

**NOAA'S BLUE ECONOMY INITIATIVE:
SUPPORTING COMMERCE IN AMERICAN OCEANS
AND GREAT LAKES**

HEARING

BEFORE THE

SUBCOMMITTEE ON OCEANS, ATMOSPHERE,
FISHERIES, AND COAST GUARD

OF THE

COMMITTEE ON COMMERCE,
SCIENCE, AND TRANSPORTATION

UNITED STATES SENATE

ONE HUNDRED FIFTEENTH CONGRESS

SECOND SESSION

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JULY 24, 2018
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Printed for the use of the Committee on Commerce, Science, and Transportation



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

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U.S. GOVERNMENT PUBLISHING OFFICE

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED FIFTEENTH CONGRESS

SECOND SESSION

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**NOAA'S BLUE ECONOMY INITIATIVE:
SUPPORTING COMMERCE IN AMERICAN
OCEANS AND GREAT LAKES**

TUESDAY, JULY 24, 2018

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

The Subcommittee met, pursuant to notice, at 10:03 a.m., in room SR-253, Russell Senate Office Building, Hon. Dan Sullivan, Chairman of the Subcommittee, presiding.

Present: Senators Sullivan [presiding], Wicker, Gardner, Young, Baldwin, Nelson, Cantwell, Blumenthal, Schatz, Markey, and Peters.

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

Senator SULLIVAN. Good morning. The Commerce, Science, Transportation Subcommittee on Oceans, Atmospheres, Fisheries, and the Coast Guard will come to order.

Today, we are here to discuss the National Ocean and Atmospheric Administration, or NOAA's, Blue Economy Initiative. And I want to thank Admiral Gallaudet, the Acting Administrator and Assistant Secretary for NOAA, for being here.

This initiative is focused on increasing the economic contribution of the United States Exclusive Economic Zone and Great Lakes over the next decade, or, in other words, the economy related to our oceans and the Great Lakes. The U.S. EEZ extends out 200 nautical miles from our shores, covering some 3.5 million square nautical miles of water that are home to diverse ecosystems and vast natural resources, including fish, energy, and minerals, transportation, and much, much more.

A full third of the EEZ, more than any other state, extends from Alaska's 33,904 miles of shoreline. That's more shoreline than the rest of the Lower 48 states, combined. In Alaska, the ocean economy accounts for 21 percent of the state's total gross domestic product, generating over \$3 billion a year in wages. We are the Nation's largest employer in the living resource sector of our oceans. The Seafood and Fisheries Department, where I like to say Alaska constitutes the superpower of seafood for America, over 50 percent of all seafood, commercial, recreational, subsistence harvested in America comes from Alaska. Also, we are the Nation's second-larg-

est contributor in the offshore mineral extraction sector, and, like many states represented here, Alaska's natural beauty attracts more than two million visitors each year, half of which come by the cruise ship industry.

NOAA plays a critical and central role in managing ocean resources and in providing environmental observations to America's—who make a living from the oceans. And again, it's great to have the Acting NOAA Administrator, Admiral Gallaudet, who's no stranger to the ocean, having served 32 years in the Navy, culminating his military career as the oceanographer of the Navy and the commander of the Navy Meteorology and Oceanography Command. He holds a master's and doctoral degrees in oceanography, and has served in NOAA in his current capacity since his confirmation in October 2017.

The United States is often viewed as having the best-managed and healthiest fisheries in the world, through the Magnuson-Stevens Fisheries Conservation and Management Act, which we are working on a reauthorization in this committee. And if you've ever seen "The Deadliest Catch," you know that Alaska's Bering Sea can be unforgiving, and fishermen rely on accurate weather forecasts from NOAA to stay safe.

So, this is a broad-based initiative that I think is going to impact many, many states. And we're looking—I'm glad to have so many of my colleagues here. One of the other areas that I know NOAA is focused on is that, through foreign trade, America's seaports are critical to our overall economy. NOAA provides the nautical charts that mariners use to safely navigate and also provide real data on environmental conditions that help get ships in and out of ports safely. Many of the nautical charts in my state on Alaska's coasts are woefully outdated and rely on surveys conducted in the early 1900s. Over 100 years old. Many of those measurements came from throwing a weighted rope over the side of a ship. Can you imagine, our mariners are still relying on charts based on measurements that came from a weighted rope? We are hoping your initiative, Admiral, can help with that.

Given the importance of the oceans to our overall economy in the United States, it only makes sense that we, as a Nation, coordinate our use of oceans and coastal areas in an efficient manner. Last year, I had the opportunity of chairing this Subcommittee to hear stakeholders' perspective on the National Ocean Policy. I'm glad to say that, in response to that hearing and concerns, the Trump administration and the President signed an executive order regarding Ocean Policy to Advance Economic Security and the Environmental Interests of the United States, which improves public access to marine data and information, improves Federal agency coordination, and encourages government engagement with maritime industries, science, and technology.

Finally, Admiral, as you know, for the Blue Economy to thrive, we must make sure we have clean and sustainable oceans. Senator Whitehouse and I had a bill, the Save Our Seas Act, which highlights the challenge of ocean debris, plastics, ocean pollution, in which NOAA will play an increasingly critical role. That passed the Senate, and it's due to pass the House this week. So, we are making good progress, in a bipartisan way.

I very much appreciate your leadership. I think this initiative on the Blue Economy can bring a bipartisan group of Senators together to support you in what you're doing. And I'm glad that you're here to testify on that initiative.

I now turn the remarks over to Senator Baldwin, who I know has great interest in this, being a Great Lakes Senator.

Senator Baldwin.

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

Senator BALDWIN. Thank you.

The term "Blue Economy" is probably not used very often at Wisconsin dinner tables, but what the term represents is integral to the economies of the eight Great Lakes states. By surface area, the Great Lakes are the largest freshwater body in the world. They contain 18 percent of the world's freshwater supply. Thirty-five million people are dependent upon the Great Lakes for their drinking water, and more than 1.5 million jobs are directly connected to the Great Lakes, generating \$62 billion in wages.

In Wisconsin, we're blessed with water, both our two Great Lakes and our third coast, the Mississippi River, and our 15,000 inland lakes. So, it's no surprise, then, that one-third of all registered voters in the United States reside in the Great Lakes Basin. The last comprehensive report to put a value on Great Lakes boating found that 911,000 boaters spend \$2.36 billion per year on trips, \$1.44 billion per year on boats, equipment, and supplies, and creates 60,000 jobs that contribute \$1.77 billion in personal income. Recreational boating can increase the quality of life and the appreciation of the environment for many Americans, and it depends on access to clean, safe water and healthy fisheries and ecosystems.

Shipping is also important as an industry for Wisconsin. The Saint Lawrence Seaway was completed in 1959, which made it possible for high-quality Wisconsin products to be shipped not only to other Great Lakes ports, but internationally. Now over 200 million tons of cargo are shipped every year through the Great Lakes.

An integral part of the shipping industry is construction and repair of the vessels themselves. In the mid-1830s, the first Wisconsin shipyards opened in Milwaukee and Manitowoc. Nowadays, Fincantieri Marinette Marine, in Wisconsin, builds Navy ships, Coast Guard ships, and, in 2013, the NOAA research vessel *Reuben Lasker*. In fact, Mr. Chairman, the University of Alaska-Fairbanks regional Research vessel was built at Marinette Marine. There is an opportunity to expand our domestic shipbuilding industry, and I hope that all of my colleagues can support my Made in America Shipbuilding Act to do just that. And finally, Great Lakes commercial, recreational, and tribal fisheries are collectively valued at more than \$7 billion annually and support more than 75,000 jobs.

But, the economic viability of the Blue Economy hangs in the balance. Pollution, invasive species, harmful algal blooms, and climate change are bad for business in Wisconsin. And, while I'm always happy to highlight the ways in which the Great Lakes support Wisconsin jobs, this administration has taken several steps that undermine that very same economic prosperity, from budget

proposals that would slash the Great Lakes Restoration Initiative to recently released NOAA documents that suggest climate change won't be a top priority for the agency. I'm concerned, Admiral Galaudet. While I appreciate that you have stated publicly that NOAA's mission statement will not be revised, it's troubling to me that this proposal was ever presented to the Department, because it threatens to undermine the Blue Economy.

Since 1900, average temperatures in the Great Lakes have increased by 2 degrees Fahrenheit. While we still get our cold and snowy winters, that's a troubling trend. And, in recent years, we've seen Wisconsin's iconic cross-country ski race, the Birkebeiner, canceled for lack of snow. Without snow for the skiers and snowmobilers, a lot of the tourism traffic in the winter season heads somewhere else. The warmer summers are also causing economic impacts, contributing to more algal blooms that clog waterways and close Wisconsin beaches in the summer. The lake levels seemed to peak in the 1980s, and have now fallen, possibly because of—higher temperatures increase the evaporation rates. And, if NOAA is, in fact, shifting its focus from climate science, management, and stewardship of our Great Lakes resources, as the slide-deck you presented last month indicates, that does not bode well for Wisconsin's Blue Economy and the jobs that depend on it.

I look forward to your testimony, and I hope you will take the opportunity to address those concerns.

Senator SULLIVAN. Thank you, Senator Baldwin.

And we are honored to have the Ranking Member of the full Commerce Committee, Senator Nelson, whose state of Florida knows a little bit about the Blue Economy.

And, Senator Nelson, the floor is yours for an opening statement, as well.

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

Senator NELSON. Thank you, Mr. Chairman.

And it's of interest that all the Senators here, indeed, have coastline. Obviously, Senator Schatz has a lot of coastline. So does Senator Markey, and so does Senator Peters, as well as Senator Baldwin.

Now, you said you have more coastline in Alaska than any other state, Mr. Chairman. Is that correct?

Senator SULLIVAN. Well, from the rest of all the States in the Lower 48, combined.

Senator NELSON. I see. Mr. Chairman, how many beaches do you have?

[Laughter.]

Senator SULLIVAN. Not many—not as many as you.

[Laughter.]

Senator NELSON. Well, obviously, that's why we don't just call it a "Blue Economy" in Florida, we call it "The Economy."

[Laughter.]

Senator NELSON. Our vast coastline, which is mostly beaches, pristine environment, and abundant fisheries, are among the pillars of the state's economy. It's a multi-billion-dollar tourism industry, commercial and recreational fishing, and marine manufac-

turing. All of that is inextricably connected to the health of our waters. And that's why, when the *Deepwater Horizon* oil spill happened, it really messed up—the winds brought the oil east from Louisiana, as far east as the northwest Florida beaches. It blackened the white sand beaches of Pensacola. That photograph went around the world, and the guests stopped coming for an entire year, not just on Pensacola Beach, but they thought all the beaches on the Gulf Coast, in fact, were tarred with oil, and they stopped coming. And it's why we have an economy that, when you start diverting freshwater from the River of Grass, the Florida Everglades, it has really messed up the estuaries, it has hurt businesses exposed to toxic algae blooms, which occur when you release nutrient-laden water instead of the cleansed water that the River of Grass would cleanse before it ever got to what is now Everglades National Park.

And also, our Blue Economy is being threatened by the trade war. Mr. Chairman, we have a lot of people in Florida who depend on industries that are getting hit by the trade war. And we have a major boat manufacturing business in Florida. I visited this boat manufacturer, Correct Craft. One of their famous boats is the ski boat, Nautique. And when I visited them, they pointed out that 25 percent tariff on steel and a 10 percent tariff on aluminum, that's bad enough, but now there are retaliatory tariffs. There's a 10 percent retaliatory tariff from Canada, where they sell a lot of boats, 15 percent from Mexico, and, lo and behold, 25 percent retaliatory tariff from the European Union, of which Florida boat manufacturers—indeed, American boat manufacturers—I imagine you have some of them, Senator Peters, in your state—they can't sell to Europe anymore, because the price is automatically bumped 25 percent with the retaliatory tariff. And so, they're up creek, and they can't get their boats launched.

I heard from many companies involved in the manufacturing process. It's not just the boat manufacturers. There's Power Pole of Tampa, and Engel Coolers of Jupiter. And there are Marine Metal Products and 13 Fishing of Clearwater. And there are Costa del Mar sunglasses. You know, the famous sunglasses, Costas? They're really getting hurt. They sell a lot of sunglasses that cut out those ultraviolet rays, out there on the water, to an abundant recreational fishing industry. All of these people, up and down the line of the economic chain, are getting hit.

And how about hard-working lobstermen? How about it, Senator Markey? Do you know we have lobsters in Florida, as well? And, of course, Maine, New England, and Massachusetts, have a lot of lobsters. Well, it has forced prices down, because of the global demand for lobsters to drop. The President's tariffs are causing this global demand to drop, forcing the prices down to 5 or 6 dollars a pound from what was 12 dollars a pound. That may be welcome news for consumers, but it's damaging to your fishermen and to our fishermen, who rely on the global markets to make a living and provide for their families.

And so, from lobster fishermen to boat manufacturers to the cooler manufacturers to the sunglass manufacturers, it's staggering if it happens that they are being laid off—and that is what is happening. People are getting laid off. They're feeling the pain. And

this is all coming from a trade war. It's no wonder that so many companies are worried if they're going to get crushed by the trade war. It is bad for the Blue Economy, the subject of this hearing.

And so, I'm grateful that you're holding this hearing. When it comes to discussing the Blue Economy, you can't do it without talking about the trade war and how it's going to definitely affect folks' livelihoods.

And so, who better to be here to talk to us than Admiral Gallaudet as the Acting Assistant Secretary.

Thank you, Mr. Chairman.

Senator SULLIVAN. Thank you, Senator Nelson.

Admiral, you have five minutes for your opening statement. Again, we're pleased that you're here. Thank you for your leadership on this issue. And a longer written statement can be submitted for the record, if you so desire.

The floor is yours.

**STATEMENT OF RDML TIMOTHY GALLAUDET, PH.D., USN
RETIRED, ASSISTANT SECRETARY OF COMMERCE FOR
OCEANS AND ATMOSPHERE; AND ACTING UNDER SECRETARY
OF COMMERCE FOR OCEANS AND ATMOSPHERE,
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION,
U.S. DEPARTMENT OF COMMERCE**

Admiral GALLAUDET. Good morning. It's a pleasure to be here to discuss NOAA's support to the Blue Economy. I want to thank you, Chairman Sullivan, for hosting this hearing.

Alaska is a key contributor to the U.S. ocean economy through fishing, shipping, tourism, and energy. I look forward to discussing how we can grow these sectors to benefit Alaska and the entire Nation.

Coastal regions are home to 40 percent of the U.S. population and contribute \$320 billion to our GDP. Recognizing this, the President issued a proclamation, in June, that commits the Nation to harness the vast resources of our Exclusive Economic Zone, or EEZ. By deploying new technologies from American innovators, streamlining regulations to promote economic growth, and protecting our marine environment for current and future generations, the administration intends to advance America's economic security and environmental interests.

Singled out as critical in this proclamation are NOAA's activities to support the Blue Economy, including exploration, mapping, and surveying of our Nation's waters, and employment of advanced observational technologies and forecasting capabilities. This work is one of NOAA's two major priorities. The other priority is to lead the world in weather forecasting, which will greatly benefit the coasts and the heartland by more accurate storm warnings that protect lives and property, and improved seasonal predictions that help farmers and ranchers make better water management decisions.

Key to NOAA's Blue Economy work is promoting U.S. seafood production. This includes advancing fishery science and reducing unnecessary regulations on our commercial fishermen so that they can maximize their sustainable yields. We are also working to end

the importation of illegal, unreported, and unregulated seafood to level the playing field for U.S. fishermen.

And we are supporting domestic aquaculture. The fact that the U.S. has arguably the largest EEZ in the world, but ranks 17th in worldwide aquaculture production, is unacceptable. We are changing that by executing a strategy to use existing authorities to expand aquaculture in Federal waters. We look forward to working with Senator Wicker to clarify the statutory authorities and provide the regulatory certainty required for a robust domestic aquaculture industry.

Also important to NOAA's Blue Economy work is our support for maritime transportation. Secretary Ross highlighted how NOAA improves the efficiency and safety of U.S. seaports in his Senate testimony on infrastructure. Ninety percent of U.S. overseas trade moves through our ports, adding up to \$4.6 trillion annually, so that even small improvements in port efficiencies have tremendous economic impact. For instance, NOAA provided a precision navigation capability to the Port of Long Beach, California, where a combination of high-resolution bathymetric surveys and realtime environmental data increased the allowable draft for ships to enter port, enabling them to carry up to \$2 million in extra product per foot of draft per transit.

With commerce on top of the water and seafood from the water column, there also is value on and under the seabed. NOAA is promoting energy production, mineral extraction, and pharmaceutical development while meeting our statutory obligations to protect the marine environment. One way we are doing this is through ocean exploration. The United States has mapped the Moon and Mars to a better resolution than our sea floor. NOAA is examining ways to expand mapping our EEZ with autonomous vehicles and remote sensing technologies, allowing discovery of new areas with energy and mineral potential, as well as new ecosystems and species with boundless possibilities to benefit human health and understanding.

We are also advancing research in underwater acoustics to reduce the uncertainty about the impact of noise on marine mammals. Better knowledge will help protect marine mammals while also facilitating the safe exploration for offshore energy.

Last, NOAA is ensuring our ocean, coasts, and beaches are clean, safe, and productive. We do this by implementing statutes such as the Marine Debris Act, the National Marine Sanctuaries Act, the Endangered Species Act, and the Marine Mammal Protection Act, which support recreation and tourism by improving our environment and quality of life.

Ultimately, a vibrant U.S. economy depends on healthy oceans, coasts, and Great Lakes. The science and management to conserve and sustainably use these resources is at the heart of NOAA's mission.

I look forward to answering your questions about how NOAA is promoting the Blue Economy for the benefit of our great Nation.

[The prepared statement of Admiral Gallaudet follows:]

PREPARED STATEMENT OF RDML TIMOTHY GALLAUDET, PH.D., USN RET. ASSISTANT SECRETARY OF COMMERCE FOR OCEANS AND ATMOSPHERE; AND ACTING UNDER SECRETARY OF COMMERCE FOR OCEANS AND ATMOSPHERE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, U.S. DEPARTMENT OF COMMERCE

Good afternoon. It's a pleasure to be here today to focus on one of my favorite topics: the blue economy.

