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My background

For the last thirty years I have devoted my life to the study of the oceans. For twenty-six of those years I was a college professor who ran my own laboratory focused on the study of nutrients and how they control the growth of phytoplankton and bacteria at the base of the ocean food web. I have participated in over 50 research expeditions from the Arctic to the Antarctic. Over the last decade, I have also taken what I learned in the ocean, and applied it to help water reclamation facilities.

Throughout my career I have been committed to service – to science and this country. I was a member of the Ocean Carbon and Biogeochemistry Scientific Steering Committee and the U.S. Carbon Cycle Science Plan Working Group, and have served on numerous review committees for tenure and promotion, research funding, and programs, including as chair of the institutional review of the Woods Hole Oceanographic Institution. I was elected member-at-large and then president of the Association for the Sciences of Limnology and Oceanography, the largest international scientific society dedicated to the aquatic sciences. I have also served as member-at-large, treasurer and chair of the Council of Scientific Society Presidents, an organization that represents over a million scientists in the U.S. across all scientific disciplines. From 2012 to 2015, I served at the National Science Foundation as section head and then director of the Division of Ocean Sciences where I was responsible for programs across all ocean disciplines as well as major oceanographic facilities including NSF use of the U.S. research fleet, ocean observing, and the ocean drilling program. It is an honor to continue that service by providing testimony to this committee. I offer these thoughts as a citizen based on my experience as a scientist, an educator, and a mother.

I also note that I am a middle child; we tend to be the peacekeepers. I was raised by very conservative parents that I respected and adored and I have spent my life working with many very liberal individuals who are like a second family. This means I have spent my entire life trying to look at both sides of what can be very contentious issues. When it comes to the ocean there are many.

Earth's climate is changing and human activities are responsible. As a scientist, I have been trained to be skeptical, to dig deep and to look for holes in every argument. I admit it took me longer than most of my colleagues to fully acknowledge the truth our changing climate and then only after mounting evidence across many scientific disciplines was irrefutable.

My work has taken me to the world's most remote areas and humanity's fingerprints are everywhere – on land and in the ocean. One need only look at the nighttime composite photos of the Earth from space to see how dramatically we have changed the face of this planet. From this vantage point, that we have altered our climate should come as no surprise.

There is an abundance of scientific literature documenting changes to our climate and oceans and I will not do it justice here. In the time and space allowed I have tried to provide a brief tutorial of the basics that I would want all of our elected officials to know. I direct interested readers to the many excellent summary documents prepared through the National Climate Assessments, the State of the Carbon Cycle Reports, and the many products developed through the Intergovernmental Panel on Climate Change (IPCC).

Why the climate is changing

Life exists on Earth because the planet has a blanket of atmospheric gases, including water vapor, carbon dioxide, and methane, that acts like the glass of a greenhouse and retains some of the energy from incoming solar radiation. Over the past 100 years, mankind has taken carbon buried deep within the ground as fossil fuels, and burned it to power the incredible technological advances started during the Industrial Revolution. The result raised the standard of living for billions of people around the globe. It also increased the concentration of these greenhouse gases in our atmosphere resulting in an average increase in global temperature from 1901 to 2016 of ~1.0°C (1.8°F; Hayhoe et al. 2018).

This massive alteration of Earth's atmosphere has had a profound impact on our oceans, which have absorbed more than a quarter of the carbon dioxide released. Here I highlight two direct effects this increase in greenhouse gas concentrations have had on our oceans – they are now warmer and the pH of the water has declined, making the ocean more acidic.

A. Ocean Warming

Every year, humans release about 10 gigatons (36 billion tons) of carbon into the atmosphere from burning fossil fuels and other activities (Le Quéré et al. 2018). In 2016, atmospheric levels of carbon dioxide passed 400 ppm, a striking milestone and a dramatic increase from pre-Industrial levels of 280 ppm. This huge surge in the levels of carbon and other greenhouse gases blanketing the atmosphere traps excess heat in the Earth's climate system.

The oceans have absorbed 93 percent of this excess heat and store it for two main reasons. First, water has the highest specific heat capacity of any common material, meaning that it can absorb a great deal of heat before its temperature actually increases. Second, the global ocean is vast, covering 71 percent of the Earth's surface with an average depth of 4 kilometers (12,123 feet). This incredible volume makes it a huge reservoir for heat that is continuously distributed by currents and other circulation processes.

