CLIMATE CHANGE AND HARMFUL ALGAL BLOOMS: LEGAL AND POLICY RESPONSES TO PROTECT HUMAN HEALTH, MARINE ENVIRONMENTS, AND COASTAL ECONOMIES

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"Pollution of the air or of the land all ultimately ends up in the sea."[1]

ABSTRACT

Harmful Algal Blooms (HABs) pose an increasing threat to human health, marine environments, and coastal economies. Warming, acidification, nutrification, and other human-mediated changes to marine systems work synergistically with naturally occurring environmental factors to increase the incidence, severity, and geographic range of HABs. The United States has responded to this emergent threat with a policy agenda that is heavily oriented toward research designed to provide better forecasts for HABs, but light on actions that address the direct drivers of HAB development. This Article contends that this policy approach is poorly suited to the known risks of intensifying HABs. This Article recommends a shift toward a more action-oriented policy agenda aimed at preventing the anthropogenic drivers of HABs through the use of practical solutions and statutory tools available under the Clean Water Act and the Clean Air Act.

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1 Jacques-Yves Cousteau, *Ocean Policy and Reasonable Utopias*, in 16 THE FORUM (SECTION OF INSURANCE, NEGLIGENCE AND COMPENSATION LAW, AMERICAN BAR ASSOCIATION), 897 (1981), htttp://www.jstor.org/stable/25762569.

INTRODUCTION

In 2016, a massive "blue-green" algal bloom developed in Lake Okeechobee—Florida's largest freshwater lake.[2] The bloom was so large that it was visible from space.[3] Heavy rainfall and runoff into the lake churned up nutrient-rich bottom sediment as the lake levels rose. To keep pressure off the aging, thirty-foot-high Herbert Hoover Dike that surrounds the lake and to prevent flooding of nearby

[2] *See Bloom in Lake Okeechobee*, NASA EARTH OBSERVATORY (July 2, 2016), https://earthobservatory.nasa.gov/images/88311/bloom-in-lake-okeechobee. Blue-green algae, or Cyanobacteria, exist in aquatic and marine habitats and occasionally increase rapidly in eutrophic waters to create massive blue-green algae blooms that release harmful toxins into the surrounding environment. *See Cyanobacteria (Blue-Green Algae)*, FLA. FISH & WILDLIFE CONSERVATION COMM'N, https://myfwc.com/research/wildlife/health/other-wildlife/cyanobacteria/ (last visited Dec. 22, 2020).

[3] *See Visible Earth, Bloom in Lake Okeechobee*, NASA VISIBLE EARTH (July 6, 2016), https://visibleearth.nasa.gov/view.php?id=88311.

communities, the U.S. Army Corps of Engineers (USACE) deliberately released some of this toxic water into the St. Lucie and Caloosahatchee Rivers and their tributaries.[4] Soon, the waterways became coated with thick, blue-green algae blooms that released toxins capable of causing, "nausea, vomiting and, in extreme cases, liver failure" in humans, into the air and water.[5] In one county, samples of river water contained microcystin toxin levels thousands of times higher than the level recognized as safe for human exposure.[6] Along the Atlantic and Gulf coasts, a heavy blue-green wave spread over the shoreline and guacamole-thick algae mats covered surface waters in local waterways and estuaries, harming marine life.[7] The impacts of the release were so significant that Florida's governor declared a state of emergency.[8]

Between 2017 and 2018, blue-green algae blooms emerged again, coinciding with Florida's worst "red tide" in decades.[9] Heavy

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4 *See Army Corps Concedes Lake O Discharge Toxicity*, FORT MEYERS BEACH OBSERVER AND BEACH BULLETIN (July 11, 2019), http://www.fort-myers-beach-observer.com/page/content.detail/id/635562/Army-Corps-concedes-Lake-O-discharge-toxicity.html.

5 NASA Bloom, *supra* note 2.

6 *See* Tyler Treadway, *Martin County Tests Show Algae Toxins in St. Lucie River Blooms Also Contaminate Air*, TCPALM (July 26, 2016), http://archive.tcpalm.com/news/indian-river-lagoon/health/tests-show-algae-toxins-also-contaminating-air-quality-38788367-fe2d-1b86-e053-0100007faaf1-388311361.html (reporting that an algae bloom in Stuart County contained microcystin concentrations of 33,000 parts per billion (ppb)). EPA has established drinking water standards for microsystin of limits 0.3 μg/L (0.3ppb) for infants and preschoolers and 1.6 ug/L (1.6ppb) for all others. *EPA Drinking Water Health Advisories for Cyanotoxins*, EPA, https://www.epa.gov/cyanohabs/epa-drinking-water-health-advisories-cyanotoxins (last visited Sept, 6, 2020).

7 *See* Miami Herald, *'It's Kind of Horrific': Toxic Algae Bloom Threatens Florida Coasts (Again)*, TAMPA BAY TIMES, (June 30, 2018), https://www.tampabay.com/florida-politics/buzz/2018/06/30/its-kind-of-horrific-toxic-algae-bloom-threatens-florida-coasts-again; Greg Allen, *'A Government-Sponsored Disaster': Florida Asks for Federal Help With Toxic Algae,* NPR (July 9, 2016), https://www.npr.org/2016/07/09/485367388/a-government-sponsored-disaster-florida-asks-for-federal-help-with-toxic-algae; Mayra Cuevas, *Toxic Algae Bloom Blankets Florida Beaches, Prompts State of Emergency,* CNN (July 1, 2016), https://www.cnn.com/2016/07/01/us/florida-algae-pollution/index.html.

8 *See* OFF. OF THE GOVERNOR, STATE OF FLA., EXECUTIVE ORDER NUMBER 16-155; (EMERGENCY MANAGEMENT – LAKE OKEECHOBEE DISCHARGE) (2016), https://www.flgov.com/wp-content/uploads/pdfs/16155.pdf.

9 *See* James Rogers, *Blue-Green Toxic Algae Invades Florida River*, FOX NEWS (Aug. 15, 2018), https://www.foxnews.com/science/blue-green-toxic-algae-invades-florida-river. So called "red tides," which are different than blue-

rains from Hurricane Irma, in September 2018, combined with May 2018's record rainfall, raised levels in Lake Okeechobee so high that the USACE again released water into surrounding rivers and tributaries.[10] As the algae-laden, nutrient-rich water flowed toward the coast, impacting estuarine environments, waterways once again became blanketed by thick algal mats.[11] At the same time, a red tide developed off Florida's west coast and moved toward the shore.[12] Over a fourteen-month period between 2017 and 2018, Florida's picturesque white sand beaches along the coast were transformed into killing fields.[13] Thousands of marine organisms, including large and small fish, dolphins, manatees, sea turtles (including the highly endangered Kemps Ridley), sea birds, sharks, and other marine organisms washed up dead along the coastline and inland waterways.[14] In total, more than two thousand tons of dead marine animals littered Florida beaches and waterways.[15] The mass die-off was caused by the devasting red tide bloom that grew as it reached the

green algae blooms, result when *Karenia brevis*, a species of marine algae, form massive red algae blooms in coastal waters and release harmful brevetoxins into the surrounding environment. *Compare About Red Tides in Florida*, FLA. FISH & WILDLIFE CONSERVATION COMM'N, https://myfwc.com/research/red-tide/general/about/ (last visited Dec. 22, 2020), *with* FLA. FISH & WILDLIFE CONSERVATION COMM'N, *supra* note 2.

10 *See* Press Release, U.S. Army Corps of Engr's, USACE to Begin Water Releases from Lake Okeechobee (May 31, 2018), https://www.saj.usace.army.mil/Media/News-Releases/Article/1536409/usace-to-begin-water-releases-from-lake-okeechobee/.

11 *See* Brigit Katz, *A Toxic Algal Bloom Is Spreading in Florida's Waterways*, SMITHSONIAN MAG. (July 10, 2018), https://www.smithsonianmag.com/smart-news/toxic-algal-bloom-spreading-floridas-waterways-180969586/.

12 *See* Nat'l Ocean Serv., *Fall 2018 Red Tide Event That Affected Florida and the Gulf Coast*, NOAA, https://oceanservice.noaa.gov/hazards/hab/florida-2018.html.

13 *See* Maya Wei-Haas, *Red Tide Is Devastating Florida's Sea Life. Are Humans to Blame?*, NAT'L GEOGRAPHIC, (Aug. 8, 2018), https://www.nationalgeographic.com/environment/2018/08/news-longest-red-tide-wildlife-deaths-marine-life-toxins./; Krimsky et. al., *Understanding the 2017-2018 Florida Red Tide,* U. FLA. INST. FOOD AND AGRIC. SCI., (Dec. 4, 2018), http://blogs.ifas.ufl.edu/extension/2018/12/04/understanding-the-florida-red-tide/.

14 *See* Wei-Haas, *supra* note 13.

15 *See* CNN Wire, *Florida's 'Red Tide' Linked to 2,000 Tons of Dead Marine Life; State of Emergency Issued*, KTLA5, (Aug. 23, 2018), https://ktla.com/news/nationworld/floridas-red-tide-linked-to-2000-tons-of-dead-marine-life-state-of-emergency-issued/.

coastline.[16] The bloom eventually spread along 150 miles of Florida's coastline.[17] Although animal deaths were the most visible effect of the bloom, humans were also impacted. Many people along the coastline complained of respiratory illnesses, headaches, rashes, and gastrointestinal distress because of exposure to airborne toxins.[18] Coastal tourism declined, and business owners suffered significant economic hardship.[19] The harms caused by the HABs in 2017 and 2018 were significant enough to prompt Florida's governor to again declare a state of emergency for seven counties.[20]

Florida is not the only state impacted by toxic algal blooms. Harmful blooms occur in fresh, marine, and brackish waterbodies throughout the world. Every coastal state in the United States has experienced harmful blooms.[21] Most coastal countries throughout the world have also experienced marine HABs.[22]

Over the past several decades, the variety and frequency of HAB events has increased.[23] Human activities are changing the

16 *See Fall 2018 Red Tide Event that Affected Florida and the Gulf Coast*, NOAA, https://oceanservice.noaa.gov/hazards/hab/florida-2018.html (last updated Apr. 10, 2020).

17 *See id.*

18 *See* Amy Bennet Williams, *Are the Toxic Algae Blooms Along Florida's Coasts Making People Sick?*, USA TODAY, (Aug. 7, 2018), https://www.usatoday.com/story/news/nation-now/2018/08/07/toxic-algae-red-tide-florida-public-health-sick/922230002/.

19 *See* Courtney Hann & Julia Jacobo, *State of Emergency Declared in Florida Amid Toxic Red tide Outbreak on Gulf Coast*, ABC NEWS (Aug. 14, 2018), https://abcnews.go.com/US/state-emergency-declared-florida-amid-toxic-red-tide/story?id=57164849; *see also,* TAMPA BAY REG'L PLANNING COUNCIL, THE ECONOMIC RIPPLE EFFECTS OF FLORIDA RED TIDE (2019), http://www.tbrpc.org/wp-content/uploads/2019/01/The-Economic-Ripple-Effects-of-Florida-Red-Tide_unsigned.pdf (estimating that the final economic damage from the red tide could be as high as $130 million).

20 *See* OFF. OF THE GOVERNOR, STATE OF FLA., EXECUTIVE ORDER NUMBER18-221; (EMERGENCY MANAGEMENT—RED TIDE) (2018), https://www.flgov.com/wp-content/uploads/2018/08/red-tide.pdf.

21 *See Harmful Algal Blooms*, NOAA, https://oceanservice.noaa.gov/hazards/hab/ (last updated May 10, 2020).

22 *See* D.M. Anderson et al., *Harmful Algal Blooms in the Arctic*, *in* NOAA ARCTIC REPORT CARD: UPDATE FOR 2018 81 (2018) *available at* https://arctic.noaa.gov/Report-Card/Report-Card-2018/ArtMID/7878/ArticleID/789/Harmful-Algal-Blooms-in-the-Arctic.

23 *See* Xue Fu et al., *Global Change and the Future of Harmful Algal Blooms in the Ocean*, 470 MARINE ECOLOGY PROGRESS SERIES 207, 207 (2012), https://www.int-res.com/articles/theme/m470p207.pdf.

physical and chemical factors that regulate algal growth and development in waterbodies.[24] Changes to the marine environment that are linked to climate change, such as ocean warming, acidification, and altered precipitation, combine with other stressors, such as excess nutrification of waters, to influence algae species composition and distribution in ways that increase the risk posed by HABs.[25] Yet mitigation strategies that address HABs largely ignore the projected impacts of climate change on marine and aquatic systems.[26]

This Article considers the anticipated impacts of climate disruption on HAB formation and explores opportunities to reduce the risks that HABs pose to coastal environments. Part I of this Article will examine the natural drivers of HABs and explain the growing risks that they pose. Part II will explore how fundamental changes taking place in marine systems as a result of climate disruption will work synergistically with other drivers to augment these risks. Part III will examine the legal frameworks used at the state and federal levels to mitigate the risks of HABs. Part IV will suggest additional actions that should be taken to limit the impact of HABs on human health, the marine environment, and coastal economies.

I. HARMFUL ALGAL BLOOMS AND THE MARINE ENVIRONMENT

Phytoplankton are vitally important to the marine system.[27] Diatoms, dinoflagellates, coccolithophores, cyanobacteria, and other phytoplankton account for up to half of global primary production, release oxygen into the water, and serve as the base of the ocean food chain.[28] When the right combination of physical and chemical factors emerge in a waterbody, these microalgae can experience

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24 *See id.*

25 *See id.*

26 *See infra* at Part II.

27 *See What Are Phytoplankton*?, NOAA, https://oceanservice.noaa.gov/-facts/phyto.html (last updated Oct. 9, 2019).

28 *See What are Phytoplankton?*, NASA (July 13, 2010), https://earthobservatory.nasa.gov/features/Phytoplankton; *see also* EUROPEAN SPACE AGENCY, *Phytoplankton: Shedding Light on the Ocean's Living Carbon Pump*, PHYS.ORG (May 6, 2020), https://phys.org/news/2020-05-phytoplankton-ocean-carbon.html (noting that primary production is an ecologic term used to describe the synthesis of organic material from carbon dioxide and water, in the presence of sunlight, through photosynthesis); E. Litchman et al., *Global Biogeochemical Impacts of Phytoplankton: A Trait-Based Perspective*, 103 J. ECOLOGY 1384 (2015) (noting that phytoplankton contribute about half of global primary productivity).

explosive growth that creates a beneficial bloom that provides nutrition for higher-level organisms.[29] Despite their enormous value, a small number of these phytoplankton species can be harmful due to their ability to produce and release toxic chemicals into the surrounding air and water that can seriously harm people, animals, fish, and other parts of the ecosystem.[30] These marine toxins also threaten shellfish health because they can cause neurotoxic, paralytic, diarrheic, amnesic, azaspiracid, and ciguatera shellfish poisoning.[31] When algae-laden, nutrient rich water is released from inland freshwater systems into tributaries that empty into marine systems, algae can spread toward the coast and release harmful microcystin toxin into estuarine waters.[32] Under the right conditions, these harmful, single-celled algae can grow out of control to form massive, killer blooms that negatively impact wildlife, human health, ecosystems and economies.[33]

A. *HAB Development and Environmental Health*

Physical and chemical factors, including nutrient availability, water temperature, salinity, carbon dioxide concentration, and pH, influence phytoplankton growth rates.[34] Phytoplankton convert available nutrients into the building blocks of life—proteins, fats, and carbohydrates—as they grow.[35] When one or more of these physical or chemical factors changes, algae can grow out of control to form massive harmful algal blooms that produce toxic compounds, which have harmful effects on fish, shellfish, mammals,

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29 *See Are All Algal Blooms Harmful*?, NOAA, https://oceanservice.noaa.gov/facts/habharm.html (last updated Apr. 9, 2020).

30 *See id.* (noting that less than 1% of algal species produce harmful toxins); *see also Harmful Algal Bloom (HAB) Species,* WOODS HOLE OCEANOGRAPHIC INST., (2019), https://hab.whoi.edu/species/.

31 *See* Patricia M. Gilbert et al., *The Global, Complex Phenomena of Harmful Algal Blooms*, 18 OCEANOGRAPHY 136, 137–38 (2015), https://doi.org/10.5670/oceanog.2005.49.

32 *See* Benjamin J. Kramer et al., *Nitrogen Limitation, Toxin Synthesis Potential, and Toxicity of Cyanobacterial Populations in Lake Okeechobee and the St. Lucie River Estuary, Florida, During the 2016 State of Emergency Event*, 13 PLOS ONE 1, 2 (May 23, 2018), https://doi.org/10.1371/journal.pone.0196278.

33 *See* NOAA, *supra* note 21.

34 *See* NASA, *supra* note 28.

35 *See* NOAA, *supra* note 27.

birds, and people.[36] As such, massive HABs may develop throughout the world's oceans when the lighting, water temperature, and nutrient load are conducive to explosive growth.[37]

When naturally occurring marine HABs move inshore, they can experience rapid growth as the algae overfeed on excess nutrients that flow into bays and estuaries from stormwater, fertilizer runoff, septic tanks, faulty wastewater systems, and other human sources. For example, *Karenia brevis*, the toxic algae species responsible for the mass die-off observed in Florida between 2017 and 2018, developed offshore at the bottom of the Florida shelf.[38] Over time, wind and currents transported the bloom toward the coast where it encountered coastal waters that were polluted by human sources through atmospheric deposition, releases from rivers and estuaries, and estuarine flux; these excess nutrients sustained and exacerbated the bloom.[39]

Nitrogen is a naturally occurring nutrient, but in excess quantities, it can overstimulate algal growth and lead to hypoxia—an oxygen deficiency—in marine ecosystems.[40] The growth of algae and plankton in estuaries and coastal ecosystems systems generally corresponds to the availability of nitrogen.[41] As nitrogen levels in the water increase, algal growth is stimulated,[42] blocking vital sunlight from underwater plants that need it for photosynthesis.[43] Organisms with limited mobility—such as clams or oysters—are especially

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[36] *See id.*, Xue Fu et al., *supra* note 23; NASA, *supra* note 28; Gilbert, *supra* note 31.