I want to thank Chairman Sullivan for his leadership and foresight in hosting this hearing. Alaska is a key contributor to the Nation's ocean economy, thanks to Alaska's fishing, shipping, tourism, energy development and other industries tied to the ocean. Many Alaska communities also have strong subsistence economies that depend on ocean resources. The unique relationship that Alaska has with the sea has long made Alaska a leading voice on ocean policy matters. I look forward to discussing how we can grow the blue economy to the benefit of Alaskan communities and the entire nation.

Coastal regions are home to 40 percent of the U.S. population and the U.S. ocean economy contributes \$320 billion to our GDP. Under the Department of Commerce, the National Oceanic and Atmospheric Administration (NOAA) supports the sustainable use, management and conservation of our ocean and coastal resources through research, observations and environmental forecasts. You cannot manage what you cannot measure. So we measure quite a bit at NOAA—from ocean conditions at the bottom of the sea, to the abundance of fish in the pelagic zone, to atmospheric carbon dioxide concentrations, to solar wind.

In June, the President issued a proclamation to mark National Ocean Month that states the following:

"To harness the vast resources of the EEZ [Exclusive Economic Zone], we will develop and deploy new technologies in partnership with American academic institutions and innovators. We will streamline regulations and administrative practices to promote economic growth, while protecting our marine environment for current and future generations. We will also create new opportunities for American products in the global marketplace, including through continued support of our commercial fisheries and promotion of domestic aquaculture.

To advance America's economic, security, and environmental interests, it is also critical that we explore, map, and inventory our Nation's waters and pursue advanced observational technologies and forecasting capabilities. By exploring, developing, and conserving the ocean resources of our great Nation, we will augment our economic competitiveness, enhance our national security, and ensure American prosperity."

This proclamation clearly sets the stage for how NOAA will address and prioritize the blue economy in this Administration. In particular, I will highlight how NOAA's work on fisheries management, aquaculture production, maritime transportation, and energy production and mineral extraction while protecting important marine resources supports our Nation's blue economy.

The United States leads the world in sustainable fisheries management and our domestic fisheries management system has produced great economic and environmental success stories. However, seafood is traded globally, and our domestic fishermen are rarely allowed to compete on a level playing field. The Trump Administration is working to reduce, eliminate, and streamline regulations on our commercial fishermen so that they can fish up to the maximum sustainable yield. We are also working to end the importation of illegal, unreported, and unregulated seafood. We should take great pride in our achievements in ending overfishing domestically and our global leadership in protecting fishery resources on the high seas. As this committee knows all too well, we cannot turn a blind eye to nefarious fishing practices that threaten our domestic industry and the long-term viability of fish stocks globally. This committee introduced and considered all of the key legislative tools that enable both domestic and international marine resource protection—the Magnuson Stevens Fishery Conservation and Management Act, the Marine Mammal Protection Act, the Oil Pollution Act, and the High Seas Driftnet Fishery Enforcement Act, to name just a few.

While NOAA is working to expand fishing opportunities and access to foreign markets for our wild-caught fishing industry, we must also do more to develop a viable domestic aquaculture industry. The fact that the U.S. has one of the largest EEZs in the world, but ranks 17th in worldwide aquaculture production, is shocking. One-half of the global seafood supply is farmed, but in the U.S. less than 10 percent of our seafood is from aquaculture. NOAA, as well as the Department of Commerce as a whole, is looking to change that dramatically—while keeping a sharp eye to protect our wild-caught stocks and expand export markets for wild-

caught fish. NOAA has been scaling up our aquaculture research efforts so we can grow the aquaculture industry wisely and sustainably. However, to do so this will also require a change in the regulatory regime to reduce confusion which has to date deterred investment in Federal waters. To date, the United States has been exporting our aquaculture science and expertise, rather than farmed seafood. That needs to change as the global population approaches 10 billion and the world looks to the ocean for protein. Seafood production via aquaculture can be a resource-efficient way to produce protein and has already helped improve nutrition and food security in many parts of the world.

NOAA is committed to streamlining the use of existing authorities to expand aquaculture in Federal waters. We look forward to working with Senator Wicker to clarify the statutory authorities and provide the regulatory certainty required to develop a robust domestic aquaculture industry. Whether it be a wild-caught salmon from Bristol Bay, or a farmed oyster from the Chesapeake Bay near where I now live, American consumers should have great faith and pride in the fact that all U.S. seafood is healthy, sustainable and safe to enjoy.

Human civilization sprung up along our coasts for access to food, but also for access to transportation. Today, perhaps more than ever, coastal communities and ports play a vital role in the transport of goods in the global marketplace. Earlier this year, Secretary Ross highlighted NOAA's investments to improve the efficiency and safety in our Nation's port facilities in his Senate testimony on infrastructure. Few Americans realize that 99 percent of U.S. overseas trade moves through our ports. Billions of tons of product valued in the trillions of dollars move through our ports annually, so even small improvements in our ports efficiencies have tremendous economic impact. For example, NOAA installed precision navigation products in the port of Long Beach, where a combination of high resolution bathymetric surveys of the sea floor and real-time oceanographic and meteorological data on swells, tides, currents, wind, temperature, and salinity increased the allowable draft for cargo ships to enter the port. The result was that vessels could carry up to \$2 million in extra product per foot of allowable draft per transit. Given that there are thousands of ships that enter U.S. ports every day, the potential return on investment for such precision navigation products could be very advantageous to the U.S. economy. We are looking to expand these products and services to more ports across the Nation.

Goods are transported on top of the water, seafood is harvested from the water column, and there is tremendous value beneath the seabed. NOAA has a role to play in promoting energy production and mineral extraction, while meeting our statutory obligations to protect subsistence resources, the marine environment and protected species. We can do so in a few ways. First, we can do more to explore and characterize our ocean and coastal resources. We import almost all of our Nation's critical minerals, which help build modern infrastructure from jet engines, to power plants and cell phones. Relying on foreign sources of critical minerals is a national security vulnerability that NOAA can help address through ocean exploration. The United States has mapped the moon and Mars to a better resolution than our own seafloor. Thus, NOAA is examining ways to expand activities related to the mapping of our EEZ. The advancement of autonomous vehicles and remote sensing technologies will facilitate the characterization of our EEZ which will aid navigation and identify sources of valuable minerals, energy and, potentially, pharmaceuticals.

Second, we are looking for opportunities to advance research on underwater acoustics to reduce uncertainties around the impact of noise on marine mammals. Better knowledge will help NOAA protect marine mammals while also facilitating the safe exploration of offshore energy sources. I believe we have great opportunities to work with Alaska Natives, industry, foundations and NGOs to expand our underwater acoustic observations, improve our understanding of how sound impacts mammals, and develop reasonable mitigation measures to protect threatened species. NOAA sees the cooperative process used by the Alaska Eskimo Whaling Commission and the oil industry to ensure offshore exploration does not adversely impact subsistence hunting for bowhead whales as a great example of how the blue economy can move forward.

Life began in the ocean, and humans, including myself, are intrinsically drawn to the sea. We go there for recreation, we go there for relaxation, and we go there for inspiration and reflection. NOAA works every day to ensure our ocean, coasts and beaches are clean, safe and productive. NOAA conserves and protects the marine environment through its statutory authorities, ranging from the Marine Debris Act, to the Endangered Species Act, to the Marine Sanctuaries Act, to the Marine Mammal Protection Act, to coastal management through the Coastal Zone Management Act, to protecting essential fish habitat and managing recreational fisheries through the Magnuson-Stevens Fishery Conservation and Management Act. NOAA

also consults with other agencies regarding the Endangered Species Act and Essential Fish Habitat. Thus, NOAA's work to support a healthy and productive marine environment is fundamental to supporting the blue economy.

Ultimately, a vibrant U.S. economy depends on healthy ocean, coastal, and Great Lakes resources. The science and management to conserve and sustainably use these resources is at the heart of NOAA's mission. I look forward to answering your questions about our efforts to sustainably utilize our EEZ for the benefit of this and future generations.

Senator SULLIVAN. Well, thank you, Admiral. And again, thank you for being here.

Let me begin with some just kind of basic questions that help frame the topic of discussion today and what you've been working on.

You know, the U.S. Government doesn't have an official definition of the "Blue Economy." Can you share your interpretation of the term, in terms of how you frame that, look at it?

Admiral GALLAUDET. Yes, Chairman Sullivan. Thank you for the question.

We, at NOAA, view the Blue Economy, or the aspects that we support, to it be—being or encompassing areas such as marine transportation and commerce, as well as tourism and recreation and ocean exploration and, of course, fisheries.

Senator SULLIVAN. OK. And do you have kind of a ballpark figure, in terms of the size of that economy for the United States, and maybe as a percentage of our overall annual GDP?

Admiral GALLAUDET. Yes, Chairman Sullivan.

The number that our National Oceans Service was—reported was \$320 billion, I think, which contributes about—you know, to—as a percent of our \$18 billion GDP.

Senator SULLIVAN. Trillion dollar.

Admiral GALLAUDET. Trillion. Yes, sir, thank you.

Senator SULLIVAN. Great. Let me ask another question. I know that you're going to be visiting a number of states, in your capacity, to discuss—stakeholders meetings throughout the country on this and other topics. I'm looking forward to having you in Alaska soon. Can you elaborate a little bit more on your visits, not just to my state, but to other states, I think, this summer and through the fall?

Admiral GALLAUDET. Yes, Chairman Sullivan, thank you.

I look forward to visiting Alaska, Juneau and Anchorage, in August. And that's part of a—several trips I am making across the country as part of a—the public listening sessions. And, in this, we're asking members of the public to come in and give their feedback on how we're aligning our priorities with the Department of Commerce's vision and strategy.

Senator SULLIVAN. Are you going to give public notice to, you know, not only communities in Alaska, but to other states that you plan on traveling to?

Admiral GALLAUDET. Yes, Chairman. And I think we put this on the Web today, and we'll—it's—it will be published in the *Federal Register* tomorrow.

Senator SULLIVAN. OK.

Let me ask—you know, we're having our salmon runs, back home in my state, which is obviously very important. Some of the runs have been disappointing. Some of the runs have been disastrous,

to be perfectly frank. I'd like to get your commitment, once the salmon season is done in Alaska, to have you and your top officials, like Chris Oliver, and perhaps some experts from the states like mine, and maybe some other Pacific Coast states, to have a hearing to kind of get your best sense with regard to what's happening on these runs, why some are strong, why some are weak, why some have been very challenging. These negatively impact my state, the Blue Economy, my constituents in an enormous way. And there's a real desire to get a handle on the science and what is exactly happening. Can I get your commitment on that, as well?

Admiral GALLAUDET. Yes, sir, Chairman Sullivan. You have our commitment to help you in understanding what's happening to salmon and doing the things that will continue to sustainably manage the fisheries in your state and across the country.

Senator SULLIVAN. Let me throw out a concern that relates to the last commitment you just made. One of the things that I think we see bipartisan support for, on this committee certainly, is having the best science and best data available to help you and other Federal agencies, but primarily NOAA, bring that to councils, like the different Magnuson-Stevens Act councils that manage our fisheries throughout the country so that they can make the best recommendations on fish stocks and sustainability based on science. I see a NOAA budget request that came out that proposes more than a \$17 million decrease in NOAA fisheries programs in the fishery science and management element of NOAA for FY19. If we were to enact these kind of budget figures, which I'm not going to support, wouldn't that undermine the Blue Economy and the value of our, not just commercial fisheries, but recreational fisheries, as well? And how do you square that with the initiative, which I support, but it seems like you're not requesting the full amount that I think there's a bipartisan support for, in terms of science management of our fisheries?

Admiral GALLAUDET. Chairman Sullivan, I agree with you that fishery science is very important to sustainably manage our stocks, and——

Senator SULLIVAN. Critical.

Admiral GALLAUDET. Absolutely, sir. Critical. And we are committed to continuing our stock assessment work. And I believe, in the FY19 request, we are not decreasing funding in stock assessment work, but there is efficiencies we think we can gain through improved monitoring and observations using unmanned systems technology, for example, and electronic monitoring. And so, those have—I believe, is where we can make some efficiencies. And we've already made great advances in that kind of observational work to date.

Senator SULLIVAN. Great. OK, thank you.

Senator Nelson.

Senator NELSON. Go ahead with Senator Baldwin.

Senator SULLIVAN. OK.

Senator Baldwin.

Senator BALDWIN. Mr. Chairman, at this time, I'd like to submit the slide deck that Admiral Gallaudet presented to the Department of Commerce leadership last month into the record. And I'm——

Senator SULLIVAN. Without objection.

[The information referred to follows:]

DOC Vision Setting Summit NOAA Contributions



RDML Tim Gallaudet, PhD, USN Ret.

Assistant Secretary of Commerce for Oceans and Atmosphere and
Acting Under Secretary of Commerce for Oceans and Atmosphere



NOAA Mission

Past

- To understand and predict changes in climate, weather, oceans and coasts;
- To share that knowledge and information with others; and
- To conserve and manage coastal and marine ecosystems and resources.

Present

- To observe, understand and predict atmospheric and ocean conditions;
- To share that knowledge and information with others; and
- To protect lives and property, empower the economy, and support homeland and national security.



NOAA Vision

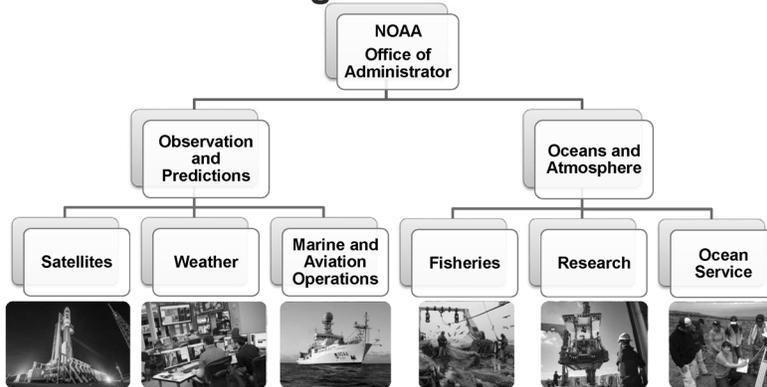
Past

- Resilient Ecosystems, Communities, and Economies; and
- Healthy ecosystems, communities and economies that are resilient in the face of change.

Present

- A Safe, Secure and Growing Economy Empowered through Accurate, Reliable and Timely Environmental Information.

NOAA Organizational Chart



NOAA Congressional Mandates

- Weather Research and Innovation Act
- Weather Service Organic Act
- Magnuson-Stevens Fishery Conservation and Management Act
- Marine Mammal Protection Act
- Endangered Species Act
- Coastal Zone Management Act
- National Marine Sanctuaries Act
- America COMPETES
- Hydrographic Services Improvement Act
- Global Change Research Act
- Coastal Zone Management Act
- Coral Reef Conservation Act
- Harmful Algal Bloom and Hypoxia Research and Control Act
- Marine Debris Act of 2012
- Coast and Geodetic Survey Act
- Coastal and Estuarine Land Conservation Program Act
- Hydrographic Services Improvement Act
- Integrated Coastal and Ocean Observation System Act of 2009
- Ocean and Coastal Mapping Integration Act
- Oceans and Human Health Act
- Oil Pollution Act
- Comprehensive Environmental Response, Compensation, and Liability Act

127 mandates and authorities applicable to NOAA's mission



Department of Commerce // National Oceanic and Atmospheric Administration // 5

NOAA Equities with the DOC Strategic Plan

Accelerate American Leadership

- Advance Innovation

Enhance Job Creation

- **Increase Aquaculture Production**
- Reduce and Streamline Regulations
- Strengthen Domestic Commerce
- Increase U.S. Exports
- Increase Inward Investment into the U.S.

Strengthen U.S. Economic and National Security

- Enforce the Nation's Trade Laws
- **Reduce Extreme Weather Impacts**



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Metrics for Tracking Progress

Accelerate American Leadership

- Innovation – ROI, R2O

Enhance Job Creation

- Aquaculture – 3x Production in 10 years
- Regulations – 50 Deregulatory Actions
- Commerce – Forecasting Skill
- U.S. Exports – Seafood Trade Deficit
- Inward Investment – Blue GDP & #Jobs Created

Strengthen U.S. Economic and National Security

- Trade Laws - Seafood Trade Deficit
- Weather Impacts – Forecasting Skill



NOAA Strategic Priorities for 2018

Implement the Weather Act

- Acquire high resolution cost-effective observations
- Develop best weather model in the world
- Improve Seasonal to Sub-seasonal Forecasts & Severe Storm Predictions

Reduce the Seafood Trade Deficit

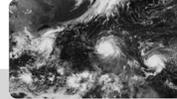
- Increase Aquaculture Production
- Promote Fair and Reciprocal Trade
- Reduce and Streamline Regulations

Advance Maritime Commerce (Blue Economy)

- Expand Offshore Activity through Ocean Exploration and Characterization
- Promote Maritime Commerce through Efficient Seaports and Tourism
- Support Maritime Policies, Programs and Plans



Implementing the Weather Act



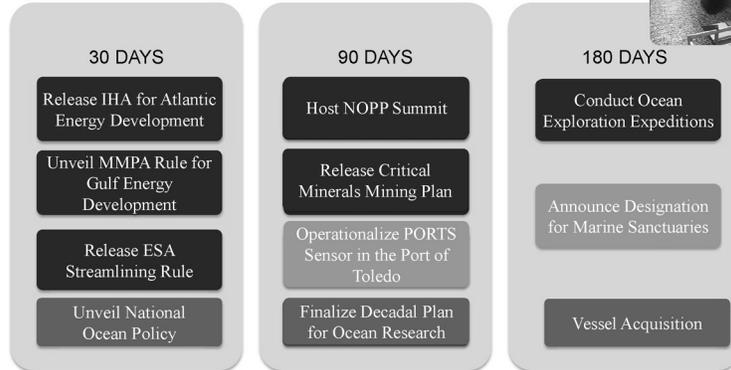
30 DAYS	90 DAYS	180 DAYS
Comments on Satellite Architecture	Fund Commercial Data Pilot	Cosmic 2-A Launch
Install REXRAD in Puerto Rico	Establish Center for Environmental Prediction	GOES-17 On-Orbit Checkout
Test FV3-GFS		Unveil Data Sharing Plan
Flash Flood Forecasting	Drought Predictions	FV3-GFS Operational

Reducing the Seafood Deficit



30 DAYS	90 DAYS	180 DAYS
Announce Seafood Competitiveness Initiative	Host Aquaculture Summit	Fund Aquaculture Grants
Release DOC Aquaculture Policy	Allocate Fishery Disaster Aid	Sign Aquaculture Legislation
Establish Seafood Task Force	Review Seafood Trade Deals	Implement Seafood Importation Rules
Reach 50 Deregulatory Actions	Propose Vessel Financing Rule	Finance Electronic Monitoring
	Permit Fishing in Marine Monuments	

Advancing Maritime Commerce



Challenges and Opportunities

Budget Constraints

Seafood Competitiveness

Data Management

NOAA



National Oceanic and Atmospheric Administration
U.S. Department of Commerce

NOAA *by the* NUMBERS

NOAA's Value To The Nation

June 2018
Chief Economist Team
Performance, Risk and Social Science
Office of the Chief Financial Officer
performance.noaa.gov/economics

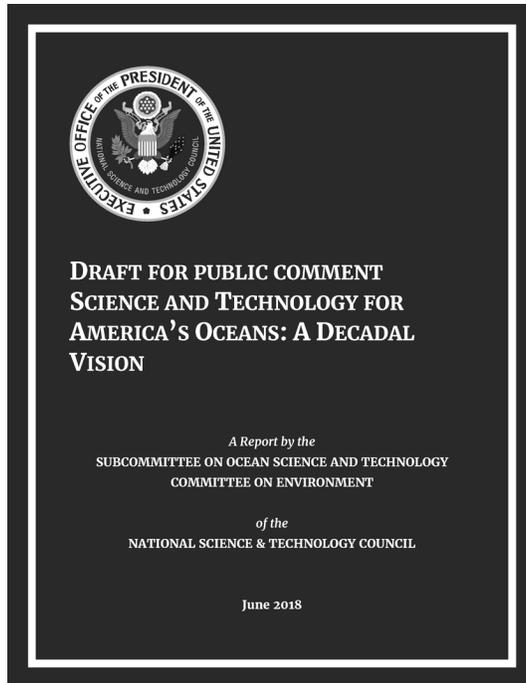
Helping the American Economy Grow



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Senator BALDWIN. Thank you. And also like to submit a draft released last month by the White House's Office of Science and Technology Policy entitled "Science and Technology for America's Oceans: A Decadal Vision."