The highest degree of warming has taken place in the upper 75 meters (246 feet), as this upper layer lies closest to the warming atmosphere. Average global temperatures in the surface ocean have increased by 0.7 ± 0.08 °C (1.3° ± 0.1°F) per century between 1900 and 2016 (Jewett and Romanou 2017). The upper ocean also mixes vigorously, distributing the heat it absorbs. As more energy enters Earth's climate system, heat penetrates deeper into the ocean. Warming at the poles is especially impactful because these are the sites of deep ocean water formation. The combination of ice formation and extreme cold makes the waters in the North Atlantic dense relative to surrounding waters. These dense waters sink carrying heat to the ocean's interior.

Most of the remaining 7 percent of this heat goes into melting sea ice, glaciers, ice caps, and warming the continent's land mass. Only a tiny fraction goes into warming the atmosphere, but even that is felt in rising global temperatures. The six warmest years on record have all occurred since 2010 (NOAA State of the Climate Report 2019). While there is much debate over the record of increasing air temperatures, the ocean does not have parking lots or heat island effects and yet still we see significant increases in temperature.

The complex interactions between continued greenhouse gas emissions, the resulting energy imbalance, and changes in ocean heat storage and transport will largely control the impacts of anthropogenic climate change. I focus on five critical impacts here – melting of sea ice, sea level rise and coastal flooding, changes in the distribution and migration of marine organisms, the decline of coral reefs and deoxygenation of the ocean.

1. Melting of sea ice

The Arctic Ocean is important to the world's ecology, climate, and economy. Due to the shape of the planet, more incoming solar radiation concentrates at the equator than at the poles. The atmosphere and ocean currents address this energy imbalance by transporting heat away from the equator. This process has driven annual average temperatures in the Arctic to increase more than twice as fast as the global average, resulting in substantial loss of sea ice and glacial mass. Climate models using the IPCC "business as usual" scenario predict average Arctic temperatures will increase 7°C (45°F) by the year 2100.

Since 1979, the annual average extent of Arctic sea ice has decreased 3.5 to 4.1 percent per decade, including an 80 percent loss in summer sea ice volume (Comiso and Hall 2014; Vaughan et al. 2013). The melting of sea ice now starts 15 days earlier than it did in the past, and it is predicted that the Arctic will be nearly free of late-summer sea ice by the middle of this century (Taylor et al. 2017). Diminishing sea ice also further amplifies Arctic warming, because blue water will absorb more energy than white ice, thus creating a positive feedback loop between warming and continued ice loss.

The lack of summer Arctic sea ice is increasing seaside erosion, undercutting villages, and washing away infrastructure. Alaskans are being forced to change their hunting strategies and even the locations of whole communities. From 2010 to 2017, I made seven trips to Barrow, Alaska, the northern most village in the U.S. In that short time, the changes to the region and community have been profound including the impending destruction of the main road from Barrow to Point Barrow due to erosion from the sea.

The effect of sea ice loss is profound because it is a key part of polar ecosystems. Large blooms of algae occur at the ice edge and form the base of the Arctic Ocean food web (Arrigo 2014). As ice coverage declines, the timing and location of the ice edge blooms change, as does critical habitat for more than a thousand species, including polar bears, seabirds, and seals. Many organisms hunt, give birth, migrate and shelter on ice, and the loss of ice is causing declines in a number of species (Laidre et al. 2015). As one example, walruses are moving farther from shore as the sea ice extent shrinks, and hunters from native Arctic communities that rely on them must now travel further across open water, threatening both people's safety and traditional ways of life.

Shrinking ice cover is also making the Arctic more accessible to shipping, with access by various countries and commercial entities. This brings both new opportunities and risks. The challenges that accompany greater access include protecting the border from new threats to national security, a heightened threat of oil spills and illegal fishing, and the need to update severely outdated nautical charts and put search and rescue plans in place.

2. Sea level rise and coastal flooding

Sea level is rising as a result of warming ocean temperatures and the melting of ice on land, such as glaciers and ice sheets. Warming water temperatures contribute to sea level rise because of thermal expansion – warm water takes up more volume than cooler water. Since 1900, average sea level has risen by about 16 to 21 cm (7 to 8 inches) globally with about a third of the increase due to thermal expansion. Even more alarming than the amount is that nearly half of this increase has occurred since 1993. Sea level continues to rise at a rate of about one-eighth of an inch per year (Hayhoe et al. 2018).