[37] *See* NASA, *supra* note 28.

[38] *See* Krimsky et al., *supra* note 13.

[39] *See id.*; *see also* Jenny Staletovich, *Red Tide May Be 'Natural' But Scientists Believe Coastal Pollution Is Making it Worse*, PHYS.ORG (Sept. 3, 2018), https://phys.org/news/2018-09-red-tide-natural-scientists-coastal.html#jCp.

[40] *See* Anne Bernhard, *The Nitrogen Cycle: Processes, Players, and Human Impact*, NATURE EDUC. (2010), https://www.nature.com/scitable/knowledge/library/the-nitrogen-cycle-processes-players-and-human-15644632/.

[41] *See* Hans W. Paerl et al., *Atmospheric Deposition of Nitrogen: Implications for Nutrient Over-Enrichment of Coastal Waters*, 25 ESTUARIES 677, 677 (2002).

[42] *See id.*

[43] *See The Effects: Dead Zones and Harmful Algal Blooms,* EPA, https://www.epa.gov/nutrientpollution/effects-dead-zones-and-harmful-algal-blooms (last updated Mar. 10, 2017) [hereinafter EPA Dead Zones].

vulnerable as they cannot retreat from the algal bloom.[44] The threat from these blooms continues even after the algae die because their decomposition draws oxygen from the surrounding water column.[45] For large blooms, the decay and decomposition of algae consumes enough oxygen to create hypoxic areas that cannot sustain most life forms.[46]

B. *HABs and Wildlife*

Throughout the globe, massive ocean "dead zones"—linked to the development and subsequent decay of algal blooms—have emerged.[47] Annually, the Gulf of Mexico experiences one of the largest "dead zones" in the world.[48] It is triggered by excess nitrogen, phosphorous, and other nutrients from agricultural lands, and from sewage that gets flushed into the Gulf from the Mississippi River watershed. These excess nutrients trigger a massive algae bloom followed quickly by algae die-off that rapidly consumes oxygen from the water to create a dead zone incapable of supporting most marine life.[49] In 2019, this dead zone covered about eight thousand square miles—approximately the area of Massachusetts.[50]

Since the 1960s, the number of hypoxic waterbodies in the United States has increased thirty-fold with over three hundred coastal systems now impacted.[51] Ocean warming will exacerbate

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44 *See* U.S. GOV'T ACCOUNTABILITY OFF., GAO-13-39, EPA FACES CHALLENGES IN ADDRESSING DAMAGE CAUSED BY AIRBORNE POLLUTANTS 7 (2013), https://www.gao.gov/assets/660/651522.pdf.

45 *See* Gilbert et al., *supra* note 31, at 138.

46 *See* EPA Dead Zones, *supra* note 43.

47 *See e.g.*, Press Release, NOAA, Gulf of Mexico 'Dead Zone' Is the Largest Ever Measured, (Aug. 2, 2017), https://www.noaa.gov/media-release/gulf-of-mexico-dead-zone-is-largest-ever-measured (reporting that the 2017 dead zone that measured 8,776 square miles, about the size of New Jersey, was the largest ever recorded in the Gulf of Mexico, and was driven by primarily by nutrient pollution, from agriculture and developed land runoff in the Mississippi River watershed).

48 Press Release, NOAA, NOAA Forecasts Very Large 'Dead Zone' for Gulf of Mexico, (last updated June 12, 2019), https://www.noaa.gov/media-release/noaa-forecasts-very-large-dead-zone-for-gulf-of-mexico.

49 *See id.*

50 *See id.*

51 *See Dealing with Dead Zones: Hypoxia in the Ocean*, NOAA (Feb. 18, 2020), https://oceanservice.noaa.gov/podcast/feb18/nop13-hypoxia.html; *see also* Robert W. Howarth, *Coastal Nitrogen Pollution: A Review of Sources and Trends Globally and Regionally,* 8 HARMFUL ALGAE 14, 14–20 (2008),

this problem because the concentration of dissolved oxygen in surface water is regulated by temperature; as water warms, it holds less dissolved oxygen.[52] For example, the extent of the dead zone in the Gulf of Mexico in 2019 was influenced by record sea surface temperatures in 2019.[53]

Some algae species produce toxins that kill or injure wildlife either directly through exposure, or indirectly through consumption of contaminated organisms lower on the food chain, which have themselves accumulated toxins in their tissues either directly or indirectly.[54] For example, several species of dinoflagellate, *Alexandrium fundyense,* produce saxitoxin that is highly toxic to marine vertebrates.[55] Other marine invertebrates, such as copepods and shellfish, consume the saxitoxin without significant impact, accumulate it within their soft tissue, and, when eaten, transfer the toxin to higher level organisms like birds, fish, marine mammals, and others where it causes harm.[56] A single filter feeding organism may accumulate enough toxins from the surrounding environment to kill a

https://www.sciencedirect.com/science/article/pii/S1568988308001078 (discussing the increase in coastal eutrophication globally that has led to widespread hypoxia and anoxia, habitat degradation, alteration of food-web structure, loss of biodiversity, and an increased frequency, spatial extent, and duration of harmful algal blooms); *see also* INTERAGENCY WORKING GRP. ON HARMFUL ALGAL BLOOMS, HYPOXIA, AND HUMAN HEALTH, SCIENTIFIC ASSESSMENT OF HYPOXIA IN U.S. COASTAL WATERS, 13–14 (2010) available at https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/hypoxia-report.pdf (comparing Figure 2, showing only 10 hypoxic coastal areas in the 1960s with Table 1, showing 307 hypoxic coastal areas in the present day).

52 *See Dissolved Oxygen and Water*, U.S. GEOLOGICAL SURVEY, (last visited Oct. 28, 2020), https://www.usgs.gov/special-topic/water-science-school/science/dissolved-oxygen-and-water?qt-science_center_objects=0#qt-science_center_objects.

53 *See Global Climate Report – June 2019*, NOAA, https://www.ncdc.noaa.gov/sotc/global/201906, (last updated July 2016) (noting that the global ocean-only temperature for June 2019 tied with 2016 as the highest June temperature on record at 0.81°C (1.46°F) above average).

54 *See Harmful Algal Bloom (HAB) Associated Illness*, CDC, https://www.cdc.gov/habs/illness-symptoms-marine.html (last updated Dec. 13, 2017).

55 *See* Jonathan R. Deeds et al., *Non-Traditional Vectors for Paralytic Shellfish Poisoning*, 6 MARINE DRUGS 308 (Jun. 10, 2008), https://pubmed.ncbi.nlm.nih.gov/18728730/.

56 *See id.*

large marine mammal.[57] Meanwhile, some non-toxic algae species have physical structures that can block respiratory structures when consumed or inhaled, leading to irritation or suffocation.[58]

Catastrophic die-offs of marine organisms are often strongly correlated with coastal HAB events. For example, the sudden death of more than fifty California sea lions in May 1998 was linked to exposure to a domoic acid toxin released by a HAB.[59] The toxin bioaccumulated in the soft tissue of anchovies and other small marine species eaten by the sea lions.[60] A later study revealed that the same poison likely caused large seal die-offs observed in other years.[61] In some cases, thousands of marine birds have died after consuming algal toxins in water or contaminated marine fish or shellfish.[62] Endangered and threatened marine species are also vulnerable. Estimates from the Florida Fish and Wildlife Conservation Commission, for example, suggest that 589 threatened or endangered sea turtles and 213 then-endangered manatees died as a result of exposure to the HAB event that plagued Florida's coastline between 2017 and 2018.[63] The same red tide event was also implicated in the death of 127 bottlenose dolphins.[64] Unfortunately, these mass die-offs are occurring around the world with greater frequency than ever before.[65]

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57 *See* NAT'L SCI. & TECH. COUNCIL COMM. ON ENV'T & NAT. RES., NATIONAL ASSESSMENT OF HARMFUL ALGAL BLOOMS IN U.S. WATERS, 15 (2000).

58 *See* Gilbert et al., *supra* note 31, at 138.

59 *See California, Galapagos, and Japanese Sea Lions*, SEAL CONSERVATION SOC'Y, https://www.pinnipeds.org/seal-information/species-information-pages/sea-lions-and-fur-seals/californian-sea-lion (last updated 2011).

60 *See id.*

61 *See id.*

62 *See Harmful Algal Bloom (HHAB)-Associated Illness,* CDC, https://www.cdc.gov/habs/using-ohhabs.html.

63 *See* Carlos R. Munoz, *Southwest Florida Red Tide Episode Kills Record Number of Sea Turtles*, PANAMA CITY NEWS HERALD (Jan. 16, 2019), https://www.newsherald.com/news/20190116/southwest-florida-red-tide-episode-kills-record-number-of-sea-turtles.

64 *See id.*

65 *See* Donald M. Anderson, *The Growing Problem of Harmful Algae*, 43 OCEANUS 1, 4 (2005), https://www.whoi.edu/cms/files/dfino/2005/4/v43n1-anderson_2387.pdf (discussing how a 1988 HAB that emerged in Hong Kong wiped out half of the country's annual aquaculture fish stocks).

C. *HABs and Human Health*

HABs that develop in marine environments can contaminate shellfish that are harvested for human consumption. During toxic algae blooms, filter feeders, such as clams, oysters, and scallops, ingest the algae, and the toxins then bioaccumulate within their soft tissue where they remain biologically active.[66] When humans consume tainted shellfish, they can experience varying levels of gastrointestinal and neurological problems. For example, within hours of consuming saxitoxin, a victim may experience symptoms ranging "from nausea, vomiting, and incapacitating diarrhea, to dizziness, disorientation, amnesia and permanent memory loss, and paralysis."[67] In rare cases, exposure may result in respiratory paralysis and asphyxiation,[68] which can lead to death.[69] In 1799, for example, an outbreak of paralytic shellfish poisoning following a HAB event near Sitka, Alaska killed over a hundred men.[70]

The dangers of HABs extend beyond the consumption of contaminated seafood. Wind and wave action often push HABs closer to shore where human exposure becomes more prevalent. Humans may be exposed to HAB toxins while swimming near the shore or may breathe in aerosolized toxins that are released into the air as waves break along the coastline.[71] Once inhaled, these toxins can constrict bronchioles, causing respiratory issues.[72] The magnitude

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66 *See Phytoplankton & Algal Blooms*, CENT. & N. CAL. OCEAN OBSERVING SYS., https://www.cencoos.org/focus-areas/habs/algal-blooms/ (last visited Oct. 28, 2020) (noting that bioaccumulation happens when toxins build up in an organism at a rate faster than they can be broken down).

67 *Watch What You Eat*, WHO, https://www.whoi.edu/watch-what-you-eat/ (last visited Dec. 22, 2020).

68 *See* William Hurley et al., *Paralytic Shellfish Poisoning: A Case Series*, 15 W. J. OF EMERGENCY MED. 378, 378 (2014), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4100837/.

69 *See* Anderson, *supra* note 65.

70 *See* Valerie Brown, *Could Climate Change Boost Toxic Algal Blooms in the Oceans?*, SCI. AM. (Dec. 21, 2012), https://www.scientificamerican.com/article/increase-in-harmful-algal-blooms-possible/ (describing the first recorded incidence of paralytic shellfish poisoning on the west coast of North America).

71 *See* Lora E. Fleming, et al., *Overview of Aerosolized Florida Red Tide Toxins: Exposures and Effects*, 113 ENV'T HEALTH PERSP. 618, 618 (2005), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1257557/ (discussing the generation of toxin-containing brevetoxin aerosols at the seawater–air interface).

72 *See id.* (addressing the correlation between people living and working in or near coastal areas who experience upper and lower respiratory irritation and their aerosol exposures during active Florida red tides); *see also* William M. Abraham

of these impacts in the United States is unclear, because the Centers for Disease Control and Prevention (CDC) only tracks HAB-associated illnesses through a voluntary reporting system.[73]

Despite the risks associated with exposure to algal toxins and the fact that HABs occur seasonally in coastal waters, there are currently no antidotes available to protect the public from harm.[74] States, in cooperation with the federal government, have created HAB monitoring programs to detect outbreaks that pose a risk to the public.[75] These programs track the biological, chemical, and physical pressures that promote algal growth in marine systems in order to predict HAB development and to provide early warning of potential risks to decision-makers.[76] The systems are primarily designed to limit human exposure by ensuring that commercially harvested fish and shellfish contaminated with algal toxin are not harvested or consumed.[77]

D. *HABs and Economic Impacts*

HABs have significant economic impacts on coastal states.[78] A single HAB can "reduce tourism, close beaches and shellfish beds,

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et al., *Airway Responses to Aerosolized Brevetoxins in an Animal Model of Asthma*, 171 AM. J. RESPIRATORY AND CRITICAL CARE MED. 26, 28–29 (2004) (reporting that mammals that inhaled crude brevetoxins developed significant bronchoconstriction).

73 *See* CDC*, supra* note 62.

74 *See* Frances M. Van Dolah, *Marine Algal Toxins: Origins, Health Effects, and Their Increased Occurrences*, 108 ENV'T HEALTH PERSP. 133, 138–39 (2000), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1637787/; *see also* Thomas C. Arnold, *Shellfish Toxicity Treatment and Management*, MEDSCAPE, https://emedicine.medscape.com/article/818505-treatment (noting that therapy for all shellfish poisonings is supportive and symptom-driven); Hurley et al., *infra* note 47.

75 *See generally State HABs Monitoring Programs and Resources*, EPA, https://www.epa.gov/cyanohabs/state-habs-monitoring-programs-and-resources (last updated Aug. 27, 2020).

76 *See id.*, *see, e.g.*, *HAB Forecasts*, NAT'L CTRS. FOR COASTAL & OCEAN SCI. (NCCOS), https://coastalscience.noaa.gov/research/stressor-impacts-mitigation/hab-monitoring-system/hab-forecasts/ (last visited Dec. 22, 2020) (explaining the federal and state roles in HAB management); *An Early Warning System for Pseudo-nitzschia Harmful Algal Blooms on Pacific Northwest Outer-Coast Beaches*, NCCOS, https://coastalscience.noaa.gov/project/early-warning-pseudo-nitzschia-harmful-algal-blooms-pacific-northwest/ (describing part of Washington's approach to address HABs in coastal waters).

77 *See* EPA, *supra* note 75.

78 *See Why Do Harmful Algal Blooms Occur?*, NOAA, https://oceanservice.noaa.gov/facts/why_habs.html (last updated June 25, 2018).

and decrease the catch from both recreational and commercial fisheries."[79] Other costs associated with HABs include public health costs from hospital and doctor visits, beach cleanup costs, lost work productivity, lost local business income, and economic damages to tourism.[80] HAB monitoring programs also add to the total.[81]

Several recent HABs illustrate these costs. In 2015, the west coast of the United States experienced a devastating HAB comprised of the toxin-producing diatom *Pseudo-nitzschia*.[82] The bloom shut down the area's lucrative Dungeness crab and razor clam fisheries, and resulted in losses of $97.5 million in crab landings and $40 million in tourism.[83] In 2011, Florida experienced a large HAB that shaded the water and resulted in a sixty percent loss of ecologically valuable sea grasses in the Indian River Lagoon.[84] The following year, another algal bloom emerged and prevented the sea grasses from recovering.[85] The economic impact of the loss was estimated to range from $235 to $470 million.[86] HABs were also responsible for a loss of $42 million to the tuna industry in Baja California, Mexico and for the mortality of more than forty thousand tons of farm-raised salmon in Chile.[87] The real costs of failing to respond to HABs will likely increase as global climate change

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[79] *Id.*

[80] *See, e.g.*, *Harmful Algal Blooms Economic Impacts,* FLA. DEP'T HEALTH, http://www.floridahealth.gov/environmental-health/aquatic-toxins/_documents/economic-impacts.pdf (last visited Dec. 22, 2020).

[81] *See* Krimsky et al., *supra* note 13.

[82] *Hitting Us Where It Hurts: The Untold Story of Harmful Algal Blooms*, NOAA, https://noaa.maps.arcgis.com/apps/Cascade/index.html?appid=9e6fca29791b428e827f7e9ec095a3d7 (last visited Sept. 18, 2020).

[83] *See id.*

[84] *See id.*

[85] *See id.*

[86] *See id.*

[87] *See* Enersto García-Mendoza et al., *Mass Mortality of Cultivated Northern Bluefin Tuna* Thunnus Thynnus Orientalis *Associated with* Chattonella *Species in Baja California, Mexico*, 5 FRONTIERS MARINE SCI. 10, 14, (2018), https://www.frontiersin.org/articles/10.3389/fmars.2018.00454/full; *see also* Jonathan Garcés, *Algae Fish Death Toll Tops 4,000 Tonnes in Chile,* FISH FARMING EXPERT (Feb. 3, 2018), https://www.fishfarmingexpert.com/article/algae-fish-death-toll-tops-4000-tonnes-in-chile/.

effects changes in marine systems that are conducive to HAB formation, toxin development, and geographic expansion.[88]

II. Impacts of Anthropogenic Influences and Climate Disruption on HABs

HABs occur naturally in both aquatic and marine environments in response to changes in nutrient availability, water temperature, light, chemistry, currents, and other factors.[89] But HAB development and expansion is strongly correlated with human activities that alter the environment, such as nutrient enrichment from agriculture, aquaculture, atmospheric deposition, industrial discharge, coastal development, and others.[90] Industrialized agriculture practices, combustion of fossil fuels, coastal development, and other human activities continue to augment natural nutrient flows, increase atmospheric concentrations of greenhouse gases, and alter ocean chemistry in ways that are harmful to the marine environment.[91] While some of the factors that cause or contribute to HABs are unknown, human activities are influencing the global expansion of HABs.[92]

Algae produce toxins in response to a variety of environmental factors such as light, water temperature, and nutrient levels.[93]

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88 *Harmful Algal Bloom and Hypoxia Research and Control Act*, NOAA, (last visited Oct. 28, 2020), https://coastalscience.noaa.gov/research/stressor-impacts-mitigation/habhrca/.