Senator SULLIVAN. Without objection.
[The information referred to follows:]



About the National Science and Technology Council

The National Science and Technology Council (NSTC) is the principal means by which the Executive Branch coordinates science and technology policy across the diverse entities that make up the Federal research and development enterprise. A primary objective of the NSTC is to ensure science and technology policy decisions and programs are consistent with the President's stated goals. The NSTC prepares research and development strategies that are coordinated across Federal agencies aimed at accomplishing multiple national goals. The work of the NSTC is organized under committees that oversee subcommittees and working groups focused on different aspects of science and technology. More information is available at <http://www.whitehouse.gov/ostp/nstc>.

About the Office of Science and Technology Policy

The Office of Science and Technology Policy (OSTP) was established by the National Science and Technology Policy, Organization, and Priorities Act of 1976 to provide the President and others within the Executive Office of the President with advice on the scientific, engineering, and technological aspects of the economy, national security, homeland security, health, foreign relations, the environment, and the technological recovery and use of resources, among other topics. OSTP leads interagency science and technology policy coordination efforts, assists the Office of Management and Budget with an annual review and analysis of Federal research and development in budgets, and serves as a source of scientific and technological analysis and judgment for the President with respect to major policies, plans, and programs of the Federal Government. More information is available at <http://www.whitehouse.gov/ostp>.

About the Subcommittee on Ocean Science and Technology

The purpose of the Subcommittee on Ocean Science and Technology (SOST) is to advise and assist on national issues of ocean science and technology. The SOST contributes to the goals for Federal ocean science and technology, including developing coordinated interagency strategies, and fostering national ocean science and technology priorities.

About this Document

This document was prepared by the SOST. This document serves as the second U.S. ocean science and technology decadal plan, following *Charting the Course for Ocean Science for the United States for the Next Decade: An Ocean Research Priorities Plan and Implementation Strategy* (2007)—which was updated in 2013 with the release of *Science for an Ocean Nation: An Update of the Ocean Research Priorities Plan*.

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 Goal III. Ensure Maritime Security
 Goal IV. Safeguard Human Health
 Goal V. Develop Resilient Coastal Communities
 Moving Forward

LIST OF ACRONYMS

AIS—Automatic Identification System
 AUV—Autonomous Underwater Vehicle
 DMAC—Data Management And Communications
 eDNA—Environmental DNA
 EEZ—Exclusive Economic Zone
 eMSI—Enhanced Marine Safety Information
 EOY—Essential Ocean Variable
 FDA—Food and Drug Administration
 FEMA—Federal Emergency Management Agency
 GDP—Gross Domestic Product
 GOOS—Global Ocean Observing System
 HAB—Harmful Algal Bloom
 IARPC—Interagency Arctic Research Policy Committee
 IDSS—Impact-based Decision Support Services
 IMO—International Maritime Organization
 IOOS—Integrated Ocean Observing System
 IUU—Illegal, Unregulated, and Unreported
 LRIT—Long-Range Identification and Tracking
 MSI—Marine Safety Information
 MTS—U.S. Marine Transportation System
 NAIS—Nationwide Automatic Identification System
 OECD—Organization for Economic Cooperation and Development
 OSSE—Observing System Simulation Experiments
 OSE—Observing System Experiments
 PAH—Polycyclic aromatic hydrocarbon
 PCB—Polychlorinated biphenyl
 PORTS—Physical Oceanographic Real-Time System
 QPF—Quantitative Precipitation Forecast
 R&D—Research and Development
 ROV—Remotely Operated Vehicle
 S&E—Science and Engineering
 S&T—Science and Technology
 SES—Social-Ecological System
 SLR—Sea Level Rise
 SOCCOM—Southern Ocean Carbon Climate Observation and Modeling
 SOLAS—International Convention for the Safety of Life at Sea
 STEM—Science, Technology, Engineering, and Math
 UUV—Unmanned Underwater Vehicle
 VTS—Vessel Traffic Services

EXECUTIVE SUMMARY

America's unrestricted access to the Atlantic and Pacific Oceans, Gulf of Mexico, Western Rivers, Great Lakes, and Arctic region powers domestic and global commerce. The ease of moving cargo and people beyond its coasts fuels the Nation's competitive advantage, advances trade, generates capital, and drives the domestic economy forward, in turn projecting strength abroad and safeguarding its national interests. Ensuring responsible ocean stewardship with science and technology (S&T) breakthroughs depends on a strategic Federal portfolio supported by foundational basic research. *Science and Technology for America's Oceans: A Decadal Vision* identifies pressing research needs and areas of opportunity within the ocean S&T enterprise for the coming decade, 2018–2028. This vision identifies five goals to advance U.S. ocean S&T and the Nation in the coming decade: (1) Understand the Ocean in the Earth System; (2) Promote Economic Prosperity; (3) Ensure Maritime Security; (4) Safeguard Human Health; and (5) Develop Resilient Coastal Communities. Each goal is supplemented with specific objectives and actionable prior-

ities to achieve those objectives. The objectives for the five goals as well as an additional section that outlines areas of immediate ocean research and technology opportunities are summarized below:

Goal I. Understand the Ocean in the Earth System:

- 1) Modernize Research and Development (R&D) Infrastructure;
- 2) Harness Big Data;
- 3) Develop Models of the Earth System;
- 4) Facilitate Research to Operations

Goal II. Promote Economic Prosperity:

- 1) Expand Domestic Seafood Production;
- 2) Explore Potential Energy Sources;
- 3) Assess Marine Critical Minerals;
- 4) Balance Economic and Ecological Benefits;
- 5) Promote the Blue Workforce

Goal III. Ensure Maritime Security:

- 1) Improve Maritime Situational Awareness;
- 2) Understand a Changing Arctic;
- 3) Maintain and Enhance Marine Transportation

Goal IV. Safeguard Human Health:

- 1) Improve Forecasts of Marine Contaminants and Pathogens;
- 2) Combat Harmful Algal Blooms;
- 3) Discover Natural Products

Goal V. Develop Resilient Coastal Communities:

- 1) Prepare for Natural Disasters and Weather Events;
- 2) Reduce Risk and Vulnerabilities;
- 3) Empower Local and Regional Decision-Making

Areas of immediate ocean research and technology opportunities include:

1. *Fully integrate Big Data approaches in Earth system science;*
2. *Advance monitoring and predictive modeling capabilities;*
3. *Improve data integration in decision support tools;*
4. *Support ocean exploration and characterization;*
5. *Support ongoing research and technology partnerships*

Two cross-cutting topics that are relevant to each of the five goals are a modernized ocean infrastructure, and an educated, diverse, and dynamic “blue” workforce. Continued investments in these two areas will contribute to U.S. global leadership within ocean S&T.

This document presents a decadal vision for an innovative and collaborative ocean S&T enterprise that promotes American security and prosperity while conserving the marine environment for present and future generations. Carrying out the research goals will require investments in and coordination of ocean S&T across all levels of government and private industry, academia, and nongovernmental organizations over the long term. These goals will be achieved over years, working with Federal and non-Federal partners to direct and leverage the necessary resources. Additionally, while this document will provide important guidance to Federal agencies on ocean S&T priorities, implementation of this plan is dependent upon available resources and will vary year to year.

INTRODUCTION

The ocean, our coasts, and the Great Lakes are among the United States’ most treasured resources. They are an integral part of our national identity and our Nation’s future. The ocean¹ covers 71 percent of the Earth’s surface and hundreds of

¹ For the purposes of this document, “ocean” includes the open ocean, coasts, estuaries, coastal watersheds, and Great Lakes.

millions of people rely on a viable ocean to sustain them.² The ocean provides and creates jobs, gives mobility to our Armed Forces, helps feed our Nation, secures our borders, fuels our economy, enables safe movement of goods, and provides places for recreation. A healthy, productive, and resilient ocean contributes significantly to our quality of life. Understanding the physical, chemical, biological, and geological changes in the ocean is vital to the survival and prosperity of humanity.

In the United States, the ocean and its wealth of natural resources have played a critical role in fueling American prosperity and energy dominance, protecting our country, generating jobs, sustaining industries, and contributing to Americans' overall well-being. Our coastal ports and global waterways make up the epicenter of world trade, facilitating a thriving U.S. economy through the maritime enterprise. At the same time, the coastal communities that take part in and benefit from the ocean economy are also vulnerable to events such as hurricanes and sea level rise. Many of these changes to the ocean and its services³ are evident by human observation, exhibiting visible alterations to coastlines and ecosystems, navigation routes, water quality, species compositions, the timing and occurrence of pathogens, abundance of marine debris, and populations of commercially and ecologically important marine species.

The ocean science and technology (S&T) enterprise can provide the foundational knowledge needed to address many complex ocean-related challenges and inform decision-making that will ultimately strengthen our Nation and its communities. One essential objective of this document is to facilitate the integration of natural and social sciences. No single discipline can comprehensively address the complex and pressing problems facing the ocean, which can no longer be studied in isolation but must be considered as a part of a dynamic Earth system. This document recognizes the connections among ocean, land, ice, and atmosphere. Humans are an important element of the Earth system as agents of change to Earth system processes. They are beneficiaries of Earth's natural resources and are at risk from Earth's natural hazards. The inclusion of human dimensions in ocean S&T ensures holistic understanding of the Earth system. The scientific understanding of the Earth system,⁴ the need to obtain, analyze, and manage Big Data,⁵ and the relevance of dynamic feedbacks between socioeconomics and biophysical systems,⁶ are key concepts that are evident throughout this document. As an ocean Nation and a global leader, the United States can advance the ocean S&T enterprise by fostering innovation and investing in basic and applied ocean research, technology, education, and workforce development—all key to increasing knowledge and understanding of the ocean system and maintaining our country's influence and leadership in an ever-challenging global arena.

Two cross-cutting topics emerged as critical components among all goals in this document. They include the modernization and management of ocean-related research infrastructure, including ocean-observing and modeling capabilities, and an educated, diverse, and dynamic workforce. State-of-the-art research infrastructure provides the United States with unique competencies, allows for advances in discovery, minimizes potential economic and societal losses, and ensures the S&T workforce has the capabilities it needs to conduct world-leading ocean research. Infrastructure and advanced technologies such as airborne, underwater, and land-based assets support U.S. ocean research and technology interests. Modernized technologies, and improvement in capabilities such as data acquisition and high-performance computing, are two related priorities relevant to all goals in this document. U.S. economic well-being and global leadership in S&T depends on an ocean-literate society and a well-trained workforce of the future. A strong "blue" workforce

²Hoegh-Guldberg, O. *et al.*, (2015) *Reviving the Ocean Economy: the case for action—2015*. WWF International, Gland, Switzerland. Geneva, p. 60. <https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/WWF-Report-Reviving-the-Ocean-Economy-Summary.pdf> (accessed April 17, 2018).

³Ocean services are the benefits humans derive from different aspects of ocean structure and function. These can be partitioned into (1) Provisioning Services, (2) Supporting Services, (3) Regulating Services and (4) Cultural Services. More information can be found at: NOAA (2017) *Ecosystem Status Report for the Northeast Large Marine Ecosystem* <https://www.nepsc.noaa.gov/ecosys/ecosystem-status-report/ecosystem-services.html> (accessed June 12, 2018).

⁴Cornell, S., I.C. Prentice, J. House, and C. Downing. (2012) *Understanding the Earth system: Global change science for application*. Cambridge: Cambridge University Press, p. 267. <https://doi.org/10.1017/CBO9780511921155> (accessed June 15, 2018).

⁵Jin, X., B.W. Wah, X. Cheng, and Y. Wang. (2015) *Significance and challenges of big data research*. *Big Data Research* 2:59–64. <https://wah.cse.cuhk.edu.hk/wah/Wah/papers/J94/J96.pdf> (accessed June 15, 2018).

⁶National Ocean Service. *Socioeconomics* <https://sanctuaries.noaa.gov/science/socioeconomic/> (accessed April 17, 2018).

will enable the Nation to address tomorrow's ocean needs and contribute more jobs, enhanced production, and national prosperity.

The vision for the coming decade is a Nation that recognizes the importance of a science-based and technologically driven understanding of the ocean to American livelihoods, national security, and economic independence. This same knowledge enhances the conservation and stewardship of the ocean and its resources. Advancing the ocean S&T enterprise enables a better understanding of the past, enhanced opportunities to observe the present, and the ability to predict the future.

About this Document

Science and Technology for America's Oceans: A Decadal Vision identifies research priorities and areas of opportunity within the ocean S&T enterprise for the coming decade, 2018–2028. The aim of this document is not to prescribe policies, but to provide guidance for U.S. Federal agencies and non-Federal sectors to align their resources and areas of expertise, and further build the scientific and technological foundation that will improve our knowledge and stewardship of the ocean, address issues of national and global importance, and inform decision-making for the coming decade.⁷ This document considers the needs of researchers, resource managers, policymakers, educators, tribal, State, territorial, and local governments, and other stakeholders and will rely on the continuous stream of information and knowledge derived from fundamental basic research by and for the ocean S&T community for the well-being of the Nation.

This document builds on a number of initiatives outlined in *Charting the Course for Ocean Science for the United States for the Next Decade: An Ocean Research Priorities Plan and Implementation Strategy* (2007)⁸—the first comprehensive national ocean research priorities plan—which was updated in 2013 with the release of *Science for an Ocean Nation: An Update of the Ocean Research Priorities Plan*. Over the last decade, the ocean community has advanced novel ocean technologies, discovered new marine life and ocean-derived therapeutics, helped marine populations recover, tracked environmental changes, and answered important questions about how the ocean works. This document charts the course for the next decade.

Organization of this Document

This document presents five high-priority ocean S&T goals: (1) Understand the Ocean in the Earth System; (2) Promote Economic Prosperity; (3) Ensure Maritime Security; (4) Safeguard Human Health; and (5) Develop Resilient Coastal Communities. The first goal serves to improve the foundational understanding of the global ocean and is followed by the application of such scientific knowledge into more specific goals. Within each goal are S&T objectives, identified as key areas to advance the U.S. ocean S&T enterprise in the next decade. Subsections describe specific research and development (R&D) priorities to advance the U.S. ocean S&T enterprise. These priorities will likely evolve as the U.S. ocean S&T enterprise advances during the next decade. Many of these actions will produce short-term benefits that respond to immediate needs of communities, industries, ocean stakeholders, and the public. Others create building blocks to support key outcomes in the medium-to long-term. The goals, objectives, and priorities in this document were developed through a collaborative effort involving Federal agencies and stakeholders with interests and responsibilities linked to the ocean.

GOAL I. UNDERSTAND THE OCEAN IN THE EARTH SYSTEM

Overview

The ocean is the largest habitat and is home to some of the most biodiverse areas of the planet. To date, we have explored less than five percent of the global ocean.⁹ The ocean is the predominant physical feature on our planet and drives the global climate through the absorption, retention, and transportation of heat, water, and carbon. The global ocean S&T enterprise has made significant progress in understanding the physical, chemical, and biological aspects of the ocean system, but the dynamic ocean environment is changing in terms of ocean chemistry, temperature,

⁷ Prospectus: Ocean Research in the Coming Decade. (October 2016) <https://www.nsf.gov/geo/oc/orp/orp-prospectus.pdf> (accessed April 17, 2018).

⁸ NSTC Joint Subcommittee on Ocean Science and Technology. (2007) *Charting the Course for Ocean Science in the United States for the Next Decade. An ocean research priorities plan and implementation strategy*, p. 85. <https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/nstc-orppis.pdf> (accessed April 17, 2018).

⁹ National Ocean Service. How much of the ocean have we explored? <https://ocean.service.noaa.gov/facts/exploration.html> (accessed April 17, 2018).

sea-level, and currents, all of which affect marine biology.¹⁰ Consequently, we must make observations, refine our models, and develop new predictive capabilities to be able to sustainably manage our ocean resources.

Scientific and technological advances have brought significant improvements in our understanding of the ocean. Exploration, discovery, and assessment of marine resources, processes, and ecosystem structure and function are vital to capitalize on economic opportunities, improve human health, and protect life and property at sea. Molecular and chemical techniques and biological tools allow us to identify and understand the contributions of the smallest organisms, while satellites and autonomous vehicles have revealed ocean behavior on temporal and spatial scales that were previously inaccessible. Developments in electronic technologies have opened new research and technological horizons. However, a combination of existing and emergent technologies and modeling capabilities are needed to further elucidate the ocean's behavior, its future trajectories, and its connections to other components of the Earth system. These technological capabilities will inform evidence-based stewardship, ensuring continued safeguarding of the air we breathe, the water we drink, and the food we eat.