The ultimate magnitude of sea level rise will vary based on how land ice responds to continued warming. Predictions for the century between 2000 and 2100 vary from one to four feet of sea level increase, with extreme increases of over eight feet if the Antarctic ice sheets collapse. If the ice sheet on Greenland were to melt, sea level could increase by an incredible 21 feet. These scenarios are unlikely, but I note that past increases have been larger and occurred more rapidly than expected. As a nation, we need to prepare for the worst.

There will be many consequences of higher sea levels. Destructive and deadly storm surges will reach farther inland, bringing more frequent flooding with high tides. These floods are disruptive and expensive. Today, nuisance flooding is estimated to be from 300 percent to 900 percent more frequent within U.S. coastal communities than 50 years ago (Sweet et al. 2014).

As ocean and atmospheric warming trends persist, sea level rise over the next centuries will ramp up to rates significantly higher than what we see today. Nearly 40 percent of people in the United States live in high-population-density coastal areas, where they will be subject to the flooding, shoreline erosion, and hazardous storms that come with rising sea levels. These impacts will also be felt globally – eight of the 10 largest cities in the world are near a coast as are four of the 10 largest cities in the U.S.

Specific locations will experience sea level rise differently based on local factors, such as subsidence and rebounding from natural geological processes, changes in regional ocean currents, and withdrawal of groundwater and fossil fuels. Sea level rise has already increased the frequency of flooding at high tide by a factor of 5 to 10 since the 1960s for several U.S. coastal communities. The frequency and extent of tidal flooding are expected to continue to increase in the future and its anticipated that there will be more severe flooding associated with coastal storms, hurricanes and nor'easters (Sweet et al. 2014). The infrastructure essential for local and regional industries in urban environments will be threatened, including roads, bridges, oil and gas wells, and power plants.

3. Changes in the migration and distribution of marine organisms

Increases in water temperatures and its associated effects have caused alterations to global patterns of ocean and atmospheric circulation, precipitation, and nutrients. Collectively, these effects are having a drastic impact on the abundance, diversity, and distribution of marine organisms – from the smallest bacteria to the largest fish.

Most of the life in the ocean is microscopic. While we cannot see these microorganisms without a microscopic, they produce half of the oxygen we breathe and form the base of ocean food webs. As most are single-celled organisms that can only drift in the water column, these vital plankton are highly vulnerable to ocean changes.

Broadly speaking, the ocean has two parts – a warmer, less dense layer at the surface that receives sunlight but has low nutrients (because the microorganisms have taken them all up) and a deep layer that is denser and colder, with no light but lots of nutrients (because decomposing organisms sink and release nutrients as they decompose). Rapid warming of surface water is increasing the temperature difference between these layers, increasing the stratification of the ocean and preventing the surface and deep water from mixing efficiently. As a result, most phytoplankton have a harder time staying near the sunlight that they need to grow, and the greater stratification restricts the delivery of nutrients phytoplankton need from the deep ocean.

These changes to the base of the ocean food web reverberate through other marine species including the fishing sector, which contributes over $200 billion in economic activity each year and supports 1.6 million jobs (NOAA Fisheries 2017). The species this industry relies upon are changing as a result of warming waters. These shifts in species distributions are complicating fishery management by changing the nature of traditional fisheries and efforts to protect endangered species.

These shifts are especially prominent of the U.S. east coast. For example, surveys conducted by state and federal agencies have documented a number of shifts in distribution in fish, shellfish and other species along the mid-Atlantic with a trend toward poleward movement and/or movement to deeper cooler water (Lucey and Nye 2010). Recent research at Bigelow Laboratory shows that copepods (tiny crustacean that eat phytoplankton and are then eaten by higher organisms) are less viable if grown in warmer waters. Shrinking copepod populations will threaten numerous marine species that rely on them for nutrition, including the endangered North Atlantic right whale. As another example, surf clams, an important fishery in the Mid-Atlantic region, have migrated to deeper waters at the southern edge of their range, causing regulatory issues for this industry (Weinberg 2005).

I have provided a few examples of shifts in the distribution of organisms but I note that detecting and quantifying these changes are a challenge because each species within a community may response differently due to differences in their life history, where they live, and what they eat.

Organisms also vary with respect to the outside forces that affect them such as fishing, destruction of their habitat or pollution. Due to this complexity, detecting and understanding shifts in species and populations requires a commitment to long-term monitoring programs, which have historically been very difficult to maintain.

