome our witness, Patrick Neu. He lives in Wisconsin, but he also comes down to Florida to fish. And I know he's——

Senator SULLIVAN. I hope he gets up to Alaska to fish, as well.

Senator NELSON. And I know he's going to have a great perspective on this.

Thank you, Mr. Chairman.

Senator SULLIVAN. Thank you, Senator Nelson.

And, as you indicated, we do have four outstanding witnesses. I want to thank them all for, essentially, again, giving us insights on an oversight hearing that we think's very important, and, as Senator Nelson mentioned, very bipartisan.

So, I want to welcome our witnesses. First, we have Mr. Don Anderson, who's a Senior Scientist at Woods Hole Oceanographic Institution and Director of the U.S. National Office for Harmful Algal Blooms.

Welcome, Mr. Anderson.

Next is Mr. Ivory Engstrom, Director of Special Projects and lead engineer, McLane Research Labs. We also have Mr. Bryan Stubbs, who is the Executive Director and President of the Board, the Cleveland Water Alliance; and Mr. Patrick Neu, the Executive Director, the National Professional Anglers Association.

Each of you will have 5 minutes to deliver an oral argument, or an oral statement, and a longer written statement may be included for the record, if you so choose.

So, Mr. Anderson, we'll begin with you. The floor is yours, sir.

STATEMENT OF DR. DONALD M. ANDERSON, SENIOR SCIENTIST, BIOLOGY DEPARTMENT, WOODS HOLE OCEANOGRAPHIC INSTITUTION; AND DIRECTOR, U.S. NATIONAL OFFICE FOR HARMFUL ALGAL BLOOMS

Dr. ANDERSON. Thank you, Mr. Chairman and members of the Subcommittee.

As you said, I am a Senior Scientist in the Biology Department of the Woods Hole Oceanographic Institution, and I'm a scientist who has been studying red tides and harmful algal blooms for over 40 years. I am also Director of the U.S. National Office for Harmful Algal Blooms.

The key message for me, for you, a takeaway message today, is that HABs, or H-A-Bs, in their various forms, are a truly national problem that requires a comprehensive national research, monitoring, and mitigation strategy. When events like the red and green tides happening in Florida capture the attention of the public, the media, and Congress, there's a temptation to target funding on the problem at hand. But, to do so ignores the need for balanced, sustained, national support that will enable other regions to respond to similar outbreaks that will inevitably occur elsewhere in the country.

So, prominent in everyone's mind right now are these ongoing Florida red and green tides that are causing so much devastation in the state. And I fully understand and am sympathetic there. But, we only need to look at a few recent cases to see the diversity and the complexity and the severity of HAB outbreaks nationally. Several of you have mentioned some. I'll mention a few others.

In 2015, a bloom of one HAB species stretched from Alaska to central California. That species produces a neurotoxin that causes brain damage and permanent memory loss in humans and wildlife who eat contaminated seafood. That bloom closed the Dungeness crab and shellfish fisheries, with economic losses on the order of $30 million in California and $23 million in Washington, alone. And the next year, that very same organism bloomed for the first time in New England, causing extensive shellfish closures in three states.

And of direct interest to the Chairman is the apparent spread of toxic HAB species within Alaska, including into the Bering Sea and the Arctic Ocean. Someone from my lab just returned from a cruise

above into the Chukchi Sea, we were finding Alexandrium and the PSP-causing organisms up there.

Looking inland, 2014, algal toxins in the Toledo water supply left nearly 500,000 people without drinking water for several days. And, more recently, a similar event occurred in Salem, Oregon, affecting 150,000 people.

So, resource managers nationwide are facing increasing threats from multiple HAB species and poisoning syndromes, but these occur in different habitats, at different times, and in different scales. And most states lack the resources to adequately respond, and so are in need of new approaches and tools. And so, recognizing this and other challenges, my colleagues and I have worked with Federal agencies and Congress to establish a National HAB Program, and the funding for NOAA's base and competitive research programs has led to a number of accomplishments that I describe in detail in my written testimony. These include: new sensors to support detection and monitoring and early warning of HAB cells and toxins, greater understanding of bloom causes and dynamics leading to forecasting systems, operational forecasting systems, and promising new bloom control and mitigation strategies.

Now, I could go on, but, in the interest of time, I'm just going to close with a few summary comments and recommendations.

First of all, HABs are a serious and growing problem in the U.S., affecting every state in the Union. And these HAB problems will not go away, and are increasing in severity and diversity. A U.S. HAB Program exists, but the level of funding for competitive and internal programs has fluctuated significantly. And even with the recent increases over the last several years, it remains well below what is needed for an appropriate response.

Targeting scarce resources on each new HAB outbreak is inefficient and limits the responses elsewhere. What we need is a coordinated national effort to focus research, personnel, facilities, and financial resources to the common goal of this comprehensive national strategy, and the support should be consistent and sustained. Freshwater HABs cannot be comprehensively addressed in NOAA programs, other than in the Great Lakes. Current legislation authorizes EPA to address HABs, but does not provide a clear path, and does not authorize funding.

NOAA also requires additional funding for operations in support of HAB management, and Congress needs to authorize these activities with specific language and specific funding. That's for internal NOAA operations in support of HABs. And, likewise, a clear mandate and funding for a national HAB observing system are needed, possibly under NOAA's IOOS, or Integrated Ocean Observing System.

So, to close, I can speak on behalf of the HAB science and management communities in voicing appreciation to Congress for recent increases to HAB research funding, for proposed increases in the FY19 appropriations, and to the Senate specifically for passing the Harmful Algal Bloom and Hypoxia Research and Control Amendments. This commitment needs to grow, however. And we believe that a strengthened competitive research program, working in coordination with enhanced agency core funding, is the way to

ensure the best expertise, technology, and strategies are brought bear on this national problem.

And, Mr. Chairman, that concludes my testimony.

[The prepared statement of Dr. Anderson follows:]

PREPARED STATEMENT OF DR. DONALD M. ANDERSON, SENIOR SCIENTIST, BIOLOGY DEPARTMENT WOODS HOLE OCEANOGRAPHIC INSTITUTION; AND DIRECTOR, U.S. NATIONAL OFFICE FOR HARMFUL ALGAL BLOOMS

Mr. Chairman and members of the Subcommittee. I am Donald M. Anderson, a Senior Scientist in the Biology Department of the Woods Hole Oceanographic Institution, where I have been active in the study of red tides and harmful algal blooms (HABs) for over 40 years. I am here to provide the perspective of an experienced scientist who has investigated many of the harmful algal bloom (HAB) phenomena that affect coastal waters of the United States and the world. I am also Director of the U.S. National Office for Harmful Algal Blooms, a former co-Chair of the National HAB Committee, and have been actively involved in formulating the scientific and legislative framework and the agency partnerships that support and guide our national program on HABs. Today my testimony will summarize the national scale of the HABs problem in the U.S.—their distribution, impacts, and trends as well as the challenges that face those responsible for monitoring and managing these phenomena. I will also highlight recent research accomplishments as well as developments that are needed to improve the national response to HABs, and will provide my perspective on the programmatic, legislative, and funding needs of the national HAB program.

A key take-away message is that HABs, in their various forms, are a national problem that requires a comprehensive national research, monitoring, and mitigation strategy. Their increasing frequency and intensity are impacting the economics and environmental health of communities, states, tribes, and regions around the Nation. Congress has responded by increasing HAB funding for some agencies, in particular for NOAA's base and competitive programs, which is essential if we are to improve our understanding of how these blooms develop and strategies to mitigate their impacts. These increases, however, do not fully restore major funding cuts made in previous years, and back then, the national HAB problem was much smaller than what we face now. *Clearly, sustained funding at a higher level is a critical need.* Enhanced support is also needed for HAB programs in the EPA, USGS, and multiple other agencies with mandates that include HAB issues. When major HAB events like the current Florida red tide, the drinking water crises that occurred in Toledo, OH in 2014 and Salem, OR in 2018 and the 2015 west coast HAB that stretched from Alaska to Mexico capture the attention of the public, the media, and Congress, the temptation to target funding to that one problem ignores the need for balanced, sustained national support that will allow other regions to respond to the inevitable outbreaks that will occur elsewhere in future years.

Background

HABs and Their Impacts. HABs are caused by simple aquatic plants called algae and cyanobacteria, the latter commonly referred to as blue-green algae. Many of them are microscopic and form the base of most aquatic food webs. The vast majority of algae are beneficial, but a number of species can cause harm to humans and ecosystems through "blooms" of cells that can result in one or more of the following: discolored water (hence the frequent use of the term "red tide"); illness and death of humans who have consumed contaminated shellfish or fish, drunk contaminated water, or come in contact with blooms through recreational activities; mass mortalities of fish, seabirds, and marine mammals; and respiratory problems caused by breathing aerosolized toxins. HAB impacts are serious and diverse, and include the following:

- Filter feeders like shellfish can accumulate algal toxins to levels that can be lethal or cause serious illness in humans, aquatic animals, and wildlife. The syndromes are referred to as paralytic, diarrhetic, neurotoxic, amnesic, or azaspiracid shellfish poisoning (PSP, DSP, NSP, ASP, and AZP respectively), depending on the causative organism(s) and the toxins they produce. Poisonings are also possible from the consumption of fish, seabirds or other animals that have accumulated HAB toxins through the food chain. This latter pathway is of particular concern in areas such as the Alaskan Arctic where these are critical food resources.

- A sixth human illness, ciguatera fish poisoning (CFP), is caused by biotoxins produced by certain HAB species that grow on seaweeds and other surfaces in coral reef communities. Ciguatera toxins are transferred through the food chain from herbivorous reef fishes to larger carnivorous, commercially valuable finfish.
- Some algal toxins become airborne in sea spray, causing respiratory irritation and more serious illness in those with respiratory diseases.
- Fish, seabirds, manatees, sea lions, turtles, whales, and dolphins are among the many animals commonly affected by HABs. These animals, as well as humans, can be exposed to algal toxins through the food they eat, the water they drink or swim in, or even the air they breathe. Oftentimes mortalities occur because of algal-produced compounds that are not toxic to humans, but nevertheless can kill fish, shellfish, and other aquatic animals.
- Negative impacts to ecosystems can occur when large and dense blooms form. These can degrade habitat through shading of aquatic vegetation on the ocean floor that serves as critically-important habitat for juvenile commercially important fish and shellfish. A related impact occurs when these high-biomass blooms terminate and the algae decay, removing oxygen from the water.
- High-biomass blooms can also be a nuisance to humans as they wash up on beaches, causing foul odors as they decay and providing a habitat for harmful bacteria to grow and produce toxins (*e.g.,* avian botulism). These blooms can also threaten important infrastructure (*e.g.,* power plants, desalination plants).
- Macroalgal or seaweed blooms also fall under the HAB umbrella. Excessive seaweed growth, often linked to pollution inputs, can displace natural underwater vegetation, cover coral reefs, and wash up on beaches, where the odor of masses of decaying material is a serious deterrent to tourism.
- Freshwater systems like lakes, ponds, rivers, and streams are also subject to HABs,[1] primarily caused by cyanobacteria (blue-green algae) that can turn the water green and slimy, endangering humans through exposures from drinking water and recreational activities. Cyanobacteria are found in virtually all ecosystems, but are primarily a problem (termed cyanoHABs) in fresh and brackish waters. CyanoHABs are increasingly affecting waterbodies in all 50 states, making these events a national crisis. Recently, however, it is becoming clear that the toxins in these systems are also making their way to coastal marine waters, where shellfish and other marine animals can be exposed, adding yet another HAB threat to those areas.

CyanoHABs often consist of dense scums or aggregations of cells floating on the water surface, causing the water to become the consistency of paint. The most serious human health concern associated with these events is that cyanobacteria produce some of the most potent natural toxins known to man; these include the microcystins, formerly known as "fast-death factor" and anatoxins, formerly known as "very fast-death factor." Freshwater HABs thus pose serious risks for human and animal health, aquatic-ecosystem sustainability and economic vitality. One example of how blooms can be significant public health threats occurred in 2014 when a cyanoHAB near Toledo, Ohio's drinking water intake source in Lake Erie resulted in 500,000 water customers being advised not to drink their tap water for nearly three days. A similar event just occurred in Salem, Oregon, this year, affecting a similar number of people but for a longer interval. The scale of these blooms can be massive, evidenced by the largest bloom in recorded history in western Lake Erie in 2015—an event that produced a surface scum that covered nearly 300 square miles. A secondary problem that arises from cyanoHABS is that these huge masses of organic material create serious environmental problems by reducing water transparency, resulting in light limitation that can inhibit the growth of suspended and bottom-dwelling plants, and by depleting oxygen as the blooms collapse, killing fish and other organisms that are unable to escape to oxygenated waters. *Every single state has experienced CyanoHAB events.*

Another important freshwater HAB problem is caused by the "golden algae" *Prymnesium parvum* which blooms in reservoirs, rivers, and lakes, and causes large fish kills. These blooms have killed millions of fish in Texas year after year, and to date have impacted nearly half of the U.S. states (Figure 1)

Causative mechanisms. As noted above, HABs are highly diverse in the U.S. in terms of species, habitats, and impacts. While we know that the underlying causes leading to HAB development vary between species and locations, we do not have a

[1] Hudnell, H.K. ed., 2008. *Cyanobacterial harmful algal blooms: state of the science and research needs* (Vol. 619). Springer Science & Business Media.

full understanding of all the factors involved. In general, algal species grow best when environmental conditions (such as temperature, salinity, nutrients, and light) are optimal for cell growth. Other biological and physical processes (such as predation, disease, toxins and water currents) determine whether enhanced cell growth will result in bloom formation. The challenge for understanding the causes of HABs stem from the complexity and interrelationship of these processes for individual species and habitats. Knowledge of how these factors control the initiation, development, and decline of a bloom is a critical precursor for advancing HAB management.

Human activities are thought to contribute to the increased frequency of some HABs, but certainly not all HABs. Of considerable concern, particularly for coastal resource managers, is the relationship between the apparent increase in HABs and accelerated anthropogenic eutrophication of coastal marine and freshwaters, also known as human-influenced nutrient pollution.[2] Overall, there is a strong scientific consensus that links marine and freshwater HABs to human-influenced eutrophication.[3,4] Coastal marine and freshwaters are receiving massive and increasing quantities of industrial, agricultural and sewage effluents through a variety of pathways. Just as the application of fertilizer to lawns can enhance grass growth, algae and cyanobacteria can grow in response to various types of nutrient inputs. Shallow and restricted coastal waters that are poorly flushed appear to be most susceptible to nutrient-related algal problems in marine systems.

Freshwater HABS are also frequently enhanced by excess nutrient inputs, often as a result of fertilizer applications on land. Recent assessments by the U.S. Environmental Protection Agency indicate that 44 percent of river and stream miles and 64 percent of lake and reservoir acres are impaired pursuant to section 303(d) of the U.S. Clean Water Act.[4] However, these numbers are likely to be conservative, as since that assessment, many other systems have been added to the 303d list including parts of the Great Lakes, our Nation's largest and most important surface freshwaters. The open waters of western Lake Erie, where the large cyanoHABs generally occur, were not deemed impaired until 2016 when Michigan declared its portion of western Lake Erie to be impaired based on impacts of cyanoHABs to aquatic life and other wildlife. In 2018, Ohio also declared its portion of the open waters to be impaired for recreational use after consulting with a team of scientists to develop the Nation's first standard methodology to designate a waterbody as impaired by cyanoHABs, per the Clean Water Act sections 305(b) and 303(d).

Climate change will almost certainly influence HABs since many critical processes governing HAB dynamics such as temperature, water column structure, upwelling and water circulation patterns, and nutrient inputs are influenced by climate. Freshwater cyanoHABs are expected to worsen as temperatures rise, as the causative species are strong competitors at high temperatures.[5] The interactive role of climate change with the other factors driving the frequency and severity of HABs is in the early stages of research, but climate change is expected to exacerbate the HAB problem in some regions and shift species distributions geographically.

One area where this is of particular concern is in the Alaskan Arctic. With present-day warming leading toward major reductions in ice cover and changes in regional hydrography, biogeographic boundaries of a wide range of marine species at all trophic levels will be greatly impacted, particularly in summer ice-free shallow waters. Although many organisms may spread into Arctic waters or become more abundant there as a result of warming trends, few present such significant threats to human and ecosystem health as HAB species. If this occurs, human health and ecosystem impacts will be significant in a region where traditional monitoring programs for toxins in shellfish, fish, or other animals are not feasible, and where the ecosystems and human populations have no prior exposure to these toxins. There

---

[2] Heisler, J., Glibert, P.M., Burkholder, J.M., Anderson, D.M., Cochlan, W., Dennison, W.c., Dortch, Q., Gobler, C.J., Heil, C.A., Humphries, E., Lewitus, A., Magnien, R., Marshall, H.G., Sellner, K., Stockwell, D.A., Stoecker, D.K., and Suddleson, M. 2008. Eutrophication and Harmful Algal Blooms: A Scientific Consensus. Harmful Algae 8(1): 3–13.

[3] Anderson, D.M., Burkholder, J.M., Cochlan, W.P., Glibert, P.M., Gobler, C.J., Heil, C.A., Kudela, R.M., Parsons, M.L., Rensel, J.J., Townsend, D.W. and Trainer, V.L., 2008. Harmful algal blooms and eutrophication: examining linkages from selected coastal regions of the United States. *Harmful Algae, 8*(1), pp.39–53.

[4] EPA. 2009. National water quality inventory: report to Congress, 2004 reporting cycle. U.S. Environmental Protection Agency, EPA 841–R–08–001, Washington, D. C., pp. 37.

[5] O'Neil, J.M., Davis, T.W., Burford, M.A., Gobler, C.J., 2012. The rise of harmful cyanobacteria blooms (CHABs): The potential roles of eutrophication and climate change. *Harmful Algae* 14: 313–334.

[6] Lefebvre, K.A., Quakenbush, L., Frame, E., Huntington, K.B., Sheffield, G., Stimmelmayr, R., Bryan, A., Kendrick, P., Ziel, H., Goldstein, T. and Snyder, J.A., 2016. Prevalence of algal toxins in Alaskan marine mammals foraging in a changing arctic and subarctic environment.

is now clear evidence that multiple HAB toxins are present in the Arctic food web at dangerous levels, and a strong likelihood that the problems will worsen. For example, recent surveys have found two different families of HAB toxins in many harvested or stranded marine mammals (Figure 1).[6] Notably, all species tested contained the toxin domoic acid, in spite of different foraging strategies. Some toxin levels were comparable to those found in marine mammals that were diagnosed with HAB poisoning during severe blooms along the U.S. West Coast. Impacts from these toxins have been devastating to regions elsewhere in the world, and now threaten the safety of the subsistence diet and the health of wildlife in Arctic waters.