The study and exploration of the ocean begins at the sea surface and reaches to the deepest depths, where the ocean interacts with the sediments on the seafloor and, further still, the deep biosphere found in the ocean sediments and crust beneath the seafloor. Recent studies have demonstrated the increasing importance of the deep ocean for heat storage and of ocean variability on global climate and weather patterns. The ocean's heat content and stratification have increased, which in turn have affected its oxygen content and pH, and other key biogeochemical and ecological components. The increase in ocean heat content accounts for most (over 90 percent) of the overall changes in the Earth's energy budget.¹¹ Coastal oceans are regions of high carbon storage and rapid change, and are especially important to fisheries. To understand present conditions, determine rates of change, and make reliable projections of the future states of the Earth system and climate, we need to understand the underlying characteristics of our environment. This first goal seeks to improve the foundational understanding of the global ocean, which is paramount to achieving the other four goals highlighted in this document.

Modernize R&D Infrastructure

Access to the sea has always been a fundamental hurdle for marine research as the ocean can be a harsh, unforgiving, and dangerous environment. Consequently, our research infrastructure is critical to our Nation's leadership role in ocean science, and plays a significant foundational role in each of the areas this document addresses. The infrastructure and technology necessary for successful ocean research includes ships, submersibles, aircraft, satellites, land-based radar, moorings and cabled buoys, and various unmanned underwater, surface, and airborne vehicles. Research infrastructure also includes land-based facilities, *i.e.*, state of the art laboratories, to support deployed ocean assets and to receive, analyze, and manage incoming data using high-performance computing and communications networks that support wide access to and use of information. Additionally, investment in modern laboratories is critical to conducting corresponding experiments that are essential to our understanding of the changes we observe in nature.

Ocean observations, both remote and *in situ*, remain vitally important for advancing knowledge of and detecting changes in the ocean system over time, and for predicting weather impacts on community infrastructure, safety, and commerce (Box 1.1). They also feed into tactical models and decision aids for marine operators, as well as critical information for economic and national security activities. Observations and regular surveys are supported by essential infrastructure, including ship and aircraft fleets, and ocean remote sensing assets. Networks of fixed monitoring stations and moorings, drifting floats, and cabled observatories also represent foundational infrastructure for ocean research. Autonomous underwater vehicles (AUVs) and remotely operated aerial and surface vehicles are innovative technologies that are changing marine research and rapidly expanding and improving accessibility to the research and technology seascape. With precision navigation, high endurance, and multiple sensors, these vehicles now routinely launch from

¹⁰Lenton, T.M., H. Held, E. Kriegler, J.W. Hall, W. Lucht, S. Rahmstorf, and H.J. Schellnhuber. (2008) Tipping elements in the Earth's climate system. *Proceedings of the National Academy of Science* 105(6):1786–1793. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2538841/> (accessed June 15, 2018).

¹¹IPCC Fourth Assessment Report: Climate Change 2007. Working Group I: The Physical Science Basis. 5.2.2.3 Implications for Earth's Heat Balance. https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch5s5-2-2-3.html (accessed June 15, 2018).

ships and land stations with the capability to efficiently collect and automatically send large volumes of valuable data.

Box 1.1. Connecting Observations to the Distant Ocean, an Example from the Southern Ocean

The Southern Ocean Carbon Climate Observation and Modeling (SOCCOM) project seeks to extend sparse physical and biogeochemical observations of the remote Southern Ocean by deploying a robotic observing system composed of some 200 autonomous profiling floats to provide greatly increased coverage in time and space of the Southern Ocean. The Southern Ocean plays an important role in regulating global ocean circulation and long-term climate patterns. The processes and changes occurring therein will be analyzed and used to improve the next generation of high resolution coupled Earth system models used to project the future changing paths of the Earth's climate and biogeochemistry. As well as SOCCOM's mission to transform scientific and public understanding, the education of a new generation of ocean scientists is needed to extend the SOCCOM float technology to a broader user community.

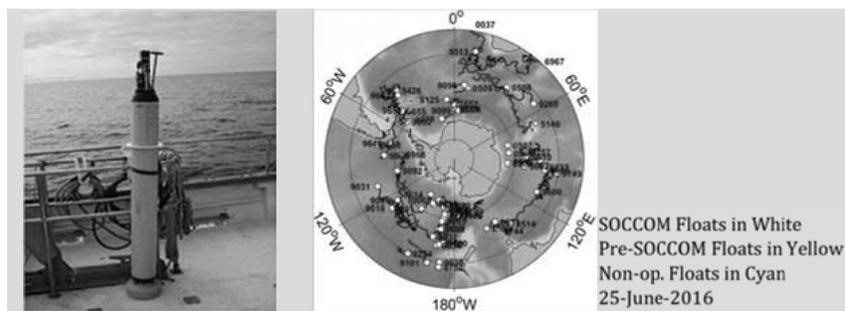


Figure 1.1. SOCCOM technology and map. (Images courtesy of NSF)

Presently, most observations occur in the upper few hundred meters of ocean, and mostly take place in the Northern Hemisphere. However, ship-based observations, complemented by sustained deployment of subsurface floats, moored instruments, and autonomous vehicles (*e.g.*, ocean gliders and other AUVs) have enabled significant expansion of our reach in observations of biological, chemical, physical, and geological variables (Box 1.2) as well as energy resources throughout the ocean.

Box 1.2. Essential Ocean Variables

Ocean observations are often prioritized based on nationally and globally agreed upon Essential Ocean Variables (EOVs) that are key to assessing change and causes of change in the ocean.¹² These variables include physical, biogeochemical, biological, and acoustic measurements that influence societal needs such as ocean health as well as short- and mid-term weather forecasting, and longer-term changes in climate. EOVs provide input to numerical models, and improve our ability to more quantitatively project changing ocean and atmospheric conditions. Emerging technologies should consider current EOVs and develop technologies to improve measurement of EOVs, while maintaining the quality required for sustained observational records that can capture EOVs, while maintaining the quality required for sustained observational records that can capture events, as well as identify the emergence of longer trends through time.¹³

Ocean research infrastructure is one of the highest priorities of the ocean S&T community. Our Nation's ocean research infrastructure needs to align capabilities with the requirements, including the number and type of research vessels, to ensure that our assets are optimized through coordination and collaboration while also retaining the capacity to meet its goals. This includes satellite and other autonomous data collection efforts and the related archive and data storage infrastructure. The

¹²The Task Team for an Integrated Framework for Sustained Ocean Observing. (2012) A Framework for Ocean Observing. UNESCO, Washington, D.C. IOC/INF-1284 rev. p. 25. <http://unesdoc.unesco.org/images/0021/002112/211260e.pdf> (accessed June 15, 2018).

¹³Henson, S.A., C. Beaulieu, and R. Lampitt. (2016) Observing climate change trends in ocean biogeochemistry: when and where. *Global Change Biology* 22(4):1561-1571. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4785610/> (accessed June 15, 2018).

increase in autonomous data collection will result in increased storage and processing of Big Data¹⁴ and improve analytical methods.

Next-generation observing systems are needed to meet the growing risk and limited understanding of the physical processes controlling the occurrence, timing, and magnitude of geohazards and extreme weather events. Fundamental understanding of Earth processes and basic research of the subduction zone phenomena¹⁵ will lead to the scientific understanding needed for robust forecasts of future geohazards and related events and can ultimately greatly assist risk mitigation. Obtaining long-term, high-quality seismic observations on the seafloor, and regularly telemetering these data to shore, is now feasible due to recent technological advances in timing, power, shielding, underwater and satellite telemetry, and autonomous vehicles (Box 1.3). While hurricane track forecasts have improved dramatically, improvements in hurricane intensity predictions have lagged. At-sea observations of water column temperatures are essential for improving both hurricane track as well as hurricane intensity forecasts.

Box 1.3. CubeSats and Other Readily Available Sensing Technologies

Satellites once exclusively operated by nation states now have the simplicity to be built by high-school students.¹⁶ As launch opportunities grow, the ocean science community is better poised to rapidly enhance global observations of the world's oceans. Similarly, autonomous and remote-controlled air vehicles can now be equipped with sophisticated sensors suitable for shipboard and coastal studies. Multi- or hyper-spectral electro-optical sensors can now routinely measure ocean biological parameters over wide areas. Day-night, all-weather sensing of the ocean surface using radar allows measurement of ocean winds and waves, as well as detection of vessels. Transmission of data from satellites to users will soon be significantly enhanced by Wi-Fi satellites, so that high fidelity data can be readily transmitted without regard for bandwidth limitations. Likewise, data from drifters, gliders, and unmanned surface vessels can be rapidly routed to users.



Figure 1.2. Students contribute to collecting Earth observations while getting hands-on experience building CubeSats: inexpensive, small, 3-pound satellites. (Image courtesy of NASA)

¹⁴“Big data” refers to data sets so large and complex that commonly used or traditional data processing tools to capture, curate, and manage data within a tolerable elapsed time are inapplicable. Compared to traditional data, “Big Data” is characterized by high volume (enormous size of data), high velocity (timely response requirements), high variety (diversified data types), low veracity (uncertainties in the data), and high value (significance in knowledge and products).

¹⁵Gomberg, J.S., and K.A. Ludwig. (2017) Reducing risk where tectonic plates collide: U.S. Geological Survey Fact Sheet 2017. 302:1–4. <https://pubs.usgs.gov/fs/2017/3024/fs20173024.pdf> (accessed May 9, 2018).

¹⁶Buck, J. (2013) NASA Helps Launch Student-Built Satellites as Part of CubeSat Launch Initiative. NASA Public Release 13-343. <https://www.nasa.gov/press/2013/november/nasa-helps-launch-student-built-satellites-as-part-of-cubesat-launch-initiative> (accessed April 20, 2018).

Priorities

- Sustain critical ocean monitoring and support new observations and discovery in the world's ocean to provide the continuous information streams that inform research, advance forecasts, and support resource management decisions.
- Prioritize new observing methods focused on processes that lack fundamental understanding, such as the recently released biogeochemical versions of Argo floats¹⁷ and gliders, especially in areas identified as being important for human health and safety.
- Identify and expand observations for unique processes and locations for extreme events, as well as in under-sampled areas of the global ocean, such as the deep-sea, offshore frontiers, the Southern Hemisphere, and key continental margins (Box 1.1).
- Support the development and accuracy of technologies in controlled environments at the interfaces: where land meets water, where water meets air, where water meets ice, and where water meets the ocean bottom.
- Utilize data from local hydrographic, geophysical, and atmospheric variables, and bathymetric maps of the ocean floor to serve as boundary conditions for observations and models and to advance early tsunami and earthquake warning systems.

Harness Big Data

Big Data is revolutionizing our understanding of the ocean Earth system. Big Data allows scientists to measure and gain large amounts of information about the environment and directly translate that knowledge into enhanced scientific models and products to improve decision-making.¹⁸ From a broad perspective, Big Data is the bond that connects and integrates the environment, human society, and cyberspace.⁵ Big Data allows for the assessment of relationships between the ocean and other elements of the Earth system through rigorous, data-driven methods. Advancements in Big Data capabilities can improve general circulation models and, ultimately, integrated Earth system models, as well as improve dynamic, integrated and/or coupled biophysical models for future condition forecasting. Two sources of Big Data in oceanography are: (1) large amounts of multi-dimensional data measuring a wide range of ocean variables collected by remote and *in situ* sensors across the globe, and (2) well-constrained and ground-truthed model simulations of ocean processes on global, regional, and local scales with high spatial and temporal resolution.

Critical to sustaining ocean biodiversity is a mixed set of research and applications including, but not limited to, sustained ocean observations, the infrastructure needed for those observations in support of Essential Ocean Variables (EOVs), and blending in new approaches such as “omics.” Omics,¹⁹ a subset of molecular tools including genomics, proteomics, and metabolomics, is an emerging Big Data field with the potential to transform our ability to characterize the biological composition of the ocean efficiently, comprehensively, and at reduced costs (Box 1.4). For example, using metagenomics to inventory the microbiomes of various ocean habitats has allowed for a greater understanding of diverse microbial population structure and gene expression (*i.e.*, behavior) over space and time. Metagenomics tools can be extended beyond bacteria to include the study of marine viruses (an emerging area of epidemiology), phytoplankton, zooplankton, and holobionts such as sponges and corals. A challenge for the coming decade is determining how microbial population structure and function vary with physical and chemical oceanographic parameters. Addressing such a challenge will enhance marine monitoring by measuring food web function, species biodiversity, prevalence of pathogens and pollution, and the rate

¹⁷Tollefson, J. (2016) Massive network of robotic ocean probes gets smart upgrade. *Nature* 531:421–422. <http://dx.doi.org/10.1038/531421a> (accessed June 15, 2018).

¹⁸McAfee, A., and E. Brynjolfsson. (2012) Big Data: The management revolution. *Harvard Business Review* 3–9. <https://hbr.org/2012/10/big-data-the-management-revolution> (accessed April 17, 2018).

¹⁹The term omics refers to fields of study in molecular biology with the suffix—omics, which aim to better detect, characterize, quantify, and understand pools of biological molecules [such as genes (genomics), mRNA (transcriptomics), proteins (proteomics), and metabolites (metabolomics)] in a given sample. More information can be found at: Horgan, R.P., and L.C. (2011) ‘Omic’ technologies: genomics, transcriptomics, proteomics and metabolomics. *The Obstetrician & Gynaecologist* 13:189–195. <https://obgyn.onlinelibrary.wiley.com/doi/full/10.1576/toag.13.3.189.27672>; Gilbert, J.A., G.J. Dick, B. Jenkins, J. Heidelberg, E. Allen, K.R. Mackey, and E.F. DeLong. (2014) Meeting report: Ocean ‘omics science, technology and cyberinfrastructure: current challenges and future requirements (August 20–23, 2013). *Standards in Genomic Sciences* 9(3):1251. <https://doi.org/10.4056/sigs.5749944> (accessed June 15, 2018).

at which microbes degrade materials. Such omics technologies can augment traditional observation programs and are being integrated into buoy-deployed and mobile AUVs.

The ocean S&T enterprise must continue to support data repositories, cloud computing, and data-sharing efforts. Observing System Simulation Experiments (OSSE)²⁰ and Observing System Experiments (OSE)²¹ used in parallel with ocean models and data assimilation strengthen the impact of fewer observations and cost-effectively optimize remote and *in situ* ocean sampling. A unified national effort should aim to establish common frameworks across diverse computing systems and facilitate data integration. These efforts will establish a common structure for Big Data datasets and promote efficient data sharing while minimizing costs and resources.²²

Box 1.4. Big Data from Environmental DNA

As organisms move through the ocean, they leave in their wake a path of tiny particles which scientists can sample for DNA. Environmental DNA (eDNA) is an emerging omics technology that allows researchers to sample water, soil, or air in order to determine the species found in that area. eDNA is a cost-efficient and quick surveillance tool useful for assessing a habitat's biodiversity, monitoring for invasive species, and tracking the movements of threatened and endangered species. Informing on the presence, absence, and abundance of certain species has great potential for better understanding and managing vulnerable ocean habitats. Ensuring quality control of eDNA data, managing the massive amount of data generated from sampling eDNA, and applying eDNA data to support decision-makers will allow the Federal government to capitalize on the potential benefits of eDNA technology.

Priorities

- Advance Big Data analytics and cloud computing platforms to identify and forecast changes in ocean circulation and heat transport, ocean biogeochemical cycling, marine ecosystems and ecosystem services, and sea level rise.
- Increase and sustain the ocean community's access to usable Big Data, and strengthen the interactions between the ocean observing, research, and modeling communities.
- Strengthen high-performance computing to effectively process and use Big Data analytics and omics technologies that enhance the understanding of the ocean Earth system.
- Deploy recent technological advances such as environmental DNA (eDNA) and other omics approaches to ocean assessments.

Develop Models of the Earth System

The foundational research and technology needed to advance our understanding of the ocean within the Earth system includes modeling ocean conditions, atmospheric and weather dynamics, and climate. In particular, monitoring and understanding changes in the coastal zone is fundamental to improving capacity to predict how the coastal ocean may respond to future changes, the associated impacts on marine ecosystem services, and the resilience of the communities that depend on them.

Coastlines consist of distinct, but tightly coupled systems that are connected to nearby terrestrial systems by the flow of water and materials from coastal and estuarine drainage areas to the ocean (Box 1.5). Understanding and quantifying the impacts and feedbacks of human and environmental influences on coastal ecosystems requires comprehensive, multi-and-inter-disciplinary research, including steps toward development of predictive capabilities. Added emphasis should be placed on particularly vulnerable systems, such as bays, estuaries, coastal wetlands, marshes and mangrove systems, and high latitude regions, such as the Arctic.

²⁰ Masutani, M., T.W. Schlatter, R.M. Errico, A. Stoffelen, E. Andersson, W. Lahoz, J.S. Woolen, G.D. Emmitt, L-P Riishøslash;jgaard, and S.J. Lord. (2010) Observing System Simulation Experiments. 647–680. In: Lahoz W., B. Khattatov B., and R. Ménard (eds.) Data Assimilation. Making sense of observations. Springer, Berlin, Heidelberg.

²¹ Lord, S., G. Gayno, and F. Yang. (2016) Analysis of an observing system experiment for the Joint Polar Satellite System. *Bulletin of the American Meteorological Society* 97(8):1409–1425. <https://doi.org/10.1175/BAMS-D-14-00207.1> (accessed June 15, 2018).

²² For example, ongoing efforts by NOAA, the U.S. Navy, and others are focusing on building a common ocean modeling framework merging Arbitrary Lagrangian Eulerian (ALE) ocean models by establishing a merged code-base permitting options for different spatial resolutions and temporal model integration extents.

Box 1.5. The Interconnected Earth System

Focused research and application to advance our knowledge of the Earth system includes a variety of many ocean S&T perspectives to account for the interconnectedness of key components. The flow of water and constituents (dissolved and particulate) from land to the coastal ocean connect the terrestrial and marine systems. Natural and anthropogenic processes add and alter riverine constituents that flow to the coastal ocean; inputs are regulated by hydrology (precipitation and evaporation), land use, and condition of the drainage network (including reservoirs and ecological condition of estuaries). In the coastal zone, physical and biogeochemical processes control the transport and fate of the discharged material, which may be recycled or removed (via export) from the system.