4. Coral reef decline

Coral reefs are the foundations of many tropical ecosystems. Temperature is a powerful controlling variable for the health and location of coral reefs, and many exist at or near their upper temperature limit (Schoepf et al. 2015). As a result, ocean warming has had a devastating effect on coral reefs around the world. When corals are exposed to waters even slightly above their temperature maximum, they can release the symbiotic algae, called zooxanthellae, that live within their tissues. This process is known as bleaching because of the stark white color it turns corals. The symbiotic algae provide vital nutrients to the coral, and so bleaching often kills them.

During the last 30 years, there have been several global-scale coral bleaching events (in 1987, 1998, 2005, and 2015–2016) that have resulted in a dramatic reduction of live coral. This puts the entire community of plants and animals that rely on the reefs in jeopardy. In the United States, mass bleaching events and outbreaks of coral diseases have occurred in the waters off Florida, Hawaii, Puerto Rico, the U.S. Virgin Islands, and the U.S.-Affiliated Pacific Islands (Miller et al. 2009; Rogers and Muller 2012).

In addition to the direct physiological stress of elevated temperatures, ocean warming also increases the incidence of coral disease, and ocean acidification affects the ability of corals to produce their calcium carbonate structures (discussed further in section B below). When these effects compromise reef-building corals, the entire reef ecosystem becomes threatened (Jones et al. 2004). This includes a vast number of invertebrates and fish, organisms that many coastal communities depend on for subsistence. Corals also provide storm protection to coastal ecosystems and can form the basis of local or regional tourism economies (Prachett et al. 2008).

5. Low oxygen

Oxygen makes up 21 percent of the air we breathe and supports life on Earth, and half of this oxygen was produced by phytoplankton in the ocean. In water, oxygen exists in a dissolved form and acts as a limiting resource that controls the growth of many marine species. One consequence of climate change is the loss of oxygen from the oceans, known as ocean deoxygenation.

Levels of oxygen in the ocean depend on a balance between oxygen production through phytoplankton photosynthesis, depletion through respiration by animals, and physical mixing processes. Climate change is shifting this balance in several ways. At the most fundamental level, warmer water holds less oxygen than cold. As the oceans warm, they lose their ability to physically hold oxygen.

In addition, the surface ocean is warming fastest due to its proximity to the atmosphere. This makes the surface water less dense and less able to mix with the colder, denser water below, limiting the distribution of oxygen. At the same time, global ocean circulation patterns are shifting with climate change. Slower circulation and more upwelling of oxygen-poor deep water are further decreasing oxygen levels in the ocean.

Long-term monitoring efforts reveal that oxygen concentrations have declined during the 20th century, and the IPCC 5th Assessment Report predicts that they will decrease 3-6 percent during the 21st century due to ocean surface warming. In coastal regions, low oxygen is a particularly devastating problem and dead zones where most organisms cannot live because of insufficient oxygen have been reported for more than 479 systems and their numbers have doubled every decade since the 1960s (Diaz and Rosenberg 2008).

This decline will be particularly impactful in hypoxic and suboxic areas of the ocean where oxygen is already in low concentrations. In hypoxic areas, oxygen is so low that it is detrimental to most organisms. In suboxic areas, oxygen levels are so low that most life cannot be sustained and water chemistry is severely altered. Oxygen minimum zones are severely oxygen-depleted waters that underlie productive surface waters and comprise eight percent of the global ocean (Paulmier and Ruiz-Pino 2009). These zones are expanding through the globe's tropical ocean basins and the subarctic Pacific Ocean, compressing the habitat available to marine species around the globe. A mere 1°C warming in the upper ocean, less than predicted by even optimistic warming scenarios, will increase hypoxic areas by 10 percent and triple suboxic areas (Deutsch et al 2011).

Changes to biological processes are also contributing to this issue. Warmer water temperatures increase oxygen demand from organisms, leading to the faster depletion of available oxygen and threats to a vast range of species, including those that comprise valuable fisheries. For example, off the coast of California, waters between 200 and 300 meters have lost 20-30 percent of their oxygen in the last 25 years (Bograd et al. 2008), threatening important fisheries. In the tropical Atlantic Ocean, the vertical habitat of tuna and blue marlin reduced by 15 percent between 1960 and 2010 due to expanding oxygen minimum zones (Stramma et al. 2012; Schmitko et al. 2017).