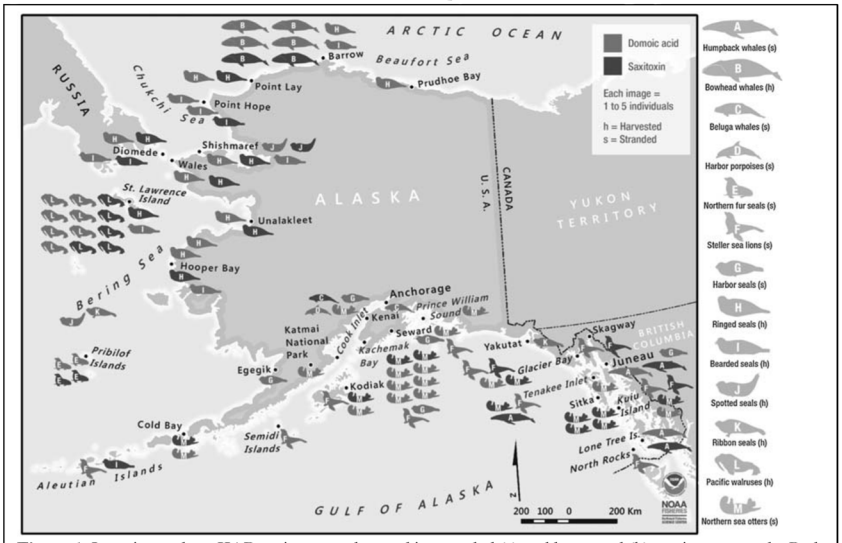


Figure 1. Locations where HAB toxins were detected in stranded (s) and harvested (h) marine mammals. Red represents species positive for domoic acid and purple represents species positive for saxitoxin. Marine mammal species are listed as follows: (A) humpback whales, (B) bowhead whales, (C) beluga whales, (D) harbor porpoises, (E) northern fur seals, (F) Steller sea lions, (G) harbor seals, (H) ringed seals, (I) bearded seals, (J) spotted seals, (K) ribbon seals, (L) Pacific walruses and (M) northern sea otters. (Source: Lefebvre et al., 2016).

HAB distribution in the U.S. All coastal and inland states experience HABs (Figure 2), including all five of the North American Great Lakes, but the specific organisms and thus the nature of the impacts differ dramatically from region to region. All of the human poisoning syndromes and other HAB impacts described above are known problems within the U.S. and its territories, affecting large expanses of coastline.

- *PSP* occurs on a near-annual basis in all coastal New England states as well as New York, extending to offshore areas in the Northeast such as Georges Bank, and along much of the West Coast from Alaska to Southern California. The current distribution of PSP in the U.S. has greatly expanded over the past several decades, with areas like Long Island, Puget Sound, and Florida (both coasts) now affected. Overall, PSP affects more U.S. coastline than any other marine algal bloom problem.
- *NSP* occurs along Gulf of Mexico coasts, with the most frequent outbreaks along western Florida and Texas. Outbreaks are near-annual, with some lasting for as long as a year. Louisiana, Mississippi, North Carolina and Alabama have also been affected in recent years, causing extensive losses to the oyster industry and killing birds and marine mammals.

[6] Lefebvre, K.A., Quakenbush, L., Frame, E., Huntington, K.B., Sheffield, G., Stimmelmayr, R., Bryan, A., Kendrick, P., Ziel, H., Goldstein, T. and Snyder, J.A., 2016. Prevalence of algal toxins in Alaskan marine mammals foraging in a changing arctic and subarctic environment. *Harmful algae, 55,* pp.13–24.

- *ASP* has been a problem for all of the U.S. Pacific coast states since it was first discovered in 1987 in Canada.[7] Outbreaks are episodic, and some can be massive, as in 2015 when a bloom extended along the entire West Coast of the U.S., including Alaska, following a year of unusually warm offshore water temperatures.[8] The bloom resulted in enormous economic losses due to closure of recreational harvesting of shellfish in three states, as well as targeted closures for Dungeness crab, anchovy, and sardines. Toxin levels were the highest ever reported for anchovy, mussels and crabs—10 times the regulatory limits. Shortly thereafter in 2016, extensive shellfish closures were implemented in Maine, Massachusetts, and Rhode Island due to the first-ever recording of ASP toxins in that region. The ASP toxin, which can cause permanent brain damage and memory loss in affected consumers, has recently caused shellfish closures in Gulf of Mexico waters as well.
- Until recently, *DSP* was virtually unknown in the U.S., but a major outbreak was reported along the Texas coast in 2008, resulting in an extensive closure of shellfish beds in that area.[9] Since then, DSP toxins have been reported on both the East and West Coasts.

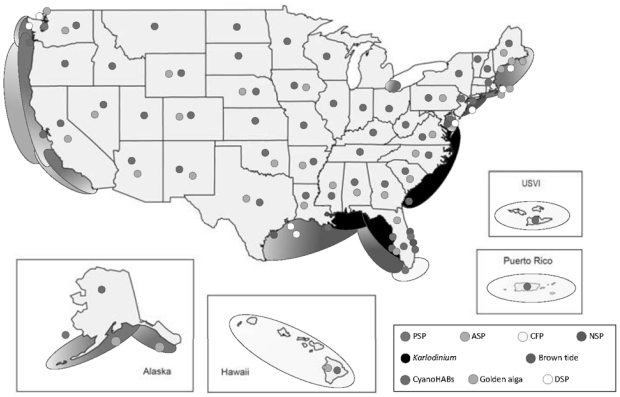


Figure 2. A generalized view of the U.S. showing the various HAB poisoning syndromes and other impacts that occur in specific areas. Colored dots or ovals indicate where a particular syndrome or impact has been reported. Ovals are used to depict regional phenomena that occur at multiple locations along a coastline. All 50 states are impacted by cyanobacterial HABs, in a variety of freshwater systems: rivers, streams, reservoirs, etc. The same is true for 23 states impacted by golden algal blooms caused by *Prymnesium parvum*. It is not practical to indicate the location of each cyanobacterial or golden algae bloom, so each state experiencing these blooms is indicated using a single green and/or gold dot. Larger green ovals denote widespread cyanoHABs in those areas. Source: NOAA U. S. National Office for Harmful Algal Blooms (http://www.whoi.edu/redtide/page.do?pid=14898), Woods Hole, MA.

- *CFP* is the most frequently reported non-bacterial illness associated with eating fish in the U.S. and its territories, but the number of cases is probably far higher since reporting is voluntary and there is no confirmatory laboratory test. In the U.S. Virgin Islands, it is estimated that nearly 50 percent of the adults have been poisoned at least once, and some estimate that 20,000—40,000 individuals are poisoned by ciguatera annually in Puerto Rico and the U.S. Virgin Islands alone. CFP occurs in virtually all sub-tropical to tropical U.S. waters (*i.e.,* Florida, Texas, Hawaii, Guam, Virgin Islands, Puerto Rico, and many Pacific Terri-

[7] Trainer, V.L., Bates, S.S., Lundholm, N., Thessen, A.E., Cochlan, W.P., Adams, N.G. and Trick, C.G., 2012. Pseudo-nitzschia physiological ecology, phylogeny, toxicity, monitoring and impacts on ecosystem health. *Harmful Algae, 14,* pp.271–300.

[8] Trainer, V., Moore, S., Mccabe, R., Hickey, B., Kudela, R., Marin, R., Mickett, J. and Mikulski, C., 2017. A massive harmful algal bloom on the U.S. West Coast and the future of monitoring for early warning.

[9] Campbell, L., Olson, R.J., Sosik, H.M., Abraham, A., Henrichs, D.W., Hyatt, C.J. and Buskey, E.J., 2010. First harmful dinophysis (dinophyceae, dinophysiales) bloom in the U.S. is revealed by automated imaging flow cytometry1. *Journal of Phycology, 46*(1), pp.66–75.

tories). As tropical fish are increasingly exported to distant markets, ciguatera has become a problem for consumers far from the tropics. For example, poisonings of restaurant patrons in the Washington DC area and elsewhere were linked to fish caught in the Flower Garden Banks National Marine Sanctuary in the Gulf of Mexico south of Texas.[10]

- *CyanoHABs* occur in freshwater systems of all 50 states, including all five of the North American Great Lakes (Figure 3). The primary cyanotoxins of concern in many of these events are microcystins. There have been many examples of how microcystins impact human and animal health as mentioned previously. However, it should be noted that several other emerging toxins of concern are becoming more prevalent in freshwaters across the Nation. These include anatoxins (neurotoxins), saxitoxins (PSP toxins) and cylindrospermopsins. Anatoxin-a has been the confirmed cause of deaths in dogs that have ingested toxic waters in California and elsewhere in North America. The 2007 National Lakes Assessment (NLA) revealed that 7 percent percent of U.S lakes were impacted by saxitoxins,[11] consistent with a recent California survey that detected STX in 7 percent of wadeable streams.[12] Regionally though, the problem may be much worse. For example, in 2016 the Ohio EPA detected saxitoxins at 18 drinking water intake sites (15 percent of all sites sampled). Furthermore, low levels of saxitoxins were detected in the finished drinking water at eight Ohio public water systems, indicating a potential risk to human health.

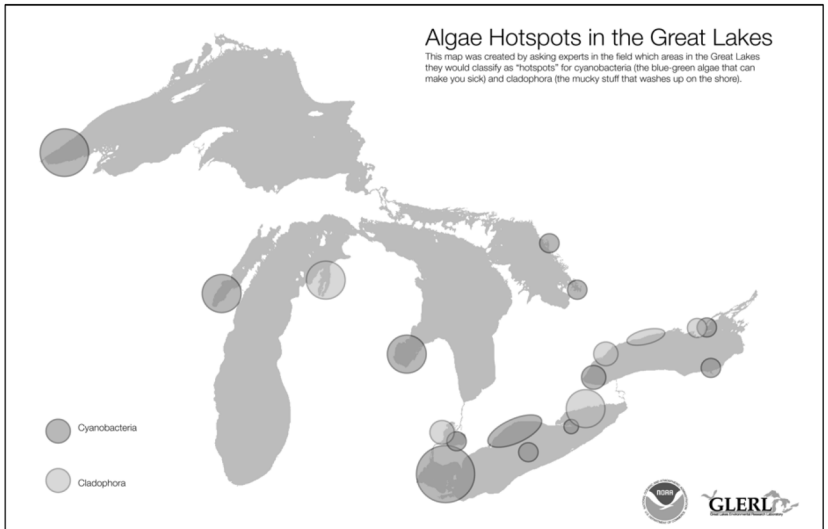


Figure 3: Current spatial distribution of HABs in the Great Lakes.

Recent Trends. The nature of the HAB problem has changed considerably over the last 50 years in the U.S. *Virtually every coastal state is now threatened by harmful or toxic marine algal species, whereas 30—40 years ago, the problem was much more scattered and sporadic* (Figure 4). In inland states, HABs in rivers, lakes, reservoirs, and other water freshwater bodies have increased dramatically as well. Overall, the number of toxic blooms, the economic losses, the types of resources affected, and the

[10] *https://flowergarden.noaa.gov/visiting/ciguatera.html*

[11] Loftin, K. A., J. L. Graham; E. D. Hilborn, S. C. Lehmann, M. T. Meyer, J. E. Dietze, C. B. Griffith. 2016. Cyanotoxins in inland lakes of the United States: Occurrence and potential recreational health risks in the EPA National Lakes Assessment 2007. Harmful Algae. 56:77–90. DOI: 10.1016/j.hal.2016.04.001.

[12] Fetscher, A. E., M. D. A. Howard, R. Stancheva, R. M. Kudela, E. D. Stein, M. A. Sutula, L. B. Busse, and R. G. Sheath. 2015. Wadeable streams as widespread sources of benthic cyanotoxins in California, USA. Harmful Algae. 49:105–116. DOI: 101.1016/j.hal.2015.09.002.

number of toxins and toxic species have all increased dramatically in recent years in the U.S. and around the world.[13]

There are many reasons for this expansion, some of which involve human activities, such as nutrient pollution as noted above. Some new bloom events likely reflect newly discovered populations from better detection methods and more observers rather than new species introductions or dispersal events. Other "spreading events" are most easily attributed to dispersal via natural currents, while it is also clear that man may have contributed to the global HAB expansion by transporting toxic species in ship ballast water or in aquaculture species. The U.S. Coast Guard, EPA, and the International Maritime Organization are all working toward ballast water control and treatment regulations that will attempt to reduce the threat of HAB species introductions worldwide.

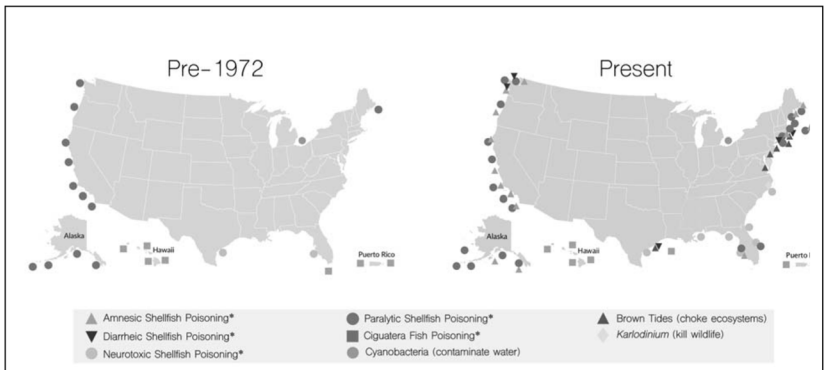


Figure 4. Expansion of the national U.S. HAB problem over the last 50 years. Note that freshwater cyanobacterial blooms are only indicated in Lake Erie, though similar problems occur in all inland states, many with problems only becoming apparent in recent years. These maps show both the spreading of HABs within regions, as well as the emergence of new HAB problems unknown to science until recently (e.g., ASP, DSP, brown tides, *Karlodinium*). Source: NOAA U. S. National Office for Harmful Algal Blooms. (http://www.whoi.edu/redtide/page.do?pid=14898), Woods Hole, MA.

Economic and Societal Impacts. HAB events have a wide array of economic impacts, including the costs of conducting routine monitoring programs for shellfish and other affected resources, short-term and permanent closure of harvestable shellfish and fish stocks, reductions in seafood sales (including the avoidance of "safe" seafoods as a result of over-reaction to health advisories), mortalities of wild and farmed fish, shellfish, submerged aquatic vegetation and coral reefs, impacts on tourism and tourism-related businesses, and medical treatment of exposed populations. A conservative estimate of the average annual economic impact resulting from marine HABs in the U.S. is approximately $82 million (Hoagland and Scatasta, 2006). However, single events can sometimes approach this annual average. For example, in 2005, a HAB event in New England resulted in a loss of $18 million in shellfish sales in Massachusetts alone.[14] Furthermore, harvesting closures in Maine (soft-shell clams, mahogany quahogs, and mussels) are estimated to cost $2.9 million each week, with typical closures ranging from 4 to 16 weeks, and occurring nearly every year.[15] Likewise, the direct economic impact from commercial closures due to the West Coast ASP outbreak in 2015 was estimated to be approximately $30 million for the Dungeness and rock crab fisheries in California alone, in addition to the substantial but unquantified impacts to other fisheries.[16] That same outbreak caused an estimated $23 million loss in the state of Washington.[17]

---

[13] HARNESS 2005. HARRNESS—a framework for HAB research and monitoring in the United States for the next decade. Ramsdell, J.S., D.M. Anderson, and P.M. Glibert (Eds.). Ecological Society of America, Washington D.C. 96 pp.

[14] Jin, D., Thunberg, E., and Hoagland, P. 2008. Economic Impact of the 2005 Red Tide Event on Commercial Shellfish Fisheries in New England. Ocean and Coastal Management. 51(5): 420–429.

[15] K. Ahearn. 2008. Economic losses from closure of shellfish harvesting areas in Maine. Prepared for the Maine Department of Marine Resources.

[16] *http://www.oceansciencetrust.org/wp-content/uploads/2016/11/HABs-and-CA-Fisheries-Science-Guidance-10.25.16.pdf*

[17] D. Ayres, personal communication.

The economic impacts from freshwater HABs is also substantial, with some estimates exceeding several billions of dollars per year when the decline in property values is included. One example is the closure of Grand Lake St. Marys in Ohio in 2011 due to toxic cyanoHAB blooms. That event cost the local community an estimated $200 million in lost tourism income. In addition, countless fish, waterfowl, and pets were sickened and killed by the lake's toxic conditions. The state of Ohio confirmed seven illnesses (and potentially 21 additional cases) were linked to exposure to toxins in lakes, including a case in which an individual was temporarily blinded. A recent report on the economic benefits of reducing HABs in Lake Erie[18] found that the annual economic impacts of the 2011 bloom (second largest in recorded history) and 2014 (the year of the Toledo water crisis) were $71 million and $65 million, respectively. Notably, 2014 data did not include the direct economic losses associated with the water crisis so that value is likely a gross underestimate. The study also estimated the 30-year economic impact to the region if blooms that range between the size of the 2011 and 2014 events continue to occur to be between $1.3 and $1.5 billion. Furthermore, another recent study from The Ohio State University found that people who wanted to use western Lake Erie for recreational purposes spent $800,000–$1 million more in travel costs to avoid the bloom-impacted areas.[19] *Cumulatively, the costs of HABs have exceeded 10–20 billion dollars over the last several decades, and* these estimates do not include the application of "multipliers" that are often used to account for the manner in which money transfers through a local economy.

In addition to impacting public health, ecosystems, and local economies, HABs can also have significant social and cultural consequences. For example, along the Washington and Oregon coasts, tens of thousands of people visit annually to participate in the recreational harvest of razor clams. However, a series of beach closures in recent years due to high levels of the ASP toxin domoic acid prevented access to this recreational fishery. These harvesting closures have not only caused economic losses, they have also resulted in an erosion of community identity, community recreation, and a traditional way of living for native coastal cultures.

HAB Program Development

Marine HABs. To better understand the nature of the national approach to researching and managing HABs, the following background is offered on the development of the suite of activities, facilities, and funding programs that constitute our national strategy for dealing with this significant problem.

The national HAB "program", or strategy, is viewed by many colleagues in other disciplines as a model program that has succeeded because of its organization, structure, and planning. As recently as 30 years ago, this was not the case, as there was very little research on HABs, and that being conducted in the academic community was scattered and unfocused. To rectify this problem, we formulated a *National Plan for Marine Biotoxins and Harmful Algae* (Anderson *et al.,* 1993) that guided activities in this field for the next 10–15 years. The *National Plan* was broadly based, and encompassed ecology, physiology, toxicology, human health, economics, ecosystem health, and a variety of other issues. This breadth of topics exceeded the mandate and resources of any single agency or program, and therefore for implementation purposes, it was necessary to break the plan into a series of programs based on complementary topics. The first thematic area was the *Ecology and Oceanography of HABs,* which was addressed by the ECOHAB program. This was followed by MERHAB (*Monitoring and Event Response of HABs*), and then by *Prevention, Control and Mitigation of HABs* (PCMHAB) and then the *Ocean and Human Health* (OHH) programs. The latter began with a partnership between the National Institute of Environmental Health Sciences (NIEHS) and the National Science Foundation (NSF), who have supported multiple *Centers for Oceans and Human Health* (COHH) that conduct significant HAB research and outreach activities.