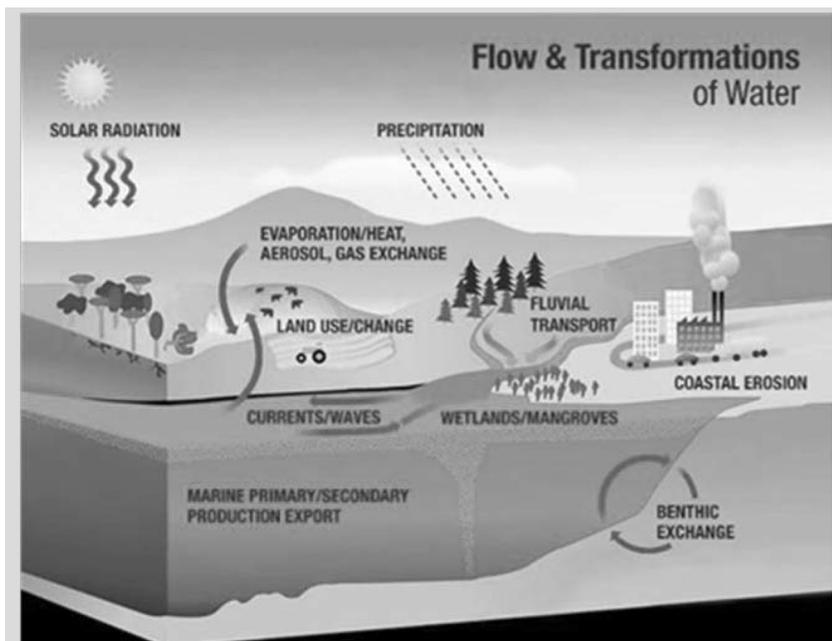


Figure 1.3. Water flow and transformations with the Earth system. (Image courtesy of NASA)

Adaptation to and mitigation of coastal change, and resilience to extreme events, requires understanding the vulnerability of coastal zones.²³ Reliable and validated models that integrate coastal processes, hydrography, and land use and change, and include biogeochemical processes and biodiversity, are essential to predict changes in ecosystem services. Such models are also important to project potential impacts on public health, infrastructure, and the economy, and to provide communities and decision-makers with options and cost-benefit analyses. Understanding the interaction between land and ocean cannot be limited to the development of technologies or model improvement. In order to ensure ocean resource sustainability, biological, chemical, geological, and physical process studies should consider applications useful to decision-making by coastal managers, and should forge synergies across disciplines to put forward an integrated understanding of the coastal system.

Priorities

- Focus research and modeling activities that integrate dynamic parts of the Earth system, including the interface of the ocean-cryosphere, the ocean-atmosphere, and the land-ocean coastal zones.
- Improve and validate Earth system models that feature interactions between the ocean and atmosphere to better predict and forecast weather around the globe.

²³ Adger, W.N., J. Barnett, K. Brown, N. Marshall, and K. O'Brien. (2013) Cultural dimensions of climate change impacts and adaptation. *Nature Climate Change* 3(2):112–117. <https://www.nature.com/articles/nclimate1666> (accessed June 15, 2018).

- Engage various research communities, including academia, to enhance model success and provide continuous improvement and support.
- Improve biological modeling and the development of bioinformatic analyses to better predict effects caused by stressors on coastal and marine ecosystems.
- Examine quantitative precipitation forecasts (QPFs) and data assimilation resulting in more accurate coupled ocean-land-weather modeling.

Facilitate Research to Operations

Applying R&D advancements to operation, commercialization, or other uses is fundamental to advance the United States in ocean S&T, and to enhance economic prosperity, maritime security, human health, and resilient coastal communities. Such transitioning of research concepts requires a comprehensive understanding of the ocean Earth system including the role of external factors. Research which adopts a social-ecological system (SES) lens and considers the whole system, particularly context-specific factors, is more likely to observe operational success. Coupled physical, biological, chemical, and socioeconomic models support the systems based approach that many ocean S&T applications depend upon.

For example, much progress has been made in weather forecasting in the last decade, both with respect to more accurate modeling, and moving from forecasting (modeling) to Impact-based Decision Support Services (IDSS). Sustained progress in forecasting and IDSS will critically depend on a more holistic approach to environmental modeling, particularly on shorter “weather” time scales, by expanding coupled modeling experiences gained with seasonal forecasting, tropical cyclone and weather-ice-ocean models to fully-coupled global and regional atmosphere-ocean-ice-land-aerosol-wave prediction for weather time scales.

Priorities

- Integrate environmental observing and prediction systems with multi-use prediction and simulation systems to promote economically efficient, environmentally sound, and successful operations across the broad spectrum of marine operations.
- Support global operational modeling capabilities in order to improve the ability to protect global operational forces, installations, and equipment from hazardous conditions of the physical environment.
- Develop programs that provide a more accurate, validated, longer range, global ocean, atmosphere, and sea ice forecast system for decision support to safety of flight, safety of navigation, and mission planning.
- Advance interagency collaborations in order to pursue goals such as the deployment of unmanned underwater gliders prior to hurricane season, which will provide better awareness of storm intensity leading to improved hurricane forecasts.
- Sustain forecasting capabilities, for example, by maintaining a network of drifting buoys in the Arctic Ocean, which collect sustained weather and oceanographic observations for 3–5 years and provide operational and scientific communities access to *in situ* data.²⁴

GOAL II. PROMOTE ECONOMIC PROSPERITY

Overview

Optimizing sustainable use of our exclusive economic zone (EEZ) and the high seas is vital to America’s global economic leadership (Box 2.1). The U.S. ocean economy, which includes six economic sectors that depend on the ocean, is estimated to have contributed more than \$320 billion to the U.S. Gross Domestic Product (GDP) and supported 3.2 million jobs directly dependent on these resources in 2015.²⁵ These economic sectors include: living resources, marine construction, offshore mineral extraction, tourism and recreation, ship and boat building, and marine transportation.

Our ocean is home to a vast array of living and non-living marine resources. Much of the ocean is underexplored, and offers great potential for advancing science, technology, and our growing economy. Our resources are central to the national economy

²⁴ As also supported by Performance Element 3.1.2 in the Interagency Arctic Research Policy Committee. (2016) Arctic Research Plan FY2017–2021. Washington D.C. p. 84. <https://www.iarpccollaborations.org/plan/objective/3.1> (accessed April 17, 2018).

²⁵ NOAA. (2018) Report on the U.S. Ocean and Great Lakes Economy. Charleston, SC: NOAA Office of Coastal Management, p. 27. <https://coast.noaa.gov/data/digitalcoast/pdf/econ-report.pdf> (accessed May 31, 2018).

and American quality of life, and thus we must balance our present use of ocean resources with a productive and healthy ocean for future generations. Characterizing the primary uses of the marine environment (including fisheries, aquaculture, transportation/shipping, energy, national security, land values, mineral extraction, recreation, and protected species habitat) and the goods and services, beneficiaries, and market and non-market values attributable to those uses, is key to understanding the ocean's potential.

Living marine resources serve critical roles in their ecosystems and in sustaining life on land; they are used for food, medicine, and cosmetics, and support services such as fisheries and tourism, as well as processes that may regulate climate (*e.g.*, biologically-controlled marine processes absorbing excess atmospheric carbon dioxide and the absorption and transport of atmospheric heat). Non-living marine resources also serve multiple roles, in powering our communities, reducing our dependence on foreign sources of minerals, providing avenues for transportation, and controlling climate (*e.g.*, through thermohaline adjustments). The ocean S&T enterprise can expedite and better inform the exploration, assessment, and sustainable management of America's living and non-living marine resources.

Emerging innovative technologies serve a critical role in capitalizing on marine resource economic opportunities while sustaining future options. S&T advancements will provide the necessary information to guide future development and investment opportunities and allow resource-dependent communities to adapt to ocean changes. As resource identification and surveying progresses, it is critical to ensure balance among multiple ocean uses, such as between exploring energy resources while also supporting recreational activities. Ocean education will drive technological breakthroughs, will strengthen public understanding and engagement in best using and protecting ocean resources, and will provide a foundation for the Nation's growing blue workforce. Readily available data and user-friendly quality assured tools incorporating the best available environmental and social data will empower our resource managers and policy makers to harness America's resources responsibly.

Box 2.1. The U.S. EEZ

The United States' Exclusive Economic Zone (EEZ) is one of the largest in the world, encompassing approximately 4.38 million square miles.²⁶ Coastal counties contain approximately 40 percent of the U.S. population, yet account for only 10 percent of the area within the U.S.²⁷ As the U.S. population is expected to surpass 400 million by the middle of this century,²⁸ it is important to understand how ocean changes will impact the Nation's economic security, safety, environment, and health:

- 42 percent of the U.S. labor force is employed in coastal watersheds.²⁹
- In 2014, counties adjacent to the shore contributed to 43 percent of the U.S. GDP.²⁹
- The offshore mineral industry contributed over 170,000 jobs in 2013 and \$122 billion, the majority of which was predominantly from the oil and gas sector.²⁹
- Approximately 88,000 square miles of the Nation's coastal wetlands provide nursery areas for commercially harvested fish and places of refuge for migrating birds.²⁹
- In 2015, the commercial and recreational fishing industry supported 1.6 million jobs and contributed \$208 billion in sales to the U.S. economy.³⁰
- Ocean measurements, observations, and forecasting generate about \$7 billion in revenues annually.³¹

²⁶ NOAA. (2011) The United States is an Ocean Nation. https://www.gc.noaa.gov/documents/2011/012711_gcil_maritime_eez_map.pdf (accessed June 18, 2018).

²⁷ NOAA. (2013) National Coastal Population Report: Population Trends 1970 to 2020. <http://oceanservice.noaa.gov/facts/coastal-population-report.pdf> (accessed April 17, 2018).

²⁸ Colby, S.L., and J.M. Ortman. (2014) Projections of the size and composition of the U.S. Population: 2014 to 2060. Current Population Reports, P25-1143, U.S. Census Bureau, Washington, D.C. <https://census.gov/content/dam/Census/library/publications/2015/demo/p25-1143.pdf> (accessed June 18, 2018).

²⁹ NOAA. (2016) State of the U.S. Ocean and Coastal Economies 2016 Update. National Ocean Economics Program. National Marine Fisheries Service. http://midatlanticocean.org/wp-content/uploads/2016/03/NOEP_National_Report_2016.pdf (accessed April 19, 2018).

³⁰ National Marine Fisheries Service. (2016) Fisheries Economics of the United States, 2015. U.S. Dept. of Commerce, NOAA Tech. Memo. NMFS-F/SPO-163, p. 237. <https://www.fisheries.noaa.gov/feature-story/fisheries-economics-united-states-2015> (accessed June 15, 2018).

³¹ ERISS Corporation, the Maritime Alliance. (2016) The Ocean Enterprise. A study of U.S. business activity in ocean measurement, observation and forecasting. <https://ioos.noaa.gov/project/ocean-enterprise-study/> (accessed April 19, 2018).

Priorities

- Support development and deployment of sensors to detect, identify, and quantify target and protected species.
- Employ real-time data techniques and modern data management to reduce uncertainty in fishery management.
- Leverage and evolve scientific tools and information to support a clear road map for aquaculture permitting including effective siting, water quality, genetics, and other science-based computer tools to aid industry with applications for aquaculture sites and compliance with government mandates.
- Develop and test genetic approaches that safeguard wild genetic diversity while allowing for genetic improvement of resources such as farmed shellfish stocks, and use the hatcheries to develop such genetic selection programs for a range of commercially valuable resources such as mollusks.
- Advance ocean-based biomass research and technologies to better produce food, fiber, biofuel, and other products from sources such as seaweed farms and transfer technology to industry.

Explore Potential Energy Sources

America's coastline and extensive EEZ contains vast untapped renewable (wave, tidal, wind, thermal) and non-renewable (oil and gas) energy sources to help power the Nation (Box 2.2). The Federal government has an interest in harnessing American energy sources safely and efficiently through new and innovative technologies. In particular, the United States can use emerging technologies to rapidly increase seafloor mapping and further assess the ocean's potential as an energy source. New acoustic technologies will expand ocean exploration and discovery, and provide a better understanding of energy development impacts on the marine environment.

The ocean floor is similar to the terrestrial environment; it has mountains, canyons, channels, and hills. Most of these features are unmapped and unexplored, with only 5–15 percent of the ocean floor currently mapped. Detailed mapping and depth measurements, *i.e.*, bathymetry, are important to better understand climate, earthquakes, tsunamis, and weather forecasting, habitat, and biodiversity, as well as ocean resource use and exploration. "Seabed 2030" is an international collaboration of public and private partners focused on compiling a high-resolution map of the global ocean over the coming decade.³⁷ The Federal government will continue to map and better characterize America's EEZ. Bathymetric data will provide the necessary information to identify energy sources, and will also have cascading benefits for fisheries management, mineral extraction, cable and pipeline routing, natural hazard preparedness, and military and defense applications.

Box 2.2. Potential Untapped Sources of Energy

Oceanic and coastal gas hydrates are possible significant sources of untapped energy, albeit which are environmentally challenging due to their role in destabilizing continental shelf and slopes as well as their presence in regions with permafrost. Similarly, untapped energy may exist in deep ocean hydrothermal systems. Understanding the processes of hydrothermal systems requires a systematic approach integrating magmatic, tectonic, geochemical, fluid flow, heat and mass flux, mineral formation, circulation, and biological processes. These hydrothermal systems produce deep-ocean mineral deposits, seafloor massive sulfides, and contribute to ferromanganese crusts and nodules through fluxes of metals to seawater. Iron and manganese play key roles in the geochemical balance of the ocean, including processes relevant to the production of carbon and its flux within and out of the ocean.

³⁷ Seabed 2030 is a collaborative partnership between the General Bathymetric Chart of the Oceans (GEBCO) and the Nippon Foundation aimed to facilitate the complete mapping of the ocean floor by 2030. More information can be found at: <https://seabed2030.gebco.net/> (accessed May 8, 2018).

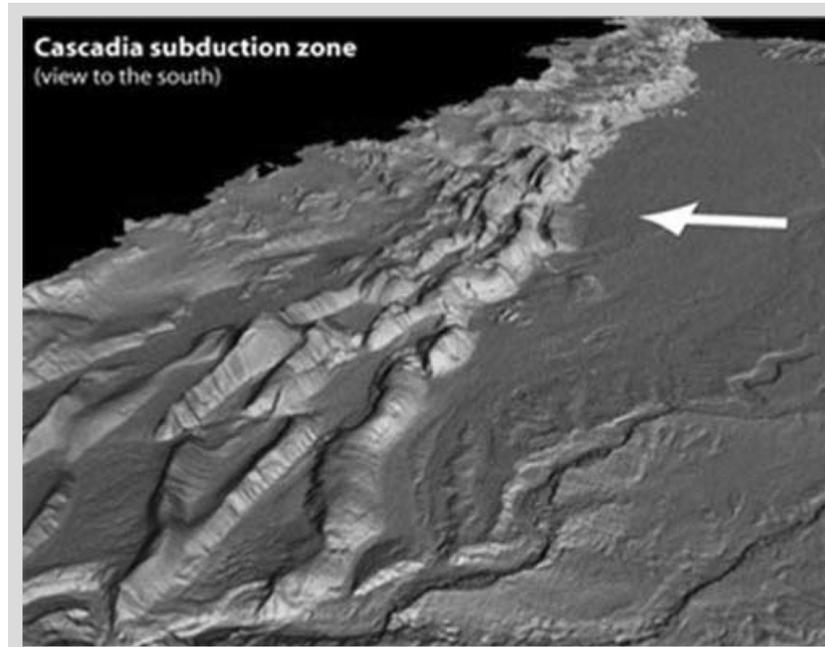


Figure 2.2. Perspective bathymetric image looking southeast of Cascadia margin (Image from Pratson and Haxby 1996)³⁸

Priorities

- Continue mapping the U.S. EEZ and perform surveys and characterizations of ocean resources and their habitats, data tools, and logging platforms to provide temporal and spatial coverage, and assessments of classification, condition, and valuation mapping.
- Develop efficient and cost-effective at-sea power generation (wave, methane, etc.) for ocean observation platforms.
- Study contaminant releases (*e.g.*, oil spills, natural seeps, pollutant loading) and benthic disturbances to improve understanding of their effects on coastal communities and transportation routes.
- Support new technologies to measure underwater noise levels and acoustic conditions in coastal and open ocean environments in order to quantify long-term trends in ocean noise levels, monitor changes in acoustic habitats, and assess the impacts of increases in human produced noise.

Assess Marine Critical Minerals

U.S. offshore and deep-sea areas remain mostly unexplored and unused. Especially important for American independence and prominence in the global market is access to critical minerals in the marine environment. Given that China is the top supplier of many of the 35 critical minerals identified in the U.S. 2018 list of critical minerals,³⁹ the U.S. needs policies, infrastructure, and technologies to produce and maintain supplies of critical minerals. A recent Executive Order highlighted the importance of “identifying new sources of critical minerals” and “increasing activity at all levels of the supply chain, including exploration, mining, con-

³⁸ Pratson, L.F., and W.F. Haxby (1996) What is the slope of the U.S. continental slope? *Geology* 24(1):3–6. <https://pubs.geoscienceworld.org/gsa/geology/article-abstract/24/1/3/206427/what-is-the-slope-of-the-u-s-continental-slope> (accessed April 15, 2018).

³⁹ Department of Interior. (2018) Final list of critical minerals 2018. <https://www.gpo.gov/fdsys/pkg/FR-2018-05-18/pdf/2018-10667.pdf> (accessed June 15, 2018).

centration, separation, alloying, recycling, and reprocessing critical minerals.”⁴⁰ Such efforts can be supported by exploration of the outer continental shelf to the abyssal plains and hydrothermal vents and seamounts along the mid-ocean ridges for valuable resources including manganese nodules, cobalt-rich crusts, and polymetallic sulfides.

In the past, the harsh environment and inaccessibility of potential extraction sites have meant that the marine environment was often discounted as a source for critical minerals. In the coming decade, the ocean S&T enterprise can support the United States in the discovery and assessment of marine resources. Basic mapping, baseline data, and ocean condition observations are foundational for understanding these resources and planning how to best use them.