B. Ocean Acidification

In addition to warming, excess carbon dioxide in the atmosphere has a direct and independent effect on the chemistry of the ocean. Ocean acidification is the process of carbon dioxide being absorbed by the oceans and causing significant changes to seawater chemistry. Global chemical processes keep gasses in the ocean and the atmosphere in equilibrium. While humans have drastically increased the amount of carbon dioxide in the atmosphere, the ocean has been working to keep up. About a quarter of the carbon dioxide we generate through industrial activity ends up in the ocean, and the resulting change in chemistry has caused the surface ocean to become 30 percent more acidic. This has occurred at a rate at least 10 times faster than any natural acidification event in the past, and affects everything from chemical processes to sea life.

When carbon dioxide in the atmosphere dissolves in seawater, it changes three aspects of ocean chemistry. First, it increases levels of dissolved carbon dioxide and bicarbonate ions, which are the fuel for photosynthesis in phytoplankton and plants. Second, it increases the concentration of free hydrogen ions, which makes the water more acidic. Third, it reduces the concentration of carbonate ions. Carbonate is critical to many marine organisms, which use the mineral calcium carbonate to form their shells or skeletons. For some species, rising temperatures and decreasing oxygen levels in the ocean may exacerbate the effects of ocean acidification.

The cold temperature of high latitude ecosystems results in great carbon dioxide solubility making polar regions highly vulnerable to ocean acidification. Sea ice loss is causing Arctic waters to acidify faster than expected. Further, acidification along the United States coast is greater than the global average for a number of reasons, including the natural upwelling of acidic waters off the Pacific Northwest and California coasts, changes to freshwater inputs in the Gulf of Maine, and anthropogenic nutrient input into urban estuaries. Here I'll focus on two major consequences of ocean acidification – changes to the ocean carbon cycle and the impact on organisms and the industries built around them including fisheries and aquaculture

1. Changes to the ocean carbon cycle

Carbon is recycled and reused through biological and physical ocean processes including photosynthesis, respiration by animals, and mixing. The carbon cycle drives important biogeochemical processes that shape the character of the global ocean and planet as a whole. When organisms die, they sink, bringing the carbon that composes their bodies into the deep ocean. This is referred to as the biological pump because it pumps carbon from the surface to the deep ocean and can sequester carbon away for hundreds of years. The oceans are by far the largest carbon sink, or storage reservoir, in the world.

The combined effect of ocean warming and acidification lowers the ability of the ocean to take up additional carbon dioxide in three general ways. First, as noted above, warmer water can simply hold less gas than colder water. Second, the warmer water in the surface ocean becomes, the more stratified the water column will be. Greater stratification reduces mixing and so reduces the ability for carbon dioxide dissolved in surface water to be mixed into deeper waters. Third, it is generally harder for organisms to build shells out of calcium carbonate in more acidic waters. This means that phytoplankton that build shells (such as coccolithophores), and are therefore heavier and so sink faster, are at a disadvantage. As the ocean continues to acidify, any selection away from organisms that build shells and towards organisms that do not, will likely weaken the biological pump and decrease the transport of carbon into the deep ocean as phytoplankton die. These effects are already being seen and the oceans are becoming less able to absorb carbon dioxide (e.g. Khatiwala et al. 2016).

2. Threats to organisms, including fisheries and aquaculture

The impacts of ocean acidification are diverse. Although certain species are favored by more acidic waters, ocean acidification appears to negatively impact more marine species than it helps. Organisms that use carbonate minerals to build skeletons or shells struggle with this basic function in more acidic waters. Organisms like clams, mussels, and phytoplankton that use calcium carbonate to build shells and other structures are important in environments and economies around the globe. Under the IPCC low emissions scenario, seven to 12 percent of calcifying species would be significantly affected by lowering pH, and 21 to 32 percent of calcifying species would be impacted under the high emissions scenario (Azevedo et al. 2015).

Ocean acidification also appears to favor some toxic phytoplankton species that form harmful algal blooms, allowing them to become more abundant in changing ecosystems. Including freshwater and marine ecosystems, harmful algal blooms are a significant environmental problem in all 50 states (EPA).

Entire coral reef ecosystems are also severely threatened by ocean acidification. Corals depend on calcium carbonate to build their exoskeletons, and acidification impedes this process. The acidic water also literally dissolves coral structures, and the bulk of a coral reef itself. Many reefs around the world are dissolving faster than they can build themselves back up. In addition to forming the foundations of ecosystems, corals also provide storm protection to coastal ecosystems and can form the basis of local or regional tourism economies. By the end of this century, the loss in recreation from coral reefs in U.S. is expected to reach $140 billion (Pershing et al. 2018).