In 1998, Congress recognized the severity of these threats and authorized the Harmful Algal Bloom and Hypoxia Research and Control Act (HABHRCA 1998; embedded in Public Law 105–383). The Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2004 (HABHRCA 2004, Public Law 108–456) and 2014 (HABHRCA 2014, Public Law 113–124) reaffirmed and expanded the mandate for NOAA to advance the scientific understanding and ability to detect, monitor, assess, and predict HAB and hypoxia events. Another HABHRCA reauthorization is currently moving through Congress, and I strongly support passage of this legisla-

[18] M. Bingham, S. K. Sinha and F. Lupi . 2015. Economic Benefits of Reducing Harmful Algal Blooms in Lake Erie", Environmental Consulting & Technology, Inc., Report, 66 pp,

[19] *https://theconversation.com/whats-the-value-of-a-clean-beach-heres-how-economists-do-the-numbers-94805?utm_source=twitter&utm_medium=twitterbutton*

tion. I do have comments on some sections of the draft legislation, and would be pleased to provide details if requested.

The 2014 reauthorization called for Federal agencies to provide integrated assessments on the causes and consequences of and approaches to reducing HABs and hypoxia nationally, with particular emphasis on the Great Lakes. This led to the creation of the Interagency Working Group on HABHRCA (IWG–HABHRCA), tasked with coordinating and convening Federal agencies and their stakeholders to discuss HAB and hypoxia events in the U.S., and to develop action plans and assessments of these situations. NOAA co-chairs the IWG–HABHRCA with EPA. Other member agencies include FDA, USDA, CDC, USACE, NASA, NPS, USGS, BOEM, Navy, NIEHS, and NSF. A detailed report was recently issued,[20] providing an assessment of the U.S. HAB problems and recommendations for action.

The 1993 *National Plan* provided the initial guidance and perspective that led to the creation of several multi-agency partnerships and individual agency initiatives, many of which continue to this day. Together, ECOHAB, MERHAB, and PCMHAB have funded nearly $140 million in marine and freshwater (Great Lakes) HAB research since the programs began in 1996, 2000, and 2010 respectively. Significant funding in excess of $45 million has also been provided by the NSF—NIEHS COHH program, with another $25 million anticipated over the next five years. Smaller contributions have been made by other programs and agencies, including Sea Grant, NASA, EPA and the NSF geoscience core programs.

After more than 10 years of strong program growth and diverse research activities, the 1993 National Plan became outdated, and was replaced by HARRNESS (*Harmful Algal Research and Response: A National Environmental Science Strategy 2005–2015* [21]). Several hundred scientists and managers, from a wide array of fields, contributed to the knowledge base on which this new national science and management strategy was developed. HARRNESS is continuing to guide U.S. HAB research and monitoring, though updates to the program are now under consideration.

At the conceptual level, HARRNESS is a framework of initiatives and funding programs that identify and address current and evolving needs associated with HABs and their impacts. ECOHAB is a critical, core program that is needed to address the fundamental processes underlying the impacts and dynamics of HABs. ECOHAB's research results have been brought into practical applications through MERHAB, a program formulated to transfer technologies and foster innovative monitoring programs and rapid response by public agencies and health departments, as well as through PCMHAB, a program dedicated to HAB prevention, control and mitigation. All of these programs serve important topic areas, and collectively form a strong basis for progress.

The COHH initiative of NIEHS and NSF fills an important niche by creating linkages between members of the ocean sciences and biomedical communities to help both groups address public health aspects of HABs. The partnership between NIEHS and NSF clearly needs to be sustained and expanded in order to provide support to a large network to address the significant problems under the OHH umbrella. This is best accomplished through additional funds to these agencies, as well as through the involvement of other agencies with interests in oceans and human health, including, for example, EPA, NASA, FDA, and CDC.

Freshwater HABs

With the exception of the Great Lakes, which fall under NOAA's jurisdiction, freshwater systems that are impacted by HABs have not been comprehensively addressed in ECOHAB, MERHAB, or the COHH programs. This is because NOAA's mandate includes the Great Lakes and estuaries up to the freshwater interface, but does not include the many rivers, ponds, lakes, and reservoirs that are subject to freshwater HAB problems.

The reauthorization of HABHRCA in 2004 expanded the Act to include blooms in all U.S. freshwaters. The Act mandated an assessment of freshwater HABs,[22] lead-

---

[20] National Science and Technology Council Subcommittee on Ocean Science and Technology. 2016. Harmful Algal Blooms and Hypoxia Comprehensive Research Plan and Action Strategy: An Interagency Report.

[21] HARNESS 2005. HARRNESS—a framework for HAB research and monitoring in the United States for the next decade. Ramsdell, J.S., D.M. Anderson, and P.M. Glibert (Eds.). Ecological Society of America, Washington D.C. 96 pp.

[22] Lopez, C.B., Jewett, E.B., Dortch, Q., Walton, B.T. Hudnell, H.K. 2008. Scientific Assessment of Freshwater Harmful Algal Blooms. Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, D.C., 65 pp.

ing to an interagency monograph that described science and research needs.[23] This effort to address freshwater HABs at the national level was hampered because the Act did not contain a mandate or funding authorization for the EPA, which is the appropriate Agency to establish and maintain such a plan. All U.S. freshwaters are within the purview of the EPA, as defined in the Clean Water Act (2002) and the Safe Drinking Water Act (2002). The Agency acknowledges its mandate for safe and clean water in Goal 2 of the 2006–2011 EPA Strategic Plan (EPA, 2008), "Ensure drinking water is safe. Restore and maintain oceans, watersheds, and their aquatic ecosystems to protect human health, support economic and recreational activities, and provide healthy habitat for fish, plants, and wildlife." Because of this, many studies of inland HABs are funded through state programs such as the Ohio Department of Higher Education Harmful Algal Bloom Research Initiative as one example or by Sea Grant in states that have Sea Grant programs.

As detailed in the 2016 IWG–HABHRCA report, in 2010, the interagency Great Lakes Restoration Initiative (GLRI) was created to protect and restore Great Lakes natural resources, including HAB projects. After the 2014 Lake Erie HAB, $12 million in GLRI funding was provided to Federal and state programs to minimize HABs and hypoxia in the western basin of Lake Erie. Specific projects supported by this funding include upgrading controlled drainage systems, funding best management practices (BMPs) at livestock facilities, and planting cover crops. It also provides funding for the Environmental Quality Incentives Program, a voluntary program through USDA NRCS that provides financial and technical assistance to agricultural producers to plan and implement conservation practices that improve soil, water, plant, animal, air, and related natural resources on agricultural land and non-industrial private forestland.

In 2015, EPA announced the award of 14 GLRI grants totaling over $17 million, to fund projects that will improve Great Lakes water quality by preventing phosphorus runoff and solid erosion that contribute to algal blooms, and by reducing suspended sediments in Great Lakes tributaries. These projects focus on high-priority watersheds and receiving waters with high potential or known risk for HABs and hypoxia.

NOAA and EPA have shared responsibility under HABHRCA for the Great Lakes. HABHRCA gives EPA responsibility for inland freshwaters, but in reality, multiple agencies conduct intramural research in freshwater, however none are funded specifically for research on inland HABs.

Recent Research Accomplishments

Given the challenges above, it is worth highlighting some of the recent accomplishments that show how properly administered and directed research funding can lead to big strides in our ability to understand and manage HAB phenomena. Progress has been rapid in many areas, and new approaches and technologies for research and management are now available, a few of which are listed here.

- DNA technology has led to the development of species-or strain-specific "molecular probes" that can label HAB cells of interest so they can rapidly be detected visually, electronically, or chemically. Progress has been significant and probes and assays of multiple types are available for many HAB species, with this technology now routinely employed in HAB research and monitoring programs [24]
- New optical-and DNA-based sensors are now available that can be moored in open waters or placed on docks and other structures where they can monitor the water for HAB cells and toxins continuously. These in situ sensors are dramatically changing the nature of research and monitoring as they open the door to an era where remote, subsurface, near real-time detection of HAB species and toxins can be envisioned. One example is an array of IFCBs (Imaging FlowCytobots, or underwater microscopes) that take hundreds of thousands of images of algal cells every day, identifying and counting HAB species autonomously, and sending that data to shore 24/7. IFCB sensors in the Gulf of Mexico have provided early warning of seven HABs in the Texas region in recent

[23] Hudnell, H.K. (Ed.). 2008. *Cyanobacterial Harmful Algal Blooms: State of the Science and Research Needs,* Advances in Experimental Medicine and Biology, Vol. 619, Springer Press.

[24] Anderson, D.M., Keafer, B.A., McGillicuddy Jr, D.J., Mickelson, M.J., Keay, K.E., Libby, P.S., Manning, J.P., Mayo, C.A., Whittaker, D.K., Hickey, J.M. and He, R., 2005. Initial observations of the 2005 Alexandrium fundyense bloom in southern New England: General patterns and mechanisms. *Deep Sea Research Part II: Topical Studies in Oceanography, 52*(19–21), pp.2856–2876.

years,[25] [26] with text messages and e-mail alerts being sent to managers and scientists automatically when HAB species exceed specified cell concentration thresholds. Because they can be located in the water and thus in close proximity to the cells in a bloom, these instruments have also begun to reveal details of HAB dynamics that were not possible before. In one series of deployments in New England, IFCBs have revealed that the cells responsible for PSP outbreaks grow faster, swim faster, and are much more toxic than was previously thought on the basis of laboratory studies.[27]

- Technological advances have expanded our capabilities for research and monitoring of HABs, but the blooms will always be under sampled because of the large space and time scales over which they occur. As a result, numerical models are being used to help extrapolate and interpret these sparse observations. ECOHAB regional programs all developed large-scale models of the HABs in those study areas, and many of these are now adding greatly to our understanding and management of these phenomena. In particular, some are the basis of operational HAB forecast systems that are providing information to managers and the public on daily, weakly, and seasonal scales.
- Sustained ecosystem studies of the causes and impacts of HABs is leading to the ability to predict when and where HABs will occur. Forecasts for *Karenia brevis* on the Gulf Coast and cyanobacterial blooms in Lake Erie have been operationalized in NOAA, so that forecasts are offered every few days during blooms seasons. Other forecasts are in pilot stages, including *Alexandrium* in the Gulf of Maine and *Pseudo-nitzschia* on the Washington-Oregon coast and California. In all cases the purpose is to provide early warning to protect human health and help businesses dependent on these fish/shellfish or tourism to be prepared.
- Combining the previous highlights, a realistic vision for the future would be that of arrays of moored instruments capable of detecting HAB cells and their toxins and transmitting this information to shore where the data can be assimilated into numerical models and forecasts, to be used by managers to make decisions for harvesting closures or other mitigation strategies to reduce HAB impacts. An exciting development in this regard is the advent of ocean observing systems (OOSs), arrays or networks of moored and mobile instruments that can collect and transmit data continuously from remote locations to shore-based scientists and managers. Just as networks of meteorological stations and numerical models of atmospheric dynamics greatly improved our ability to provide accurate forecasts of weather events, OOSs and their associated numerical models of ocean dynamics have the potential to document long-term patterns and changes in the sea, to detect infrequent events that previously went unobserved, and to make predictions or forecasts about these and other phenomena that directly affect human populations and marine ecosystems. The HAB sensors described above are viewed by many as an important component of the emerging ocean observing system infrastructure worldwide.
- One of the most frequent questions addressed to HAB scientists is "what can you do to stop these blooms?" To address this need, NOAA established the PCMHAB program in which all funding applications fall within the same topic area, ensuring that unfair comparisons between practical versus fundamental science are not made during the peer review process. The program is still young, but promising approaches are already emerging, including some that can directly lead to bloom prevention or even suppression. Some of the latter approaches include water clarification using dispersed clay solutions, and cell and toxin destruction using ozone. *Progress has been made, but this is a long-neglected area that can benefit from enhanced, targeted funding.*
- One significant outcome of a number of regional HAB research programs is the development of integrated research and response communities that include scientists, Federal and state agencies, tribes, and industry. In the past, many of

[25] Campbell, L., Olson, R.J., Sosik, H.M., Abraham, A., Henrichs, D.W., Hyatt, C.J. and Buskey, E.J., 2010. First harmful dinophysis (dinophyceae, dinophysiales) bloom in the U.S. is revealed by automated imaging flow cytometry1. *Journal of Phycology, 46*(1), pp.66–75.

[26] Jochens, A.E. and Watson, S.M., 2013. The Gulf of Mexico Coastal Ocean Observing System: An integrated approach to building an operational regional observing system. *Marine Technology Society Journal, 47*(1), pp.118-133.

[27] Brosnahan, M.L., Velo-Suarez, L., Ralston, D.K., Fox, S.E., Sehein, T.R., Shalapyonok, A., Sosik, H.M., Olson, R.J. and Anderson, D.M., 2015. Rapid growth and concerted sexual transitions by a bloom of the harmful dinoflagellate *Alexandrium fundyense* (Dinophyceae). *Limnology and oceanography, 60*(6), pp.2059–2078.

these individuals and groups worked independently and with little exchange of ideas and data. The networks that now exist in many parts of the country are active and productive, and should continue to be a major element in the growing capabilities of the national HAB program.

- In this context, outreach and communication by HAB research programs has led to greatly improved understanding of HAB phenomena by the general public and stakeholders. HAB bulletins are now produced and widely distributed in multiple regions of the country.
- The new technologies developed to study and manage HABs and their impacts have had important commercial benefits. New companies or product lines have been established to build instruments, toxin test kits, and many other tools used in HAB management. Research has also led to increased exploitation of aquatic resources. One example is the opening of offshore hard clam resources on Georges Bank that had been closed for nearly two decades due to PSP toxins. An ECOHAB-funded regional project called GOMTOX provided background data and samples that helped in the development of an Onboard Screening, Dockside Testing Program that allows fishermen to use new toxin testing kits on board their vessels to determine if areas are safe for harvesting in the offshore waters of Georges Bank, an area with an estimated $10–15 million sustained fishery of surf clams and ocean quahogs.[28]

Challenges in HAB Research, Monitoring and Management

As is evident from the diverse and large nature of the national HAB problem described above, *managers responsible for the protection of human health and coastal resources are facing a growing and daunting challenge. Many regions are now subject to multiple HAB species, with many blooming at different times of the year, affecting multiple resources. All states now have HAB problems which appear to be getting worse, in part due to human activities. Monitoring programs that used to focus on a single HAB poisoning syndrome are now struggling to cover two, three, and even four different concurrent threats, greatly stretching scarce personnel and financial resources.* In some cases, this has led to blanket harvesting closures in which entire coastlines are quarantined for months at a time on an annual basis, even though the affected resources may not be toxic across that entire expanse and time.

Some species need to be present in very high abundances before harmful effects occur, which makes it easier to detect and track those HABs. However, other species cause problems at very low concentrations, essentially being hidden among other benign algae, making them difficult to detect and track. The factors that cause and control HABs, from their initiation to their decline vary, not only by species, but also by region due to differences in local factors such as the shape of the coastline, runoff patterns, oceanography, nutrient regime, other organisms present in the water, etc. *This diversity in species, toxins, habitats, and impacts means that there is no "one size fits all" approach to HAB research and management—each type of HAB needs to be studied individually.* An important conclusion in this regard is that it is necessary to sustain multiple HAB research and monitoring capabilities throughout the country. If funds are directed predominantly to individual, high-visibility events such as the massive 2015 West Coast ASP event or the ongoing Florida red and green tides, personnel and capabilities in other regions of the country will diminish, making those areas less able to deal with the outbreaks that will surely occur in future years. *Consequently, a national approach to coordination and funding is needed, following the framework that has already been established through the programs described above.*

[28] *https://www.whoi.edu/news-release/Georges_Bank_fisheries*

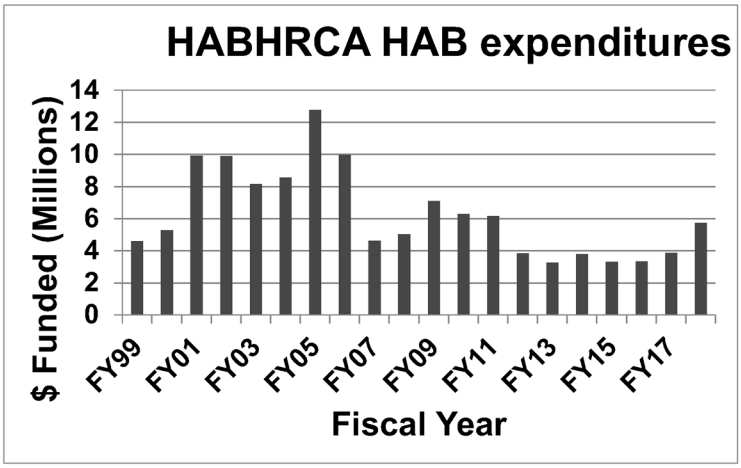


Figure 5. HAB HABHRCA expenditures from the NOAA CSCOR program. These values were determined under the assumption that HAB funding represents an average of 63% of the HABs plus hypoxia totals. 2018 data are preliminary.

NOAA is the only agency with extramural funding programs devoted solely to research on HABs. Within that agency, one significant challenge has been that funding for HAB research has fluctuated widely, greatly impacting the pace and extent of progress. Since 1999, competitive funding for HAB research ranged from $3.3 to $12.8 million per year[29] (Figure 5). The number of research projects started varied from 0 to 25 per year, with significant intervals with no new starts (Figure 6). *Figures 5 and 6 demonstrate how funding has decreased dramatically since 2005–2006, even as the national HAB problem has expanded.* Recent increases are promising, but we are still far below the levels of prior years. Even if the prior years' maximum were re-established, however, the funding would not be enough to address all of the HAB problems in the US. For example, one five-year project to understand the causes of a single HAB in a single region costs $5 million in order to develop the appropriate model and a rudimentary HAB forecast, and more would be needed to refine the forecast and move it into an operational environment. The fluctuation in funding has meant that promising new technologies and approaches are lost or delayed, scientific capacity is lost as research teams disband, and new ideas do not get developed. As students and young professionals trained to work in the field move on to other pursuits, as has happened in recent low-funding years, our national response capabilities are greatly weakened. Scientists in our field talk about the "lost generation" of young HAB scientists who could not continue their training during the gap years seen in Figure 6. *Clearly, sustained funding at a higher level is a critical need.*

[29] It was not possible to obtain a separate funding history for HABs since the competitive funding line within NOAA CSCOR is for HABs and hypoxia research and data are not available in early years for each program. Using the average percentage of the total that was used for HAB funding since 2007 (63 percent), these values in Figure 5 were calculated.