Priorities

- Identify and quantify the location, size, and nature of important deep-sea minerals to better understand the complexity and scalability of resource use through sediment characterization and geochemical signals.
- Conduct basic and applied research to characterize the effects of deep-sea mining on vulnerable marine ecosystems, including the impact of light, heat, rock debris, underwater sediment plumes, noise, and biodiversity loss. Such research should include documentation of deep sea biodiversity, and improved prediction of the scale and extent of environmental impacts from deep sea exploration.
- Study the physical conditions at environmentally sensitive and important areas using surveys and gap analyses to assess effectiveness of current monitoring efforts and platforms.
- Continue involvement in global endeavors such as the SeaBed 2030 Initiative, which aims to map the entire ocean floor by 2030; and the International Seabed Authority, which aims to limit harm to the marine environment from deep seabed mining.

Balance Economic and Ecological Benefits

Adaptive management allows U.S. managers and decision-makers to effectively govern America’s ocean resources according to new information and changes in context, while also balancing short-term gains with long-term objectives. Decision-makers rely on research on the changes in resource and habitat condition as well as up-to-date information on human uses (*e.g.*, frequency, duration, and intensity of use).

The United States is exceptional because of its wide range of coastal ecosystem types, from the cold Arctic waters of Alaska to the temperate Gulf of Mexico to the tropical reefs of southern Florida. Management of these unique ecosystems requires location-specific data and information to be included in adaptive management strategies. Regional knowledge provides the context needed for successful adaptive management of marine resources.

Adaptive management which adopts a systems lens can contribute to balancing economic and ecological goals. System-based management relies on decision-support tools that incorporate socio-economic data, include stakeholder knowledge, and better link physical and chemical ocean changes with corresponding biological responses. Research on how organisms and marine populations respond to environmental changes will enable better predictions of economic and societal effects from environmental changes, especially for the most at-risk industries such as fisheries, ocean recreation, and marine tourism. Trade-offs are inevitable in using and managing natural resources, and decision-support tools can provide management options when assessing use of ocean resources. Further understanding of ecological and economic relationships can better support effective valuation methods (*e.g.*, for food, transportation, land values, extraction of minerals and other natural products, and recreation). Integrating socioeconomic and ecosystem-based management can facilitate more adaptive management.

Understanding of cumulative impacts is also critical to improving adaptive management and to optimizing objectives. Ocean resources are exposed to many different stressors, such as eutrophication, marine debris, and ocean noise. Our Nation will rely on research to evaluate cumulative impacts of multiple human influences as well as data on how changes in natural environmental stressors exacerbate stressor impacts. Recent developments have led to the increased use of advanced technologies such as DNA-probes and biosensors. Monitoring and forecasting efforts

⁴⁰ See Executive Order 13817, issued on December 20, 2017, A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals. <https://www.whitehouse.gov/presidential-actions/presidential-executive-order-federal-strategy-ensure-secure-reliable-supplies-critical-minerals/> (accessed June 18, 2018).

will be enhanced through state-of-the-art passive acoustic observing capabilities by the national Ocean Sound and Noise Monitoring Network.⁴¹

Priorities

- Develop biological and ecosystem indicators and determine their efficacy for understanding cumulative impacts and assessing the overall vulnerability of marine resources and ecosystem services to human influences at all trophic levels, particularly in light of shifting baselines.
- Identify evaluation and performance criteria that managers can use to gauge effectiveness of management strategies.
- Continue quantitatively monitoring coastal and open ocean biogeochemical trends to characterize changes in ocean acidification, and assess impacts of Sea Level Rise (SLR) on ocean resources.
- Explore “intervention” science and techniques that recognize and leverage the inherent resistance and adaptive qualities of species under the threat of degradation or mortality with changing environmental conditions.
- Support development of next generation biodegradable plastics to reduce marine debris impacts on marine life and coastal communities.
- Explore low impact, alternative fuel sources for maritime and port-related uses, balancing stewardship with energy efficiency, cost-effectiveness, and marine safety.⁴²

Promote the Blue Workforce

The United States has excelled as a leader in scientific research and technological innovation; but today’s world and environmental-related challenges continue to evolve. Meeting these challenges requires enhancing our knowledge about the ocean. It is essential to our economic well-being that we create and support an ocean-literate society focused on the development of an educated and diverse workforce. This workforce would ensure that the United States maintains a competitive advantage in our understanding of the oceanic environment by capitalizing on a strong knowledge base and is in support of Executive Order 13801.⁴³ Studies reveal that advances in science, technology, engineering, and math (STEM) are central to our Nation’s ability to create new jobs, improve quality of life, and maintain our position as a global leader in S&T.⁴⁴ STEM fields are also vital for national defense purposes to build ocean models, create systems that protect our nation, and maintain tactical advantage.

A well-trained, diverse, and dynamic workforce, capable of addressing tomorrow’s career needs, has long been identified as a priority for our Nation.⁴⁵ There is a growing need for a dynamic workforce to address national ocean challenges focusing on Big Data analysis, computational modeling, offshore renewable energy, and instrumentation operation and maintenance. It is imperative that we bridge the gap between identified challenges and the workforce training required in order to effectively pursue S&T that may be relevant to the ocean enterprise. The development of cutting edge, advanced training opportunities will give the present ocean workforce the ability to make educational advancements outside of the traditional training opportunities. Investments in people, basic and applied research, and facilities are key to a strong workforce, professional development, and growing economic pros-

⁴¹ Gedamke, J., J. Harrison, L. Hatch, R. Angliss, J. Barlow, C. Berchok, C. Caldwell, M. Castellote, D. Cholewiak, M.L. DeAngelis, R. Dziak, E. Garland, S. Guan, S. Hastings, M. Holt, B. Laws, D. Mellinger, S. Moore, T.J. Moore, E. Oleson, J. Pearson-Meyer, W. Piniak, J. Redfern, T. Rowles, A. Scholik-Schlomer, A. Smith, M. Soldevilla, J. Stadler, S. Van Parijs, C. Wahle. (2016) Ocean Noise Strategy Roadmap. NOAA, p. 144. https://cetsound.noaa.gov/Assets/cetsound/documents/Roadmap/ONS_Roadmap_Final_Complete.pdf (accessed April 17, 2018)

⁴² Such efforts can be enhanced through interagency initiatives, such as through the CMTS-led Maritime Energy and Air Emissions Working Group <https://www.cmts.gov/topics/energy-and-air-emissions> (accessed June 14, 2018).

⁴³ See Executive Order 13801, issued on June 15, 2017, Expanding Apprenticeships in America. <https://www.whitehouse.gov/presidential-actions/3245/> (accessed June 15, 2018).

⁴⁴ National Science Board. (2010) Preparing the Next Generation of STEM Innovators: Identifying and Developing our Nation’s Human Capital. NSB–10–33. <https://www.nsf.gov/nsb/publications/2010/nsb1033.pdf> (accessed June 15, 2018).

⁴⁵ Cuker, B. (2005) Programmatic approaches to building diversity in the ocean sciences. *Marine Technology Society Journal* 39(4):8–11. <https://doi.org/10.4031/002533205787465869> (June 15, 2018).

perity.⁴⁶ These opportunities and investments will foster the workforce's ability to adapt to dynamic technological advancements made within the S&T enterprise.

At the same time, the ocean S&T enterprise offers workforce opportunities for workers at all education levels—not just those with advanced degrees—and across demographic groups. America's skilled technical workforce, which consists of individuals who may use STEM knowledge and skills in their jobs but don't have a four-year degree, are important to U.S. economic competitiveness. In addition, unemployment rates of skilled technical workers in science and engineering (S&E) or S&E-related jobs were significantly lower than those of workers in non-S&E jobs without bachelor's degrees, and their earnings were significantly higher.⁴⁷ The Federal government is well positioned to encourage courses and programs in marine technology and coastal engineering and to facilitate student-led missions related to the ocean workspace, such as through remotely operated vehicle (ROV) competition challenges.⁴⁸

Community and technical colleges can help expose a more diverse body of students to job opportunities in the blue workforce. Special degree programs geared toward ocean work, hands-on experience, and professional development offered through these institutions can prepare students for marine occupations, including marine forecasters, ocean instrument technicians, and underwater ROV developers.

Priorities

- Develop and enhance programs between agencies and education institutions that provide certification in Unmanned Maritime Systems. These programs would enable students to participate in short (*e.g.*, 3-month) training cycles where they study nautical science, 3-D positioning, ocean policy, autonomous systems, and the interfaces of all aspects of unmanned maritime systems.
- Share resources to support shallow water bathymetric surveys and unmanned system operations, allowing operators from multiple agency oceanographic fleets to identify best practices and apply lessons learned through joint cooperation.
- Improve and support cooperation between the Federal government and academic universities to successfully recruit researchers and ocean policy experts into the ocean science workforce, including the Federal component.⁴⁹
- Support coastal communities to provide them with the latest skills necessary to conserve coastal resources, protect traditional livelihoods, and capitalize on future opportunities (*e.g.*, offshore renewables, etc.).

GOAL III. ENSURE MARITIME SECURITY

Overview

Maritime security is essential to the Nation's ability to defend the homeland and to sustain military advantages, both globally and in key regions.⁵⁰ Maritime security is the foundation for the Nation's economic prosperity. Approximately 90 percent of all products sold worldwide are transported by the ocean.⁵¹ Maritime security is essential to the Nation's economic prosperity, national and homeland security, and global leadership. An efficient, safe, and secure maritime environment enables commerce, including: marine public transportation, tourism, merchant ship traffic, aquaculture to improve nutrition and food security, economic activities in the Nation's EEZ, and on the high seas. Given the Nation's coastal ocean and inland waterways act as gateways of commerce and that the United States has one of the most extensive maritime transportation systems in the world,⁵² the ability to effec-

⁴⁶The White House. (2015) National Security Strategy. Washington, D.C. p. 35. <http://nssarchive.us/wp-content/uploads/2015/02/2015.pdf> (accessed June 15, 2018).

⁴⁷National Science Board. (2018) Science and Engineering Indicators 2018 Digest. NSB-2018-2. Alexandria, VA: National Science Foundation, p. 28. <https://www.nsf.gov/statistics/digest/> (accessed June 15, 2018).

⁴⁸National Science Foundation. (2013) Underwater Robotics Competition Helps Students Build Skills for Ocean Occupations https://www.nsf.gov/discoveries/disc_summ.jsp?cntn_id=128911 (accessed June 1, 2018).

⁴⁹This cooperation includes the Knauss Sea Grant Marine Policy Fellowship Program. More information can be found at: <https://www.seagrant.noaa.gov/knauss> (accessed May 28, 2018).

⁵⁰Department of Defense. (2018) National Defense Strategy of the United States of America: Sharpening the American Military's Competitive Edge, p. 14. <https://www.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf> (accessed June 19, 2018).

⁵¹George, R. (2013) Ninety Percent of Everything: Inside Shipping, the Invisible Industry That Puts Clothes on Your Back, Gas in Your Car, and Food on Your Plate. Metropolitan Books: New York, p. 304.

⁵²National Chamber Foundation. (2003) Trade and Transportation: A Study of North American Port and Intermodal Systems. U.S. Chamber of Commerce. Washington, D.C., p. 7. <https://>

tively navigate, map, chart, and predict ocean variability is critical for maritime security.

The rapid global growth of information dissemination and evolving technologies including artificial intelligence, and satellite remote sensing, has added immense complexity to both national defense (military) and homeland security (law enforcement and safety) challenges, as well as to the emergence of new operations such as automated cargo and naval vessels. An agile, rapid, and economical approach to ocean S&T investment will continue to contribute to national security.

Maritime security for National defense and law enforcement must be strengthened by continued scientific and technological advance to keep America competitive in an increasingly complex global maritime environment. Developing the next generation of ocean S&T capabilities is a tremendous challenge that must be undertaken to ensure not only the Nation's maritime security, but its maritime superiority.⁵³

Improve Maritime Situational Awareness

Maritime domain awareness and security operations require continuous, near-real-time monitoring of the ocean and its changing conditions. The rapid growth of a range of sensing capabilities can be leveraged for the benefit of ocean sciences and other vital purposes. The increased understanding of the ocean enhances environmental protection, safe navigation of the ocean, and other uses, while providing essential information required for maritime security and military operations. In concert with this is the need to acquire situational awareness and context to better interpret the totality of data.

While an immense amount of data is collected in the physical, chemical, geological, acoustical, and biological observations of the ocean, we can improve the way we both model ocean environments and spark new innovations through the use of newly enabled machine learning and artificial intelligence algorithms. Both advanced hardware and software are required to assimilate and understand new observations, analyze the vast existing amounts of ocean data, and run the integrated models that are used to predict the maritime environment for operational decision making. Ship-based seafloor and sub-seafloor surveys are now being supplemented by autonomous and remotely operated vehicles to assess the ocean (Box 3.1). Continued development of not only vehicles but autonomous behaviors and technologies is needed to reduce the need for human intervention. The United States should take better advantage of its technological workforce to develop systems for Earth system models, which have unique architecture requirements.

Box 3.1. Tactical Advantage

Only 5 percent of the world's oceans have been explored. Unmanned underwater vehicles, i.e., gliders, allow researchers to explore more of the ocean, and faster, at a fraction of the cost of a manned submersible or a ship. Gliders are propelled by ocean currents and navigate with fins by diving and surfacing. These gliders have no active propulsion system and can operate to depths of 1,000 meters, for up to four months before retrieval and servicing. Gliders have the ability to provide hundreds of profiles per month, thus freeing oceanographic ships to perform missions in other areas.

The temperature and salinity data collected by the gliders are used by ocean models to forecast future environmental ocean conditions. The model forecasts are provided in near-real time to support strategic, operational, and tactical fleet requirements and activities. These forecasts allow better prediction of ocean currents, density, sea states and tides, which provide physical battlespace awareness and a common operational picture for U.S. Armed Forces.

ftp.dot.state.tx.us/pub/txdot-info/library/projects/la_entrada/portstudy.pdf (accessed June 18, 2018).

⁵³United States Navy. Chief of Naval Operations. (2016) A Design for Maintaining Maritime Superiority. p. 10. http://www.navy.mil/cno/docs/cno_stg.pdf (accessed June 19, 2018).



Figure 3.1. An unmanned underwater vehicle (UUV) is deployed from a Naval Oceanographic Office (NAVOCEANO) survey vessel. (Image courtesy of U.S. Navy)

A thorough understanding of a range of oceanographic parameters and their interactions is critical for homeland security and commercial operations to safely operate and deploy in the marine environment. Direct observations of ocean currents, waves, tides, sound propagation, ocean temperature, and salinity provide robust predictive models. Safety at sea for commercial, security, and defense operations is also influenced by factors such as wave height and period, winds over water, and the sudden onset of hazardous conditions, compounded by lack of open sea, *in situ* weather observations.

Remote sensors are unable to observe the ocean depths existing *in situ* observation systems are sparse. More diversification in maritime observing systems will better help us establish trends in the maritime environment that are significant to our Nation's security needs. Accordingly, an important component of this strategy is to maintain and enhance the existing profiling and drifting sensor arrays, expanding capabilities through the addition of sensors, and more flexible and capable platforms. Comprehensive datasets provide essential inputs into these models to increase their fidelity, which can be achieved through a more diversified maritime observing sensor suite.

A diverse suite of space-based sensors capable of interrogating the ocean across the usable electromagnetic spectrum will support ocean models and improve forecasts of winds, waves, currents, species distributions, significant weather events, and seasonal to longer-term ocean variability. Measurements must be effectively communicated and aggregated in coupled data assimilative global models of the ocean, atmosphere, and ice to support maritime operations in nearshore and deep-ocean environments.

Such computational capabilities can address the considerable vulnerability to detrimental activities that exist in unobserved locations. Illegal, unregulated, and unreported (IUU) fishing is a risk to marine species and ecosystems, undermines sound management of sustainable fisheries, and poses significant commercial, humanitarian, and security risks. The connection to human trafficking and IUU fishing is

already strong, and the Federal government continues to assess the risk of such unmonitored transport for the smuggling of people and materials for criminals and terrorists.

Populations reliant on their coastal waters and lacking sufficient modern infrastructure are at risk for loss of food security if IUU fishermen poach fish populations on which these populations depend for sustenance, or if ocean acidification and warming leads to the loss or migration of staple fish stocks. Additional research is needed to understand the scale of both of these problems, develop monitoring and mitigation technologies, and identify effective interventions and policies.

Priorities

- Support the maritime observing framework that ensures diverse sensing capabilities for a range of U.S. end users.
- Sustain oceanographic sensors and autonomous monitoring technologies to enhance data collection under the ocean's surface and at the surface in all weather conditions to support high-spatial-resolution and near-real-time forecasting of the Earth system (terrestrial and oceanic).
- Pursue new methodologies and/or observing technologies and use of distributed networks of organic, tactical sensors⁵⁴ for collection of maritime environment variables.
- Emphasize studies of the air-sea interface to provide better understanding of the relationships between ocean characteristics, including mixing processes that transport surface momentum, and the ocean interior.
- Develop inexpensive sensors for remote sensing studies that enable observations across the electromagnetic spectrum, and for full-ocean-depth sensors that exploit soft materials.
- Establish a national glider coordination and standards to provide ocean sampling in coastal regions, strong oceanographic currents, and other regions where drifters and floats are impractical.
- Develop advanced computational capabilities to analyze vessel, operator, cargo, and infrastructure data to identify anomalous behaviors in the maritime domain, such as IUU fishing, human migration, at-sea smuggling, transnational maritime criminal activities, etc., to better support appropriate security response.

Understand a Changing Arctic

Many nations are interested in understanding the Arctic's harsh environment and its resources. Research into the Arctic is motivated by scientific curiosity and longer-range commercial considerations.⁵⁵ Arctic dynamics influence both geophysical and biochemical systems, including freshwater storage and export, ocean-ice-atmospheric interaction, primary production, and the ocean's response to acidification, and shape human activities in the region. Opinions on the future of Arctic shipping and related activities within the Northwest Passage, the Northern Sea Route, and a potential transpolar route vary. Improved coupled Arctic ocean-climate models will help constrain predictions of future conditions. Overall, the changing conditions of the Arctic, particularly the diminishing sea ice, are resulting in increased vessel traffic and extraction of natural resources. These developments impact homeland and national security operations such as search and rescue, oil spill preparedness and response, and overall domain awareness necessary to ensure that the Arctic region does not become a seam through which illegal activities can occur undetected.

Accurate operational forecasts of the environment, such as the location of the ice edge, the characteristics and evolution of sea ice, and the wind and wave conditions at the surface, will be critical to safe and efficient operations (defense and commercial) in the Arctic.⁵⁶ To achieve this, Arctic system models that integrate the ocean, ice, and atmosphere incorporate the physical processes, interactions, and feedbacks involved in the seasonal evolution of ice extent, area, thickness, and volume.