89 *See* Mark L. Wells et al., *Future HAB Science: Directions and Challenges in a Changing Climate*, 91 HARMFUL ALGAE 1, 2 (2020), https://www.sciencedirect.com/science/article/pii/S156898831930099X.

90 *See* Anderson, *supra* note 65 (noting the link between HABs and coastal pollution); Xue Fu et al., *supra* note 23, at 207 (same).

91 *See* Gustaff Hallegraeff, *Ocean Climate Change, Phytoplankton Community Responses, and Harmful Algal Blooms: A Formidable Predictive Challenge,* 46 J. PHYCOLOGY 220, 228–30 (2010), https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1529-8817.2010.00815.x; Xue Fu et al., *supra* note 23, at 207; Anderson, *supra* note 65, at 5 (noting the link between HABs and coastal pollution).

92 *See* Donald Anderson, *HABs in a Changing World: A Perspective on Harmful Algal Blooms, Their Impacts, and Research and Management in a Dynamic Era of Climactic and Environmental Change,* 3 HARMFUL ALGAE 17 (2012), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4667985/ (noting that human activities such as coastal development can lead to increased pollution of the coastal zone that can stimulate some HAB species through nutrient enrichment, to alteration of coastal hydrography, nutrient dynamics, and other means).

93 *See* NOAA, *supra* note 27.

Therefore, climate also influences the fundamental parameters regulating algal growth. Accordingly, human-caused changes in climate, such as ocean warming, acidification, altered precipitation, and other climatic disruptions will likely create marine conditions that expand the geographic range of harmful algal species, and increase the development, duration, and severity of HABs in ways that pose significant new risks to ecosystems and humans.[94] Understanding how human activities influence HABs is therefore essential to limiting their impact.

A. *Industrialized Food Production*

With the global human population expected to exceed nine billion by 2050, the demand for food will increase significantly.[95] Most of this need will presumably be met through land-based food production and exploitation of commercial fisheries. Meeting the increased food demand while reducing the amount of pollution entering the ocean and the amount of fertilizer that farmers use to grow crops will be challenging, but it is possible. Doing so will require a reevaluation of conventional farming practices and the use of fertilizers, investment in technology, and a better understanding of how land-based food production can negatively impact ocean-based food production.

Industrialized, intensive farming practices that grow high-yield crops using fertilizers and pesticides are the primary agricultural system used throughout the United States.[96] In the never-ending quest to increase food production, farmers have used increasing amounts of fertilizer, pesticides, and other harmful chemicals. In the United States, nitrogen-based fertilizer use rose dramatically over

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[94] *See* Christopher J. Gobler, *Climate Change and Harmful Algal Blooms: Insights and Perspective*, 91 HARMFUL ALGAE 101731, 101731 (2020), https://www.sciencedirect.com/science/article/pii/S1568988319302045.

[95] *See* HOW TO FEED THE WORLD 2050, FOOD AND AGRIC. ORG. OF THE U.N. (FAO), GLOBAL AGRICULTURE TOWARDS 2050 1 (2009), http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf (projecting that feeding 9 billion people would require raising overall food production by some 70 percent by 2050 from 2005 levels).

[96] *See* Fiona Harvey, *Can We Ditch Intensive Farming - and Still Feed the Human Race*? THE GUARDIAN, Jan. 28, 2019, https://www.theguardian.com/news/2019/jan/28/can-we-ditch-intensive-farming-and-still-feed-the-world/; *The Hidden Costs of Industrial Agriculture*, UNION OF CONCERNED SCIENTISTS, https://www.ucsusa.org/resources/hidden-costs-industrial-agriculture (last updated Aug. 24, 2008).

the last half century and has resulted in significantly improved yields of major crops.[97] But, studies show that farmers routinely overfertilize crops to maximize production. One study, for example, demonstrated that farmers applied more nitrogen to corn crops than could be utilized by the corn, thereby exceeding the profit-maximizing level of nitrogen.[98] Although nitrogen use efficiency in the United States has increased by approximately 30 percent, nearly half of all fertilizer applied is not used by crops and is lost to the environment, where it causes a host of adverse impacts, including nutrient loading of coastal systems.[99] This overuse of fertilizer has increased atmospheric deposition rates of nitrogen and other chemicals,[100] causing significant cost to the soil and the surrounding areas.[101]

Approximately 95 percent of global food production is land-based, so conserving and sustainably managing soils is essential to successfully feeding the growing population.[102] In contrast, repeatedly turning to industrialized, resource-intensive farming practices increases greenhouse gas emissions, depletes water resources, reduces biodiversity, depletes soil quality and quantity, and causes nutrient loss.[103] At the same time, these practices increase the risks

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97 *See* Peiyu Cao et al., *Historical Nitrogen Fertilizer Use in Agricultural Ecosystems of the Contiguous United States During 1850–2015: Application Rate, Timing, and Fertilizer Types*, 10 EARTH SYS. SCI. DATA 969, 969 (2018), https://www.earth-syst-sci-data.net/10/969/2018/essd-10-969-2018.pdf.

98 *See* Satya N. Yadav et al., *Do Farmers Overuse Nitrogen Fertilizer to the Detriment of the Environment?* 9 ENV'T AND RES. ECON. 323, 323 (1997), https://link.springer.com/article/10.1007/BF02441403.

99 *See* Cao et al., *supra* note 97, at 969; NOAA, *supra* note 51.

100 *See* David A. Wedin & David Tilman, *Influence of Nitrogen Loading and Species Composition on the Carbon Balance of Grasslands*, 274 SCI. 1720, 1720 (1996), https://science.sciencemag.org/content/sci/274/5293/1720.full.pdf (noting that atmospheric nitrogen deposition rates increased more than tenfold between 1956 and 1996).

101 *See* Richard Schiffman, *Why It's Time to Stop Punishing Our Soils with Fertilizers*, YALE ENV'T 360 (May 3, 2017), https://e360.yale.edu/features/why-its-time-to-stop-punishing-our-soils-with-fertilizers-and-chemicals (noting that decades of chemical use have depleted farmland of essential nutrients, killing off bacteria and fungi that create organic material essential to plants).

102 *See* FAO, *supra* note 95.

103 *See* FAO, THE 10 ELEMENTS OF AGROECOLOGY: GUIDING THE TRANSITION TO SUSTAINABLE FOOD AND AGRICULTURAL SYSTEMS 12 (2018), http://www.fao.org/3/i9037en/i9037en.pdf.

posed by HABs, harming ocean and coastal systems that provide another significant source of protein for consumption: fisheries.

Since 1961, global fish consumption has been increasing at twice the rate as human population growth,[104] indicating that today, more people than ever before rely on fisheries and aquaculture for food and as a source of income. In the Food and Agriculture Organization's 2018 study, fish accounted for roughly 17 percent of animal protein consumed by the global population and provided about 3.2 billion people with almost 20 percent of their average per capita intake of animal protein.[105] Since 1950, the world fishing fleet has more than doubled, yet overall the fleet is catching less seafood for the same effort due to historic overfishing, which has driven down many stocks.[106] This rise in fishing effort comes with a significant cost to marine systems. Today, approximately 93 percent of commercially exploited natural stocks are fished at or above their maximum sustainable yield.[107]

Improved management of the world's ocean resources is essential to ensuring global food security and limiting pollution must be an essential part of fisheries management. The emergence of larger, more harmful HABs—fueled by various pollutants—has the potential to significantly impact fishery management efforts and to further reduce the catch of commercially important species. HAB events often result in mass mortalities of wild and farmed fish and

[104] *See* FAO, THE STATE OF THE WORLD'S FISHERIES AND AQUACULTURE vii (2018), http://www.fao.org/3/i9540en/i9540en.pdf.

[105] *See id.* at 2.

[106] *See* Shreya Dasgupta, *Twice as Many Fishing Vessels Now, But It's Harder to Catch Fish*, MONGABAY (June 6, 2019), https://news.mongabay.com/2019/06/twice-as-many-fishing-vessels-now-but-its-harder-to-catch-fish/ (reporting that the global fishing fleet has more than doubled from about 1.7 million boats harvesting fish in 1950 to 3.7 million fishing vessels in 2015).

[107] *See* FAO, *supra* note 104, at 2, 39, 40 (explained by Figure 14). Maximum Sustainable Yield (MSY) is theoretical concept used in fisheries management. It is defined as the maximum catch that can be removed from a population over an indefinite period without negatively impacting the sustainability of the population. However, modeling assumptions used to establish the MSY for a managed stock are often inaccurate and call into question whether the MSY promotes sustainability. *See, e.g.*, FAO, INTRODUCTION TO FISHERIES MANAGEMENT ADVANTAGES, DIFFICULTIES AND MECHANISMS 2-1 (1992), http://www.fao.org/3/T0505E/T0505E02.htm#ch2 (noting work by J.P. Toadec that models upon which the production and yield curves are based take as their initial hypothesis that the environment is invariable, assume set fishing rates, and assume set fishing practices—factors that often vary over time).

shellfish.[108] More importantly, certain species that form HABs can negatively impact larvae and other early life history stages of commercially important fish species.[109] This could impact the number of new juvenile fish entering the fishery which, in turn, would reduce the number of fish capable of reaching the size and age requirements of commercial fishing. As will be discussed in Part III, current regulations to control the use of fertilizers in agricultural operations do not consider the fertilizers' impact on fisheries or the impacts that climate change will have on nutrient loading in coastal systems. Moreover, these regulations do not adequately consider how pollution loading augments the impacts of HABs on coastal communities or resources. The need to control HABs and the factors that influence their development has become more important as climate change continues to effect fundamental changes to marine systems.

B. *Ocean Warming*

Greenhouse gases in the atmosphere trap solar radiation that, in turn, warms the planet.[110] Globally, emissions of these gases have increased significantly since 1880, causing Earth to warm by more than 1.0°C (1.8°F).[111] Moreover, the warming trend is accelerating, as approximately two-thirds of the observed warming has occurred since 1975.[112] Without action to reduce emissions of greenhouse gases, the planet will likely warm to 1.5°C (2.7°F) above pre-industrial levels between 2030 and 2052, with a corresponding warming

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108 *See infra* at Part I.A.

109 *See* DONALD M. ANDERSON ET AL., WOODS HOLE OCEANOGRAPHIC INST., ESTIMATED ANNUAL ECONOMIC IMPACTS FROM HARMFUL ALGAL BLOOMS (HABS) IN THE UNITED STATES 3 (2000), https://www.whoi.edu/cms/files/Economics_report_18564_23050.pdf.

110 *See Greenhouse Gas Emissions; Overview of Greenhouse Gases*, EPA, https://www.epa.gov/ghgemissions/overview-greenhouse-gases (last visited Oct. 28, 2020). While all greenhouse gases trap energy, CO_2 has had the strongest influence in the observed warming of the planet because it is more abundant than other greenhouse gasses and it stays in the atmosphere much longer. *See* Rebecca Lindsey, *Atmospheric Carbon Dioxide*, CLIMATE.GOV (Aug. 14, 2020), https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide.

111 *See World of Change: Global Temperatures*, NASA EARTH OBSERVATORY, https://earthobservatory.nasa.gov/world-of-change/global-temperatures (last visited Oct. 28, 2020).

112 *See id.*

of ocean water.[113] Approximately 90 percent of the heat that has been trapped in Earth's climate system since 1970 is stored in the oceans.[114] Recent studies suggest that the oceans are absorbing this excess heat much faster than previous estimates.[115]

Elevated water temperatures profoundly influence the timing, duration, and intensity of HABs.[116] For example, the growth rate and bloom window for two toxin-producing algae species, *Alexandrium fundyense* and *Dinophysis acuminate,* increased significantly under elevated ocean water temperatures.[117] Rising ocean temperatures also influence community organization and structure in ways that may favor some harmful bloom-forming species relative to both their competitors and organisms that feed upon those algae species.[118]

As water temperature continues to rise, thermally restricted species are experiencing range expansion and colonizing new areas.[119] For example, the toxic dinoflagellates *Alexandrium tamarense* and *Dinophysis acuminate*, both of which cause shellfish poisoning, have expanded into regions across significant portions of the North Atlantic and isolated regions within the North Pacific, where

113 *See* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), SUMMARY FOR POLICY MAKERS 4 (2018) https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf (noting that models predict with high confidence that global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate).

114 *See* LuAnn Dahlman & Rebecca Lindsey, *Climate Change: Ocean Heat Content*, CLIMATE.GOV (Feb. 13, 2020) https://www.climate.gov/news-features/understanding-climate/climate-change-ocean-heat-content (noting that more than 90 percent of the warming that has happened on Earth over the past 50 years has occurred in the ocean).

115 *See* Chelsea Harvey, *Oceans Are Warming Faster Than Predicted*, SCI. AM. (Jan. 11, 2019), https://www.scientificamerican.com/article/oceans-are-warming-faster-than-predicted/ (reporting that Earth's seas are absorbing excess heat 40 percent faster than previous estimates).

116 *See* Christopher J. Gobler et al., *Ocean Warming Since 1982 Has Expanded the Niche of Toxic Algal Blooms in the North Atlantic and North Pacific Oceans*, 114 PROC. NAT'L ACAD. SCI. 4975, 4975–80 (2017).

117 *See id.*; *see also* Stephanie K. Moore et al., *Recent Trends in Paralytic Shellfish Toxins in Puget Sound, Relationships to Climate, and Capacity for Prediction of Toxic Events*, 8 HARMFUL ALGAE 463, 463 (2009).

118 *See* Xue Fu et al., *supra* note 23, at 210 (noting that temperature changes can differentially impact the growth rate, nitrate uptake, pigment content, light-harvesting capacity, photosynthetic carbon fixation, toxin production or other factors of many microalgae).

119 *See* Gobler et al., s*upra* note 116.

they were previously unknown.[120] A strain of the warm water toxic dinoflagellate *Gambierdiscus carpenter*, which causes fish poisoning, has also expanded its range as ocean temperature has increased.[121] Similarly, the tropical species *Ostreopsis* has expanded into temperate waters as a result of ocean warming.[122] The brown tide-causing organism, *Aureococcus anophagefferens*, has expanded from the northeastern United States and South Africa into waters off the coast of China, where it is causing massive blooms.[123] In addition to increasing ranges, rising water temperatures may also promote earlier and longer lasting blooms for the dinoflagellate *Alexandrium catenella*, which is associated with paralytic shellfish poisoning.[124] These projected changes will present new risks in areas that do not currently experience HABs.

C. *Ocean Acidification*

As atmospheric carbon dioxide (CO_2) has increased, ocean absorption of CO_2 through air-sea gas exchange has increased ocean acidification. Generally, CO_2 is released into the atmosphere through natural processes, such as respiration and volcanic eruption, and is sequestered through absorption in plants.[125] Human activities have disturbed the equilibrium of these natural processes by

[120] *See id.*

[121] *See* Leanne Sparrow et al., *Effects of Temperature, Salinity and Composition of the Dinoflagellate Assemblage on the Growth of Gambierdiscus carpenteri Isolated from the Great Barrier Reef.* 65 HARMFUL ALGAE 52, 52–60 (2017).

[122] *See* Hela Ben-Gharbia et al., *Toxicity and Growth Assessments of Three Thermophilic Benthic Dinoflagellates (Ostreopsis cf. ovata, Prorocentrum lima and Coolia monotis) Developing in the Southern Mediterranean Basin*, 8 TOXINS 297 (Oct. 15, 2016) (noting that harmful benthic dinoflagellates that usually develop in tropical areas are expanding to temperate ecosystems facing water warming).

[123] *See* Qing Chun Zhang et al., *Emergence of Brown Tides Caused by* Aureococcus Anophagefferens *Hargraves et Sieburth in China,* 16 HARMFUL ALGAE 117, 117–24 (2012). So called "brown tides," which are different than both the blue green algae blooms and red tides discussed previously, result from an algae bloom that turns seawater a murky brown color due to the concentration of algae. *See* SEA GRANT N.Y., SUNY STONY BROOK, BROWN TIDE INITIATIVE (1998), https://seagrant.sunysb.edu/btide/pdfs/Report1.pdf.

[124] *See* Moore et al., *supra* note 117, at Figure 1 (noting bloom window for *Alexandrium catenella* could expand from the historical value of 68 days to as long as 259 days in as ocean water temperature increases).