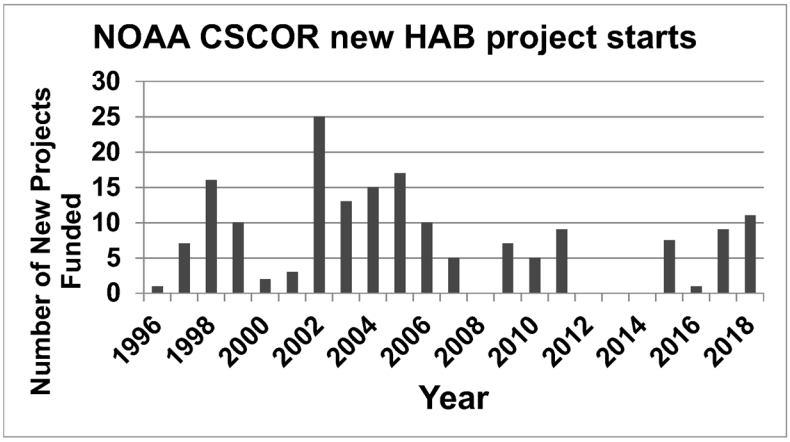


Figure 6. The number of HAB projects funded by NOAA CSCOR through the ECOHAB, MERHAB, and PCMHAB programs. Gaps indicate years when funding levels were only sufficient to support ongoing 3-5-year projects. These large gaps in new project starts and the low level of funding available in recent years (Figure 5) are in stark contrast to the rapidly expanding nature of the national HAB problem. 2018 data are preliminary.

Another challenge is that funding is needed for a wider diversity of activities. When HABHRCA was first passed in 1998, the only need was for research. That research has been highly successful and needs to continue, but now we are ready to move on to implementing the technology and approaches that have been developed, hence the creation of the MERHAB and PCMHAB programs. *Each time HABHRCA has been reauthorized there has been some wording about some of the other activities that are needed, besides research, but none of these have been explicitly authorized or funding provided.*

Research: The foregoing emphasizes that the need for research funding is greater than ever. There are emerging HAB species and toxins in every part of the U.S. While we understand the causes of some HABs in some regions, we do not understand why blooms terminate in any region, and the current situation in Florida, with a devastating bloom that has continued for over nine months, illustrates why this is critically important. The human health impacts and, as a corollary, the impacts on other animals, including endangered and threatened species, has barely been studied. We are now confronted, for example, with the possibility that shellfish may accumulate multiple diverse toxins, but all monitoring in the U.S. is focused on the health impacts of single toxins. This list could continue, but for those that ask, "Haven't we done enough research?", the answer is no, because we cannot manage what we do not understand and there is still very much that we do not understand.

Operational HAB Forecasting: Research has led to the development of HAB forecasts for specific HABs in specific regions.[30] Several are operational in NOAA and others are in various phases of transition to operations. However, making HAB forecasts operational, like weather forecasts, has taken funding away from research. *There is no clear mandate or funding for operational HAB forecasts,* although NOAA is implementing it slowly through its Ecological Forecasting Roadmap.

Operational HAB Observing: Research has led to the development of innovative and powerful HAB sensors that can be deployed autonomously at fixed locations and on a variety of mobile platforms. Some of these are highlighted in the testimony of Ivory Engstrom from McLane Laboratories for this hearing. These can provide states, tribes, and local management agencies and tourism, aquaculture and wild fisheries industries with HAB early warning and provide data for models that can forecast HABs, much as weather instruments provide data to improve the accuracy of weather forecasts. While the prices are likely to come down as more instruments are deployed, they are still too expensive for the agencies and industries that could most use them. There is a thus critical need for a National HAB Observing Network, perhaps under the auspices of the NOAA Integrated Ocean Observing Sys-

[30] *https://coastalscience.noaa.gov/research/stressor-impacts-mitigation/hab-forecasts/*

tem,[31] and the Regional Observing Associations, which would deploy these sensors as part of the larger observing network. If states or industries wanted to add additional sensors to meet their specific needs, they could do it more cheaply and easily by becoming part of this larger network. *There is no clear mandate or funding for a national HAB observing system.*

*HAB Event Respon*se: As we have seen from the events in Florida this year, the West Coast in 2015, Lake Erie in multiple years, and many other outbreaks, extensive and damaging HABs can occur at any time and any place. There are immediate, short-term needs for predicting where the bloom will go and how severe it will be, assessing the impacts, and developing management responses, as well as longer-term needs for economic assistance and efforts to improve future response. NOAA has maintained a very small HAB Event Response Program,[32] which is very effective, but much more is needed. We want to thank the Senate for passing S.1057, which includes an entire section on HAB and Hypoxia Events of National Significance. This highlights the importance of responding to events and is a great step forward. *However, some modification is required to make it effective for both short-term and long-term response, and a funding mechanism is required that will allow monies to be provided quickly.* I can provide additional suggestions at a later date, if requested, or recommend others who are more knowledgeable about the mechanics.

Freshwater HABs: The problem of inland freshwater HABs has exploded in the last five years and is only likely to get worse. While NOAA has purview over marine and coastal HABs including the Great Lakes, EPA has purview over inland freshwater HABs. *No HAB funding is authorized or appropriated for EPA* so that it can fulfill the requirements, similar to those of NOAA, for HAB programs.

Summary and Recommendations

- HABs are a serious and growing problem in the U.S., affecting every state. HAB problems will not go away and are currently increasing in severity and breadth nationwide.
- HABs have a wide array of economic and social impacts, including the costs of conducting routine monitoring programs for shellfish and other affected resources, short-term and permanent closure of harvestable shellfish and fish stocks, reductions in seafood sales (including the avoidance of "safe" seafoods as a result of over-reaction to health advisories), mortalities of wild and farmed fish, shellfish, submerged aquatic vegetation and coral reefs, impacts on tourism and tourism-related businesses as well as community well-being, and medical treatment of exposed populations. Cumulatively, the costs of marine and freshwater HABs exceed $10–$20 billion over the last several decades.
- The diverse nature of HAB phenomena and the hydrodynamic and geographic variability associated with different outbreaks throughout the U.S. pose a significant constraint to the development of a coordinated national program. Nevertheless, the combination of planning, coordination, and a highly compelling topic with great societal importance has led to integrated research and response communities that include scientists, Federal and state agencies, tribes, and industry. In the past, many of these individuals and groups worked independently and with little exchange of ideas and data. The networks that now exist in many parts of the country are active and productive, and should be a major factor in the growing capabilities of the national HAB program.
- Progress thus far has been excellent, as the U.S. HAB program is seen as a model for other scientific disciplines in the U.S. and the world. The rate and extent of progress from here will depend upon how effectively the skills and expertise of government and academic scientists can be targeted on priority topics. The HAB community in the U.S. is fully capable of undertaking the new challenges inherent in an expanded national program. *This will be successful only if a coordinated national effort can be sustained to focus research personnel, facilities, and financial resources to the common goals of a comprehensive national strategy*

Additional recommendations are summarized as follows:

- As the lead Federal agency for HABs, NOAA should retain the mandate to coordinate, conduct, and fund research and response efforts and levels of funding should reflect the importance of this responsibility.

---

[31] *https://ioos.noaa.gov/*

[32] *https://coastalscience.noaa.gov/research/stressor-impacts-mitigation/rapid-response/*

- Funding needs to be sustained and enhanced for the existing NOAA HAB competitive programs—ECOHAB, MERHAB, and PCMHAB. These programs should be explicitly addressed in HABHRCA reauthorizations and appropriations.
- Given the breadth of environmental, economic, and human health impacts from HABs, funding is also required across a suite of Federal agencies with different mandates, including NSF, NASA, EPA, NIEHS, and USGS.
- Specifically, freshwater HABs are an important focus but cannot be comprehensively addressed in NOAA programs other than in the great Lakes. HABHRCA authorizes EPA to address HABs, but does not provide a clear path and does not authorize funding. EPA should be authorized and appropriated funding to address freshwater HABs in a manner to similar to NOAA. Clear direction should be provided so that EPA and NOAA move this program forward in a productive and efficient manner. One way to accomplish this is to require EPA to establish programs similar to the NOAA ECOHAB, MERHAB, PCMHAB and Event Response, perhaps in coordination with NOAA.
- Recognize that NOAA will require funds for *operations* in support of HAB management, such as HAB forecasting; authorize these activities with specific language, and specific funding allocations.
- Likewise, a clear mandate and funding for a National HAB Observing System are needed, possibly under NOAA's Integrated Ocean Observing System (IOOS).
- In the HABHRCA reauthorization that is moving through Congress, the Event Response program requires some modifications to make it effective for both short-term and long-term response, and a funding mechanism is required that will allow funding to be provided rapidly.

I would like to reiterate the importance of the national HAB program's role in helping understand and address the increasing frequency and intensity of bloom events. The extramural HAB science community also appreciates Congress's recent increases in funding for HAB work, and proposed increase in the FY'19 appropriation bills. We believe that a strengthened competitive research program working in coordination with enhanced agency core funding will ensure the best expertise, technology, and strategies are brought to bear on this growing problem.

Mr. Chairman, that concludes my testimony. Thank you for the opportunity to offer information that is based on my own research and policy activities, as well as on the collective wisdom and creativity of numerous colleagues in the HAB field.

I would be pleased to answer any questions that you or other members may have.

Senator SULLIVAN. Great, thank you, Dr. Anderson.

Mr. Engstrom.

STATEMENT OF IVORY B. ENGSTROM, DIRECTOR, SPECIAL PROJECTS, MCLANE RESEARCH LABS, INC.

Mr. ENGSTROM. Thank you, Mr. Chairman, members of the Subcommittee, for the opportunity to introduce myself, Ivory Engstrom, the Director of Special Projects for McLane Research Labs.

McLane Labs is a manufacturer of advanced ocean sensors and samplers in Cape Cod, Massachusetts. Roughly 50 percent of our products are shipped internationally, earning us the distinction of Massachusetts Small Business Exporter of the Year for 2017. My job as a technologist for McLane is to identify and commercialize promising technologies for wider use in the oceanographic and environmental monitoring communities, enabling broad deployment of innovative sensing systems.

As you've heard, harmful algal blooms are a growing threat to our economy and our well-being. As such, McLane has made significant investments in commercializing promising technologies for use as early warning systems. Increased demand for these products has required McLane to add new personnel and new capabilities. In addition to jobs created at McLane, we are proud to employ other local companies in various supporting fields, such as welding,

machining, optics, electronics, and biotechnology. We are only one of the many small businesses acquiring technology from independent labs for developing instruments in-house that are critical to the rise of the Blue Economy nationwide. McLane has been fortunate to build on the successes of, and investments in, American ingenuity through our work, bringing technologies out of the lab and into the hands of new users.

This testimony will focus on two of the newer autonomous biological sensing instruments that we manufacture for the detection of harmful algal bloom species and their toxins. It is important to note that development of these biosensors would not have been possible without the support of government funding and philanthropic contributions.

First is an instrument called the Imaging FlowCytobot, or IFCB. It was developed at the Woods Hole Oceanographic Institution in Woods Hole, Massachusetts, and licensed by McLane. The IFCB is a "smart" underwater microscope that takes pictures of microorganisms in the water. Image recognition similar to the facial recognition technology used in airports, identifies potentially harmful algae automatically. Typically, these images are posted to the Internet to facilitate scientific collaboration. Because the IFCB identifies and counts individual cells, it can detect harmful algal bloom species in very low concentrations. This allows managers to make informed decisions quickly, based on the existing organisms in the water.

In the summer of 2017, McLane partnered with a local aquaculture farm to perform a pilot study of the usefulness of this instrument to the growing U.S. aquaculture industry. Upon deployment of the IFCB near their oyster nursery, a developing harmful algal bloom was instantly detected in the water. Rapid countermeasures enabled them to save their stock of juvenile oysters. And, according to Dr. Daniel Ward, owner of the aquafarm, "If the IFCB wasn't deployed, I most likely wouldn't have known the bloom started, and most of the seed oysters in the nursery would have died." If the U.S. is to boost its domestic aquaculture output while maintaining the highest standards for seafood safety, we must consider how these tools can assist in enhancing protection efforts and event response.

The second instrument I wish to introduce is the Environmental Sample Processor, or ESP. It was developed at the Monterey Bay Aquarium Research Institute in Moss Landing, California, and is also licensed by McLane. The instrument is a robotic fluidic system used to detect harmful algae and their toxins. ESP is deployed underwater to perform genetic tests autonomously, determining whether certain species are present, and at what concentration. It also detects harmful algal bloom toxins directly, having great benefit to drinking-water protection and monitoring. ESP will generate data from the field in a matter of hours after sampling, significantly faster than traditional methods. ESPs are now routinely deployed in the Pacific Northwest, the North Atlantic, and, most recently, the Great Lakes. The ESP acts as both an early warning system for harmful algal blooms and a critical data source for inputs into predictive models and operational forecasts.

McLane has continued innovation on the ESP platform, with direct support from NOAA's PCMHAB competitive research program. McLane has also made significant investments in exploring these new technologies, and we would like to thank our partners for their enduring support and capacity for innovation.

Thank you, Mr. Chairman and members of the Subcommittee. I hope that my testimony has been helpful in highlighting a couple of these tools available for harmful algal bloom detection and monitoring developed in cooperation with our partners and research teams. I welcome any questions that you or other members may have. And that concludes my testimony.

[The prepared statement of Mr. Engstrom follows:]

PREPARED STATEMENT OF IVORY B. ENGSTROM, DIRECTOR OF SPECIAL PROJECTS, MCLANE RESEARCH LABS, INC.

Mr. Chairman and members of the Subcommittee. Thank you for the opportunity to introduce myself: Ivory Engstrom, Director of Special Projects for McLane Research Laboratories (MRL), Inc. As Director of Special Projects for MRL, my job is to identify and commercialize promising technologies for wider use in the oceanographic and environmental monitoring communities, as well as to work with researchers and developers to enhance existing technologies and enable broad deployment of innovative sensing systems. While some of our traditional product line of samplers have already been used to collect and enumerate Harmful Algal Bloom (HAB) species,[1] this testimony will focus on a couple of the newer biological sensing instruments that we manufacture for the identification and detection of HAB species and their toxins. I will also highlight some of the research that our users are performing with these new biosensors.

McLane Research Labs, Inc., East Falmouth, Massachusetts, was founded in 1983 to provide advanced time-series samplers and engineering design services to the international oceanographic community. MRL's product lines include a range of biogeochemical and physical oceanography sampling and profiling instruments for use in oceanographic research and environmental monitoring. MRL has grown steadily over its 35-year lifetime, and much of our growth can be attributed to the addition of new cutting-edge sensors and monitoring tools.

Imaging FlowCytobot

Of particular relevance to this hearing are two of our technologies, both developed at outside institutions and licensed to MRL though the technology transfer process. The first technology is an instrument called the Imaging FlowCytobot, or IFCB. Developed at the Woods Hole Oceanographic Institution (WHOI), Woods Hole, Massachusetts, by Dr. Heidi Sosik and Dr. Robert Olson,[2] the IFCB is designed to operate continually, 24 hours a day, 7 days a week. The IFCB is essentially an automated, underwater microscope and flow-cytometer with a laser-based, phytoplankton detection system. The instrument acquires images of cells in the water that are available for remote retrieval. Electronically transmitted to shore, these data are processed by performing automatic image recognition and quantification of microorganisms in the water, similar to the facial-recognition technology used in airports. Typically, these data are publicly available via the Internet using a WHOI-developed software package called the "IFCB Dashboard." Provision of immediate access to high-resolution information is critical when assessing the dynamic nature of HAB events.

---

[1] Pilskaln, C.H., Anderson, D.M., McGillicuddy, D.J., Keafer, B.A., Hayashi, K., Norton, K. Spatial and Temporal Variability of Alexandrium cyst fluxes in the Gulf of Maine: Relationship to seasonal particle export and resuspension. *Deep-Sea Research II,* Vol. 103, 2014 (40–54)

[2] Olson, R.J., Sosik, H.M. A submersible imaging-in-flow instrument to analyze nano-and microplankton: Imaging FlowCytobot. *Limnol. Oceanogr.: Methods* 5, 2007 (195–203)

Figure 1: Imaging FlowCytobot

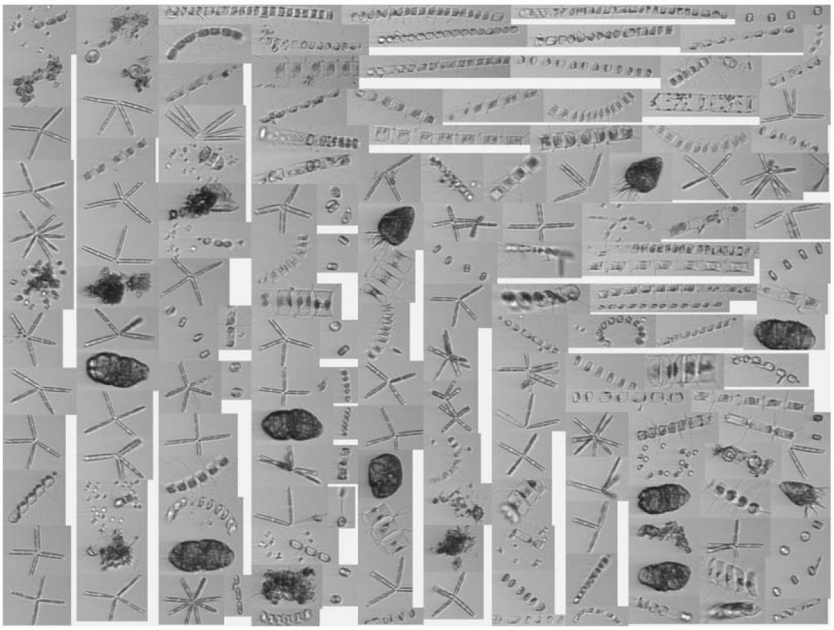


Figure 2: IFCB Dashboard Mosaic

The IFCB was originally designed to study general phytoplankton (algal) ecology, but it has quickly established itself as an effective HAB monitoring tool. Because the IFCB detects and counts individual cells, it has the capacity to discover HAB species in low concentrations and enables researchers and resource managers to make informed decisions quickly based on the existing organisms in the water. Many HAB species can be identified by the imagery, although the toxicity of individual cells may be unknown, as there are toxic and non-toxic strains of some species. In general, the IFCB provides the early warning necessary for resource managers to implement management actions to quantify HABs and their associated toxins. As HAB toxins often accumulate in shellfish, the possible impacts on aquaculture production and seafood safety are serious and significant.