⁵⁴ Shipboard or *in situ* sensors that are incorporated into a larger body, and are used to collect and present integrated situational awareness data.

⁵⁵ Interagency Arctic Research Policy Committee. (2016) Arctic Research Plan FY2017–2021. Washington D.C. p. 84. <https://www.iarpcollaborations.org/plan/> (accessed April 17, 2018).

⁵⁶ This objective aligns with IARPC Research Goal 9: Enhance Frameworks for Environmental Intelligence Gathering, Interpretation, and Application toward Decision Support. Interagency Arctic Research Policy Committee. (2016) Arctic Research Plan FY 2017–2021. Washington D.C. p. 84. <https://www.iarpcollaborations.org/plan/research-goal/environmental-intelligence> (accessed April 17, 2018).

Space-based observation of oceanographic parameters and ice in the Arctic can supplement *in situ* measurements in the harsh polar environment. Such observations will be increasingly important to understand processes in the marginal ice zones as ice coverage diminishes and the Arctic becomes a commercially viable transportation route. To achieve this, a change in how we approach Arctic system models that integrate the ocean, ice, and atmosphere must occur, for example, through the use of evolutionary computation⁵⁷ and artificial intelligence. Many of these priorities will be addressed in collaboration with the Interagency Arctic Research Policy Committee (IARPC).

Priorities

- Support validated integrated ocean-ice-wave-atmosphere models for improved Arctic prediction at multiple time scales.
- Improve models for enhanced forecasting and prediction of Arctic weather.
- Promote collaborative networks of researchers, communities, and native peoples to advance and disseminate knowledge and prediction of the sea ice and Arctic weather systems.
- Support domestic and international R&D focused on innovative response technologies and procedures suitable for the Arctic environment.
- Study the use of dispersants and the impacts of petrochemicals and other hazardous materials in order to provide better oil spill response options and protection for Arctic sea life and migratory marine mammals.

Maintain and Enhance Marine Transportation

The U.S. Marine Transportation System (MTS)⁵⁸ is critical to the economy and national security (Box 3.2). Vital commercial, government (including military), and recreational traffic rely on a safe, secure, and efficient transportation system. The Nation's maritime critical infrastructure—ports, inland waterways, and systems and structures supporting maritime commerce—contributes some \$4.6 trillion in economic activity and millions of jobs each year.⁵⁹ This includes about \$1.5 trillion of cargo annually through U.S. seaports to and from international trading partners.⁶⁰ Ocean S&T can support improved waterway management and safety, expanded shipping infrastructure and vessel capabilities, cyber resilience, and enhanced port operations and productivity. Understanding of cyber vulnerabilities in the maritime domain—both ashore and shipboard, mapping and predicting cyber-threats, as well as developing cyber-resilient options for maritime systems—would support mitigation strategies to manage cyber risks in the MTS.⁶¹

Box 3.2. America is a Maritime Nation

- Our Nation enjoys tremendous geographic advantages in its unhindered access to the Atlantic and Pacific Oceans, the Gulf of Mexico, and the Arctic region.
- America possesses a vast network and thousands of miles of navigable rivers, canals, and other waterways, on which ships and barges carry massive amounts of commodities and products both within the United States and to and from the world market, taking advantage of 360 major ports. For example, sixty percent of U.S. grain exports are moved by barge for at least part of the journey.⁶⁵
- The MTS is the economic lifeblood of the American and global economy, and plays an essential role in U.S. national security and economic interests. It enables critical national security sealift capabilities, where it supports U.S. Armed Forces logistical requirements around the globe.
- Any disruption to the MTS, whether man-made or natural, would have a potentially devastating impact on the domestic and global supply chain.
- New technologies, which often add complexity to vessel designs, propulsion systems, operations, automation, robotics, and networked systems, and new methods for offshore natural resource exploration, production, and transportation, make the MTS even more vulnerable to disruption.

⁵⁷Eiben, A.E., and J. Smith. (2015) From evolutionary computation to the evolution of things. *Nature* 521:476–482. <https://www.nature.com/articles/nature14544> (accessed June 18, 2018).

⁵⁸Consists of ocean, coastal, and inland waterways, intermodal connections, and vessels.

⁵⁹U.S. Coast Guard. (2018) 2018 State of the Coast Guard. Admiral Zukunft. March 1, 2018. <https://www.uscg.mil/SOTCG2018/> (accessed May 15, 2018).

⁶⁰The National Ocean Service. (2018) How important is our ocean economy? <https://oceanservice.noaa.gov/facts/oceaneconomy.html> (accessed April 15, 2018).

⁶¹U.S. Coast Guard. (2017) Cyber Risks in the Marine Transportation System. p. 10. https://www.dco.uscg.mil/Portals/9/CG-FAC/Documents/USCG_Paper_MTS_CyberRisks.pdf?ver=2017-07-19-070403-473 (accessed April 19, 2018).

- The Federal government, in its enduring role of promoting safety, security, and stewardship, safeguards the MTS and helps ensure the uninterrupted flow of maritime commerce.

The maritime community relies on critical data during voyage planning and while transiting through U.S. navigational waterways (*e.g.*, data from the Nationwide Automatic Identification System (NAIS),⁶² the Physical Oceanographic Real-Time System (PORTS),⁶³ and Marine Safety Information (MSI)⁶⁴). Such technologies allow for tracking and monitoring of vessel movements using systems along the coast or, when out of range of terrestrial networks, through a growing number of satellites equipped with automatic identification system (AIS) receivers. The International Maritime Organization's (IMO) International Convention for the Safety of Life at Sea (SOLAS) requires AIS to be equipped aboard vessels of 300 or more gross tons engaged in international voyages, and all passenger ships regardless of size. The IMO also requires a similar global system, Long-Range Identification and Tracking (LRIT) for applicable vessels, to provide global identification and tracking in the maritime domain.

In addition to technological advances, the ability to effectively communicate and maintain connections across ocean networks enhances safe navigation, search and rescue operations, and domestic and global trade. This can be achieved through advancing knowledge of the impact of invasive species on maritime transportation, electronic information to support cargo risk assessments, capability to screen cargo at loading, techniques to prevent smuggling of weapons, enhanced container security technologies, and other measures to ensure cargo integrity and in-transit visibility through maritime domain awareness.⁶⁵

Priorities

- Modernize the delivery of Marine Safety Information by experimenting with transmitting enhanced MSI (eMSI) via AIS technology for display on integrated bridge systems.
- Support ocean/maritime information sharing and cybersecurity to deploy maritime surveillance and communications in remote regions.
- Support and validate field detection equipment to detect nuclear, chemical, disease, biological, and other threats at ports of entry.
- Develop and validate systems to identify and track vessels failing to transmit required identification signals (*e.g.*, AIS).
- Examine the vulnerabilities and dependencies between national security and a sustainable national and international commerce (*e.g.*, stable currency value, safe ship transit, reliable transportation, and enhanced infrastructure).
- Improve port security through diversified monitoring systems; *e.g.*, use of autonomous platforms, monitoring of undersea cables, and improvement of detection technologies at the entrance to the Nation's ports and other navigable waterways for counter-terrorism evaluation and enhanced maritime security.

GOAL IV. SAFEGUARD HUMAN HEALTH

Overview

The ocean More than 28,000 biochemicals have been isolated from marine species; many are important pharmaceutical products and hundreds of new compounds from the marine environment are discovered each year.⁶⁶ The ocean provides a vast array of resources, natural products, and ecosystem services that impact human health and support our quality of life. It also provides safe and nutritional sources of food and drinking water, and natural products that ameliorate health issues and offer

⁶²The NAIS is an automatic tracking system used by ships, Vessel Traffic Services (VTS), and other maritime community users.

⁶³PORTS is a program of NOAA's National Ocean Service that supports safe and cost-effective navigation by providing accurate real-time information required to avoid groundings, allisions, and collisions. The information provided at key hubs (currently 31 locations) includes tide/water level, current, wave, meteorological, and bridge clearance information.

⁶⁴MSI is currently provided by the U.S. Coast Guard through "Local Notice of Mariners" and via VHF-FM marine band broadcasts.

⁶⁵U.S. Department of Agriculture. (2015) A Reliable Waterway System is Important to Agriculture. <https://www.ams.usda.gov/sites/default/files/media/Importance%20of%20Waterways%2010-2015.pdf> (accessed June 15, 2018).

⁶⁶Blunt, J.W., B.R. Copp B.R., R.A. Keyzers, M.H.G. Munro, and M.R. Prinsep. (2015) Marine natural products. *Nature Product Report* 32:116-211. <https://doi.org/10.1039/c4np00144c> (accessed June 18, 2018).

safer alternatives to cosmetics, anti-fouling agents, pharmaceuticals, and other products.

Despite these benefits, the ocean also contains hazards such as marine pathogens and harmful algal blooms (HABs),⁶⁷ both of which can produce toxic chemicals detrimental to human health, and pose a threat to our growing economy.^{68,69} For example, the seafood, restaurant, and tourism industries lose about \$82 million dollars every year due to the impacts of HABs.⁷⁰ In addition, knowledge gaps impede decision-makers from effectively mitigating emerging threats to human health, such as microscopic plastic (microplastics) debris found in the ocean (Box 4.1). Advances in ocean S&T to improve seafood quality and safety, and harness the health benefits of seafood consumption, can benefit communities home and abroad.

Recent advances in ocean science have led to discovering new products derived from nature and improving risk management. There is still a need, however, to increase our understanding of ocean dynamics and resources, spur technological innovations, and improve the discovery and use of ocean products and services. This can be accomplished by expanding exploration and discovery into unexplored ocean regions, collecting and studying natural products, and developing improved resource management practices, which can reduce the strain on known resources. Prediction, monitoring, and mitigation capabilities can also allow for a more strategic approach for how we use the ocean.

Box 4.1. Microplastics Accumulation in the Food Chain

Microplastics are particles of plastic that range in size from 1 nanometer to < 5 millimeters.⁷¹ They can be manufactured for household products or result from larger pieces of marine debris breaking down over time into smaller pieces. It is estimated that 269,000 metric tons of microplastics are floating at or near the surface of the ocean, affecting over 700 marine species.⁷² The long stability of plastic debris can result in bioaccumulation over time. Depending on the material, microplastics may float or sink, contaminating both coastal and deep-sea sediments.⁷³ Ingestion of microplastics by marine organisms at all trophic levels is well documented, showing that persistent exposure is toxic, causing infertility and poisoning.⁷⁴ The transfer of microplastics from marine organisms to humans through seafood consumption

⁶⁷HABs are hyper-proliferating colonies of algae that produce toxic or harmful effects on people, animals, and surrounding ecosystems. More information can be found at: Interagency Working Group on Harmful Algal Bloom and Hypoxia Research and Control Act. (2018) Harmful Algal Blooms and Hypoxia in the United States. A report on interagency progress and implementation. Washington D.C. p. 153. https://cdn.coastalscience.noaa.gov/page-attachments/research/FINAL_USEC%20signed%20-%20Progress%20and%20Implementation%20Report_HABH_RCA.pdf (accessed June 15, 2018).

⁶⁸Chen, C.Y., C.T. Driscoll, K.F. Lambert, R.P. Mason, L.R. Rardin, C.V. Schmitt, N.S. Serrill, and E.M. Sunderland. (2012) Sources to Seafood: Mercury Pollution in the Marine Environment. Maine Sea Grant College Program. Orono, Maine. p. 26. http://www.dartmouth.edu/~toxmetal/assets/pdf/sources_to_seafood_report.pdf (accessed April 17, 2018).

⁶⁹Evers, D.C., J.G. Wiener, C.T. Driscoll, D.A. Gay, N. Basu, B.A. Monson, K.F. Lambert, H.A. Morrison, J.T. Morgan, K.A. Williams, and A.G. Soehl (2011) Great Lakes Mercury Connections: The Extent and Effects of Mercury Pollution in the Great Lakes Region. Biodiversity Research Institute. Gorham, Maine. Report BRI 2011–18, p. 44. http://www.briloon.org/uploads/BRI_Documents/Mercury_Center/Mercury_Connections/GLMC_FinalReport.pdf (accessed April 17, 2018).

⁷⁰National Ocean Service. (2017) Why Do Harmful Algal Blooms Occur? https://oceanservice.noaa.gov/facts/why_habs.html (accessed April 19, 2018).

⁷¹National Ocean Service. (2018) What are Microplastics? <https://oceanservice.noaa.gov/facts/microplastics.html> (accessed June 15, 2018).

⁷²Eriksen, M., L.C.M. Lebreton, H.S. Carson, M. Thiel, C.J. Moore, J.C. Borerro, F. Galgani, P.G. Ryan, and J. Reisser. (2014) Plastic pollution in the world's oceans: More than 5 trillion plastic pieces weighing over 250,000 tons afloat at Sea. *PLoS one* 9:e111913 <https://doi.org/10.1371/journal.pone.0111913> (accessed June 18, 2018); Wilcox, C., N.J. Mallos, G.H. Leonard, A. Rodriguez, and B.D. Hardesty. (2016) Using expert elicitation to estimate the impacts of plastic pollution on marine wildlife. *Marine Policy* (65):107–114.

⁷³Woodall, L.C., A. Sanchez-Vidal, M. Canals, G.L.J. Paterson, R. Coppock, V. Sleight, A. Calafat, A.D. Rogers, B.E. Narayanaswamy, and R.C. Thompson. (2014) The deep sea is a major sink for microplastic debris. *Royal Society Open Science* 1:140317. <http://rsos.royalsocietypublishing.org/content/1/4/140317> (accessed June 18, 2018).

⁷⁴Gregory, M. (2009) Environmental implications of plastic debris in marine settings-entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. *Philosophical Transactions of the Royal Society of London* 364:2013–2025. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2873013> (accessed June 18, 2018); Fossi, M.C., S. Casini, and L. Marsili. (2007) Potential toxicological hazard due to endocrine-disrupting chemicals on Mediterranean top predators: state of art, gender differences and methodological tools. *Environmental Research* 104:174–182. <https://www.ncbi.nlm.nih.gov/pubmed/16996053> (accessed June 15, 2018).

may present a risk to human health, yet research is lacking.⁷⁵ Likely, plastic-mediated toxin bioaccumulation occurs due to the preferred binding of persistent organic pollutants (including polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs)) to plastic particles, while the accumulation of microplastics themselves leach into the tissue of marine organisms that consume them.⁷⁶ For the coming decade, we should learn how these processes and direct exposure of microplastic chemicals through the food chain ultimately impact human health. In addition, further research is appropriate to determine the extent to which microbes in the ocean environment consume persistent plastics and what might be done to enhance the success of such natural processes.

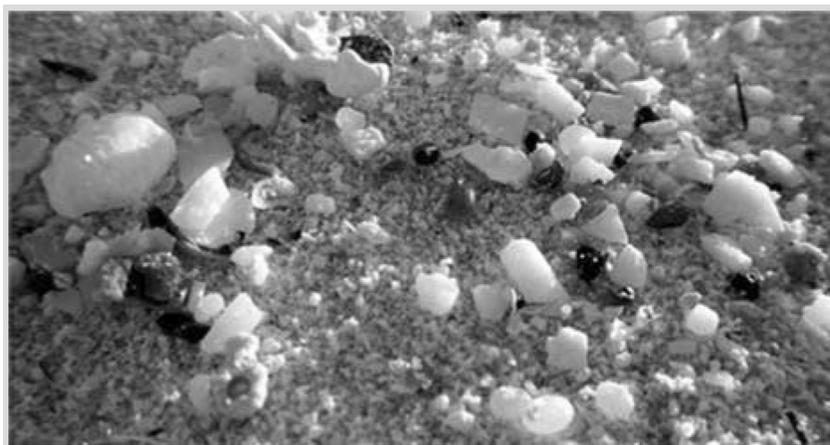


Figure 4.1. Accumulation of microplastics on a shoreline. (Image courtesy of NOAA)

Improve Forecasts of Marine Contaminants and Pathogens

Ocean chemistry can enhance human well-being by supplying healthy compounds in our food, but it can also put human health at risk, such as exposing people to toxins. Through state-of-the-art forecasting capabilities of ocean chemicals and conditions, researchers and managers have been able to reduce the risk of threats such as seafood-borne illness (*e.g.*, shellfish and finfish poisoning). Through monitoring levels of known toxins and pathogens, the seafood industry provides healthier products, and the United States guards its citizens against potential health risks from the ocean.⁷⁷ Predictive capabilities depend on research in ocean hydrodynamics, chemical fate and transport, and human reactions to toxins and pathogens. For example, continuous monitoring of temperature and salinity in coastal regions can help predict overgrowth of *Vibrio vulnificus*, the bacterium responsible for 95 percent of seafood-related death in the United States.⁷⁸ Bacterial infections can result from ingestion of contaminated seafood or enter via the bloodstream by way of open wounds exposed to tainted seawater. Toxin-associated illnesses occur in a similar fashion via ingestion of animals (namely shellfish) that have been feeding on several species of toxin-producing algae.

There are also large uncertainties in emission rates and ocean-mediated biogeochemical cycling mechanisms. An increased understanding of such processes can better inform consequences such as that of halogens and isoprene emissions from the ocean that can exert significant influences on atmospheric chemistry, including

⁷⁵ Caruso, G. (2015) Microplastics in marine environments: Possible interactions with the microbial assemblage. *Journal of Pollution Effects and Control* 3:e111. <https://www.omicsonline.org/open-access/microplastics-in-marine-environments-possible-interactions-with-the-microbial-assemblage-2375-4397-1000e111.pdf> (accessed June 18, 2018).

⁷⁶ Seltnerich, N. (2015) New Link in the food chain? Marine plastic pollution and seafood safety. *Environmental Health Perspectives* 123(2):35–123. <https://ehp.niehs.nih.gov/wp-content/uploads/123/2/ehp.123-A34.alt.pdf> (accessed April 17, 2018).

⁷⁷ McMichael, A.J., C.D. Butler, and J. Dixon. (2015) Climate change, food systems and population health risks in their eco-social context. *Public Health* 129(10):1361–1368. <https://www.ncbi.nlm.nih.gov/pubmed/25896548> (accessed June 15, 2018).