Some of the animals at risk from acidification also comprise lucrative fisheries in the U.S., like lobsters in the Northeast and squid in California. These animals are physically compromised by acidification, and they may find it harder to get the food they need in acidifying oceans. Acidification impairs the senses of some fish and invertebrates, causing them to misinterpret cues from predators and engage in risky behaviors, like swimming far from home. Damage to key phytoplankton and zooplankton species can reverberate through entire food webs, affecting the fisheries that they support.

The U.S. aquaculture industry is already shifting in response to ocean acidification. Larval shellfish cannot build shells under high acidity, and high mortality rates have afflicted the Pacific Northwest's $270 million shellfish industry since 2005. The poor conditions have prompted some shellfish aquaculture facilities to relocate. In Maine, some shellfish farmers are also growing kelp in an effort to improve local water quality and the health of their stocks.

Concluding thoughts

Climate change is bringing societal disruption on a global scale. As with any disruption, there will be winners and losers. Our challenge as a nation moving forward is to reduce the risks of climate change while capitalizing on its benefits, and I believe there will be plenty of both. The nation who will own the future will be the one that *invests* in the science of climate change so that decisions are based on sound data, that educates its citizen on ways to *mitigate* its effects, and that *adapts* to the new reality we all face. Here I will focus on the investments needed in the science.

The ultimate cause of climate change is the burning of fossil fuels and the resulting release of greenhouse gases. There has been much talk about reducing greenhouse gas emissions and as a nation we need to make this a priority. At Bigelow we occupy a Platinum LEED certified laboratory building that is cost effective to run and have a residence powered by a solar array. Supporting programs to advance the science and reduce the cost of green technology is critical to our country's future. I believe it is too late, however, to rely solely on this approach to mitigate severe climate disruption. The carbon ship has left the dock and humanity has shown little commitment to taking it back into port.

There is no doubt in my mind that to limit the effects of climate change, humanity will geoengineer the planet. This could take many forms including seeding the atmosphere with reflective particles, ocean fertilization, or large-scale industrial carbon sequestration. I do not advocate for this approach but fear that we will quickly reach a point where it will seem inevitable. When that time comes, and I fear it will come soon, we need the scientific data to maximize the chance of success and limit the many risk. We will also need an international regulatory and ethical framework to protect the humanity it seeks to serve.

With respect to the science, we need to dramatically increase our investments in understanding our own planet if we are to succeed. The National Science Foundation (NSF) is the federal agency that supports basic research across all science and engineering disciplines. I believe NSF is our secret sauce and the reason the US has been a leader in science and technology on this planet. This foundational research supports the many other mission agencies that address ocean issues, the National Oceanographic and Atmospheric Administration and National Aeronautics and Space Administration being two of the most important. As director of the Division of Ocean Science at NSF, I managed a budget of $356M and was responsible for basic research across all scientific disciplines. This is a lot of money until one considers that it is only about a dollar per person in this this country. Considering the importance of understanding how the ocean works and the rapid changes we see in the world, it is not nearly enough. This country must increase its investments in basic and applied research at the federal, state, and local level if it is to efficiently understand and mitigate the problems we are facing and it needs to do it now.

Climate change is a global issue and its root causes will only be addressed through international cooperation. Just as it took an international effort to synthesize and build scientific consensus around climate change through the IPCC, so will it take an international effort to regulate and control geoengineering with all of its many risks. Any regulations will need to be built on a foundation of an ethical framework. As the recent birth of two babies born with edited genomes has shown, there are real dangers when scientific capabilities get ahead of established standards for its ethical use.

In conclusion, despite the doom and gloom of the proceeding pages, I am optimistic about our future. We live in a time of rapid scientific advancement where each of us is able to access much of the collective knowledge of humanity on our cellphone. That so many scientists around the world, a group of people trained to be skeptical, hypercritical, and, dare I say, argumentative, have found a way to reach consensus and to speak with one voice on climate change is another reason to hope. Through my work at the Bigelow Laboratory for Ocean Sciences, I interact daily with brilliant scientists that are thinking outside of the box, students committed to changing the world, people of wealth who are stepping in to support innovation, and my fellow citizens who care enough to show up for talks, beach clean ups, and recycling events. The will is there and we will find the solutions we need but the time to act is now. As I have said many times – I believe in science, I believe in this county and I believe in good old-fashioned American ingenuity.

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