As an example of the manner in which this technology can assist the aquaculture industry, in the summer of 2017, MRL partnered with a local aquaculture farm, Ward Aquafarms, to perform a pilot study of the IFCB technology. The species of interest in this case was the dinoflagellate *Cochlodinium polykrikoides,* which causes larval and juvenile shellfish mortality. Upon deployment of the sensor on July 28, 2017, *C. polykrikoides* was instantly detected in the water. Dr. Daniel Ward, the owner of the aquafarm, was immediately notified by the MRL project team who were monitoring the IFCB dashboard and, as a result, juvenile shellfish in the affected nursery area were moved to an alternate grow site where the concentration of the HAB species was much lower. According to Dr. Ward, *"I checked the IFCB, and sure enough, there was C. polykrikoides at high densities, so we moved all of our seed oysters out into deeper water to get away from the bloom. If the IFCB wasn't deployed, I most likely wouldn't have known the bloom started, and most of the seed oysters in the nursery would have died."*[3] This pilot study confirmed that deployment of autonomous, in situ sensors such as IFCB can have significant benefits for aquaculture production and protection of valuable domestic sources of seafood. We look forward to continuing our IFCB testing in aquaculture applications and to the prospect of automating mitigation strategies at the grow site based on IFCB data interpretation.

The IFCB has been in development at WHOI for over 10 years, and, in that time, WHOI partners and early adopters have demonstrated the value of this sensor in shellfish management. Dr. Lisa Campbell of Texas A&M University, College Station, Texas, has been a user of the technology from its earliest incarnation, even before MRL's acquisition of the technology in 2012. Dr. Campbell has set up a monitoring system in Port Aransas, Texas, using IFCB from September 2007 through August 2017. In early February 2008, manual inspection of collected IFCB images revealed that, unexpectedly, the water contained cells of the toxin-producing dinoflagellate *Dinophysis.* Continuous monitoring by IFCB showed the formation of a *Dinophysis* bloom and its subsequent termination. Manual sampling of surface water near the intake of the IFCB was performed, confirming the presence of *Dinophysis.* These observations led to the first-ever closure and recall of oyster harvests due to Diarrhetic Shellfish Poisoning (DSP) in the United States. This closure and recall occurred shortly before the Rockport Oysterfest event in the Port Aransas region, an event typically attended by up to 30,000 people. Many people were prevented from consuming contaminated shellfish and thus avoided potentially serious health consequences.[4]

Since its commercialization in 2013, MRL has manufactured over 30 IFCB instruments that are in use on the East, West, and Gulf Coasts of the United States as well as in Japan, Finland, and Chile. Other orders are expected from Hong Kong, Singapore, Germany, and Sweden.

Environmental Sample Processor

The second MRL technology relevant to this hearing is the Environmental Sample Processor, or ESP.[5] It was developed at the Monterey Bay Aquarium Research Institute (MBARI) in Moss Landing, California, by Dr. Chris Scholin and his team at MBARI. This instrument—often called a "Microbiology Lab in a Can"—is about the size of a 55-gallon drum, and may be deployed in the water to collect microorganisms and perform genetic testing on the sample to determine whether certain spe-

---

[3] McLane Research Labs, "Imaging FlowCytobot Guides Operational Response for Aquaculture Farm" *Environment Coastal & Offshore.* September 2017: 48–51. Print

[4] Campbell, L., Olson R.J., Sosik, H.M., Abraham, A., Henrichs, D.W., Hyatt, C.J., Buskey, E.J. First Harmful *Dinophysis* (Dinophyceae, Dinohysiales) Bloom In The U.S. Is Revealed By Automated Imaging Flow Cytometry. *Journal of Phycology.* Vol. 46, Issue 1, 2010 (66–75)

[5] Greenfield, D.I., Marin III, R., Jensen, S., Massion, E., Roman, B., Feldman, J., Scholin, C.A. Application of environmental sample processor (ESP) methodology for quantifying *Pseudonitzschia australis* using ribosomal RNA-targeted probes in sandwich and fluorescent in situ hybridization formats. *Limnol. Oceanogr.: Methods* 4, 2006 (426–435)

cies of interest are present and at what concentration. Not only is this instrument able to detect certain species in the water, it is also able to detect HAB toxins directly. Traditional methods of toxin detection have relied on testing shellfish tissue and do not necessarily characterize the actual amount of toxin in the water.

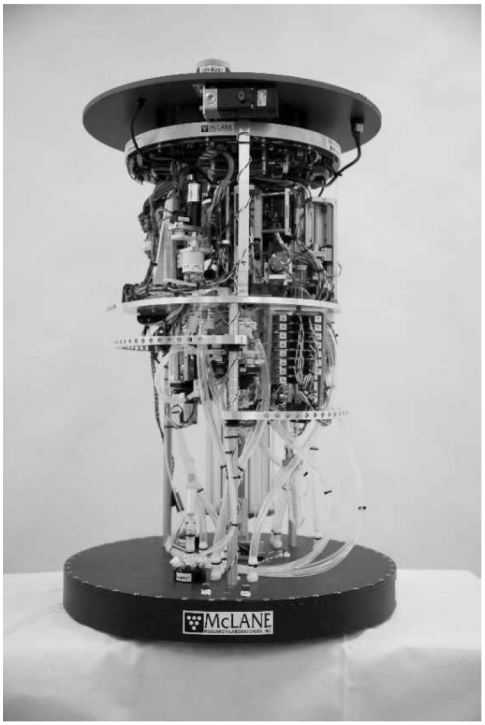


Figure 3: Enviromental Sample Processor

This biosensor is an extremely powerful tool providing information that would otherwise be difficult to obtain with traditional techniques. Typically, a water sample would need to be collected onsite using a small boat or research vessel, and then be brought back to the lab for analysis. The delay associated with traditional sampling methods means that stakeholders are less equipped to make informed decisions in a timely manner, and weekly manual sampling may miss important trends or spikes in toxins or associated species.

ESPs are routinely deployed in the Pacific Northwest,[6] the North Atlantic, and, most recently, the Great Lakes.[7] The ESP acts as both an early-warning system for HABs and a critical data source for inputs into predictive models. With more deployments occurring each year, HAB population models are being refined based on ESP data and observations from other marine sensors. These data are not only valuable to scientists and the public, but also to aquaculture stakeholders. Having the ability to detect harmful species at low concentrations before they become a problem can enable managers to implement countermeasures quickly, mitigating the harmful effects of HAB species on their stocks.

MRL development of ESP is ongoing and has enjoyed significant Federal support from the National Oceanic and Atmospheric Administration's Prevention, Control and Mitigation of Harmful Algal Blooms (PCMHAB) program.[8] We were awarded

[6] PSEMP Marine Waters Workgroup. 2014. Puget Sound marine waters: 2013 overview. S. K. Moore, K. Stark, J. Bos, P. Williams, J. Newton and K. Dzinbal (Eds). URL: *http://www.psp.wa.gov/downloads/psemp/PSmarinewaters_2013_overview.pdf*

[7] Mikulski, C., Ritzenthaler, A., Ruberg, S., Davis, T., Doucette, G. Development of an Immunoassay for Autonomous, Subsurface Detection of Particulate Microcystins in Lake Erie. USHAB 2015 Poster

[8] National Oceanic and Atmospheric Administration, National Centers for Coastal Ocean Science, Prevention, Control and Mitigation of Harmful Algal Blooms (PCMHAB) Award no.

a research grant to make improvements to the ESP system and to increase the sample carrying capacity of the instrument. As a result, the ESP received numerous mechanical and electrical improvements as well as a 50 percent increase in the number of available samples. In the spring of 2018, an initial test of the new and improved ESP was performed in collaboration with WHOI, under the leadership of Dr. Don Anderson (WHOI) and Dr. Mike Brosnahan (WHOI). The ESP was deployed alongside an Imaging FlowCytobot in a known HAB hotspot on Cape Cod.[9] In this particular case, we were monitoring for the presence of *Alexandrium catenella,* a toxic dinoflagellate. The study site was chosen within the Cape Cod National Seashore in anticipation of a recurring annual bloom that had previously been observed and was expected to form again in 2018. There were a number of technical challenges to overcome, but ultimately *Alexandrium catenella* were observed and detected by ESP in reasonable numbers and in general agreement with IFCB observations. In this case, only species detection was performed, but MRL continues to work on qualifying hardware and chemistry changes for toxin detection.

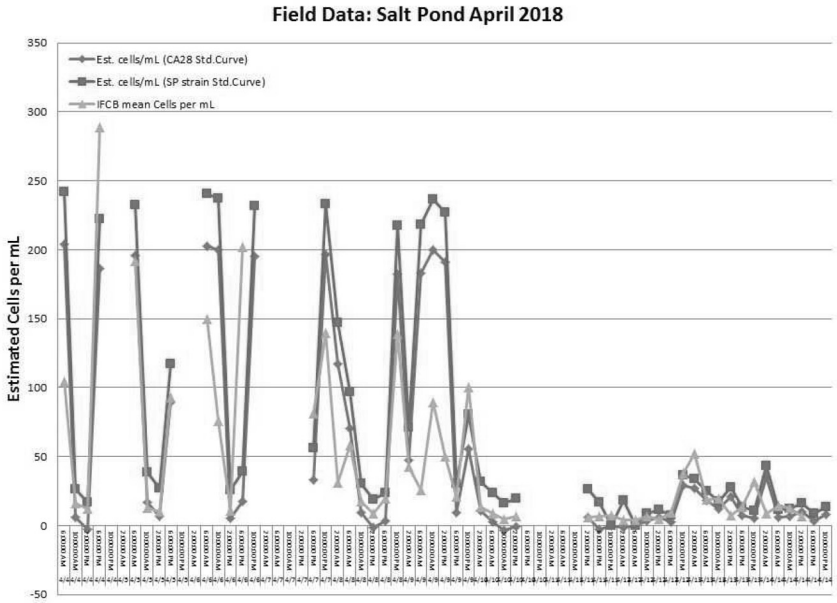


Figure 4: Preliminary Results from ESP/IFCB Study, (M. Brosnahan & T. Fougere, unpublished)

Collaborative Development

Much of MRL's success is owed to our customers, who we view as partners. Our partners are the research scientists and technicians out in the field deploying these sensors and identifying the challenges associated with implementing such technologies and supporting information systems. We maintain very close relationships with our development partners as we continue to industrialize their designs and support them in creating new functionality, new detection protocols, and improved methods for data processing and visualization. In this way, our partnerships are highly collaborative. In the process of developing updates to hardware, software, and chemistry, we work together with the original developers to ensure that they are able to continue innovating on the platforms that MRL manufactures.

Indeed, it bears reiterating that the pioneering research is being done by our customers. We view our role as that of supporting our partners and providing high-quality instruments for their cutting-edge research. Our core expertise is in tech-

NA11NOS4780022. Environmental Sample Processor (ESP) Development: Targeting Cost Reductions, Robustness and an Improved User Interface.

[9] Richlen, M.L., Erdner, D.L., McCauley, L.A.R., Libera, K., Anderson, D.M. Extensive genetic diversity and rapid population differentiation during blooms of *Alexandrium fundyense* (Dinophyceae) in an isolated salt pond on Cape Cod, MA, USA. *Ecology and Evolution,* Vol. 2, Issue 10, 2012 (2583–2594)

nology transfer and identification of new, innovative tools that may be beneficial to the research and monitoring communities. Against this background, we rely on the expertise of our partners and collaborators to guide our efforts and, ultimately, to provide an evidence-based strategic model that others may adopt.

Investment in HAB Sensing Technology

There is a budding industry in development of tools for HAB monitoring. However, to my knowledge, there are currently few commercial offerings capable of providing near real-time biological data on HABs autonomously from remote locations. Experts such as Dr. Don Anderson of WHOI will attest that marine HABs appear to be increasing in severity and frequency, affecting nearly all coastal states. Additionally, all 50 states experience freshwater HAB events in one form or another. As these threats are increasing, there is a clear need for innovative instrumentation that provides valuable information for understanding, modeling, predicting, and finally mitigating the effects of HAB events.

HABs are a growing threat to our economy and our well-being, and as such, MRL has made significant investments in commercializing promising technologies for use as HAB early-warning systems. Bringing new technologies to market presents a number of challenges, both financial and technical. Initial costs are incurred not only during the technology transfer process itself, but also—and significantly—when launching a new product. The manufacture and support of these new products require increased resources, causing MRL to add new personnel and new capabilities. New products require documentation for assembly, testing, and user operation. Specialized equipment or expanded facilities may be required to manufacture these instruments. Production models must also be extensively tested before a product launch is enacted. In addition to jobs created at MRL, we are proud to employ other local companies in various supporting fields such as welding, machining, optics, electronics, and biotechnology.

We are only one of the many small businesses critical to supporting the research community. Other businesses are making similar investments in HAB monitoring and testing tools. Either by acquiring technology from independent labs or by developing instruments in-house, these businesses are important components of the "Blue Economy." MRL has been fortunate to build on the past successes of and investments in American ingenuity through our work in bringing technologies out of the lab and into the hands of new users.

Recommendations

Development of the biosensors described above would not have been possible without the support of government funding and private philanthropic contributions. It is my sincere hope that HAB-related funding will continue to be a priority. Competitive research programs such as NOAA's PCMHAB program, among others, offer a unique opportunity to push the limits of the current state of technology, and MRL is excited to continue our support of and involvement in various proposals and projects.

The deployment of new sensors and technology will create needs for supporting infrastructure and personnel to handle data products, interpret these products, and create notification systems to inform managers, stakeholders, and the public of potential HAB events. Not only are new information systems needed, but also deploying sensors on a large scale requires technicians, engineers, and scientists to service and maintain these sensors and information networks. New jobs will be created to address these demands, requiring skilled workers in varying disciplines.

The costs of maintaining a comprehensive network of sensors may be significant. However, in my view, the benefits far outweigh the costs. Consuming tainted seafood can result in serious human illness or death, leading to lost wages, lost workdays, and significant costs for medical treatment and *ex post* investigation.[10] HABs are not only toxic to humans, but also to other marine mammals, finfish, birds, dolphins, manatees, and sea turtles.[11] This has serious implications for recreation and tourism; recreational and commercial fishing; aquaculture production; and seafood safety. If the U.S. is to boost its domestic aquaculture output while maintaining the highest standards of seafood safety, we must consider how these tools can assist in enhancing protection efforts and HAB mitigation.

---

[10] Hoagland, P., Anderson, D.M., Kaoru, Y., White, A.W. The Economic Effects of Harmful Algal Blooms in the United States: Estimates, Assessment Issues, and Information Needs. Estuaries, Vol. 25, No. 4b, 2002 (819–837)

[11] Corcoran, A., Dornback, M., Kirkpatrick, B., Jochens, A. A Primer on Gulf of Mexico Harmful Algal Blooms. October 2013. URL: *http://gcoos.tamu.edu/documents/HabPrimer-10162013.pdf*

Summary

In conclusion, there are various types of tools available to stakeholders for monitoring HAB species and bloom dynamics. In particular, both the ESP and the IFCB have a proven track record of success. The IFCB has demonstrated its value in our study at Ward Aquafarms, in Dr. Campbell's monitoring efforts on the Texas Gulf Coast, and in many other deployments and studies not mentioned in this testimony. The ESP continues to be used in the Great Lakes and on the East and West coasts, and is simultaneously undergoing further development and optimization at MRL and with our scientific partners. MRL has made significant investments in exploring these new technologies, and we would like to thank our partners for their enduring support and capacity for innovation.

Thank you, Mr. Chairman and members of the Subcommittee. It has been a pleasure to introduce MRL and some of our technologies. I hope that my testimony has been helpful in shining a light on just a couple of the tools available for HAB detection and monitoring, developed in cooperation with research teams in their studies of HABs. I welcome any questions that you or other members of the Subcommittee may have.

Senator SULLIVAN. Great, thank you, Mr. Engstrom.

Mr. Stubbs.

STATEMENT OF BRYAN STUBBS, EXECUTIVE DIRECTOR, CLEVELAND WATER ALLIANCE

Mr. STUBBS. Good afternoon, and thank you. I'm Bryan Stubbs, Executive Director of the Cleveland Water Alliance. We are a water-innovation Blue Economy economic-development cluster consisting of a coordinated group of industry, academic, research, water utility, and government partners. We leverage our region's assets and resources to create a water innovation ecosystem that harnesses technologies, spurs the economy, and drives the research.

Much of our work centers on the challenges presented by harmful algal blooms, or HABs. HABs and nutrient pollution in the Great Lakes region presents a significant and complex challenge that is directly impacting human, economic, societal, and environmental health. In particular, the western and central basins of Lake Erie, which includes source drinking water for millions of our citizens while driving billions in water-enabled industrial economic output, are impacted by annual outbreaks of toxic algal blooms. In recent years, these blooms involving a cyanotoxin called microcystin have led to several temporary "Do Not Drink" warnings around the western Lake Erie Basin. If left unchecked, the economic impact of HABs on Ohio's Lake Erie Basin system drinking water utilities will be in excess of $2.5 billion over the next two decades.

To begin to overcome this challenge, the Cleveland Water Alliance, together with support from regional partners in Ohio and Michigan, is spearheading a technical approach to addressing HABs by making the Great Lakes "smart," starting with Lake Erie. A "smart lake" is instrumented with digital and physical sensing infrastructure that transforms diverse data streams into usable tools to enable more effective management actions impacting the open waters of the Great Lakes up through the watershed. We have launched a series of innovation challenge to the—to support this effort.

In October 2017, we began work on a three-year project and partner with the Great Lakes Observing System, funded by the Inte-

grated Ocean Observation System, or IOOS, a NOAA program, to facilitate technology transition of a Lake Erie harmful algal bloom early warning system from a prototype deployed rapidly beginning in 2014 on the heels of the Toledo water crisis to a sustainable long-term program with stable funding and supported system operations and maintenance. This project includes numerous buoys and land-based sensors, including NOAA's ESP, or Environmental Sample Processor, for tracking the levels of dangerous toxins produced by cyanobacteria that bloom each year, along with specialized software, Web data products, digital portals, and market-based solutions. The project works with more than two dozen drinking-water utilities and is driven to create a model to cost-effectively drive near-realtime feedback on harmful algal blooms, including leveraging data to provide predictive analytics for more effective and efficient utility operations. This project also ties into NOAA's hypoxia warning system.