[125] *See, e.g.*, Holli Riebeek, *The Carbon Cycle*, NASA EARTH OBSERVATORY (June 16, 2011), https://earthobservatory.nasa.gov/features/CarbonCycle.

emitting enormous quantities of CO_2 into the atmosphere and destroying natural carbon sinks like tropical forests.[126] Through the combustion of fossil fuels, agriculture, deforestation, and others actions, humans have fundamentally altered the concentration of greenhouse gases in the atmosphere.[127] Today, these activities release approximately thirty-five billion tons of CO_2 into the atmosphere annually.[128] As a result, atmospheric CO_2 concentrations have steadily risen from approximately 280 parts per million (ppm) at the start of the Industrial Revolution to almost 413 ppm as of November 2020.[129]

Approximately one-third of all of the CO_2 emitted into the atmosphere since the Industrial Revolution has been absorbed by the ocean, and new studies show that the rate of oceanic absorption of CO_2 has accelerated over the last few decades.[130] Once absorbed

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[126] *See* Daisy Dunne, *Tropical Forests Are 'No Longer Carbon Sinks' Because of Human Activity,* CARBONBRIEF (Sept. 28, 2017), https://www.carbonbrief.org/tropical-forests-no-longer-carbon-sinks-because-human-activity (noting that tropical forests now emit more carbon than they are able to absorb from the atmosphere as a result of the dual effects of deforestation and land degradation).

[127] *See Greehouse Gas Emissions; Overview of Greenhouse Gases*, EPA, https://www.epa.gov/ghgemissions/overview-greenhouse-gases (last visited Oct. 29, 2020); *see also* Florence Pendrill et al., *Agricultural and Forestry Trade Drives Large Share of Tropical Deforestation Emissions*, 56 GLOB. ENV'T CHANGE 1, 1 (2019) (noting that deforestation is the second largest source of anthropogenic greenhouse gas emissions); *The Contribution of Agriculture to Greenhouse Gas Emissions*, FAO (Feb. 18, 2020), http://www.fao.org/economic/ess/environment/data/emission-shares/en/ (reporting total CO_2 and total Green House gas emissions for global agricultural activities).

[128] *See Global Carbon Budget: Summary Highlights*, GLOBAL CARBON PROJECT, https://www.globalcarbonproject.org/carbonbudget/19/highlights.htm (last visited Oct. 29, 2020) (noting that Global CO_2 emissions from fossil fuels and industry have increased every decade from an average of 11.4 $GtCO_2$ in the 1960s to an average of 34.7±2 yr-1 during 2009-2018).

[129] *See* Scott Waldman, *Atmospheric Carbon Dioxide Hits Record Levels*, SCI. AM.: CLIMATEWIRE (Mar. 14, 2017), https://www.scientificamerican.com/article/atmospheric-carbon-dioxide-hits-record-levels/ (noting that the concentration of carbon dioxide in the atmosphere was 280 parts per million at the start of the Industrial Revolution); *see also The Keeling Curve*, SCRIPPS INST. OF OCEANOGRAPHY, https://scripps.ucsd.edu/programs/keelingcurve/ (last visited Nov. 18, 2020) (showing atmospheric concentrations of CO_2 as of November 18, 2020).

[130] *See Global Ocean Absorbing More Carbon,* NOAA NAT'L CTRS. FOR ENV'T INFO. (Mar. 15, 2019), https://www.ncei.noaa.gov/news/global-ocean-absorbing-more-carbon (noting that the global oceans absorb approximately 31

into ocean water, atmospheric CO_2 is converted to a weak acid that decreases the pH of the water.[131] Since around the mid-1700's, when industrialization began, ocean pH has declined by approximately 0.1 pH unit, which equates to a 30 percent increase in surface-ocean acidity.[132] Today, the world's oceans are more acidic than they have been at any point in the last twenty million years, and under current emissions rates, surface acidity may increase 150 percent by 2100, as compared to current levels.[133] The last time marine environments experienced a comparable level of acidification was 55.8 million years ago during the Paleocene-Eocene Thermal Maximum (PETM).[134] That change in ocean chemistry led to severe extinction events for some marine life living on the deep-sea floor.[135]

The modern rapid accumulation of CO_2 has made it more difficult for natural ocean cycling to neutralize the resulting acid, which has the potential to cause major ecological problems.[136] Rapid changes in ocean chemistry pose significant challenges to organisms that evolved over millions of years in relatively stable pH conditions.[137] Decreasing seawater pH negatively impacts critical biological processes, such as oxygen uptake or metabolism, in many marine species.[138] Some marine organisms such as corals, oysters,

percent of all carbon emissions, and that since 1994 the rate of absorption has accelerated).

131 *See generally What is Ocean Acidification?; The Chemistry*, NOAA: PMEL CARBON PROGRAM, https://www.pmel.noaa.gov/co2/story/What+is+Ocean+Acidification%3F (last visited Aug. 24, 2020).

132 *See id.*

133 *See* Richard A. Kerr, *Ocean Acidification Unprecedented, Unsettling*, 328 SCI. 1500, 1500–01 (June 18, 2010).

134 *See id.*

135 *See id.*; *see also* Phil Jardine, *The Paleocene–Eocene Thermal Maximum*, 1 PALAEONTOLOGY ONLINE 1, 4 (Jan. 1, 2011), https://pdf.palaeontologyonline.com/articles-2011/The_Paleocene-Eocene_Thermal_Maximum-Jardine_P-Oct2011.pdf (noting a 30-50% decline in foraminifera during the PETM).

136 *See* Kerr, *supra* note 133, at 1500 (noting that it takes the ocean approximately 1000 years to flush carbon dioxide accumulated in surface waters to deep sea where sediments can eventually neutralize the added acid).

137 *See* Ocean Portal Team, *Ocean Acidification*, SMITHSONIAN: OCEAN (Apr. 2018), https://ocean.si.edu/ocean-life/invertebrates/ocean-acidification.

138 *See* COMM. ON THE REVIEW OF THE NAT'L OCEAN ACIDIFICATION RESEARCH AND MONITORING PLAN, NAT'L RES. COUNCIL, REVIEW OF THE FEDERAL OCEAN ACIDIFICATION RESEARCH AND MONITORING PLAN 2 (2013),

mussels, and other skeleton and shell-building organisms are already exhibiting the impacts of decreasing ocean pH.[139]

Some species, however, including some algae, may thrive in lower pH seawater.[140] Ocean acidification may disrupt marine communities in ways that negatively impact the base of the marine food chain. For example, under the elevated CO_2 concentrations predicted for the future, toxic microalga *Vicicitus globosus* increased its abundance in natural plankton communities and decreased the amount of zooplankton.[141] More generally, these types of changes disrupt the transfer of primary-produced organic matter to higher levels of the food chain.[142] Because coastal primary production plays a significant role in global productivity, changes in ocean chemistry that alter plankton communities pose emergent threats to the health of the marine environment and to those who depend upon ocean resources for food.[143] In studies examining the long-term impacts of warmer, lower pH water on various species, ocean acidification had a significant negative effect on survival, calcification, growth, development, and abundance of all taxa studied.[144] These results have profound implications for future global

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https://oceanfdn.org/sites/default/files/Federal%20Ocean%20Acidification%20Research%20And%20Monitoring%20Plan.pdf.

139 *See* Kerr, *supra* note 133, at 1500 (discussing observed effects of ocean acidification on some calcifying species).

140 *See* Ulf Riebesell et.al., *Toxic Algal Bloom Induced by Ocean Acidification Disrupts the Pelagic Food Web*, 8 NATURE CLIMATE CHANGE 1082, 1084–85 (2018); *see also* Ocean Portal Team, *supra* note 137 (noting plants and many algae species may thrive under acidic conditions).

141 Riebesell et al., *supra* note 140.

142 *See* Kerr, *supra* note 133.

143 *See id.*; *see also* Göran E. Nilsson et al., *Near-Future Carbon Dioxide Levels Alter Fish Behaviour by Interfering with Neurotransmitter Function*, 2 NATURE CLIMATE CHANGE 201, 201–03 (2012); *see also* Paul Webb, *7.4 Patterns of Primary Production*, *in* PATTERNS OF PRIMARY PRODUCTION (2019) (ebook) (noting that oceans are about as productive as terrestrial systems and that coastal waters are more productive than the deep ocean), available at: https://rwu.pressbooks.pub/webboceanography/chapter/7-4-patterns-of-primary-production/.

144 *See* Hans-O. Portner, *Ecosystem Effects of Ocean Acidification in Times of Ocean Warming: A Physiologist's View*, 373 MARINE ECOLOGY PROGRESS SERIES 203, 203, 209 (2008), https://www.int-res.com/articles/theme/m373p203.pdf; *see also* Riebesell et al., *supra* note 140; Kristy J. Kroeker, *Meta-analysis Reveals Negative Yet Variable Effects of Ocean Acidification on Marine Organisms*, 13 ECOLOGY LETTERS 1419, 1421 (2010) (reporting predicted ocean acidification had significant negative effects on survival, growth, calcification, and reproduction of many marine species).

food security, because the fish upon which humans rely for food also need to eat.

Ocean acidification will likely act synergistically with other environmental stressors, such as elevations in ocean temperature, hypoxia, and nutrient loading, to change the composition, abundance, and production of biological communities.[145] Some HAB forming species increase their cellular toxin content in response to changes in ocean chemistry.[146] For example, the growth and toxicity of the red tide algal species *A. fundyense* increase in waters subjected to nutrient loading and acidification.[147] Other harmful algae species have displayed significantly faster growth rates under elevated levels of CO_2.[148] Some species, like certain brown tide species, are even directly aggressive, lowering the pH in their environments in order to bloom further and out-compete harmless phytoplankton.[149] Warming, nutrient loading, and other changes in water chemistry can also lead to blue-green algae outbreaks.[150]

The current changes taking place in marine systems favor some toxic algae species, which could have wide-ranging implications for human health, marine food webs, and ecosystems worldwide.[151] Certain toxic algae species benefit from ocean acidification, which

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145 *See* NAT'L RES. COUNCIL, *supra* note 138, at 9.

146 *See* Theresa K. Hattenrath-Lehmann et al., *The Effects of Elevated CO2 on the Growth and Toxicity of Field Populations and Cultures of the Saxitoxin-Producing Dinoflagellate,* Alexandrium Fundyense*,* 60 LIMNOLOGY & OCEANOGRAPHY 198, 198 (2015); Avery O. Tatters et al., *High CO2 and Silicate Limitation Synergistically Increase the Toxicity of Pseudo-Nitzschia Fraudulenta*, 7 PLOS ONE e32116, e32116 (2012), https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0032116&type=printable.

147 *See* Elizabeth Turner, *Ocean Acidification Promotes Disruptive and Harmful Algal Blooms on Our Coasts*, NOAA NAT'L CTRS. FOR COASTAL OCEAN SCI., (Jan. 13, 2014), https://coastalscience.noaa.gov/news/ocean-acidification-promotes-disruptive-and-harmful-algal-blooms-on-our-coasts/.

148 *See* Hattenrath-Lehmann et al., *supra* note 146, at 198.

149 *See* Turner, *supra* note 147.

150 *See* Jessica Richardson et al., *Response of Cyanobacteria and Phytoplankton Abundance to Warming, Extreme Rainfall Events and Nutrient Enrichment*, 25 GLOB. CHANGE BIOLOGY 3365, 3366 (2019); *see also Cyanobacterial (Blue-Green Algal) Blooms: Tastes, Odors, and Toxins*, USGS, https://www.usgs.gov/centers/kswsc/science/cyanobacterial-blue-green-algal-blooms-tastes-odors-and-toxins-0?qt-science_center_objects=0#qt-science_center_objects (last visited Oct. 29, 2020).

151 *See, e.g.*, Riebesell et al., *supra* note 140.

has implications for the marine food web and ecosystem services.[152] Other anticipated impacts from climate change, such as vertical stratification, changes in salinity, and altered precipitation, may also act synergistically to promote HAB frequency, intensity, geographic distribution, and duration. These possibilities all point to a future where HABs regularly wreak havoc on marine ecosystems, with grim consequences from the lowest levels of global food chains to the highest.

D. *Altered Precipitation, Atmospheric Deposition, and HABs*

As the land and ocean warms, changes in the hydrological cycle drive extreme weather events, alter precipitation, and foster climate variability in ways that will likely increase anthropogenic nutrient loading of waterbodies.[153] These changes will likely exacerbate the impacts of HABs and hypoxia in marine systems.[154] Upwelling events, tidal mixing, and changes in surface water chemistry, resulting from increased precipitation, will likely alter vertical mixing dynamics that supply nutrients from below and support offshore blooms.[155] As the blooms are then pushed near shore by wind and currents, land-based nutrient sources will work together with ocean acidification and warmer, shallow water to exacerbate toxic marine algal blooms.[156]

Extreme weather events such as hurricanes and El Niño events can also influence the intensity and duration of HABs.[157] Storms that drop massive volumes of water along coastal watersheds can trigger or exacerbate HABs as the water picks up nutrients from land before

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152 *See id.*

153 *See* Casey Smith, *Heavier Rainfall Will Increase Water Pollution in the Future*, NAT'L GEOGRAPHIC (July 27, 2017), https://www.nationalgeographic.com/news/2017/07/water-quality-hypoxia-environment-rain-precipitation-climate-change/.

154 *See* S.S. Rabotyagov et al., *The Economics of Dead Zones: Causes, Impacts, Policy Chanllenges, and a Model of the Gulf of Mexico Hypoxic Zone*, 8 REV. OF ENV'T ECON. & POL'Y 58, 60 (2014).

155 *See* Scott C. Doney et al., *Ocean Acidification: The Other CO_2 Problem*, 1 ANN. REV. OF MARINE SCI. 169, 179–82 (2009), https://www.ocean.washington.edu/courses/geol330/Doney2009.pdf; Hallegraeff, s*upra* note 91.

156 *See* Hallegraeff, s*upra* note 91.

157 *See* Edward J. Phlips et al., *Hurricanes, El Niño and Harmful Algal Blooms in Two Sub-Tropical Florida Estuaries: Direct and Indirect Impacts*, 10 SCI. REPS 1910, 1910 (2020), https://www.nature.com/articles/s41598-020-58771-4.

eventually emptying into coastal waters and altering salinity.[158] Short term changes in salinity—for example through the introduction of freshwater—can encourage bloom development, while long-term changes in salinity are, in some species, associated with changes in growth and toxicity.[159] In 2019, for example, a record volume of freshwater flowed into the Chesapeake Bay ecosystem following record-breaking rainfall the previous year.[160] The historic inflow of freshwater caused changes in salinity and washed enormous amounts of nutrient pollution into the Bay, triggering massive algae blooms.[161] As a result, dissolved oxygen levels fell to the third-lowest level ever recorded and a 2.1 cubic mile dead zone emerged that dramatically impacted the Bay's underwater grass habitat and other living resources.[162] Overall, the hypoxic volume was 28 percent higher than the previous year.[163] Increasing water temperatures in the Bay likely exacerbated the problem because oxygen solubility decreases with increasing water temperatures.[164] In the same year, abnormally high spring rainfalls led to a dead zone of increased size in the Gulf of Mexico.[165]

Land-based nutrient loading of coastal systems represents only part of the problem. The deposition of gases and nutrients into coastal systems contributes to acidification and eutrophication of coastal ecosystems which, as discussed above, creates optimal conditions for algal blooms.[166] Atmospheric nitrogen deposition has

158 *See id.* (noting that in Florida's Indian River Lagoon, both hurricanes and El Niño periods have had a direct positive effect on HABs of internal origin (i.e., autochthonous) predominantly through the enhancement of nutrient loads).

159 *See* Xue Fu et al., *supra* note 23, at 216; Kramer et al., *supra* note 32, at 2.

160 *See* Dylan Reynolds, *Bay Health Impacted by Record Flows*, CHESAPEAKE BAY PROGRAM (Nov. 26, 2019), https://www.chesapeakebay.net/news/blog/bay_health_impacted_by_record_flows.

161 *See id.*

162 *See id.*

163 *See id.*

164 *See id.*

165 *See* Press Release, NOAA, NOAA Forecasts Very Large 'Dead Zone' for Gulf of Mexico, (June 10, 2019), https://www.noaa.gov/media-release/noaa-forecasts-very-large-dead-zone-for-gulf-of-mexico.

166 *See* Fei Da et al., *Impacts of Atmospheric Nitrogen Deposition and Coastal Nitrogen Fluxes on Oxygen Concentrations in Chesapeake Bay*, 123 J. OF GEOPHYSICAL RES.: OCEANS 5004, 5004 (2018) (noting that direct atmospheric dissolved inorganic nitrogen (DIN) deposition can significantly influence hypoxia). Eutrophication results from the addition of excess nutrients to a waterbody that overstimulate plant and algae growth. When these plants and algae later die,

increased substantially as a result of industrialization and intensive agriculture.[167] Approximately 10 to 45 percent of the nitrogen input to estuarine and coastal waters can be traced to atmospheric deposition from industrial, agricultural, and urban sources.[168] According to some estimates, emissions of reactive nitrogen into the atmosphere, which are ultimately deposited into coastal marine systems and environments, are increasing.[169] The combination of an increasing reliance on industrial agriculture, anthropogenic climate change, and ocean acidification has created the perfect conditions for HABs to thrive—an ominous prospect for marine life and those who rely on it as a food source.

III. Existing Legal Frameworks Regulating HABs

Nutrient loading, elevated water temperature, acidification, decreased salinity, increased freshwater flow from intensified storms, and other changes increase the risks posed by HABs. Yet, current federal and state HAB response efforts fail to strike at the root of the problem because they primarily focus on predicting outbreaks and mitigating their impacts after they occur.

A. *Federal Programs to Address HABs*

Congress has addressed HABs in several ways. First, acknowledging emerging scientific evidence that HABs posed a growing threat to human welfare and the environment, and evidence of their increasing frequency and intensity in coastal waters of the United States, Congress passed the Harmful Algal Bloom and Hypoxia

their decomposition consumes oxygen from surrounding waters and releases large amounts of carbon dioxide that contributes to ocean acidification. *See* Nat'l Ocean Serv., *What Is Eutrophication*, NOAA (last updated June 3, 2020), https://oceanservice.noaa.gov/facts/eutrophication.html.