In March of this year, in partnership with research and private-sector partners, we submitted a $3 million proposal to the National Science Foundation, entitled "Smart and Connected Infrastructure Nutrient Management Pilot," submitted through the Smart and Connected Communities Program. The goal of the smart-lake pilot is to leverage the urgency to address nutrient loading, non-point-source nutrient loading, harmful algal blooms, and watershed management actions by building a scale of Lake Erie's first demonstration "Smart Lake," a new breed of Smart and Connected Infrastructure that enables intelligent community water management. The proposal includes, one, distributed sensors, satellite spectrometry, unmanned vehicles, realtime telemetry, and advanced algorithms to understand water-quality dynamics as it relates to nutrient loading and provide realtime feedback for policy and management actions on land; two, to leverage Smart and Connected Infrastructure to identify hotspots, enable effective prioritization of future projects, and allow realtime responses to events; and three, develop user-facing Smart and Connected products to inform and empower the actions of institutional users and the general public.

In conclusion, solutions to this country's growing water challenges lie, in part, with the development and adoption of new tools, technologies, and approaches, yet investment in water innovation, as compared to other sectors, is extremely low. Well-managed, collaborative, and directed innovation has a key role to play in addressing HABs and the HABs challenge. In addition to dedicated technology-driven funding, priority solutions should include IoT-based technology, new sensor development—in particular, new and cost-effective electrochemical phosphorous and microcystin sensors—advanced networking solutions, "Data as a Service" market-driven solutions, along with appropriate use of data and data analytics, all leading to realtime feedback loop systems for nutrient management actions along with creating tools that will serve to educate informed citizens and policymakers. A dedicated, organized, and funding effort will improve outcomes, will reduce cost, will drive collaborative investment from the private sector, will accelerate economic development and will transform data into insight. As we like to say, "Data is water infrastructure."

I appreciate this time, Mr. Chairman and the Subcommittee, and am happy to answer any questions.

Thank you.

[The prepared statement of Mr. Stubbs follows:]

PREPARED STATEMENT OF BRYAN STUBBS, EXECUTIVE DIRECTOR, CLEVELAND WATER ALLIANCE

Good afternoon and thank you Mr. Chairman for holding today's hearing regarding Harmful Algal Blooms. I'm Bryan Stubbs, Executive Director of the Cleveland Water Alliance. We are a water innovation economic development cluster consisting of a coordinated group of industry, academic, research, water utility and government partners. We leverage our region's assets and resources to create a water innovation ecosystem that harnesses technology, spurs the economy and drives research.

Much of our work centers on the challenges presented by harmful algal blooms, or HABs. HABs and nutrient pollution in the Great Lakes region presents a significant and complex challenge that is directly impacting human, economic, societal, and environmental health. In particular the western and central basins of Lake Erie, which include source drinking water for millions of our citizens while driving billions in water enabled industrial economic output, are impacted by annual outbreaks of toxic algal blooms. In recent years, toxic algae blooms involving a cyanotoxin called microcystin have led to several temporary "do-not-drink" warnings around the western Lake Erie basin. If left unchecked, the economic impact of HABs on Ohio's Lake Erie businesses and drinking water utilities alone will be in excess of $2.5b over the next two decades.

To begin to overcome this challenge the Cleveland Water Alliance, together with support from regional partners in Ohio and Michigan, is spearheading a technical approach to addressing HABs by making the Great Lakes *Smart,* starting with Lake Erie. A Smart lake is instrumented with digital and physical sensing infrastructure that transforms diverse data streams into usable tools to enable more effective management actions impacting the open waters of the Great Lakes up through the watershed. We have launched a series of initial innovation challenges to support this including the Internet of H_2O challenge where we deployed five end-to-end solutions for the monitoring and analyzing of nutrient loading into Lake Erie.

In October of 2017 we begun work on a 3-year project in partnership with the Great Lakes Observing System, funded by the Integrated Ocean Observing System (IOOS), a NOAA program, to facilitate technology transition of the Lake Erie HABs early warning system from a prototype deployed rapidly beginning in 2014 on the heels of the Toledo water crisis, to a sustainable long-term program with stable funding and supported system operations and maintenance. The project includes numerous buoy and land-based sensors including NOAA's Environmental Sample Processor (ESP) for tracking the levels of dangerous toxins produced by cyanobacteria that bloom each year, along with specialized software, web data products, digital portals and market-based solutions. The project works with more than two dozen drinking water utilities and a dozen soil and water conservation districts, and is driven to create a model to cost effectively drive near real-time feedback on harmful algal blooms including leveraging data to provide predictive analytics for more effective and efficient utility operations. This project ties into the related work of NOAA's Hypoxia Warning System.

In March of this year, in partnership with Ohio State University's Ohio Sea Grant program, Case Western Reserve University, along with other research institutions plus industry partners, the Cleveland Water Alliance submitted a $3m proposal to the National Science Foundation (NSF) entitled 'Smart and Connected Infrastructure Nutrient Mitigation pilot' for the Sandusky Bay and Sandusky River Watershed. Submitted through the Smart and Connected Communities program, the goal of this Smart Lake pilot proposal is to leverage the urgency to address nutrient loading, non-point source nutrient loading, harmful algal blooms, and watershed management actions by building at scale Lake Erie's first demonstration "Smart Lake," a new breed of Smart & Connected Infrastructure (S&CI) that enables intelligent community water management. The proposal includes (1) distributed sensors, satellite spectrometry, unmanned vehicles (UAF/USV/UUV), real-time telemetry, and advanced algorithms, to understand water quality dynamics as it relates to nutrient loading and provide real time feedback for policy and management actions, (2) Leverage S&CI to identify hotspots, enable effective prioritization of future projects, and allow real time responses to events, and (3) Develop user-facing Smart and Connected Products (S&CP) to inform and empower the actions of institutional users and the general public.

In conclusion, solutions to the country's growing water challenges lie, in part, with the development and adoption of new tools, technologies and approaches. *Yet investment in water innovation as compared to other sectors including the electric power utility sector is extremely low.* Well managed, collaborative and directed innovation, spread out to key regional HAB hotspots such as Ohio and Florida, has a key role to play in addressing the harmful algal bloom challenge. In addition to dedicated technology driven funding, priority solutions should include IoT based technology, new sensor development (in particular new and cost-effective electro/chemical phosphorous and microcystin sensors), advance networking solutions, Data as a Service market driven solutions, along with appropriate use of data and data analytics. . .all leading to a real-time feedback loop systems for nutrient management actions, along with creating tools that will serve to educate and inform citizens and policy makers. A dedicated, organized and funded effort will:

1. *Improve Outcomes and Reduce Cost*—Innovation leverages the cutting-edge. The commercial and research-driven technologies activated by this investment will improve outcomes at lower costs. Enabling the inception, development, and implementation of these new tools will ultimately bring greater value and return on investment than an exclusive focus on maintaining or bolstering traditional and localized practices;
2. *Drive Collaborative Investment*—Innovation activates ecosystems. The excitement and opportunity created by new solutions attract private sector and research partners looking to get in on the ground floor and constituents looking to improve intractable issues. Investments to water innovation will create a situation where companies, institutions, and organizations can easily share ideas and solutions. In this way, promising innovations can serve as platforms that enable the construction of diverse coalitions of companies, institutions, and residents with the capacity to effect real change;
3. *Accelerate Economic Development*—Innovation begets commercialization. Connections formed through collaborative investment will lead to substantive working partnerships between businesses, researchers, and regulators. These nodes of collaboration are perfectly positioned to match developing technologies with regulatory support, test beds for pilot studies, and anchor clients as means to facilitate transfer to the market. Additionally, a commitment to clean water improves gross regional product and water innovation will help us better tie environmental health into economic health and societal benefit; and,
4. *Transform Data into Insight*—Innovation relies on information. Without data to analyze and optimize risks and outcomes, investments in water solutions lack intelligence. It is time that we start to understand that *data IS water infrastructure* and needs to see the same investments as our pipes and pumps. Today, much of our water is not used into giving us insight into long term health and opportunities. Further, rarely is that data tied into broader big data analytics and trends that speak to broader impacts. Investment in a robust data infrastructure for our Great Lakes will help address these challenges by enabling intelligent investment targeting and improved evaluation of investment performance. Tying these insights into broader impacts will lead to additionally lead to improved articulation of Great Lakes investments and better allow policy makers to justify past and future outlays.

I thank you for this opportunity and am happy to answer any questions.

Senator SULLIVAN. Great, thank you, Mr. Stubbs.
Mr. Neu.

STATEMENT OF PATRICK NEU, EXECUTIVE DIRECTOR, NATIONAL PROFESSIONAL ANGLERS ASSOCIATION

Mr. NEU. Good afternoon, Mr. Chairman, Ranking Member Senator Baldwin, and other members of the Subcommittee. Thank you for the opportunity to testify today.

As a lifelong resident of Wisconsin, and now a part-time resident of southwest Florida, I have been exposed to algae blooms my entire life. For nearly 50 years, I've made my living in the outdoor industry, and was recently inducted into the National Freshwater Fishing Hall of Fame. I'm Executive Director of a group of anglers

called the National Professional Anglers Association, and President and founder of the Future Angler Foundation.

Why have I followed this path? Because I have a passion for the outdoors. Angling and the outdoors dominate my life and the life of many others in the State of Wisconsin. I believe that, of the 49 million anglers in this country, passion and concern surrounding the future of our sport run rampant. I'm here today to share my concerns.

Firsthand knowledge. Yesterday, as I was putting together this oral statement, we had a heavy rainfall, four and a half inches in an hour. I knew, as I sat there, that that rain was going to end up in the Bay of Green Bay and in Lake Michigan, and have a detrimental effect on the HABs in the future. Growing up in Madison, it was—there's a chain of lakes there. Lake Mendota, Lake Monona were lakes that I often frequented when I was growing up. They were affected by algae blooms even at the time I was a young child.

Recently, my wife, Sarah, and I went and fished on Lake Winnebago during a walleye tournament during the first week of July. It was not a pleasant experience. We had to go to find areas to fish where we could actually fish and not have an issue with the algae that was running rampant. My wife turned to me, when we got done with that tournament, and said, "We are not going to come back here in 30 days for the championship that we did qualify for." What's even more scary is, 35 of the 90 teams that qualified to fish that event chose not to fish, as well, because of the algae bloom.

Algae blooms are naturally occurring. The Bay of Green Bay was named Green Bay because there was an algae bloom when the explorers found it at the—in the 1800s. But, warmer temperatures, record rainfall have contributed to the worst algae blooms in recent memory. Algae blooms that, in Florida have likely contributed to this year's red tide event. I am not a scientist. I am not here to testify as such. But, common sense dictates that the increased nutrients in aquatic—in our aquatic ecosystems are contributing to these algae blooms.

Algae blooms affect how we fish and where we fish. They affect anglers, boaters, sports participants, like water skiers, swimmers, and others. These blooms cause economic loss to the communities that surround the bodies of water that have the blooms. Algal blooms cause health issues, including respiratory distress and infections. In Florida, the Caloosahatchee, the St. Lucie, with discharges from Lake Okeechobee and their blue-green algal blooms, have most likely contributed to this red tide event that's going on, that's so talked about.

Nationally, what's at risk? In my opinion, a percentage of the $125 billion that angling and boating contribute to our national economy.

In conclusion, I feel that algae blooms are something that we all need to get together and figure out a solution to. They're not new to our public waters. They have occurred naturally for centuries. But, urban sprawl, commercial farming, and climate change are causing these outbreaks to be more severe. Programs like the Great Lakes Restoration Initiative and those directed under the Harmful Algal Bloom and Hypoxia Research and Control Act are critical Federal programs that advance the scientific understanding of

harmful—HABs. I applaud the Senate for passing S. 1057, the Harmful Algal Bloom and Hypoxia Research and Control Amendment Act of 2017. And I hope that the House will quickly pass a similar legislation.

I have a passion for angling, my entire life. It's what I live to do, and many others. Our outdoor culture in this country increases our quality of life and makes our country unique. We all need to do our part to protect our aquatic resources so that the future generations can utilize them.

It has been an honor to have been asked to testify in behalf of those who cherish our public waters as much as I do. Thank you for the opportunity to testify.

[The prepared statement of Mr. Neu follows:]

PREPARED STATEMENT OF PATRICK NEU, EXECUTIVE DIRECTOR, NATIONAL PROFESSIONAL ANGLERS ASSOCIATION

Good morning, Mr. Chairman, Ranking Member Senator Baldwin, Senator Johnson and Members of the Subcommittee. Thank you for the opportunity to testify before you today on "Harmful Algal Blooms and The Impact on our Nation's Waters."

As a lifelong Wisconsin resident and now a part time SW Florida resident I have been exposed to algae blooms my entire life. With a passion for angling that began very early in my life, I spent countless hours on the Madison chain of lakes while growing up in Madison, Wisconsin in the 60s and 70s. During those years I had first had experience with the effects algae blooms had on those lakes.

Now 50 years later after having made my living in the outdoor industry and having been recently inducted into the National Freshwater Fishing Hall of Fame, I am more passionate than ever for the outdoors and for sportfishing. I am currently serving as Executive Director of the National Professional Anglers Association (NPAA), a 1200 member association comprised of anglers who have taken the step from "Passion to Profession." I am also president of the Future Angler Foundation (FAF) a non-profit organization that I helped create in 2012 to support volunteerism among anglers who are willing to share their passion and knowledge about angling through education and outreach to help grow the sport they love.

Angling and the outdoors have dominated my life and I believe that the nearly 49 million anglers in this country share my concerns surrounding the future of our sport. I am here today to help convey to you the importance that clean waters and healthy aquatic ecosystems play in the utilization of the plentiful aquatic resources we have in this country by anglers, boaters, and others who share my passion for the outdoors.

First Hand Knowledge

This hearing on harmful algal blooms is timely considering the awareness that has been brought to these blooms this year across the country. Algae blooms have occurred naturally for centuries, however, through nutrient loading of our waters, humans have caused these blooms to intensify to a level where they are now negatively affecting utilization of our public waters. Warmer than normal temperatures this year and record rainfall in many areas have contributed to some of the worst algal blooms we have experienced in years, including the blooms that have occurred in Florida that have helped to feed the deadly "Red Tide" and blue-green algae outbreaks.

I am not a scientist and I am not here to testify as such. I will leave explanation of the causes of these algal blooms to those who are the experts on them, but I do understand that these harmful outbreaks are related to increased nutrients in the aquatic ecosystem. That said, I fear that these blooms are having a negative effect on the utilization of the resource by anglers, boaters, and others who utilize our public waters.

I have seen it firsthand this year as my wife and I fished a tournament event on Lake Winnebago, a large basin lake in central Wisconsin, where during the first week of July an algae bloom on the lake was so bad that it forced us and other anglers to search out areas of the lake where the algae wasn't present in order to fish effectively. Even more concerning we did such so as not to have the fumes emanating from the algae mats negatively affect our respiratory system. The experience we had on Lake Winnebago that week prompted us to cancel our plans to fish the lake again in early August for the championship event for the tournament series.

This tournament series lost not only our entry, but also approximately 35 other teams out of the 90 teams that qualified to fish the event.

In preparing to testify today I also reached out to numerous friends and NPAA members to get their input on the severity of the algae blooms this year. The prevailing answer was this has been the worst year they have seen in years for algae blooms. Additional research found articles about the algal bloom issues this year. The images attached to the end of this testimony are an example of what the communities in Wisconsin are dealing with when an algae bloom occurs.

What are the Consequences?

Harmful algal blooms, whether in Wisconsin, Florida, or many other parts of the country that are experiencing this phenomenon, have consequences to the communities surrounding the bodies of water where the blooms occur.

From an angler's perspective, algae blooms affect the way anglers fish and where they chose to fish. This becomes evident when you talk to anglers about targeting fish during these blooms. The blooms are not always detrimental to anglers or the fishing, in fact sometimes they help us target certain species that position themselves to feed on the minnows and other small fish that feed on the invertebrates that feed on the algae. But, given the choice anglers would definitely prefer not to deal with the smell, buildup of algae on their lines and boats, or the bug hatches that occur around the mats of this floating algae mess.

Algal blooms are of such concern to anglers that In-Fisherman, one of the leading publications on angling "how to" and angling knowledge, has written articles on how to catch fish during these blooms (*http://www.in-fisherman.com/walleye/walleye-fishing-during-algae-blooms/*) and have written articles about the concerns they have for the future of the resource as a result of these blooms (*http://www.in-fisherman.com/midwest-finesse/algae-bloom-woes-and-more/*).

Boaters and swimmers have learned to avoid the lakes during these blooms. In some cases swimming or participating in water sports like water skiing in these waters can be hazardous to your health and that of your pets if they are exposed. Signs are often posted at boat landings warning of the health issues that can occur during these blooms.

From an economic standpoint, communities affected by algal blooms are at risk of losing signifigant revenue when local residents and tourists choose not to utilize the waters for recreation. Hotels, motels, restaurants, fishing guides, sport/bait shops, marine dealers, and marina's all experience a loss of business during these algal bloom outbreaks.

This loss of resource utilization revenue occurs in all states and this year it has been in the news frequently with the outbreak of "Red Tide" on Florida's Southwest coastline, as well as the disastrous blue-green algae outbreaks that result from Lake Okeechobee discharges into the Caloosahatchee and St. Lucie rivers. In the short-term, these outbreaks have caused significant losses in tourism, especially those related to cancelled recreational fishing trips, as well as massive fish kills. The long-term impacts of this year's algal bloom outbreak are yet to be seen, but common sense dictates it will affect tourism in the state in the coming months and beyond. Fishing guides in the affected area will certainly lose business due to the extensive media coverage of the fish kills that have occurred during this recent outbreak.

To my knowledge there hasn't been a study done on what the total economic impact is as a result of these algal blooms in the U.S. Sportfishing alone adds $125 billion dollars to our economy each year on a national basis. *[ML1]* The potential loss to our economy due to harmful algal blooms is likely a staggering number.

Conclusion

As I have testified, algae blooms are not new to our public waters. They have occurred naturally for centuries, but urban sprawl, commercial farming, and our changing climate are causing these outbreaks to be more severe. Programs like the Great Lakes Restoration Initiative and those directed under the Harmful Algal Bloom and Hypoxia Research and Control Act are critical Federal programs that advance the scientific understanding and ability to detect, monitor, assess, and predict harmful algal blooms. I applaud the Senate for passing S. 1057—the Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2017—and hope the House will quickly pass similar legislation before the current authorization expires so that the very important work conducted under this program can continue.

The United States has vast aquatic resources that we need to protect for future generations of anglers, boaters and outdoor recreational users. I have spent a considerable amount of my time, both personally and professionally, in trying to bring new anglers, especially youth, into the sport of fishing so that they can develop the same lifelong appreciation for our aquatic resources and dedication to preserving

them. Our outdoor culture in this country increases our quality of life and helps makes our country unique.

It's an honor to have been asked to testify on behalf of those who cherish our public waters as much as I do. Thank you for the opportunity.

ATTACHED IMAGES BELOW

Photo Courtesy of U.W. Sea Grant-Lake Winnebago in Neenah, WI

Photo Courtesy of U.W. Sea Grant-Lake Mendota & Monona in Madison, WI

Photo Courtesy of the Wisconsin Rapids Daily Tribune

Senator SULLIVAN. Well, thank you, Mr. Neu.

And I want to thank all the witnesses and panelists here for your testimony.

We're now going to turn to questions. And let me just get into, I think, one of the most important ones. And, you know, Mr. Neu, you mentioned that these are cycles that have been, really, occurring for centuries. But, as—and this is a question for all the panelists—but, as we look into increasing reoccurrences, what are some of the gaps in the scientific understanding of HABs? And what's your recommendation on how we address those gaps?

And again, I'll open this up to anyone. Perhaps, Dr. Anderson, we'll start with you.

Dr. ANDERSON. Yes, thank you, Mr. Chairman.

The list is long of the gaps, but I will say, we do know quite a bit about many of these outbreaks around the country. But, if I choose just a few—and I'll—let's use the example of Florida. One of the gaps we have there—or there are two that really come to mind—the first is, What is fueling that bloom? What is keeping it going so long? How—these are plants. They require nutrients, just like the plants on your—in your shelf in—you know, on your windowsill.

Senator SULLIVAN. And do we have a theory on that? I mean, what is that? Or is that, like, a gap right now that we really don't understand?

Dr. ANDERSON. Well, it's a gap down there, in that region. If you asked me, in my region of the country, in the Gulf of Maine, I would say the nutrients that fuel the blooms there—and it's true in Alaska, too—are entirely natural. Florida is in a different situa-

tion, where it could be natural, it could be coming from land and from fertilizer. And it takes some very dedicated and targeted programs to try to tease apart what nutrients are actually happening there. And so, that's a gap that needs to be addressed.

But, another one down there is, Why is it—what—why isn't that bloom ending? Why—what—termination of blooms is a big gap. We often understand how they start and how they grow, but how they end remains another mystery.

And now, if I go back up to Alaska, I could say another big scientific gap is, What is happening as waters warm in certain areas? And I personally believe that the Arctic is the place where a lot of the action is happening, in terms of species extending their ranges, and problems moving. And so, that's still a hypothesis, but it's a huge gap for us to try to understand, to be out ahead of those problems before they move into new areas.

So, those are just two or three of the scientific gaps that I would suggest now.

Senator SULLIVAN. Any other witnesses want to talk to that issue, in terms of scientific gaps or data gaps, in terms of the understanding of HABs?

Mr. STUBBS. Thank you, Mr. Chairman.

For the Great Lakes, and for Lake Erie in particular, a lot of the research is in. We know what is causing this. And it's not to say we didn't have blue-green and Lake Erie 200 years ago. We did. But, at this level, this is—we've never seen this.

We know it has to do with nutrient-loading. We know that it has to do with things such as total phosphorous versus, you know, available reactive phosphorous. We have a lot of those answers. What we need to do, from a research standpoint, I view, is kind of two angles. One is more on understanding, on the sensor side, how we can go up a watershed and better understand how this is coming off of farm fields. Overuse of phosphorous, drain tiles. We need to do research in more of the technology and the innovation side of this, things such as, you know, "smart" drain tiles that might actually have sorbents built into them to capture phosphorous and/or nitrogen. To me, that's the missing part, along with just, bluntly, societal, kind of, you know, human thinking. We have to realize that this is an all-of-us problem. We all eat. We all need those ag lands to be productive. But, we need to do it smarter, so we need to do some research around there.

Thank you.

Senator SULLIVAN. All right. Anyone else on that issue?

[No response.]

Senator SULLIVAN. OK, thank you.

Senator Baldwin.

Senator BALDWIN. Thank you.

I want to start with you, Mr. Neu. I appreciate your talking about your experience in the recent fishing tournament on Lake Winnebago. You are also somebody who runs a nonprofit trying to bring up the next generation of enthusiastic anglers. And so, as you work to get that next generation of anglers out on the water, how are you seeing these harmful algae blooms impacting your work in that respect?

Mr. NEU. The issue comes up when we're at an event that we support. So, our members go out, share their passion with young anglers and with their families. And when we're at an event that would happen to have had a bloom, it's spoken about frequently. One of the things that we make sure we do is try to educate those that attend our Future Angler events on aquatic invasive species and how they affect the ecosystem. And we—we'll discuss algae, as well. You know, we're all in this together. This is something that needs to be addressed. And, you know, it's critical that we address these harmful algae blooms, because they will affect utilization of the resource, and we have this next generation of anglers coming up that we want to have pleasant experiences on the water. And it's not going to happen if that—if algae blooms are occurring to the degree that they have been in the past due to nutrient-loading, as was mentioned earlier, I'm sure.

Senator BALDWIN. Thank you.

Mr. Stubbs, in the Great Lakes, as you know, Lake Erie has become, in some ways, a poster example, a poster child, of harmful algal blooms. But, as I mentioned in my opening statement, we're seeing more and more of them in Lake Michigan and Lake Superior. I'm concerned for the 35 million people who depend on the Great Lakes for their source of drinking water, and for the millions of jobs across the region, and the myriad ecosystems. So, I'm curious about how you and your organization, the Cleveland Water Alliance, have been working. You have been working to help Lake Erie communities. Can similar solutions be adapted to communities on the other Great Lakes? And when does that fit, and when is it not a fit?

Mr. STUBBS. I think it's always a fit. And it's——

Senator BALDWIN. Sure.

Mr. STUBBS.—our job, in honest, to figure out how to take—as you put it, Lake Erie is, unfortunately, the poster child for this within the Great Lakes region. But, out of bad things, much as out of the Cuyahoga River catching on fire 49 years ago, we have 200 companies in northeast Ohio in the water space. Similarly, we can do the same thing by really driving good, innovative solutions.

Right now, we're taking part in a pretty unique program, through the Great Lakes Protection Fund, that's funding us to work with all of the community foundations surrounding the Great Lakes, called Great Lakes One Water. And we made a recommendation to that group about embracing technology and innovation as part of the solution. We've gotten it through and convinced for our Lake Erie Working Group, and it's now going to the other four Great Lake areas. So, with that, absolutely, we are moving that forward. Now, it always comes down to capacity and resources and getting everybody on the same page. But, organizations such as research organizations like IAGLR, organizations like the Great Lakes Commission, the Great Lakes Protection Fund, we've been really pushing them to work more collaboratively. That's the key thing.

Now, I know, in Milwaukee, we have an excellent relationship with Dean in the Milwaukee Water Council. We work with them. We work with the other peer in Chicago, called Current, another Blue Economy cluster. And that's how we're going to do it, is by

rolling up our sleeves and sharing our innovations and sharing our collaboration, not putting the egos first, but putting—you know, Lake Erie is all connected. It's one water system. It's 20 percent of the world's fresh surface water.

Senator BALDWIN. Yes.

Thanks.

Senator SULLIVAN. Senator Peters.

STATEMENT OF HON. GARY PETERS,
U.S. SENATOR FROM MICHIGAN

Senator PETERS. Thank you, Mr. Chairman and Ranking Member, for holding this meeting.

Senator Baldwin, you and I share concerns over the Great Lakes, and we have seen these algal blooms, as you mentioned, even in Lake Superior. I know there was a large one from northern Michigan all the way to the Apostle Islands in Washington, in—or in Wisconsin. And, you know, you normally—we didn't think that would happen.

As you know, we—Lake Erie is a shallower and warmer body of water. Lake Superior is a very cold body of water, and extremely deep, but doesn't seem to—this doesn't seem like the same types of mechanics are involved there, and yet something very significant is happening. So, I appreciate the testimony, of all of yours, as we try to deal with this.

Dr. Anderson, you mentioned your support for the bill, which I'm proud of—cosponsored with Senator Nelson, that's passed the Senate and is now before the House. We've been getting some resistance from House members who have suggested that the bill may not be needed; in fact, that there are already too many Federal agencies that are involved in this research. How would you respond to the—to folks who are making those critiques?

Dr. ANDERSON. Well, thank you for this opportunity, because I totally disagree with that viewpoint.

As one who has been down here many times, talking to various delegations, talking to government agencies and program managers, that authorization is very, very important. It—there's scarce money within NOAA or these other agencies, and there are a lot of competing hands out, trying to use it. And having an authorization for this program sends a message to the people in control of some of those discretionary-type internal funds, and even competitive funds. And I think that having the authorization lapse would be a—just a real terrible thing.

We've built up a program that has that backing. You can see it's getting worse. I mean, the stories we're hearing basically involve every state in the country. I think we deserve our own legislation, and not to have it die.

Senator PETERS. You also mentioned, in your testimony, various regions—Florida and Alaska, and particularly the climate change in Alaska that may be contributing to these outbreaks. Would the Great Lakes also be in that category?

Dr. ANDERSON. Well, the—especially, I think, the Great Lakes and freshwater systems. When we talk about climate change and HABs, for a lot of us it's still not exactly clear what's going to happen. I mentioned range expansions. That, I think, for sure, is—spe-

cies are going to start moving north, and—but, there—it's really quite clear that the species that cause problems in the freshwater systems, these cyanobacteria, are real winners when it comes to a warming climate. They grow better than all of their competing species in the water, whether it's cyanobacteria—other cyanobacteria or other algae. They—there's a paper out about "they like it hot." You know, the cyanos like it hot. And it's true. They grow well. So, given that that's really the problem that the Great Lakes are going to face, or cyanobacteria, as they warm, then, I think, yes, you will see them even in the cold and deep Lake Superior.

Senator PETERS. Right. That's probably why we're starting to see that already.

Dr. ANDERSON. Yes, I think so.

Senator PETERS. Early warning——

Dr. ANDERSON. And that's, I think, why things are happening up in Alaska, as well, that, as the waters warm there, a lot of species are moving up. And I just think of all the species that could move into the region. I don't think any of them are as big a threat to the indigenous communities and the ecosystems up there as the HABs.

Senator PETERS. The other question I have related to that, for Mr. Anderson, is that—you mentioned that the spreading of these HABs can also be as a result of transportation systems. As you know, we have an issue with ballast water. And when—there's some legislation before us here. Senator Baldwin and I have raised—as well as others—have raised many issues related to ballast water in the Great Lakes. Would you speak to the danger of not effectively controlling ballast water, and what that could mean for spreading these toxic organizations even further?

Dr. ANDERSON. Certainly. The—there's no question that ballast is—ballast water discharges are a potential way to move these species into new areas. We have scientific papers out there that document this. There's—there are some strategies that these species have that make them especially capable of benefiting from that type of a situation. They—so, a lot of the ones I study, the ones that occur up in Alaska, have a very resistant stage, called a cyst, that falls to the sediment most of the year. It's down on the bottom of the ocean. And then it germinates and starts a bloom. Well, those cysts can readily be transported all over the world. The—you know, they—they're resistant, they—they're dormant. And so, they don't require light, they don't require a lot of things that—and therefore, a ballast water tank is a great place for them to just take a—hitch a ride around the world. And then, when they're discharged, and the conditions are right, away they go.

So, I—we've always, in our field, been very supportive of ballast water regulations and technologies to try to make sure that what's discharged is safe, including killing all the HAB species there.

Senator PETERS. Yes. And, if I may, you talked about spreading it around the world, but, just within the Great Lakes basin and the Great Lakes watershed and a number of lakes that we have, just transporting it from Lake Erie to Lake Superior can be a significant harm, potentially.

Dr. ANDERSON. I totally agree. I—I'm sorry, I should have said that, as well. But, yes, it's certainly within the Great Lakes system,

it's the same as going from one part—one port in the ocean to another. It's the same exact concern.

Senator PETERS. Great.

Thank you.

Senator SULLIVAN. Well, as Senator Peters knows, we're working hard on that in the Coast Guard bill, so I think we're getting close to a compromise on a good bill that reflects that issue.

Senator Baldwin.

Senator BALDWIN. I want to just ask a follow-up. This was already dealt with in your testimony, to a certain degree. But, just the tools for predicting HABs. So, I represent a state on two Great Lakes—Lake Michigan and Lake Superior, Mighty Mississippi on our west coast, St. Croix River—and then all these—you know, the biggest lake inland is Lake Winnebago, but I grew up learning how to swim, Mr. Neu, in Lake Mendota. So, all in between. And it seems to me that HABs can be very dynamic, with some appearing to form practically overnight, and with them shifting rapidly in location because of wind. This unpredictability might make it difficult for public officials to issue timely warnings to beach-goers or businesses. So, what are some of the challenges with predicting, monitoring, and assessing HABs in the Great Lakes, but also in much smaller inland waters? And what will it take to improve our HAB forecasting capabilities? And I present that to anyone on the panel who wants to jump in.

Starting with——

Mr. STUBBS. I'm happy——

Senator BALDWIN.—Mr. Stubbs.

Mr. STUBBS.—to take that one first, since we're working on a NOAA IOOS-funded program right now. What we're finding as we're building the infrastructure for our harmful algal bloom warning system is input. Again, it comes down to sensors. We need more realtime—and when I say "realtime," also affordable realtime sensors in the watershed and on the open waters. It's limited in what we can afford to put out there right now. So, as an example, McLane's Environmental Sample Processor, we've got one that we've ordered through the GLERL lab, the Great Lakes NOAA Research Lab in Ann Arbor, that is going to take a year just to finish assembling and is over half a million dollars. We're out there exploring technologies that will take that down to, potentially, $20,000. As we can drive down that kind of innovation, we will be able to deploy more of these and get those inputs.

In same breath, look, we're leveraging private sector. So, Smart and Connected cities, that sort of intelligence, we're bringing that into the watershed. So, IBM's Lake George project is an excellent example, where we've brought in their machine learning to help us build up those analytics and those predictive analytics models. And you can't do this in a research lab. You know, for us, we are in the labs of water utilities. These water utilities on Lake Erie are just amazing in how they've had to, basically, bandaid solutions together. We've got to get them, you know, the realtime monitoring solutions. No more of a researcher going down, taking a grab sample, and wondering. We have to get through things like data-sharing amongst utilities, and encourage that. I think it starts there. We know how to do this. It's just putting all the pieces together.

Senator BALDWIN. OK.

Senator SULLIVAN. Well, thank you.

I want to thank all the witnesses for this hearing. Unfortunately, we have a vote coming up, so we're going to have to cut it a little bit short.

But, the hearing record will remain open for two weeks. During this time, Senators may submit additional questions from our witnesses for the record. Upon receipt, the witnesses are respectfully requested to submit their written answers to the Committee as soon as possible.

And I want to thank everybody again for appearing today. This is a important issue. Hopefully, you're seeing there's a lot of bipartisan interest, not just on gaining knowledge, but on the actions we need to take as a Senate.

Oh. Senator Markey. You made it at the buzzer, so I'm——

[Laughter.]

Senator SULLIVAN. I was this close to tapping. But, given that I know you care a lot about this issue, the floor is yours for some additional questions.

STATEMENT OF HON. EDWARD MARKEY,
U.S. SENATOR FROM MASSACHUSETTS

Senator MARKEY. Thank you.

OK. No, I appreciate it very much. Thank you, Mr. Chairman, Ranking Member Baldwin. Thank you so much.

And, first, I want to give a warm Bay State welcome to Don Anderson, Senior Scientist at Woods Hole, and Mr. Ivory Engstrom, Director of Special Projects at McLane Research Labs in East Falmouth. Thank you for being here. Thank you for sharing your expertise.

And when I say "warm Bay State," that's what I mean. It is warm. The water off of the coast of Massachusetts, with the exception of up in the Arctic, is at the top of the list of the fastest-warming body of water in the world. So, we've got a big issue that we have to deal with. And today's hearing, Harmful Algal Blooms, which are increasing in frequency because of warming waters.

Just last year, Tufts University led a study forecasting that we will see more harmful algal blooms due to climate change, higher water temperatures, changes in rainfall, in flooding, and increased fertilizer runoff. That's a bad recipe for harmful algal blooms.

Dr. Anderson, do you agree that climate change increases the occurrence and severity of harmful algal blooms?

Dr. ANDERSON. Thank you, Senator Markey.

I agree, it increases some of them, but, in fact, it can cut both ways, and it may even cut both ways in our region; for example, where, if it gets too warm, some species may not actually be able to thrive there, and they will move north. And it's happening with fish. It's many—and many other organisms, as well. So, yes, it can get worsened, sir, in some cases, but I do at least want to say that there—that usually there's another side, as well. But, I think that the case in freshwater is crystal clear, that warmth is a—is contributing to the problem. In the marine realm, I think we are seeing it, as well, but much more as a movement of species, like——

Senator MARKEY. Right.

Dr. ANDERSON.—we are now getting warm-water species in the Gulf of Maine that we didn't used to see.

Senator MARKEY. And you're saying that, in the same way that lobster are looking for——

Dr. ANDERSON. Exactly.

Senator MARKEY.—colder water, and cod are looking for colder——

Dr. ANDERSON. Exactly.

Senator MARKEY.—water.

Dr. ANDERSON. Yes.

Senator MARKEY. They start leaving us——

Dr. ANDERSON. So——

Senator MARKEY.—and head north, yes.

Dr. ANDERSON. So, the species—one of the species that causes a lot of problems in Florida, it just bloomed up in Portland and along the coast of Maine last year.

Senator MARKEY. Incredible. Incredible.

So, do you think we need higher levels of funding for research on this question?

Dr. ANDERSON. Absolutely. And I think I can answer this question, as well as what Senator Baldwin asked, about what we can do about forecasting and so forth. The message really is that there are increasing—there are more blooms, there are more species, more toxic syndrome. So, how do you deal with that? And one of the answers was: sensors and better and ability to detect and forecast. And if we put that together, sensors plus better models, computer models, will get us a long way toward what you're—what you wanted. Think of the weather forecasts that you look at. I look at it in the morning, and it gives me a computer model that shows whether rain is coming over the next 2 or 3 days. It's a—that's a combination of a computer model and the—you know, the sensors that are out there measuring what's going on in the atmosphere. We need that in the ocean. And it's expensive. It's—you—but, once you get that infrastructure, like the Weather Service has, you can start doing the kind of predictions and early warning that can really help us manage this worsening problem.

Senator MARKEY. Thank you.

Dr. ANDERSON. So, there's no question.

Senator MARKEY. Appreciate it. Thank you.

Mr. Engstrom, you say in your testimony that, for detecting harmful algal blooms, quote, "the cost of maintaining comprehensive network of sensors may be significant." How can we bring down the cost of sensors?

Mr. ENGSTROM. Well, that's a very complex and yet simple question at the same time, and that's—I believe, is scale. You know, right now our industry is such a niche. But, as we know, the problem is growing. My company, we do instruments in small quantities at high dollar. And if we can find demands beyond our niche, into aquaculture, into other monitoring efforts, I think that that brings the cost down. And also significant are research initiatives, competitive research programs, like NOAA, for technology development, not only just ecological forecasting, but developing tools, like Mr. Stubbs has mentioned, lower-cost tools. There may be a myriad

of technologies that are out there that companies such as ours would love to——

Senator MARKEY. In your opinion, what should our agencies be doing, the best combined satellite data with on-the-ground sensors in order to get the most accurate picture of what is occurring in these harmful blooms?