167 *See* Robert A. Duce et. al., *The Impacts of Atmospheric Deposition to the Ocean on Marine Ecosystems and Climate*, 58 WORLD METEOROLOGICAL ORG. BULL. 4, 4–5 (2009), https://public.wmo.int/en/bulletin/impacts-atmospheric-deposition-ocean-marine-ecosystems-and-climate.

168 *See* RICHARD A. VALIGURA ET AL., NOAA COASTAL OCEAN PROGRAM, ATMOSPHERIC NUTRIENT INPUT TO COASTAL AREAS: REDUCING THE UNCERTAINTIES xvii (1996), https://repository.library.noaa.gov/view/noaa/1782/noaa_1782_DS1.pdf.

169 *See* Duce et. al., *supra* note 167, at 5 (noting atmospheric deposition is the most important process supplying anthropogenic reactive nitrogen to unmanaged terrestrial and marine ecosystems, and that the amount of nitrogen emitted into the air for later deposition is expected to increase by 2050).

Research and Control Act of 1998 (HABHRCA 1998),[170] in which it recognized that excessive nutrients and other pollutants in coastal waters may contribute to HABs.[171] Second, Congress later passed the Federal Ocean Acidification Research and Monitoring Act of 2009 to address the growing threat of ocean acidification.[172] Lastly, these two Acts work in conjunction with the Clean Water Act and the Clean Air Act, either directly or indirectly, to address HABs.

1. The Harmful Algal Bloom and Hypoxia Research and Control Act of 1998 and Reauthorizations

The Harmful Algal Bloom and Hypoxia Research and Control Act (HABHRCA) of 1998 established the Inter-Agency Task Force on Harmful Algal Blooms and Hypoxia (Task Force).[173] The Task Force was charged with completing a comprehensive assessment of HABs and their impacts throughout the United States.[174] It was also charged with completing an assessment of hypoxia in the northern Gulf of Mexico and its link to the nutrients delivered from the Mississippi River by May 30, 1999, and with submitting a plan to control that hypoxia by March 30, 2000.[175] Congress authorized $15

[170] *See* Harmful Algal Bloom and Hypoxia Research and Control Act of 1998, Pub. L. No. 105–383, 112 Stat. 3447 (1998) [hereinafter HABHRCA]. *See id.* §§ 602(1)–(2) (explaining Congress' findings following outbreaks of "red tides in the Gulf of Mexico and the Southeast; brown tides in New York and Texas; ciguatera fish poisoning in Hawaii, Florida, Puerto Rico, and the United States Virgin Islands; and shellfish poisonings in the Gulf of Maine, the Pacific Northwest, and the Gulf of Alaska, and others.").

[171] *See id.* § 602(4).

[172] *See* Omnibus Public Land Management Act of 2009, Pub. L. 111–11, § 12402, 123 Stat. 1436 (2009) [hereinafter Omnibus Public Land Management Act of 2009].

[173] *See* HABHRCA, *supra* note 170, at § 603(a) (the Task Force was comprised of representatives from "(1) the Department of Commerce . . . ; (2) the Environmental Protection Agency; (3) the Department of Agriculture; (4) the Department of the Interior; (5) the Department of the Navy; (6) the Department of Health and Human Services; (7) the National Science Foundation; (8) the National Aeronautics and Space Administration; (9) the Food and Drug Administration; (10) the Office of Science and Technology Policy; (11) the Council on Environmental Quality; and (12) such other Federal agencies as the President considers appropriate.").

[174] *See id.* § 603(b)(1). The Task Force was charged with completing an assessment that addressed the ecological and economic consequences of HABs, methods of reducing, mitigating, and controlling HABs, and the costs and benefits of response actions.

[175] *See id.* §§ 604(a)–(b).

million dollars for fiscal year 1999, $18.25 million for fiscal year 2000, and $19 million dollars for fiscal year 2001, and directed the Secretary of Commerce to utilize the funds for research, education, and monitoring activities aimed at preventing, reducing, and controlling harmful algal blooms.[176]

In 2000, the Task Force submitted the first national assessment of harmful algal blooms in U.S. waters.[177] The Task Force found that "HABs threaten human health and natural resources throughout U.S. coastal waters,"[178] and that there were "more HAB species, more HAB events, more algal toxins, more areas affected, more fisheries impacted, and higher economic losses today compared to twenty-five years ago."[179] Although the observed changes were partly explained by heightened scientific awareness and surveillance, the Task Force also found that the observed changes were caused by human activities, such as nutrient loading, that perturbed natural systems.[180] Not surprisingly, the Task Force noted one of the most important steps to prevent HABs is reducing pollution inputs to coastal waters, particularly industrial, agricultural, and domestic effluents, which result from fertilizers used in residential areas and are high in plant nutrients.[181] The report noted that "controlling pollution inputs is one approach that may reduce the incidence of those HAB species that are stimulated by nutrient enrichment."[182] The report added that HAB monitoring and other mitigation efforts were important when prevention efforts were inadequate, but stressed that it is preferable to prevent HABs rather than to treat their symptoms.[183] In response to these recommendations, Congress established a national monitoring program, but did not mandate controls on nutrient loading.[184] The program is generally designed to forecast bloom development and movement to provide early warning of the

[176] *See id.* § 605.
[177] *See* NAT'L SCI. & TECH. COUNCIL COMM. ON ENV'T & NAT. RES., *supra* note 57, at 15.
[178] *See id.* at 8.
[179] *Id.*
[180] *See id.*
[181] *See generally id.* at 8–9.
[182] *Id.*
[183] *See id.* at 9.
[184] *See Harmful Algal Bloom Monitoring System*, NOAA NAT'L CTRS. FOR COASTAL OCEAN SCI. (last visited Oct. 21, 2020), https://coastalscience.noaa.gov/research/stressor-impacts-mitigation/hab-monitoring-system/.

future risks of HABs to communities.[185] One component, the Ecology and Oceanography of HABs (ECOHAB) program, provides data to communities on the growth and toxin dynamics of major toxic species along the entire U.S. coast.[186]

In 2004, the Harmful Algal Bloom and Hypoxia Amendments Act of 2004 was signed into law.[187] The reauthorization retained the Task Force.[188] It also required the President, in consultation with the chief executive officers of the States, to develop and submit a report to Congress describing the effectiveness of the measures used to predict and respond to HABs.[189] The Act also authorized the development of a national research program aimed at the prevention, control, and mitigation of harmful algal blooms on coastal ecosystems, new regional-scale assessments of HABs and hypoxia, and scientific assessments of freshwater HABs, coastal HABs, and hypoxia.[190] Annual funding for these programs was increased slightly.[191] But as before, the Act took no direct action to reduce nutrient loading of coastal systems.

Congress reauthorized HABHRCA in 2014.[192] The reauthorization gave the National Oceanic and Atmospheric Administration (NOAA) primary responsibility for administering a national harmful algal bloom and hypoxia program.[193] NOAA was charged with increasing the scientific understanding and ability to detect,

[185] *See* NAT'L SCI. & TECH. COUNCIL COMM. ON ENV'T & NAT. RES., *supra* note 57, at 9.

[186] *See Ecology and Oceanography of HABs (ECOHAB)*, NOAA NAT'L CTRS. FOR COASTAL OCEAN SCI., (2007), https://coastalscience.noaa.gov/research/stressor-impacts-mitigation/ecohab/; *Description of Ecology and Oceanography of Harmful Algal Blooms Program*, NOAA NAT'L CTRS. FOR COASTAL OCEAN SCI., (2009), https://cdn.coastalscience.noaa.gov/page-attachments/research/ECOHAB%20Description%20Detailed.pdf.

[187] *See* Harmful Algal Bloom and Hypoxia Amendments Act of 2004, Pub. L. No. 108–456, 118 Stat. 3630 (2004).

[188] *See id.* § 102.

[189] *See id.* § 103.

[190] *See id.* § 104.

[191] *See id.* § 105 (amending section 605(2) to provide $23.5 million for fiscal year 2005, $24.5 million for fiscal year 2006, $25 million for fiscal year 2007, and $25.5 million for fiscal year 2008).

[192] *See* Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2014, Pub. L. No 113–124, 128 Stat 1379 (2014).

[193] *See id.* § 4 (adding § 603A(h) to the original Act).

monitor, assess, and predict HAB and hypoxia events.[194] The reauthorization also added the Centers for Disease Control and Prevention (CDC) to the Task Force.[195] In addition to its existing duties, the Task Force was charged with coordinating the interagency review process and promoting the development of new technologies for predicting, monitoring, and mitigating HABs and hypoxic conditions.[196] The reauthorization extended the scope of the research involving freshwater HABs and hypoxia.[197] Despite these added responsibilities, however, total appropriations declined from prior years.[198]

Section 9 of the National Integrated Drought Information System Reauthorization Act of 2018 further amended the Harmful Algal Bloom and Hypoxia Research and Control Act of 1998.[199] The amendment added USACE to the Task Force, and required the Task Force to complete a scientific assessment of harmful algal blooms in U.S. coastal waters and freshwater systems at least every five years.[200] Under Section 9, "each assessment shall examine both marine and freshwater harmful algal blooms . . . including those that originate in freshwater lakes or rivers and migrate to coastal waters."[201] The amendment further required that the National Harmful Algal Bloom and Hypoxia Program "accelerate the utilization of effective methods of intervention and mitigation to reduce the frequency, severity, and impacts of harmful algal bloom and hypoxia events."[202]

In a step towards providing for mitigation of HABs, the amendment also grants NOAA and EPA the authority to declare a harmful algae bloom a "Harmful Algal Bloom of Significance," which

194 *See id.* § 5 (adding § 603B to the original Act).

195 *See id.* § 3 (adding the CDC to the task force under § 603(12) to the original Act).

196 *See id.* § 4 (adding §§ 603AI(1)–(7) to the original Act).

197 *See id.* § 4 (adding § 603A(h) to the original Act).

198 *See id.* § 11 (adding § 609 authorizing $20,500,000 for each of fiscal years 2014 through 2018).

199 *See* National Integrated Drought Information System Reauthorization Act of 2018, Pub. L. No. 115–423, § 9, 132 Stat. 5454, 12–16 (2018).

200 *See id.* §§ 9(g), 9(c) (adding § 603(a)(13) to the original Act that adds the Army Corp of Engineers).

201 *Id.*

202 *Id.* § 9(e)(1)(D).

triggers availability of federal funding.[203] The declaration may be made independently at the discretion of the Undersecretary of Commerce for Oceans and Atmosphere, if the event occurs in marine or coastal waters, or by the Administrator of the EPA, if the event occurs in freshwater.[204] The declaration may also be made at the request of the Governor of an affected State.[205] A harmful algal bloom event qualifies as an "event of national significance" when the event "has had or will likely have a significant detrimental environmental, economic, subsistence use, or public health impact on an affected State."[206] In making the declaration, the official must consider:

> The toxicity of the harmful algal bloom, the severity of the hypoxia, its potential to spread, the economic impact, the relative size in relation to the past 5 occurrences of harmful algal blooms or hypoxia events that occur on a recurrent or annual basis, and the geographic scope, including the potential to affect several municipalities, to affect more than 1 State, or to cross an international boundary.[207]

Once the declaration is made, federal funds become available to affected state or local governments for the purposes of "assessing and mitigating the detrimental environmental, economic, subsistence use, and public health effects of the event of national significance."[208] The Federal government will pay up to half of the cost of any activity carried out under this provision of the Act.[209] Despite adding new requirements, however, the amendment still kept funding at existing levels through 2023.[210] And again, no steps were taken to directly address nutrient loading to coastal systems.

2. Federal Ocean Acidification Research and Monitoring Act of 2009 and Reauthorizations

Congress passed the Federal Ocean Acidification Research and Monitoring Act of 2009 (FOARAM) to assess how changes in seawater chemistry due to ocean acidification may affect marine

203 *Id.* § 9(g).
204 *See id.* §§ 9(g)(2)–(3).
205 *See id.* § 9(g)(2)(A).
206 *Id.* § 9(g)(3)(B).
207 *Id.* § 9(g)(2)(B).
208 *Id.* § 9(g)(1)(A).
209 *See id.* § 9(g)(1)(B).
210 *See id.* § 9(h) (providing $20,500,000 for each of fiscal years 2019 through 2023).

organisms, marine ecosystems, and the resources and services that they provide.[211] Although not expressly intended to address HABs, FOARAM represents a critical component of HAB control because HAB development is influenced by ocean acidification. FOARAM represented the first formal federal effort to address ocean acidification directly, through the creation of an interagency research and monitoring program.[212] FOARAM required the development of adaptation and mitigation strategies to conserve marine organisms and ecosystems exposed to ocean acidification.[213] Through FOARAM, Congress directed federal agencies to work collaboratively to develop and coordinate a comprehensive interagency plan to: (1) engage in studies designed to understand the processes and likely impacts of declining ocean pH on marine organisms and ecosystems and (2) establish an interagency research and monitoring program on ocean acidification.[214] The Act required the Joint Subcommittee on Ocean Science and Technology of the National Science and Technology Council to provide reports to Congress every two years on federal activities related to addressing ocean acidification.[215] Currently, federal activities include:

> [R]esearch that seeks to understand ocean acidification[,]… monitor ocean chemistry and biological impacts[,]… modeling to predict changes in ocean chemistry and impacts on marine ecosystems and organisms[,] … technology development and standardization of measurements[,]… assessment of socioeconomic impacts and development of adaptation and mitigation strategies[,] … education, outreach, and engagement[,]… data management and integration.[216]

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211 *See* Omnibus Public Land Management Act of 2009, *supra* note 172.

212 *See* Cheryl Logan, *A Review of Ocean Acidification and America's Response*, 60 BIOSCIENCE 819, 825 (2010).

213 *See* Omnibus Public Land Management Act of 2009, *supra* note 172, § 12402(a), at 1437.

214 *See id.* § 12402(a), at 1436–37. Agencies involved include NOAA, NSF, Bureau of Ocean Energy Management (BOEM), Department of State (DOS), EPA, NASA, USFWS, USGS, and U.S. Navy. *See* INTERAGENCY WORKING GRP. ON OCEAN ACIDIFICATION, STRATEGIC PLAN FOR FEDERAL RESEARCH AND MONITORING OF OCEAN ACIDIFICATION 3 (2014), https://www.nodc.noaa.gov/oads/support/IWGOA_Strategic_Plan.pdf.

215 Omnibus Public Land Management Act of 2009 § 12404(c), at 1438.

216 U.S. GOV'T ACCOUNTABILITY OFF., GAO-14-736, OCEAN ACIDIFICATION: FEDERAL RESPONSE UNDER WAY, BUT ACTIONS NEEDED TO UNDERSTAND AND

This national ocean acidification program was created in May 2011 and is coordinated by NOAA.[217] In its most recent report to Congress, the Subcommittee acknowledged that ocean acidification "will likely cause serious impacts on marine ecosystems and the services those systems provide to society."[218]

In 2019, Representative Suzanne Bonamici of Oregon introduced a bill in the House of Representatives that sought to strengthen investments in ocean and coastal acidification research and monitoring and to increase understanding of the socioeconomic impacts of coastal acidification.[219] The bill would appropriate almost $51 million annually between 2020 and 2024 for the National Oceanic and Atmospheric Administration (NOAA) and the National Science Foundation (NSF) to implement authorized activities related to ocean acidification.[220] The bill was passed by the House in 2019 and, as of December 2020, awaits consideration by the Senate.[221] That same year, Representative Bill Posey of Florida introduced a related bill in the House that would require a study examining the impact of ocean acidification and other stressors on American estuaries and nearshore waters.[222] That bill expressly recognizes that the synergistic effects of multiple stressors, "including salinity, pH, temperature, sea level rise, and nutrient input, within estuarine ecosystems is inadequately understood for managing the health, economic, recreational, and environmental impacts driven by these interactions."[223] The bill is currently under review by the Senate.[224]

ADDRESS POTENTIAL IMPACTS 23–25 (2014), https://www.gao.gov/assets/670/665777.pdf.

217 *See id.* at 25.

218 LIBBY JEWETT ET AL., FIFTH REPORT ON FEDERALLY FUNDED OCEAN ACIDIFICATION RESEARCH AND MONITORING ACTIVITIES: FISCAL YEARS 2016 AND 2017 1 (2020), https://oceanacidification.noaa.gov/Portals/42/Federal%20OA%20report%20FY%2016%2017%20%20January%202020.pdf?ver=2020-01-28-122457-137&timestamp=1580233147781.

219 *See* Coastal and Ocean Acidification Stressors and Threats Research Act of 2019, H.R. 1237, 116th Cong. (2019).

220 *See id.* § 9.

221 *See* 165 Cong. Rec. H4332 (daily ed. June 5, 2019); *see* COAST Research Act of 2019, H.R. 1237, 116th Cong. (1st Sess. 2019).

222 *See* National Estuaries and Acidification Research (NEAR) Act of 2019, H.R. 988, 116th Cong. (2019).

223 *Id.* § 2(4).

224 *See* NEAR Act of 2019, H.R. 988, 116th Cong. (1st Sess. 2019).

3. Clean Air Act and Clean Water Act

Over-enrichment of nutrients and other chemicals in marine systems through land-based runoff, effluent discharge, and atmospheric deposition can trigger HAB development, leading to die-offs of fish and shellfish in estuaries and coastal waters. Neither FOARAM nor HABHRCA include provisions to address the underlying causes of the observed changes to marine systems. The Clean Air Act (CAA) and the Clean Water Act (CWA), however, both have mechanisms capable of addressing some of these causes.

a. Clean Air Act and HABs

The failure to appropriately regulate nitrogen oxides (NO_x) and CO_2 exacerbates ocean acidification and, in turn, HAB formation. This is because the pH of ocean water declines as a result of absorption of atmospheric CO_2, NO_x, and other chemicals.[225] CO_2 released through the decomposition of organic matter, including algae that form HABs, can add to this acidification.[226] Despite these known risks, and the ability to address each through the regulatory controls available under the CAA, EPA has not taken effective action to address either.

In 1970, Congress established a framework for cooperative federalism aimed at reducing air pollution throughout the country.[227] Under the CAA, the federal government established National Ambient Air Quality Standards (NAAQS) for certain criteria pollutants that individual states are required to meet through federally-approved state implementation plans (SIPs).[228] Under this approach,

225 *See* Mathilde Hagens et al., *Biogeochemical Context Impacts Seawater pH Changes Resulting from Atmospheric Sulfur and Nitrogen Deposition*, 41 GEOPHYSICAL RSCH. LETTERS, 935, 935 (2014).

226 *See* EPA, REVIEW OF THE SECONDARY STANDARDS FOR ECOLOGICAL EFFECTS OF OXIDES OF NITROGEN, OXIDES OF SULFUR, AND PARTICULATE MATTER: RISK AND EXPOSURE ASSESSMENT PLANNING DOCUMENT 3-22 (2018), https://www.epa.gov/sites/production/files/2018-08/documents/rea_plan_final-080618.pdf.

227 *See* Clean Air Act Amendments of 1970, Pub. L. No. 91-604, 84 Stat. 1676 (1970).

228 *See id.* §§ 109–10. Through State Implementation Plans, individual states identify specific strategies and emissions control measures the state will employ to meet the standards within their borders. *See* 42 U.S.C. §§ 7410(a)(2); 7502(c).

States retain the primary responsibility for assuring that air quality within their borders meets the national standards.[229]

Under the CAA, EPA is charged with promulgating primary and secondary NAAQS for pollutants that, in the judgment of the EPA Administrator, "cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare," a determination known as an endangerment finding.[230] Primary standards must be sufficient to protect public health with an adequate margin for safety.[231] Secondary standards must be sufficient to protect public welfare,[232] which includes protection against "effects on soils, water, crops, vegetation, manmade materials, animals, wildlife, weather, visibility, and climate."[233] When setting standards required to protect public health and welfare, EPA may only create standards that "are neither more nor less stringent than necessary."[234] EPA is not permitted to consider the cost, attainability, or technological feasibility of creating standards.[235] The NAAQS must be reviewed every five years and revised as warranted.[236] EPA has set standards for six priority pollutants: carbon monoxide (CO), lead

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229 *See id.* § 107 (codified as amended at 42 U.S.C. § 7407)

230 42 U.S.C. § 7408 (a) (2018).

231 *See* 42 U.S.C. § 7409 (b)(1) (2018).

232 *See id.* § 7409(b)(2) (2018).

233 *Id.*; *see also* 42 U.S.C. § 7602(h) ("All language referring to effects on welfare includes, but is not limited to, effects on soils, water, crops, vegetation, manmade materials, animals, wildlife, weather, visibility, and climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well-being, whether caused by transformation, conversion, or combination with other air pollutants.").

234 Review of the National Ambient Air Quality Standards for Lead, 81 Fed. Reg. 71,906, 71,907 (Oct. 18, 2016) (noting EPA's task in NAAQS is to establish standards that are neither more nor less stringent than necessary).

235 *See, e.g., Whitman v. American Trucking Ass'ns, Inc.*, 531 U.S. 457, 486 (2001) (noting that Section 109(b) does not permit the Administrator to consider implementation costs in setting NAAQS); *Id.* at 490–91 (Stevens, J., concurring) (noting that the Administrator should make air quality determinations without considering technological feasibility).

236 *See* 42 U.S.C. § 7409(d) ("at five-year intervals . . . the Administrator shall complete a thorough review of the criteria published under section 7408 of this title and the national ambient air quality standards promulgated under this section and shall make such revisions in such criteria and standards and promulgate such new standards as may be appropriate in accordance with section 7408 of this title and subsection (b) of this section.").

(Pb), nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM_{10} and $PM_{2.5}$) and sulfur dioxide (SO_2).[237]

Atmospheric nitrogen compounds emitted into the air by cars, trucks, electric utilities, agriculture, and industry represent one of several sources of nitrogen entering estuaries and coastal marine ecosystems.[238] By some estimates, between 10 percent and 45 percent of new nitrogen entering estuaries along the eastern U.S. coast and eastern Gulf of Mexico comes from atmospheric deposition.[239] A 2000 study of nutrient loading in the Chesapeake Bay, for example, revealed that the emission of NO_x through manmade sources contributed roughly 32 percent of the nitrogen entering the Bay.[240] Despite an overall reduction in NO_x emissions, atmospheric deposition of nitrogen continues to be one of the largest sources of nitrogen loading in the Bay.[241] Absent continued efforts to reduce NO_x emissions, climate change could lead to increased nitrogen loading of the Bay ecosystem.[242] EPA has acknowledged that atmospheric

[237] *See NAAQS Table*, EPA, (last updated Dec. 20, 2016), https://www.epa.gov/criteria-air-pollutants/naaqs-table.

[238] *See* Charles T. Driscoll et al., *Nitrogen Pollution in the Northeastern United States: Sources, Effects, and Management Options,* 53 BIOSCIENCE 357, 359, 366 (2003), http://www.eeb.cornell.edu/goodale/2003%20Driscoll%20etal%20Biosci.pdf (reporting that atmospheric deposition was the second largest nitrogen input for most watersheds studied).

[239] Atmospheric deposition of nitrogen occurs when reactive nitrogen from the atmosphere enters the biosphere as gases, dry deposition, and in precipitation as wet deposition. *See Nitrogen Deposition*, AIR POLLUTION INFO. SYS. (2016), http://www.apis.ac.uk/overview/pollutants/overview_n_deposition.htm; *see also* Valigura et al., *supra* note 168.

[240] *See* OFFICE OF INSPECTOR GEN., EPA, EPA RELYING ON EXISTING CLEAN AIR ACT REGULATIONS TO REDUCE ATMOSPHERIC DEPOSITION TO THE CHESAPEAKE BAY AND ITS WATERSHED; REPORT NO. 2007-P-00009 4 (2007), https://www.epa.gov/sites/production/files/2015-11/documents/20070228-2007-p-00009.pdf.

[241] *See* Patrick C. Campbell et al., *Projections of Atmospheric Nitrogen Deposition to the Chesapeake Bay Watershed* 124 J. GEOPHYSICAL RSCH.: BIOGEOSCIENCES 3307, 3307 (2019), https://scholarworks.wm.edu/cgi/viewcontent.cgi?article=2798&context=vimsarticles.

[242] *See id.* at 3320 (noting that when models account for climate change alone, without consideration of projected emissions reductions, there was average increases in the total nitrogen input to the Chesapeake Bay ecosystem during all seasons).

deposition degrades water quality and impairs ecosystem services.[243] However, EPA has not promulgated regulations explicitly designed to address atmospheric deposition that causes nutrient over-enrichment in marine or aquatic ecosystems. Current secondary standards for NO_x are not designed to protect marine systems from these problems. In 2011, EPA concluded that NO_x contributes to nutrient over-enrichment in estuaries and acknowledged that existing secondary NAAQS for NO_x do not provide adequate protection from these impacts.[244] EPA then determined that it lacked sufficient data on how NO_x contributed to the over-enrichment of nutrients and was therefore unwilling to set more protective standards.[245]

EPA has not revised the NO_x secondary standards since they were first passed in 1971.[246] Following a review of secondary standards for NO_x and SO_2 in 2012, EPA announced that the existing standards were not adequate to protect against adverse public welfare effects such as damage to sensitive ecosystems.[247] Nonetheless, EPA elected to retain the standards.[248] EPA chose not to change the existing standards even though it acknowledged that available evidence demonstrated:

243 *See Community Multiscale Air Quality Modeling System (CMAQ)*, EPA (Jun. 2, 2017), https://www.epa.gov/cmaq/estimating-atmospheric-deposition-cmaq.

244 *See* U.S. GOV'T ACCOUNTABILITY OFF., GAO-13-39, EPA FACES CHALLENGES IN ADDRESSING DAMAGE CAUSED BY AIRBORNE POLLUTANTS (2013), https://www.gao.gov/assets/660/651522.pdf.

245 *See id.*

246 *See* National Primary and Secondary Ambient Air Quality Standards, 36 Fed. Reg. 8,186, 8,187 (April 30, 1971) (setting identical primary and secondary standards at 0.05 parts per million (ppm) as an annual arithmetic average); *see also* Retention of the National Ambient Air Quality Standards for Nitrogen Dioxide, 50 Fed. Reg. 25,532 (June 19, 1985) (retaining the 1971 secondary standards); National Ambient Air Quality Standards for Nitrogen Dioxide, 61 Fed. Reg. 52,852 (October 8, 1996) (retaining the 1971 secondary standards); Secondary National Ambient Air Quality Standards for Oxides of Nitrogen and Sulfur, 77 Fed. Reg. 20,218 (April 3, 2012) (retaining the 1971 secondary standards).

247 *See* Secondary National Ambient Air Quality Standards for Oxides of Nitrogen and Sulfur, 77 Fed. Reg. 20,218, 20,238 (April 3, 2012) (concluding that "consideration should be given to establishing a new ecologically relevant multipollutant, multimedia standard to provide appropriate protection from deposition-related ecological effects of oxides of nitrogen and sulfur on sensitive ecosystems, with a focus on protecting against adverse effects associated with acidifying deposition in sensitive aquatic ecosystems.").

248 *See id.* at 20,218.

> [(1)] a causal relationship between nitrogen deposition and the biogeochemical cycling of nitrogen and carbon in estuaries[;] . . . [(2)] a causal relationship between nitrogen deposition and the alteration of species richness, species composition and biodiversity in estuarine ecosystems[;] . . . [(3)] atmospheric deposition of oxidized nitrogen contributes significantly to total nitrogen loadings in nitrogen sensitive ecosystems [; and (4)] atmospheric sources of nitrogen contribute to increased phytoplankton and algal productivity, leading to eutrophication.[249]

The Agency also found that "nitrogen deposition contributes significantly to eutrophication in many estuaries affecting fish production, swimming, boating, aesthetic enjoyment and tourism."[250] EPA acknowledged that the "current standards are not directed toward depositional effects," and that none of the elements of the current standard—indicator, form, averaging time, and level—are suited for addressing the effects of nitrogen and sulfur deposition.[251]

Environmental groups sued EPA and asserted that, having decided that the existing standards were inadequate to meet the statutory mandate of protecting public welfare, EPA was required to adopt new, more stringent secondary standards.[252] The reviewing court upheld EPA's decision because EPA concluded that it did not have sufficient information to make a reasoned judgment about whether any proposed standard would be "requisite to protect the public welfare."[253] In 2017, EPA began its latest review of secondary standards for NO_x.[254] The final rule is not due until 2022.[255] The review will consider, among other things, ecological effects associated with the deposition of NO_x.[256] EPA acknowledged that since the 2012 review of secondary standards, the agency has acquired considerably more information on the contribution of atmospheric

249 *Id.* at 20,235–20,238.
250 *Id.* at 20,234.
251 *Id*. at 20,238.
252 *See Ctr. for Biological Diversity v. EPA*, 749 F.3d 1079, 1090 (D.C. Cir. 2014) [hereinafter CBD].
253 *Id.* at 1091.
254 *See* EPA, INTEGRATED REVIEW PLAN FOR THE SECONDARY NATIONAL AMBIENT AIR QUALITY STANDARDS FOR ECOLOGICAL EFFECTS OF OXIDES OF NITROGEN, OXIDES OF SULFUR AND PARTICULATE MATTER (2017), https://www.epa.gov/sites/production/files/2018-08/documents/final_integrated_review_plan_for_nox_sox_pm_eco_-_011817-final.pdf.
255 *See id.* at 1-23.
256 *See id.* at 1-16.

deposition associated with ambient oxides of nitrogen.[257] The agency has stated that the current review will consider the potential impacts on the public welfare from alterations in structure and function of ecosystems.[258]

Despite making the required endangerment finding for several greenhouse gases, including CO_2, EPA has not promulgated primary or secondary NAAQS standards for these gases.[259] Thus, to date, there is no national pollution cap for carbon dioxide or other greenhouse gases. In the absence of meaningful regulation on the release of NO_x and CO_2 into the environment, acidification and nutrient loading of coastal systems will increase and create conditions more favorable to HAB formation.

b. Clean Water Act, Coastal Zone Management Act, and HABs

Two other federal statutes have potential when it comes to addressing HABs. First, the Clean Water Act (CWA) contains several provisions that, if used effectively, could protect waterbodies from pollutants that facilitate HAB development through direct discharges, land-based run off, and even atmospheric deposition. Second, the Coastal Zone Management Act provides additional mechanisms that can similarly reduce pollution.

The CWA is the primary federal law governing ocean and coastal water quality in the United States.[260] The CWA set a national goal of restoring and maintaining the "chemical, physical, and biological integrity of the Nation's waters."[261] Under the CWA, it is illegal for anyone to discharge a pollutant through a point source into a water of the United States without a permit.[262] A point source is any single identifiable source of pollution from which pollutants are discharged, such as a pipe, ditch, ship or factory effluent pipe.[263] Point sources of pollution cannot discharge without a National Pollutant Discharge Elimination System (NPDES) permit that specifies

257 *See id* at 1-9.
258 *See id.* at 2-1.
259 *See* Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act, 74 Fed. Reg. 66,496, 66,497 (Dec. 15, 2009); *NAAQS Table*, *supra* note 237.
260 *See* Federal Water Pollution Control Act Amendments of 1972, Pub. L. No. 92-500, 86 Stat. 816 (Oct. 18, 1972) (codified at 33 U.S.C. § 1251 et seq.) (1972).
261 *Id.* at § 101(a).
262 *See id.* at §§ 404, 405.
263 *See* 33 U.S.C. § 1362(14) (2012).

an acceptable level of a pollutant or parameter in a discharge that may impair water quality.[264] Anything not considered a point source is considered a nonpoint source of pollution and is not subject to the NPDES permitting scheme, or any similar permit requirement.

Under the CWA, the term "point source" does not include agricultural stormwater discharges or return flows from irrigated agriculture.[265] The CWA also exempts discharges associated with "normal farming, silviculture and ranching activities such as plowing, seeding, cultivating, minor drainage, and harvesting for the production of food, fiber, and forest products, or upland soil and water conservation practices."[266] As result, these activities continue to release large quantities of harmful chemicals into the surrounding environment.

The CWA also contains a mechanism for handling atmospheric deposition of pollutants. In order to understand that mechanism, it is necessary to first examine the general structure of the CWA. Under the CWA, every state is required to adopt water quality standards that describe the state's desired condition of a body of water and the means by which that condition will be protected or achieved.[267] These standards are adopted "to protect public health or welfare, enhance the quality of water and serve the purposes of the [Clean Water] Act."[268] They operate to place permissible limits on the volume of pollutants entering waters of the United States.[269] Because they are ambient water standards, they help regulators establish proper NPDES effluent discharge limits.[270]

Section 303(d) of the CWA requires states to identify waters that fail to meet state water quality standards despite the application of control technologies that limit point sources of pollution.[271] For

[264] *See id.* at § 402.
[265] *See id.* at § 502(14).
[266] 33 C.F.R. § 323.4.
[267] *See* Federal Water Pollution Control Act, Pub. L. No. 92-500 at § 303 (1970).
[268] 40 C.F.R. § 131.2 (1995).
[269] *See What are Water Quality Standards*?, EPA, (last updated May 21, 2020), https://www.epa.gov/standards-water-body-health/what-are-water-quality-standards.
[270] *See id.*
[271] 40 C.F.R. § 131.3(h) (defining water quality limited segment as "any segment where it is known that water quality does not meet applicable water quality standards, and/or is not expected to meet applicable water quality standards, even

these so called "water quality limited segments" (WQLS), states are required to establish a total maximum daily load (TMDL) limit for the pollutant or pollutants of concern.[272] The TMDL represents the total amount of the pollutant from all contributing (point, nonpoint, and natural) sources that a body of water can assimilate without violating the state-established water quality standard for that body of water.[273] Once the TMDL is complete, the state must allocate the allowable pollution load among all of the pollution sources in the WQLS segment and then specify a plan to reduce the pollutant sources to ensure that the daily load is not exceeded. Because nonpoint source pollution is difficult to directly regulate, TMDLs can be an effective tool for restoring water quality.

Atmospheric deposition of carbon dioxide and nitrogen threaten to further impair marine environments in potentially significant ways.[274] The CWA applies to both point sources of pollution, such as effluent discharges, and to nonpoint source pollutants, such as nutrient runoff, but its application to control atmospheric pollutants is less clear.[275] This is because the emission of pollutants into the air is addressed under the CAA.[276] However, because nutrient loading and CO_2 absorption impair water quality, the CWA can be used to control atmospheric deposition of CO_2 and NOx.

As discussed above, a TMDL applies to a pollutant, without regard to its source, and it creates a limit for how much pollution can enter a body of water. Thus, establishing a TMDL will act to reduce the introduction of the pollutant into a waterbody from all sources including those sources that might otherwise be regulated

after the application of the technology-based effluent limitations required by sections 301(b) and 306 of the Act.").

272 *See* Federal Water Pollution Control Act, Pub. L. No. 92-500 at § 303(d)(1) (1970).