Mr. ENGSTROM. I don't want to be imprecise, in that I'm not a scientist, but I think that maybe Dr. Anderson or Mr. Stubbs can answer that in——

Senator MARKEY. Dr. Anderson, do you——

Dr. ANDERSON. Well, the combination of those two sensors types is hugely powerful. It—but, it's also only going to be good in certain areas. It will be good on a lot of lakes, large lakes, where you have these surface blooms that are easy to see from space. It's good in Florida, where the bloom is quite visible. Satellites don't really help us too much in the Gulf of Maine, because our species are so toxic, they cause troubles even when the water looks blue. So, it's a little bit of a qualified question.

But, if you can put those two together, you have something—again, I keep going back to the analogy of the Weather Service—you have radar, and think about how much that tells you about storms and so forth. Well, that could be your remote sensing, and that's telling us the big picture. And then you have sensors that are also measuring things at a local level. The two together is really quite powerful.

Senator MARKEY. Thank you.

And, Mr. Chairman, very importantly, Dr. Anderson—and I think it does reflect the more temperate climate that we now have in Massachusetts, therefore giving Dr. Anderson more days in the year to accomplish his goal, is the reigning Massachusetts senior amateur golf champion. That would be made possible by that Cape Cod being more—the warming weather is definitely making it possible——

[Laughter.]

Senator SULLIVAN. Oh, I didn't see that.

Senator MARKEY. Yes, we can't—how—you can't—it doesn't get any bigger than that. OK?

[Laughter.]

Senator MARKEY. So, we thank you both. And we thank all of your for all of that great work.

Thank you, Mr. Chairman.

Senator SULLIVAN. Thank you, Senator Markey.

And again, I want to thank the witnesses for a really important issue. Hopefully, as I mentioned earlier, you're seeing a bipartisan consensus on the need to fully understand this much better, but also to take action. And that's what this hearing is focused on.

So, again, I would ask that any additional questions that come to the witnesses from other Senators who could not be at the hearing today, or additional questions from those who were, that the witnesses submit their written answers to the Committee as soon as they can.

And again, thank you for a very informative hearing.

This hearing is now adjourned.

[Whereupon, at 3:43 p.m., the hearing was adjourned.]

A P P E N D I X

PREPARED STATEMENT FROM THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, U.S. DEPARTMENT OF COMMERCE

Introduction

Chairman Sullivan, Ranking Member Baldwin, and members of the Subcommittee, the Department of Commerce and the National Oceanic and Atmospheric Administration (NOAA) appreciates the opportunity to provide this statement for the record on the issue of harmful algal blooms (HABs) in the United States. NOAA is the lead Federal agency on the topic of HABs in our coastal waters and the Great Lakes (the Environmental Protection Agency (EPA) shares jurisdiction of the Great Lakes). This statement provides the Subcommittee with scientific information on HABs and their impacts to humans, animals, and the economy and describes some of the advances NOAA has made to improving HAB research, monitoring, forecasting, and management.

HABs occur when colonies of algae or cyanobacteria—simple photosynthetic organisms that live in marine, estuarine, and freshwater environments—grow out of control and some can produce harmful toxins. HABs occur naturally, but human activities that disturb ecosystems seem to play a role in their more frequent occurrence and intensity. Increased nutrient loadings and pollution, food web alterations, introduced species, water flow modifications and temperature all play a role.

These toxic blooms have a variety of harmful effects on people, fish, shellfish, marine mammals, sea turtles, and birds. The human illnesses caused by HABs can be debilitating or even fatal. HABs harm ecosystems by smothering valuable habitats such as coral reefs and seagrass beds, piling up on beaches, or by growing to such proportions that their subsequent decomposition depletes oxygen in the water (*i.e.,* hypoxia), killing fish, shellfish, and aquatic vegetation. HABs have been reported in every U.S. coastal state, and their occurrence is on the rise. HABs are a national concern because they negatively affect not only the health of people and marine ecosystems, but also the health of local and regional economies.

In recognition of the magnitude and impact of the issue, Congress passed the Harmful Algal Bloom and Hypoxia Research and Control Act (HABHRCA) in 1998 and most recently reauthorized the Act in 2014. HABHRCA designates NOAA as the lead Federal agency responsible for advancing our country's ability to detect, monitor, assess, and forecast HAB and hypoxia events in coastal marine waters. NOAA and the Environmental Protection Agency share jurisdiction for the Great Lakes, and EPA has jurisdiction over activities that occur in non-Great Lakes freshwater areas. NOAA supports EPA and other Federal agencies in addressing freshwater HABs outside the Great Lakes. For example, we are currently providing and processing the European Space Agency's Sentinel-3A Ocean Land Color Instrument (OLCI) satellite imagery of cyanobacteria in Lake Okeechobee in Florida. The U.S. Army Corps of Engineers (USACE), United States Geological Survey (USGS), EPA, and state partners use this data to determine where to monitor HABs.

NOAA's Approach

NOAA's role is in understanding, detecting, monitoring, and forecasting HABs, and in helping communities with decision-making related to their prevention, control, and mitigation. NOAA's HAB programs are national in scope but targeted to different regional needs. Competitive research that Congress appropriated funding for in FY 2018 and in previous years have complemented NOAA's internal research on HABs.

Partnerships with state managers, academics, and citizen scientists also bring a wealth of expertise to our HAB programs. For example, the Phytoplankton Monitoring Network engages citizen scientists in the Great Lakes and Alaska in monitoring for HABs. Through this program, we have alerted managers to previously undetected toxins in commercial shellfish beds.

Coordination and collaboration between programs within NOAA and other Federal agencies ensures broad engagement and efficient use of resources in addressing

complex HAB issues. The Cyanobacteria Assessment Network (CyAN) project is a National Aeronautics and Space Administration (NASA)-funded collaboration between NOAA, EPA, and the U.S. Geological Survey (USGS) to produce a real-time satellite surveillance of harmful algal blooms in freshwater lakes and reservoirs. These data products currently support states in assessing blooms and in determining where sampling is most needed.

Research

NOAA research advances our understanding of what causes and sustains HABs and their toxins, and uses that understanding to develop forecasts, prevention strategies, and other tools. Current research priorities include studying how toxins are transferred across and up the food chain and assessing the impacts of toxins on humans. NOAA also conducts socioeconomic research to assess impacts of HAB events on coastal economies, and on the costs and benefits of mitigation strategies to aid managers in devising cost-effective management strategies. Research results guide management of coastal resources to reduce HAB development, impacts, and future threats, and will feed into other HAB programs for development of tools to improve management and response.

Monitoring and Detection

NOAA enhances HAB and toxin detection and monitoring by developing fast, accurate and cost-effective identification protocols. NOAA's recent advances in automated and field-ready capabilities that can be deployed remotely or on small boats enable rapid HAB detection and monitoring. Sensors can also be added to ocean observing systems, such as underwater gliders, for long-term monitoring of HABs. Early warning of HABs or toxins provides health officials, environmental managers, and water treatment facility operators with information to guide potential beach and shellfish bed closures or water treatment in a more appropriate timeframe.

We also build capacity within states, tribes, the seafood industry, and others, by providing access and training on proven detection technologies. This ensures that trained and equipped personnel are able to mobilize quickly during HAB events. For example, in May 2018, NOAA and partner scientists from the Phytoplankton Monitoring Network trained over thirty environmental personnel from southeast and south central Alaskan tribes in toxic phytoplankton sampling and identification.

Forecasting

NOAA's HAB forecasts serve as decision-support tools for local coastal resource managers, public health officials, and research scientists. We provide operational HAB forecasts for Lake Erie, Texas, and Florida, and are developing forecasts for the Pacific Northwest, the Gulf of Maine, and California. Short-term (twice weekly) forecasts identify which blooms are potentially harmful, where they are, how big they are, and where they are likely headed. Our HAB forecasts for the Gulf of Mexico also include information on the potential for respiratory irritation that is delivered directly to the public. Longer-term, seasonal forecasts predict the severity of HABs for the bloom season in a particular region.

NOAA is improving the spatial resolution of our monitoring and forecasts with increased use of space-based data from NOAA's Joint Polar Satellite System and leveraging European Sentinel and Metop satellite data. NOAA's National Centers for Environmental Information also provides data for retrospective analysis of past HAB events to improve future detection and response efforts.

Event Response

NOAA responds to HAB events by coordinating access to technology and expertise and ensuring proper scientific documentation to advance understanding of HABs. In some circumstances, NOAA is also able to provide financial support to defray event response costs, such as mobilization of sampling, supplies, and analytical services. For example, in August 2018, NOAA provided financial support to the Florida Fish and Wildlife Institute and Mote Marine Lab to help manage the response to a rare HAB event in Sitka, Alaska and a prolonged, severe HAB event in Southwest Florida.

Prevention, Control, and Mitigation

Over more than two decades, NOAA has produced methods and strategies to improve HAB management and response. These include toxicity test kits; technology for high volume and field-based HAB detection; and HAB forecasts. We also have funded and conduct research to move promising preventions and mitigation technologies for HABs from research to operations.

Impacts of Harmful Algal Blooms

Health Impacts

Some harmful algae produce potent toxins that cause illness or death in humans and wildlife. Both humans and animals can be exposed to algal toxins through the food they eat, the water they drink or swim in, or the air that they breathe. Toxic algae can contribute to symptoms in humans such as digestive and respiratory complications. Acute health effects associated with marine pathogens and HAB toxins costs approximately $900 million [1] annually.

Additionally, HABs have been implicated in the deaths of many marine mammals, sea turtles, and the prey they eat. The most common impacts from algal toxins on marine mammals and sea turtles are neurological symptoms such as seizures, disorientation, or death. In addition to immediate death, algal toxins have caused long-term impacts when prey is depleted, and the animals suffer malnutrition. Persistent red tides in Atlantic and Gulf waters have caused significant sea turtle and dolphin deaths numbering in the hundreds to thousands of animals.

Other harmful algae are nontoxic to humans and wildlife but form such large blooms that they can be a nuisance to humans as well as degrade habitat quality through massive overgrowth, shading, or oxygen depletion (hypoxia).

Economic Impacts

The impact of a bloom depends on its location, duration, and toxicity. Since HABRHCA was last authorized in 2014, record-setting HABs on both coasts and the Great Lakes have had severe impacts to the seafood industry, tourism, drinking water, and property values.

2014 Great Lakes Cyanobacteria Bloom

In 2014, Toledo, Ohio, officials issued a two-day ban on drinking or cooking with tap water for more than 400,000 residents due to high levels of toxins harmful to humans resulting from a massive toxic algae bloom on western Lake Erie. Testing for the microcystin toxin and removing it from the water is expensive and time-consuming. As a result of the early and large HAB of 2015, the City of Toledo spent their $6 million water treatment budget at the beginning of the Fiscal Year and required an additional $3 million for the remainder of the Fiscal Year that were borne by non-federal entities. Beyond drinking water, the bloom affected fishing, tourism, and property values. The total impact of ecosystem service interruptions due to the 2014 HAB event was estimated at $65 million.[2]

2015 West Coast HAB

In 2015, the largest HAB in at least 15 years stretched from central California to British Columbia and the Alaska Peninsula. Record-setting concentrations of domoic acid produced by the HAB event in California, Oregon, and Washington caused marine mammal deaths and devastated commercial and recreational fisheries. The commercial Dungeness crab fishery experienced a $97.5 million [3] decrease in revenue from 2014 to 2015. This generated an economic shock for fishery-dependent communities along the West Coast; the Dungeness crab fishery generates the highest revenues and has the highest vessel participation of any fishery on the West Coast.[4] The 2015 event also resulted in the closure of recreational, commercial and subsistence razor clam fisheries in Washington, Oregon and California. The recreational razor clam fishery generates significant tourism-related income associated with clam digger visits to coastal communities, particularly in Washington and northern Oregon. A season-long closure of the recreational razor clam fishery is estimated to result in $24.4 million [5] in lost expenditures (2008 dollars).

---

[1] R., P.Kite-Powell, E., H., & A. (2011, December 01). An estimate of the cost of acute health effects from food-and water-borne marine pathogens and toxins in the USA. Retrieved from *https://iwaponline.com/jwh/article/9/4/680/31135/An-estimate-of-the-cost-of-acute-health-effects*

[2] "Economic Benefits of Reducing Harmful Algal Blooms in Lake Erie", M. Bingham, S. K. Sinha, and F. Lupi, Environmental Consulting & Technology, Inc., Report, 66 pp, October 2015.

[3] National Marine Fisheries Service (2017) Fisheries of the United States, 2016. U.S. Department of Commerce, NOAA Current Fishery Statistics No. 2016.

[4] Fuller, E. M. Samhouri, J. F. Stoll, J. S. Levin, S. A. and Watson, J. R. Characterizing fisheries connectivity in marine social–ecological systems.—ICES Journal of Marine Science, doi:10.1093/icesjms/fsx128.

[5] Karen Dyson, Daniel D. Huppert, Regional economic impacts of razor clam beach closures due to harmful algal blooms (HABs) on the Pacific coast of Washington, Harmful Algae, Volume 9, Issue 3, 2010, Pages 264–271

2018 Florida Red Tide

When blooms are in the news and affecting shorelines, fewer people come to Florida's beaches, restaurants, and hotels. A study of HAB impacts in Okaloosa County (on Florida's Gulf Coast) estimated that the approximately $6.5 million[6] per month in losses to restaurants and hotels during blooms is seven times greater than monthly losses due to adverse weather. On August 13, 2018, in recognition of the scale of the impact to Florida's coastal communities and economies, Governor Rick Scott declared a state of emergency in seven counties stretching from Tampa Bay south to the fringe of the Everglades.

Success Stories

NOAA has a long record of accomplishments since the passage of HABHRCA in 1998, including improved HAB monitoring and detection capabilities, identification of methods to prevent the development of blooms, and forecasts to provide more efficient and comprehensive ways of assisting state managers and warning the public of potential exposure. Below we highlight several success stories on collaboration with our partners.

HAB Detection Technology Increases Seafood Exports in Alaska

A HAB toxin testing method developed by NOAA facilitates the continued export of Alaskan geoducks to China, by increasing the speed and lowering the cost of testing shellfish exports for the Paralytic Shellfish Poisoning (PSP) toxin. In 2014, China temporarily closed the $68 million geoduck export industry, stipulating that all shellfish imports had to be tested for Paralytic Shellfish Poisoning (PSP) toxin. At the time, testing took a week and cost $400 per clam. By the time divers received the test result, they often had only one day to harvest before new tests were needed. NOAA developed a faster and cheaper PSP testing method that is now used by the Sitka Tribe of Alaska to test locally harvested shellfish in their Environmental Research Lab.

Maintaining Safe Drinking Water for Lake Erie

More than 2,000 U.S. and Canadian subscribers receive NOAA's twice-weekly HAB bulletins with three-to five-day forecasts that include the bloom location and concentration. In 2015, water managers used NOAA's forecasts to strategically increase treatment and fill cisterns with safe water before the blooms reached intake pipes. Thus, drinking water was safe despite the most severe Lake Erie bloom on record. In 2018, the Sentinel-3A OLCI satellite is providing images with a 300-meter resolution, allowing water treatment facility and public safety managers to make decisions at the scale of water intakes and swimming beaches, avoiding system or lake-wide closures.

Reopening Shellfish Harvest in Gulf of Maine

By collaborating with the U.S. Food and Drug Administration, state shellfish control authorities, test kit manufacturers, and the seafood industry to develop an onboard screening and dockside testing protocol for PSP toxins in molluscan shellfish, NOAA enabled the reopening of shellfisheries on Georges Bank, off the coast of Maine. The fishery had been closed for two decades because toxins in shellfish sometimes exceeded regulatory limits and the area was too large and remote for routine monitoring of HAB toxins. After the protocol was developed and adopted by the Interstate Shellfish Sanitation Conference, NOAA was able to help reopen 6,000 square miles of the sea floor for surf clam and ocean quahog fishing in 2013. The fishery has production potential of up to one million bushels of surf clams and ocean quahogs a year, valued at $10 to $15 million annually.

Conclusion

NOAA provides valuable science, products, and services to mitigate the human and animal health and economic impacts of HABs nationwide. Through our research, forecast, monitoring, and response activities, NOAA provides actionable information about HABs to decision-makers responsible for water treatment, aquaculture, public health, tourism, and coastal resource management. Thank you for the opportunity to provide this statement for the record.

---

[6] Larkin, S., C.M Adams, Ballyram, D. Mulkey, A. Hodges. "Red Tides and Coastal Business: Measuring Economic Consequences in Florida." Working paper, Food and Resource Economics Department, University of Florida, Gainesville, FL (21 pp.), 2003.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. JIM INHOFE TO PATRICK NEU

Question. We have seen the negative effects of harmful algal bloom first hand in my home state of Oklahoma. In 2011, Blue Green Algae warnings at Lake Texoma resulted in a loss of $45 million in economic activity—8 percent of annual revenue generated by Lake Texoma and its recreational activities. Multiple algal blooms wiped out an entire fishery in Lake Altus-Lugert in Southwest Oklahoma in 2013 and 2014, decimating recreational fishing activity. According to a study by Oklahoma State University, Oklahoma State parks experienced a decline of 19 percent during algal blooms. Clearly there are real economic impacts to local communities.

How is the recreational industry mitigating algal blooms, and how can Federal partners work better with industry to prevent the devastating impact of these blooms or at least better predict when they would happen?

Answer. Senator Inhofe, thank you for your follow-up questions and continued interest in the impact that harmful algal blooms (HABs) have on the sportfishing industry. As I stated in my opening testimony, I applaud you, and the rest of the Senate, for passing S.1057, the Harmful Algal Bloom and Hypoxia Research and Control Amendment Act of 2017. Additionally, I urge your colleagues in the House as quickly as possible to pass the House version of the bill, H.R. 6645. It's crucial that Congress move this bill across the finish line as it would reauthorize the critically important National Harmful Algal Bloom and Hypoxia Program and Federal Interagency Taskforce, which recently expired on Sept. 30. The American Sportfishing Association, which is the trade association representing the recreational fishing industry, recently circulated a letter of support for H.R. 6645. The program that this bill would reauthorize is essential to advancing the scientific understanding and ability to detect, monitor, assess, and predict HABs.

As President of the Future Anglers Foundation and Executive Director of the National Professional Anglers Association, I'll continue educating our future anglers and the professional anglers who are members of our association on the impact these HABs have on our ecosystem, and can assure you that my partners throughout the sportfishing industry will continue shining a spotlight on this nationwide issue. Once again, thank you for your continued interest in how HABs affect the recreational sportfishing industry, and please do not hesitate to reach out if I can be of further assistance.

○