273 *See id.*; *Impaired Waters and TMDLs; Overview of Total Maximum Daily Loads (TMDLs)*, EPA, https://www.epa.gov/tmdl/overview-total-maximum-daily-loads-tmdls (last visited Sept. 22, 2020).

274 *See* Ove Hoegh-Guldberg & John F. Bruno, *The Impact of Climate Change on the World's Marine Ecosystems*, 328 SCI. 1523, 1523–24 (2010).

275 *See Basic Information about Nonpoint Source (NPS) Pollution*, EPA, https://www.epa.gov/nps/basic-information-about-nonpoint-source-nps-pollution (last visited Oct. 30, 2020).

276 *See generally Overview of the Clean Air Act and Air Pollution*, EPA, https://www.epa.gov/clean-air-act-overview (last visited Oct. 30, 2020).

under the CAA.[277] TMDLs are particularly useful in assessing the impact of atmospheric deposition on water quality for waterbodies affected by multiple, overlapping pollution sources.[278] By establishing TMDLs for a pollutant, regulators can identify the relative contributions of point sources, land-based runoff, and atmospheric deposition of the pollutant.[279] That information can then be used to implement specific control actions that reduce pollutant load from each source and meet water quality standards.

Regional TMDLs have already been successfully implemented to control atmospheric deposition of mercury into coastal waters.[280] For example, the Northeast Regional Mercury TMDL was created to reduce mercury deposition in ocean waters from all sources impacting bodies of water within the coverage area.[281] A TMDL was also established for the Chesapeake Bay in an effort to reduce land-based nutrient runoff and atmospheric deposition of nitrogen to meet water quality standards.[282] Using TMDLs to limit the coastal pollution that drives HAB development represents a viable option that should be explored.

Separately, the Coastal Zone Management Act, which was passed, in part, to supplement the CWA in coastal states, contains provisions to control nonpoint sources of pollution not regulated under the CWA through the establishment of the Coastal Nonpoint Pollution Control Program.[283] That program, jointly administered by NOAA and EPA, establishes management measures to control polluted runoff into coastal waters from agriculture, forestry, urban

[277] *See Northeast Regional Mercury Total Maximum Daily Load Fact Sheet (2007),* NEW ENGLAND INTERSTATE WATER POLLUTION CONTROL COMM'N (NEIWPCC), https://www.neiwpcc.org/mercuryold/mercury-docs/FINAL%20Northeast%20Regional%20Mercury%20TMDL.pdf. (discussing mercury emission regulation under EPA's Mercury and Air Toxics Standards) (last visited Oct. 30, 2020).

[278] *See Guidance for Water Quality-based Decisions*: *The TMDL Process,* EPA (Apr. 1991), https://www.epa.gov/sites/production/files/2018-10/documents/guidance-water-tmdl-process.pdf.

[279] *See* U.S. GOV'T ACCOUNTABILITY OFF., *supra* note 244.

[280] *See* NEIWPCC*, supra* note 277.

[281] *See Northeast Regional Mercury TMDL,* NEIWPCC, https://neiwpcc.org/our-programs/nps/mercury/mercury-tmdl/ (last visited Oct. 30, 2020).

[282] *See* EPA, CHESAPEAKE BAY TMDL EXECUTIVE SUMMARY ES-6 (2010), https://www.epa.gov/sites/production/files/2014-12/documents/bay_tmdl_executive_summary_final_12.29.10_final_1.pdf.

[283] *See* 16 U.S.C. § 1455b (2018).

areas, marinas, and hydromodification.[284] Because control of non-point sources of pollution falls outside the CWA's permit requirements and enforcement mechanisms, the Coastal Nonpoint Pollution Control Program under the CZMA provides an important tool to limit the entry of nonpoint pollution to coastal systems. But its ability to reduce inputs and improve water quality in the coastal zone is limited. The program does not address atmospheric deposition and has had only limited success in controlling land-based pollution of coastal systems. As a result, many assessed coastal waterbodies remain impaired, and over half have not even been assessed.[285]

The inability to meet the goals of the CWA and CZMA has contributed to the decline in the health and stability of many habitats and has imperiled the organisms that inhabit them. Unfortunately, states have largely opted to address the growing threat posed by HABs by engaging in research and monitoring activities.

B. *State Controls*

The U.S. states hit hardest by HABs have approached the problem in the same way that the federal government has, namely, by funding long term research and developing monitoring programs to provide early warning of HAB development. In Florida, for example, Executive Order 19-12 directed government agencies to collaborate on studies involving the impacts of red tides on coastal waters, air quality, and human health.[286] The Order also created a new Blue-Green Algae Task Force and reactivated the Harmful Algal Bloom Task Force, established in 1999, which focused on red tides.[287] The Harmful Algal Bloom Task Force is charged, along with the State's Red Tide Mitigation and Technology Development Initiative, with evaluating current policies, procedures, research and response efforts, identifying and prioritizing actions, and making

[284] *See Coastal Nonpoint Pollution Control Program*, NOAA OFF. FOR COASTAL MGMT. (Sept. 10, 2020), https://coast.noaa.gov/czm/pollutioncontrol/.

[285] *See* EPA, NATIONAL WATER QUALITY INVENTORY: REPORT TO CONGRESS COASTAL WATERS 14 (Aug. 30, 2017), https://www.epa.gov/sites/production/files/2017-12/documents/305brtc_finalowow_08302017.pdf (noting that of 87,791 square miles of bays and estuaries, only 35,094 square miles had been assessed, of which 27,483 square miles were impaired).

[286] *See* Fla. Exec. Order No. 19-12, *Achieving More Now for Florida's Environment* (Jan. 10, 2019), https://www.flgov.com/wp-content/uploads/orders/2019/EO_19-12.pdf.

[287] *See id.*

recommendations.[288] The Order also directs agencies to "review budgets and prioritize any available funding to focus on projects that reduce nutrient loading that may contribute to harmful algae blooms."[289] Despite mentioning the need for projects that reduce nutrient loading, no new funding was provided to meet the objective, although the Order does encourage continued funding of beach cleanup programs, following red tides, to limit the red tides' impact on residents and visitors.[290]

Similar research-based approaches are present around the country. In New England, HAB-related research focuses on biotic factors that influence the growth and toxicity of harmful algae species that cause Paralytic Shellfish Poisoning in humans.[291] Information obtained from the studies will be incorporated into predictive models designed to provide early warnings to state managers and the shellfish industry that prevent exposure to algal toxins and economic disruption.[292] In the Chesapeake Bay region, studies are focusing on ways to better predict algae blooms.[293] In California, research is directed to improve modeling forecasts that predict HAB development in coastal waters.[294] Other states have taken similar approaches.

There is no doubt that scientific research informs sound policy. The current research-based focus of state and federal organizations will certainly provide valuable information that will aid in responding to HABs. That said, monitoring and detection are no substitution for directly addressing the root causes of HAB development, such as nutrient pollution, ocean warming, and acidification. The current approaches inadequately address the emerging risks posed by HABs—additional action is critical to preserving public health and preventing environmental catastrophe.

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[288] *See Harmful Algal Bloom/Red Tide Task Force*, FLA. FISH AND WILDLIFE CONSERVATION COMM'N, https://myfwc.com/research/redtide/taskforce/ (last visited Sept. 10, 2020).

[289] *Id.*

[290] *See id.*

[291] *See NCCOS Funds $6.8M for New and Continuing Harmful Algal Bloom Research*, NOAA NAT'L CTRS. FOR COASTAL OCEAN SCI. (Sept. 6, 2018), https://coastalscience.noaa.gov/news/nccos-funds-6-8m-for-new-and-continuing-harmful-algal-bloom-research/.

[292] *See id*.

[293] *See id*.

[294] *See id*.

IV. Proposed Approaches to Regulating HABs

Human activities continue to alter marine environments in fundamental ways that threaten marine biodiversity and, increasingly, human health and welfare. The emergence of larger, more dangerous HABs throughout the world is emblematic of the changes occurring in the world's oceans. Globally, governments have responded to HABs by developing monitoring programs designed to detect water conditions conducive to HAB formation, in order to provide early warning of HAB outbreaks.[295] This current approach benefits local communities by providing leaders with the data needed to support early fishery and beach closures, which limits consumption of contaminated seafood and exposure to aerosolized toxins. But this approach does not address the controllable, underlying anthropogenic influences on HAB development, toxicity, and geographic expansion. It is now clear that nutrient enrichment of the marine environment acts synergistically with changes in ocean pH, temperature, and other factors to drive certain HAB events, and that human activities are fundamentally altering these factors. In the absence of meaningful regulation both to control harmful emissions of the chemicals that ultimately get deposited in marine systems and to limit nutrient run-off, the health of coastal marine systems will continue to decline and risks to human health and welfare will increase.

The devastating COVID-19 pandemic has forced countries to reevaluate their approaches to health care and has exposed the potentially crippling risks of zoonotic diseases.[296] Perhaps the most valuable result that could emerge from the horrific pandemic is a global acceptance of the interconnectedness of human health, economic stability, and disruption of natural systems.[297] With such an

[295] *See Harmful Algal Bloom Forecasts*, NOAA, https://tidesandcurrents.noaa.gov/hab_info.html (last visited Sept. 10, 2020) (NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) provides HAB forecasts to help leaders respond to bloom impacts).

[296] Zoonotic diseases are those diseases that spread between animals and humans. The COVID-19 virus is a zoonotic coronavirus, similar to SARS-CoV and MERS-CoV, that scientists believe moved from an animal to a human. *See* John S. Mackenzie & David W. Smith, *COVID-19: A Novel Zoonotic Disease Caused by a Coronavirus from China: What We Know and What We Don't*, MICROBIOL. AUST. (Mar. 17, 2020), *available at* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7086482/pdf/MA20013.pdf.

[297] *See* CATHERINE MACHALABA ET AL., *Anthropogenic Drivers of Emerging Infectious Diseases* in 2015 UNITED NATIONS GLOBAL SUSTAINABLE

understanding, policymakers can transition from current fragmented management plans that fail to address underlying causes of harm to more integrated approaches that address emerging risks holistically. This approach would be particularly beneficial to address the risk posed by HABs in marine waters. The following recommendations could protect imperiled marine systems, reduce economic harm to coastal communities from HABs, and limit human health risks posed by exposure to algal toxins.

A. *Reduce Greenhouse Gas Emissions that Impact Coastal Systems*

The magnitude, severity, and frequency of HABs' impacts to human health, wildlife, and the environment will likely increase as ocean water temperatures rise, ocean pH drops, and nutrient loading increases. To address these risks, policymakers must address the underlying drivers of HAB formation, development, and range expansion. A critical piece of this puzzle is significantly reducing greenhouse gas emissions.

Scientists attribute climate change to the accumulation of greenhouse gases that trap heat radiating from Earth toward space.[298] Absent meaningful reductions in greenhouse gases, the planet will continue to warm. China and the United States, respectively, continue to lead the world in the production of greenhouse gas emissions, together accounting for more than 40 percent of global emissions.[299] To date, neither country has committed to binding emissions limits. After years of progress toward developing a meaningful national plan to reduce greenhouse gas emissions in the United States, the federal government has retreated by embracing policies that may increase emissions. This trend must be reversed.

DEVELOPMENT REPORT, available at: https://sustainabledevelopment.un.org/content/documents/631980-Machalaba-Anthropogenic%20Drivers%20of%20Emerging%20Infectious%20Diseases.pdf (noting that the recent emergence of other diseases, including SARS, H7N9 and Marburg virus, has been linked to human practices, many of which also correlate with the leading drivers of biodiversity loss).

298 *See The Causes of Climate Change*, NASA, https://climate.nasa.gov/causes/ (last visited Sep. 3, 2020).

299 *See* Hannah Ritchie & Max Roser, *CO_2 and Greenhouse Gas Emissions*, OUR WORLD IN DATA (last updated Aug. 2020), https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions.

1. Control CO_2 Emissions: The Clean Power Plan and the Affordable Clean Energy Rule

To this point, the United States has taken little coordinated federal action towards reducing greenhouse gas emissions which, along with mitigating climate change impacts, would decrease HAB formation. The closest step, thus far, was the Clean Power Plan, finalized by EPA in 2015 but replaced with the far weaker Affordable Clean Energy Rule in 2019. In order to avoid climate change-driven increases in HAB formation, the United States must create stricter federal standards regarding CO_2 emissions.

In 2015, EPA finalized a plan dubbed the "Clean Power Plan" (CPP) to regulate greenhouse gas emissions from existing power plants.[300] The CPP was designed to "lead to significant carbon dioxide (CO_2) emission reductions from the utility power sector that will help protect human health and the environment from the impacts of climate change."[301] Under the plan, the federal government, acting through EPA, created state-specific emission reduction targets intended to reduce CO_2 emissions from the utility power sector to 30 percent below 2005 emission levels by 2030 and required states to develop plans to meet those targets.[302] Shortly after his inauguration in 2017, President Trump ordered EPA to review the CPP and to "suspend, revise, or rescind'' it.[303]

In 2019, EPA repealed the CPP after determining that the plan exceeded EPA's statutory authority under the CAA.[304] The Agency replaced the CPP with the Affordable Clean Energy Rule (ACE), which directed states to set their own emission standards for CO_2 from power plants.[305] According to EPA's press release, the ACE rule will reduce CO_2 emissions from the electric sector by as much as 35 percent below 2005 levels by 2030.[306] In reality, the impact of

300 *See* Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, 80 Fed. Reg. 64,662 (Oct. 23, 2015).
301 *Id.* at 64,663.
302 *See id.* at 64,665.
303 Exec. Order No. 13,783, 82 Fed. Reg. 16,093, 16,095 (Mar. 28, 2017).
304 *See* Repeal of the Clean Power Plan; Emission Guidelines for Greenhouse Gas Emissions from Existing Electric Utility Generating Units; Revisions to Emission Guidelines Implementing Regulations, 84 Fed. Reg. 32,520 (July 8, 2019) (to be codified at 40 C.F.R. pt. 60).
305 *See id.*
306 *See* Press Release, EPA, EPA Finalizes Affordable Clean Energy Rule, Ensuring Reliable, Diversified Energy Resources while Protecting our Environment

ACE is likely much more modest; the plan has been assailed by scientists and environmental groups on multiple levels. For example, one study determined that under the ACE rule, emissions intensity of coal plants may be reduced, but more coal plants would become operational and emit more total CO_2 in 2030, as compared to a world with no federal greenhouse gas regulation.[307] The study concluded that while the ACE rule modestly reduces national CO_2 emissions, it will actually increase CO_2 emissions by up to 8.7 percent in eighteen states plus the District of Columbia in 2030, as compared to no policy.[308] The study also concluded that under the ACE rule, SO_2 and NO_X emissions will increase in nineteen states and twenty states plus DC, respectively, in 2030, as compared to no policy.[309]

The Natural Resources Defense Council (NRDC) asserted that EPA intentionally misled the public, misrepresented emissions outcomes, and violated federal law in promulgating the final ACE rule.[310] To support its assertion, NRDC referenced EPA's own self-study on the impact of replacing the CPP with the ACE rule, wherein EPA concluded that adopting the ACE rule would lead to higher emissions of CO_2, SO_2, and NOx, than if it retained the CPP.[311] In the study, EPA also acknowledged that "deposition of nitrogen causes acidification, which can cause a loss of biodiversity of fishes, zooplankton, and macro invertebrates in aquatic ecosystems" and that "excess nutrient enrichment can lead to eutrophication" that "can disrupt an important source of food production, particularly

(June 19, 2019), https://www.epa.gov/newsreleases/epa-finalizes-affordable-clean-energy-rule-ensuring-reliable-diversified-energy.

[307] *See* Amelia T. Keyes et. al., *The Affordable Clean Energy Rule and the Impact of Emissions Rebound on Carbon Dioxide and Criteria Air Pollutant Emissions*, 14 ENV'T RSCH. LETTERS 044018 (2019), https://iopscience.iop.org/article/10.1088/1748-9326/aafe25/.

[308] *See id.*

[309] *See id.*

[310] *See* Arjun Krishnaswami, *EPA's Monkey Business Hides ACE Rule Emissions Increases*, NAT. RES. DEF. COUNCIL (June 25, 2019), https://www.nrdc.org/experts/arjun-krishnaswami/epas-monkey-business-hides-ace-rule-emissions-increases.

[311] *See id.*; *see also* EPA, REGULATORY IMPACT ANALYSIS FOR THE PROPOSED EMISSION GUIDELINES FOR GREENHOUSE GAS EMISSIONS FROM EXISTING ELECTRIC UTILITY GENERATING UNITS; REVISIONS TO EMISSION GUIDELINE IMPLEMENTING REGULATIONS; REVISIONS TO NEW SOURCE REVIEW PROGRAM ES-9, 4-8 (2018), https://www.epa.gov/sites/production/files/2018-08/documents/utilities_ria_proposed_ace_2018-08.pdf.

fish and shellfish production."[312] Unlike EPA's study, the final ACE rule did not compare its projected impact to the impacts expected under the then-existing CPP rule. If it had done so, EPA's own study results would have shown that maintaining the CPP would result in greater emissions reductions than would occur through adoption of the ACE rule. To avoid this, in the final rule, EPA chose to compare its projections under the ACE rule to what would happen if no prior regulation existed.[313] This allowed EPA to publicly state that its plan would result in emission reductions, without having to acknowledge that its plan was inferior to the plan it was replacing. The new rule impedes progress toward emission reductions because it is projected to barely reduce CO_2 emissions below those that would result with no federal regulation.[314]

The validity of both the CPP and the ACE rule has been challenged in court, with a case involving the ACE rule currently pending before the United States District Court for the District of Columbia.[315] But, as lawyers debate the legality of the ACE rule and policymakers debate its ultimate impact, greenhouse gas emissions continue to rise globally.[316] In the United States, the news is only

312 *Id.* at 4-52.

313 *See* Krishnaswami, *supra* note 310.

314 *See* Dana Nuccitelli, *The Trump EPA Strategy to Undo Clean Power Plan,* YALE CLIMATE CONNECTIONS (June 21, 2019), https://www.yaleclimateconnections.org/2019/06/the-trump-epa-strategy-to-undo-the-clean-power-plan/.

315 *See* Brief of Public Health and Environmental Petitioners, Am. Lung Ass'n v. EPA, Case No. 19-1140 (D.C. Cir. Apr. 17, 2020). EPA repealed the CPP after reinterpreting Section 111 of the CAA, which directs EPA to set standards of performance for categories of new stationary sources that cause or significantly contribute to air pollution that endangers public health or welfare, to prohibit the agency from implementing the CPP. In 2020, the American Lung Association (ALA), the American Public Health Association, and other environmental groups appealed EPA's final rule repealing the CPP. The petitioners claim that Congress' direction in the CAA that EPA select the "best system of emission reduction" that is "adequately demonstrated" authorized EPA to consider a wide range of measures to reduce CO_2 emissions. In effect, the petitioners assert that the approach utilized in the CPP was authorized, and therefore not unlawful as claimed. As such, EPA could only rescind the CPP if it provided a different reasoned explanation for the change. Asserting that the ACE rule would not reduce pollution and might actually increase it over time, the petitioners argued that the final rule rescission of the CPP should be set aside as unlawful and arbitrary and capricious because it failed to satisfy EPA's obligations under the Act. The case is currently pending before the United States District Court for the District of Columbia.

316 WMO, WMO Statement on the State of the Global Climate in 2019, at 3 (2020), https://library.wmo.int/doc_num.php?explnum_id=10211.

slightly better. Greenhouse gas emissions fell by 2.1 percent in 2019, after a sharp increase in 2018, primarily due to a decrease in coal consumption.[317] As coal use has declined, natural gas use has soared, and fossil fuels still produce approximately eighty percent of the nation's energy.[318] In addition to rolling back the CPP, the Trump Administration took steps to reduce vehicle emission standards. Obama-era Corporate Average Fuel Economy (CAFE) standards designed to increase average car fuel efficiency by 5 percent annually have been replaced with the Safer Affordable Fuel-Efficient Vehicles rule that seeks to increase average fuel efficiency by only 1.5 percent annually.[319] Relative to the CAFE standards, these weakened fuel efficiency standards will result in only a slight decrease in the overall demand for fuels[320] and, consequently, will result in fewer decreases in greenhouse gas emissions than would be expected under the original standards. The Trump Administration also plans to revoke California's ability to set its own more stringent fuel economy standards, which have been adopted by thirteen other states.[321] According to one study, this single change could increase oil consumption and significantly set back efforts to reduce greenhouse gas emissions.[322]

While it is yet unclear how the court will evaluate EPA's repeal of the CPP, it is clear that actions taken by the Trump Administration have impeded progress toward reducing harmful greenhouse

[317] *See* Trevor Houser & Hannah Pitt, *Preliminary US Emissions Estimates for 2019*, RHODIUM GRP., (Jan. 7, 2020), https://rhg.com/research/preliminary-us-emissions-2019/.

[318] *See* Drew DeSilver, *Renewable Energy Is Growing Fast in the U.S., But Fossil Fuels Still Dominate*, PEW RSCH. CTR. (Jan. 15, 2020), https://www.pewresearch.org/fact-tank/2020/01/15/renewable-energy-is-growing-fast-in-the-u-s-but-fossil-fuels-still-dominate/.

[319] 85 Fed. Reg. 24174, 24175 (Apr. 30, 2020). *See generally* Hannah Pitt and Maggie Young, *A Step Closer to a Rollback of Fuel Economy Standards*, RHODIUM GRP. (Feb. 13, 2020), https://rhg.com/research/fuel-economy-1-5/ (discussing the changes to the CAFE standards under the new rule).

[320] *See id.*

[321] *See id.*

[322] *See* Emily Wimberger and Hannah Pitt, *Come and Take It: Revoking the California Waiver*, RHODIUM GRP. (Oct. 28, 2019), https://rhg.com/research/come-and-take-it-revoking-the-california-waiver/ (finding that rolling back Obama-era rules could also boost GHGs by more than a gigaton from 2020 to 2035, and impact California's ability to meet air quality and climate targets and the United States' ability to stay within striking distance of GHG reductions needed to limit global temperature rise below 1.5 degrees Celsius).

gasses. As such, additional action to reduce climate change-causing emissions is warranted to protect vulnerable coastal systems and to reduce the rising risks posed by HABs.[323]

2. Establish More Protective Standards for NO_x Emissions

EPA has recognized that NO_x emissions are harmful to human health and the environment, and EPA has long acknowledged that nitrogen deposition is harmful to coastal ecosystems and plays a key role in increased phytoplankton and algal productivity, which leads to eutrophication.[324] The agency has also acknowledged that secondary standards for NO_x fail to protect marine systems from harm.[325] Given the known impacts of nutrient loading to coastal systems, and the emerging evidence of how nutrient loading works synergistically with other marine stressors—such as decreasing ocean pH, warming, and others factors—to augment the impact of HABs in coastal systems,[326] EPA should create more protective secondary NAAQS for NO_x. EPA can no longer reasonably claim that it has insufficient data support for this regulatory change.[327]

B. *Establish TMDLs for CO_2 and NO_x in Coastal Communities*

By finalizing the ACE rule and taking action to replace fuel efficiency standards, the Trump Administration has signaled a clear reluctance to impose meaningful federal standards that will significantly reduce emissions of greenhouse gases, which would limit future HAB formation. At the same time, EPA has not improved NO_x standards since 1970. Given this reality, coastal states must take a more active role in protecting imperiled coastal systems, using their

323 President-elect Joe Biden has pledged to make climate action a priority of his administration, but without Democratic control of the Senate, he will likely encounter significant resistance to imposing sweeping changes to address climate change.

324 *See* 77 Fed. Reg. 20,218, 20,228 (Apr. 3, 2012).

325 *Id.*

326 EPA should also evaluate current standards for SO_2 in view of CO_2- related ocean acidification, because SO_2 deposition can exacerbate acidification in coastal waters. *See Understanding the Science of Ocean and Coastal Acidification*, EPA, https://www.epa.gov/ocean-acidification/understanding-science-ocean-and-coastal-acidification (last updated Aug. 23, 2019).

327 U.S. GOV'T ACCOUNTABILITY OFF., *supra* note 244 (indicating that EPA claimed there was insufficient data to create more protective secondary standards for NO_x); *see also* CBD, *supra* note 252 (suing EPA for failure to promulgate NOx standard based on lack of scientific support for the standard).

own regulatory powers. Developing state or regional TMDLs for CO_2 and NO_x is a promising option for states to limit emissions. Each should be modeled after the regional TMDL for mercury in the Northeast and the regional TMDL for NO_x in the Chesapeake Bay region.

Atmospheric deposition of harmful nutrients and gases into coastal systems has increased substantially with the advent of the industrial age and intensive agriculture.[328] With approximately 37 percent of the world's population living within a hundred kilometers of the coast, at a population density twice the global average, land-based and airborne pollution should be expected to climb.[329] The transfer of nutrients and gases from the atmosphere to the ocean has long-term impacts on coastal and estuarine systems, particularly through HAB formation.[330] Because CO_2 and NO_x gases largely result from combustion-related emissions and travel varying distances prior to deposition, local and regional emission sources can be identified and subjected to additional regulation, as needed to meet the requirements of an established TMDL. For example, under the Northeast Regional Mercury TMDL covering Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont, stringent emission limitations have been imposed on sources of mercury, including coal-fired utilities, municipal waste combustors, and medical waste incinerators.[331] Coastal states seeking to control the impacts of CO_2 and NO_x on marine systems could benefit from taking a similar approach by placing additional emission limitations on identified sources of each pollutant.

Because atmospheric pollutants originate both in-state and out-of-state, controlling emissions requires coordinated effort on both a state and regional level. Fortunately, Section 319 of the CWA provides a mechanism to develop regional agreements to address sources of pollution.[332] Section 319(g) permits a state to petition the EPA Administrator to convene an interstate management conference if, as a result of nonpoint pollution entering from another state,

[328] *See* Duce et al., *supra* note 167, at 61-66.

[329] *See Coastal Zone Management*, UN ENV'T PROGRAMME, https://www.unenvironment.org/explore-topics/oceans-seas/what-we-do/working-regional-seas/coastal-zone-management (last visited Oct. 30, 2020).

[330] *See* Duce et al., *supra* note 167.

[331] *See* Fact Sheet, *supra* note 277.

[332] S*ee* 33 U.S.C. § 1329(g)(1).

the petitioning state is unable to meet its water quality standards.[333]All states identified as significant sources of pollution to the identified body of water must attend the conference.[334] The purpose of the conference is to develop an agreement among states to reduce the level of pollution and improve the petitioning state's federally approved water quality standards.[335] EPA has already established guidelines for states seeking to develop TMDLs for bodies of water impaired by pollutants,[336] so states impacted by HABs should utilize this tool to address the underlying causes of HABs in coastal systems.

Northeastern states have successfully used TMDLs to mitigate mercury deposition from air emissions.[337] Coastal states should follow suit and promulgate regional TMDL programs specifically for CO_2 and NO_x inputs to imperiled coastal waters. By using a TMDL approach, coastal states could reduce emissions of these harmful gases and address the key underlying human factors that contribute to HABs.

C. *Adopt Sustainable Food Production Methods to Reduce Nutrient Loading of Coastal Systems*

Industrialized agriculture is a significant cause of water pollution throughout the United States.[338] Yet most agricultural activities that contribute to water pollution are not subject to regulation under federal environmental laws. The CWA specifically exempts agricultural stormwater discharges and return flows from irrigated agriculture from the definition of point sources.[339] Thus, fertilizers, pesticides, and other chemicals that run off farmland and into waterbodies are considered nonpoint sources of pollution and are

333 *See id.*

334 *See id.*

335 *See id.*

336 *See* EPA, NEW TOOLS FOR MERCURY TMDL SUPPORT – BASIC PROJECT INFORMATION (2008), https://www.epa.gov/sites/production/files/2015-07/documents/document_mercury_tmdl_elements.pdf.

337 *See* NEIWPCC ET AL., NORTHEAST REGIONAL MERCURY TOTAL MAXIMUM DAILY LOAD (2007), http://click.neiwpcc.org/mercury/mercury-docs/FINAL%20Northeast%20Regional%20Mercury%20TMDL.pdf.

338 USGS, *Agricultural Contaminants*, https://www.usgs.gov/mission-areas/water-resources/science/agricultural-contaminants?qt-science_center_objects=0#qt-science_center_objects.

339 *Id.*

not subject to direct regulation under the CWA.[340] Additionally, the CWA exempts certain agricultural practices that discharge dredge or fill materials into wetlands, streams, rivers, and other waters of the United States from permitting.[341] These exemptions degrade coastal systems and facilitate HAB development.

Agroecology represents a promising, sustainable alternative to producing sufficient food to meet global needs, by reducing mineral fertilizer use—which is associated with HAB formation—and instead increasing nutrient and energy cycling and increasing the retentive abilities of the soil for nutrients and water.[342] Agroecology practices encourage intercropping—the practice of growing multiple crops on the same plot—which enhances the provisioning of ecosystem services while increasing productivity and resource use efficiencies.[343] Through the careful combination of "annual and perennial crops, livestock and aquatic animals, trees, soils, water and other components on farms and agricultural landscapes," agroecology enhances biodiversity, improves resource-use efficiency and resilience, and exploits natural synergies in ways that respond to a changing climate.[344] Agroecology practices reduce the use of fertilizers and other harmful chemicals by enhancing biological processes and recycling biomass, nutrients, and water.[345] These and other beneficial practices can be used to meet the world's growing food demands while also reducing the harmful impacts that contribute to climate change and harm coastal systems.

EPA has acknowledged that practices that improve nutrient management in agriculture operations are important ways to limit

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340 33 U.S.C. § 1362.

341 *Id.* § 1344.

342 *See* Harvey, *supra* note 96. The term agroecology is commonly defined as the application of ecological principles to agriculture. It references an approach that is intended to promote the ecological sustainability of agricultural systems. *See, e.g.*, *Agroecology Definitions*, FAO, http://www.fao.org/agroecology/knowledge/definitions/en/ (last visited Dec. 22, 2020).

343 *See* FAO, THE 10 ELEMENTS OF AGROECOLOGY: GUIDING THE TRANSITION TO SUSTAINABLE FOOD AND AGRICULTURAL SYSTEMS 43 (2018), http://www.fao.org/3/i9037en/i9037en.pdf. Provisioning services of an ecosystem including the material benefits humans receive from the ecosystem, such as water, food, wood, and other goods. *See, e.g.*, FAO, Ecosystem Services & Biodiversity (ESB)-Provisioning Services, http://www.fao.org/ecosystem-services-biodiversity/background/provisioning-services/en/

344 *Id.* at 5.

345 *See id.*

nutrient loss to the environment.[346] The agency has also recognized that agricultural soil management represents the largest source of nitrous oxide emissions in the United States, accounting for approximately 78 percent of total U.S. NO_x emissions.[347] Yet, EPA has largely declined to use its authority under the CWA or CAA to regulate harmful agricultural practices.[348] Congress could take a significant step forward to encourage agroecology practices by eliminating the agricultural exemptions under the CWA and by applying the CAA to farming activities. Doing so would encourage sustainable soil management while reducing the quantity of nutrient runoff to coastal waters that facilitates HAB development. However, given the long history of insulating agricultural activities from CWA regulation, it seems unlikely that Congress will take action to require additional regulation in the foreseeable future.[349] Given the clear link between agriculture and water pollution, the emerging threats to agriculture posed by climate change, and the massive amount of freshwater consumed by industrial agricultural practices, there is a clear need to shift to a more sustainable form of agriculture. A key benefit of agroecology is the ability to "mimic natural ecosystems, creating tightly coupled cycles of energy, water, and nutrients."[350]

With appropriate investments in technology, training, and education, it is possible to transition away from harmful industrial farming to a more sustainable food and agricultural system that has significant co-benefits for efforts to address climate change. Taking this approach would also provide meaningful co-benefits that promote global fisheries, by both improving water quality and reducing the impact HABs have on fish larvae. Making the switch will

[346] *See Nutrient Pollution, The Sources and Solutions: Agriculture*, EPA, https://www.epa.gov/nutrientpollution/sources-and-solutions-agriculture (last visited Oct. 30, 2020).

[347] *See Overview of Greenhouse Gases*, EPA, https://www.epa.gov/ghgemissions/overview-greenhouse-gases#nitrous-oxide (last visited Oct. 30, 2020).

[348] *See* Peter Lehner & Nathan A. Rosenberg, *Legal Pathways to Carbon Neutral Agriculture,* 47 ENV'T L. REP. 10845, 10858 (2017) (noting that "the federal government has largely declined to regulate agriculture's negative externalities").

[349] *See id.* at 10858 (recognizing that the agricultural industry enjoys added protection from environmental regulation as a result of a cabinet position and an agency charged with ensuring the sector's financial well-being).

[350] Liz Carlisle et.al., *Transitioning to Sustainable Agriculture Requires Growing and Sustaining an Ecologically Skilled Workforce*, FRONTIERS IN SUSTAINABLE FOOD SYS. (Nov. 1, 2019), https://www.frontiersin.org/articles/10.3389/fsufs.2019.00096/full.

require, among other things, a commitment to training and retaining a large agroecologically skilled workforce, action to reduce initial barriers of entry to farming, and capital investment to allow farmers to adopt more sustainable practices.[351] Although a transition to agroecology practices would require an enormous initial commitment of money and other resources, the commitment is warranted in the face of climate change and the declines observed in natural systems through pollution.[352] In time, the costs of such transformative change would likely be justified because there would be less pollution entering the environment, greater conservation of freshwater resources, increased crop diversity, and greater overall resilience to many of the anticipated impacts of climate change.[353] Integrating agriculture, climate, and clean energy legislation makes sense and has already been recognized by policymakers as a viable path forward;[354] it should be pursued. Such action will have many benefits, including the benefit of reducing nutrient flow into waterbodies that can cause HABs.

CONCLUSION

Harmful algal blooms represent a significant and growing global threat to marine environments, human health, and coastal economies. Climate change and its associated impacts of ocean warming, acidification, and altered hydrolytic cycles are effecting fundamental changes in marine environments that are conducive to HAB formation, toxicity, and geographic expansion. Absent additional action to curb greenhouse gas emissions, the likelihood of severe, pervasive, and irreversible impacts for people and ecosystems will increase.[355] The United States should take immediate action to reduce greenhouse gas emissions. In the absence of federal policies to limit harmful greenhouse gases that contribute to the

351 *See id.*

352 *See id.*

353 *See id.* (noting that, in time, input costs and production risk of switching to agroecology would decrease, carbon sequestration potential and drought resilience would increase, climate-related risks associated with monoculture crops would decrease, and farmers would obtain more flexibility for adapting to climate change and market fluctuations).

354 *See id.*

355 *See* IPCC, CLIMATE CHANGE 2014 SYNTHESIS REPORT SUMMARY FOR POLICYMAKERS 8 (2014), https://www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_SPM.pdf.

development of HABs, states should take a more active role in controlling land-based and atmospheric deposition of harmful chemicals into the marine environment by developing local and regional TMDLs for impaired waterbodies and by adopting more ecologically sustainable agricultural practices.