⁷⁸ National Centers for Coastal Ocean Science. (2017) Chesapeake Bay *Vibrio* Pathogen Forecast. <https://coastalscience.noaa.gov/project/chesapeake-bay-vibrio-pathogen-forecast/> (accessed May 30, 2018).

ozone levels. Forecasting ocean biogeochemical and physical cycling is done at multiple spatial and temporal scales. For example, forecasting of waterborne pathogen levels might be necessary over a time scale of days for a specific recreational area, whereas forecasting of contamination levels in fish in a large area such as Lake Superior might change over years to decades. Forecasting tools require accurate estimates of contaminant sources, and how these sources change over time and need to be based on validated models (Box 4.2).

Box 4.2. Building Forecasting Tools for Human Health

- Contaminants produced *in situ*, such as biotoxins, require accurate estimates of generation or production rates under different conditions.
- Understanding toxic chemicals require knowledge of loading rates from direct discharges, nonpoint sources, and indirect pathways such as watershed processes and atmospheric surface exchange, as well as the legacy distribution and amounts of the pollutant within the system resulting from past loading.
- Forecasting of atmospheric deposition requires understanding of atmospheric emissions as well as atmospheric fate and transport processes. Once the loading and/or generation rates are understood, knowledge of the dynamic behavior of the contaminant in the oceanic ecosystem is required.

Priorities

- Improve predictive mathematical models of the sources, transport, fate, and degradation of constituents immediately relevant to human health.
- Understand the pathways of human and animal exposure to waterborne pathogens, toxic chemicals, and algal toxins, including oral, dermal, and airborne routes via drinking water, food, recreational water, and aerosols.
- Advance knowledge of exchange of chemical contaminants and nutrients between the ocean and the atmosphere, impacts of the changing ocean, and other contributors to the occurrence, frequency, and severity of human health impacts from constituents relevant to human health.

Combat Harmful Algal Blooms

Understanding the incidence, severity, and persistence of hazards to human health from oceanic, estuarine, and freshwater areas requires observations at multiple spatial and temporal scales. This includes arrays and networks of monitoring sites, *in situ* measurements from buoys and instrumented moorings, and remotely-sensed data and imagery from aircraft and satellites. An example for this need to enhance monitoring capabilities is the increasing occurrence and spread of HAB events worldwide, including recent highly impactful HAB events in the United States.⁶⁷

HABs have been reported in every U.S. coastal State and occur when algal cells proliferate rapidly and produce a toxic threat to humans and their local environment.⁷⁹ This threat to the seafood and tourism industries calls for improved HAB toxin sensors, monitoring protocols, and quantification of toxins and their chemical structures. New technologies based on immunoassays, enzyme inhibition, optical biosensors, nucleic acid amplification, and other novel approaches continue to evolve under government and private funding. Federal leadership is needed on the provision and quality of reference materials (*e.g.*, specimens, toxin standards, and molecular probes) as well as data management and data visualization tools, for increased awareness of public health risks and effective response and mitigation strategies.

Policy-makers, public health authorities, and communities need the best available information to minimize current and future exposure to HABs and other known and potential ocean related health threats. Ongoing R&D should focus on analytical measurements, process understanding, and modeling to provide more reliable, useful, timely, and policy-relevant information.

Priorities

- Develop guidelines, testing methods, and rapid response strategies for accurate assessment and mitigation of pathogens, toxic chemicals, and algal toxins.
- Enhance and transfer new tools and technologies such as omics and bioinformatics into management programs that promote human health and protect humans from HABs and other ocean-related issues.

⁷⁹ Environmental Protection Agency. (2017) Nutrient Pollution: Harmful Algal Blooms. <https://www.epa.gov/nutrientpollution/harmful-algal-blooms> (accessed June 12, 2018).

- Generate data for computational and mathematical model evaluation and improvement to develop risk assessments of HABs and other known and emerging threats to human health.
- Document human and animal exposure, illness, disease, and death related to HABs and other risks.
- Emphasize public access to monitoring data, create user-friendly data formats, and ensure readily available metadata of parameters related to health risks.
- Integrate new monitoring technologies into emerging ocean observation systems (*e.g.*, U.S. Integrated Ocean Observing System (IOOS); the United Nations Global Ocean Observing System (GOOS)), while ensuring quality assurance and data comparability.
- Develop socio-economic measures to estimate societal costs from exposure to HABs and other ocean-related human health hazards, and share that information with State, local, and tribal groups.

Discover Natural Products

While many promising pharmaceutical candidates are produced through synthetic approaches, approximately half of all new pharmaceutical approvals still trace their structural origin to natural products,⁸⁰ illustrating the unique structural and chemical diversity found in the ocean environment. A substantial number of natural products with applications in medicine (anti-cancer, anti-viral, anti-fungal, anti-biotics), nutrients (dietary supplements, food additives), energy (biofuels), and other beneficial materials (*e.g.*, antifoulant, diagnostics tools, and cosmetics) derive from marine hosts.⁸¹ For example, the Alaskan deep-water green sponge produces molecules that target and kill pancreatic cancer cells in the laboratory.⁸² Microbial (bacteria and archaea) and eukaryotic (fungi) symbionts of various marine hosts also produce a wide variety of compounds with potential for drug discovery. The rich diversity of the ocean presents enormous economic and biological potential (Box 4.3). Advances in ocean exploration and discovery technologies (*e.g.*, acoustic tools, digital imaging, remote vehicles, deep-diving submersibles, and improved environmental sensors) will enable Americans to leverage such potential.

Advances in molecular approaches such as metagenomics, metatranscriptomics, and metabolomics will improve the discovery, optimize production, and increase understanding of the mechanisms for how chemicals influence our bodies. Increased computational capabilities and improvements in bioinformatics analyses, as well as may open access knowledge and sharing of raw data, will open new doors for harnessing marine natural products.

Box 4.3. Economic Potential of Marine Natural Products

- Ocean-derived pharmaceuticals are rapidly expanding in the global market, from \$5.3 billion in 2010 to about \$8.6 billion in 2016.⁸¹
- Patent applications related to marine genetic material are increasing at a rate of 12 percent each year, with over 5,000 genes derived from marine organisms already patented.⁸²
- The Marine Pharmaceuticals Clinical Pipeline⁸³ reveals over 30 natural products, which have been Food and Drug Administration (FDA)-approved or are in Phase III, II, or I of pharmaceutical development.
 - 59 percent of these compounds are isolated from bacteria associated with marine mollusks or sponges
 - 80 percent of these compounds target various cancers
- Approximately 1,340 new marine natural product compounds were isolated from various marine microbes, invertebrates, and algae in 2015.⁸¹

⁸⁰ Stratton, C., D.J. Newman, and D.S. Tana. (2015) Cheminformatic comparison of approved drugs from natural product versus synthetic origins. *Bioorganic and Medicinal Chemistry Letters* 25(21):4802–4807. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4607632/> (accessed June 15, 2018).

⁸¹ Food and Drug Administration. (2011) Fish and Fishery Products Hazards and Controls Guidance, Fourth Edition. *Florida Sea Grant College Program*. Gainesville, Florida. p. 468. <https://www.fda.gov/downloads/food/guidanceregulation/ucm251970.pdf> (accessed April 17, 2018).

⁸² Alaska Fisheries Science Center. (2017) Small, deep-water Alaska sponge has molecules that selectively target and kill pancreatic tumor cells. https://www.afsc.noaa.gov/News/Green_Sponge.htm# (accessed April 17, 2018).

⁸³ Mayer, A.M.S. (2018) Marine Pharmaceuticals: The Clinical Pipeline <http://marinepharmacology.midwestern.edu/clinPipeline.htm> (accessed April 17, 2018).

- There are currently over 20 marine natural products in FDA preclinical trials that target various diseases including bacterial and fungal infections, malaria, tuberculosis, diabetes, cystic fibrosis, and cancer.⁸⁴

Priorities

- Continue exploration and discovery of oceanic habitats and associated species, including bacteria, archaea, fungi, microbes, and viruses, to discover natural products and processes that improve human health and the environment.
- Contribute to research on sensors and collection devices for extreme and hostile ocean environments, such as the deep-sea, to facilitate expanded ocean exploration and discovery sustainably.
- Support the infrastructure (*e.g.*, analytical methods, computer data mining technology, bioinformatics, computational capabilities) to screen, identify, and make use of beneficial natural products.
- Understand opportunities for increasing macroalgae culturing for use as raw material for foods and biofuels.
- Accelerate partnerships with private industry and academia to support biosynthetic assembly lines and incubation beds (*i.e.*, demonstration projects) to more rapidly move products to market, and improve mariculture techniques to assure the supply of natural products for R&D.

GOAL V. DEVELOP RESILIENT COASTAL COMMUNITIES

Overview

In 2017, the United States experienced the most expensive year on record in terms of natural disasters, causing \$306 billion in total damage, of which \$265 billion came from hurricanes.⁸⁵ Changing climatic conditions can affect the Earth's hydrological cycle, atmospheric water vapor concentrations, clouds, precipitation patterns, and runoff and stream flow patterns.⁸⁶ Flooding and coastal storms can have huge direct costs related to damaged local infrastructure⁸⁷ as well as other indirect economic and social costs⁸⁸ that affect people throughout the country (Box 5.1).⁸⁹ To protect coastal populations and infrastructure, the Nation must find ways to encourage innovation while mitigating risk from storms and other hazards. It is critical to prepare communities for extreme weather using scientific information, adaptive management strategies, and enhanced communication to promote a more resilient weather-ready Nation.

Our coasts and associated communities are economic engines that provide transportation, recreation, tourism, and energy for the millions of people that visit and reside in coastal as well as inland areas. Comprehensive understanding of the coastal and marine ecosystems, forecasting shifts of community vulnerability due to human and natural processes, and embedding that knowledge in decision-making processes that reduce risk and vulnerability and enhance economic prosperity of U.S. communities are long-standing scientific and technological challenges. Science-

⁸⁴ Malve, H. (2016) Exploring the ocean for new drug development: Marine pharmacology. *Journal of Pharmacy and BioAllied Sciences* 8(2):83–91. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4832911> (accessed June 18, 2018).

⁸⁵ National Centers for Environmental Information. (2018) U.S. Billion-Dollar Weather and Climate Disasters. <https://www.ncdc.noaa.gov/billions/> (accessed April 17, 2018).

⁸⁶ NASA. (2018) The Water Cycle and Climate Change. <https://earthobservatory.nasa.gov/Features/Water/page3.php> (accessed April 17, 2018).

⁸⁷ Padgett, J., R. DesRoches, B. Nielson, M. Yashinsky, O.S. Kwon, N. Burdette, and E. Tavera. (2008) Bridge damage and repair costs from Hurricane Katrina. *Journal of Bridge Engineering* 13(1):6–14. [https://ascelibrary.org/doi/abs/10.1061/\(ASCE\)1084-0702\(2008\)13%3A1\(6\)](https://ascelibrary.org/doi/abs/10.1061/(ASCE)1084-0702(2008)13%3A1(6)) (accessed June 15, 2018); Kunz, M., B. Mühr, T. Kunz-Plapp, J.E. Daniell, B. Khazai, F. Wenzel, M. Vannieuwenhuysse, T. Comes, F. Elmer, K. Schröter, and J. Fohringer. (2013) Investigation of superstorm Sandy 2012 in a multi-disciplinary approach. *Natural Hazards and Earth System Sciences* 13(10):2579. <https://doi.org/10.5194/nhess-13-2579-2013> (accessed June 15, 2018).

⁸⁸ Morris, K.A., and N.M. Deterding. (2016) The emotional cost of distance: Geographic social network dispersion and post-traumatic stress among survivors of Hurricane Katrina. *Social Science and Medicine* 165:56–65. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5003656/> (accessed June 15, 2018).

⁸⁹ Shen, G., and S.G. Aydin. (2014) Highway freight transportation disruptions under an extreme environmental event: the case of Hurricane Katrina. *International Journal of Environmental Science and Technology*, 11(8):2387–2402. <https://link.springer.com/article/10.1007/s13762-014-0677-x> (accessed April 15, 2018); Becker, A.H., P. Matson, M. Fischer, and M.D. Mastrandrea. (2015) Towards seaport resilience for climate change adaptation: Stakeholder perceptions of hurricane impacts in Gulfport (MS) and Providence (RI). *Progress in Planning* 99:1–49. <https://www.sciencedirect.com/science/article/pii/S0305900614000427> (accessed April 15, 2018).

based information and tools can help coastal communities respond and adapt to a changing ocean.

The economic strength and sustainability of U.S. communities depends on services the ocean provides. Identification and measurement of communities' strengths and vulnerabilities allow managers and other decision-makers to assess management strategies to build and maintain resilient and prosperous communities, while promoting sustainable economic growth and healthy ecosystems. This baseline information also enables temporal and geographic comparisons of social-ecological systems and associated ecosystem services to understand and forecast the impacts of environmental change on the well-being of human communities.

Box 5.1. The Cost of Extreme Events

- In 2017 alone, there were 16 weather and climate related events from drought, flooding, freeze, severe storm, tropical cyclone, or wildfire events in which, for each event, economic damage exceeded \$1 billion.⁹⁰
- Estimated damages from Hurricane Harvey, including property damage, lost wages, and disrupted business, were as much as \$125 billion.⁹¹
- Superstorm Sandy made landfall on October 29, 2012, devastating coastal communities and causing over \$70 billion in property damage and at least 147 direct deaths across the Atlantic basin.⁹²



Figure 5.1. Scituate, Massachusetts, 2015. (Image courtesy of NBC News)

Prepare for Natural Disasters and Weather Events

The United States has experienced more than 219 weather and climate disasters since 1980, resulting in the total cost of more than \$1.5 trillion⁹³ which is about \$45 billion per year. Disasters are generally focused and have a disproportionately larger impact on specific locations and communities. Building a weather-ready Nation, where society is prepared for and responds appropriately to extreme weather, water, climate and environmental threats is critical. Ensuring community resilience in the face of increasing vulnerability requires collaboration across all levels of government, industry, nonprofits, and academia (Box 5.2). Decision support services,

⁹⁰ National Centers for Environmental Information. (2018) U.S. Billion-Dollar Weather and Climate Disasters: Table of Events. <https://www.ncdc.noaa.gov/billions/events/US/1980-2018> (accessed April 17, 2018).

⁹¹ Office for Coastal Management. (2018) Hurricane Costs. <https://coast.noaa.gov/states/fast-facts/hurricane-costs.html> (accessed April 17, 2018).

⁹² Hurricane Research Division. (2017) Costliest mainland United States tropical cyclones 1900–2017. Unadjusted for inflation. <http://www.aoml.noaa.gov/hrd/tcfaq/costliesttable.html> (accessed April 17, 2018).

⁹³ United States Global Research Program. (2014) National Climate Assessment. USGCRP. Washington, D.C. <http://nca2014.globalchange.gov/highlights/report-findings/extreme-weather> (accessed June 15, 2018).

along with physical, natural, and social science data and information, can help coastal communities mitigate the impacts from these threats.

Whether on a fair, sunny, and mild day or during an extreme-weather event with potential for loss of life and property destruction, improved decisions contribute to better prepared communities. Nowhere is this more important than in the coastal environment, where there is a need for continued research, support, and data for informed decision making. Connections to the marine enterprise require relationship building, gathering and streamlining of requirements, and a coordinated approach to decision-support tools. Decision-support tools help build resilience and reduce adverse consequences. This all results in safer and more secure maritime transportation and enhances safe, enjoyable coastal recreation. The goal is a future with minimal weather-related losses of life and property at sea, along our coasts, and within our watersheds.

Box 5.2. Hurricane Harvey

Hurricane Harvey in 2017 resulted in major threats to lives and property due to extensive flooding from storm surge, unrelenting rainfall, and heavy riverine discharge. Model predictions are not yet able to quantitatively link these three sources of coastal inundation, highlighting a critical gap in capabilities. Addressing the “Harvey-gap” in total coastal water-level prediction and Impact-based Decision Support Services (IDSS) capabilities requires coupled atmosphere-ocean-land-wave models. To address this, efforts are underway to develop a total coastal water plan to conduct modeling in a single estuary beginning in 2018 and expanding to a full national operational capability in 5–10 years. Initial capabilities will focus on water levels with 2-D ocean models, “end products” in the 10-year time frame will have to address navigation and water quality issues with 3D ocean models.

IDSS requires both accurate modeling and an accurate assessment of model uncertainties. Stochastic atmospheric physics and developing strategies for coupled ensemble generation (particularly for non-weather coupled components) are active fields of research that will enhance operational improvement over the next 5-10 years.

Priorities

- Conduct needs assessments to determine status of tools and information already provided, identify gaps existing and enhance the capacity and capability to offer, integrate, display, and disseminate data and information.
- Support and disseminate tools for understanding and translating science to promote resilience-based approaches in ocean and coastal communities, waterborne recreational users, and those experiencing drought and flooding.
- Identify needs, areas for coordination, methods for technology transfer, and develop and implement of a suite of integrated marine weather products to provide earlier warning and better highlight hazardous weather conditions at sea, fortify water quality efforts underway,⁹⁴ and reduce risk to coastal residents unaware of extreme weather events and storm surge.
- Produce and implement communications and outreach strategies with associated milestones, training tools and media relations platforms delivering technology, resilience and commerce-related success stories to showcase products and services, increase awareness, educate, and enable adaptation strategies.

Reduce Risk and Vulnerabilities

While natural disasters and weather events are major threats, coastal communities are at risk because of many other disturbances. In particular, many communities depend on coastal and marine resources for commercial and recreational uses, and changes to those resources provides both risks and opportunities to those industries and activities engaged in those uses. For example, fish populations may migrate along coasts, disrupting areas historically dependent on those populations, and providing new opportunities for other communities. Similarly, coastal economies and ecosystems are often dependent on their beaches and research into sediment transport and resulting changes in geomorphology is critical.

The ability of communities to overcome these disruptions depends on reducing risk, and where possible, capitalizing on opportunities by understanding community dependencies, forecasting resource responses to environmental change, and providing options for resource managers and industries to plan for the future. Because our Nation’s security and prosperity is affected by our communities’ access and use of coastal resources (*e.g.*, fisheries, energy, recreation, and cultural heritage), it is

⁹⁴More information can be found at: <https://www.epa.gov/aboutepa/about-office-water> (accessed June 12, 2018).

important to understand the factors that affect the ability of communities to respond to, and recover from, natural and manmade disturbances.

There is interest in better understanding the current state of resilience at multiple scales—from national to local—and the various determining factors that influence community resilience. Community resilience is affected by on economic stability and the ability for communities to survive and rebuild in response to diverse challenges and impacts. Coastal communities recognized as highly resilient will attract investment and strengthen the ocean economy.

Understanding how communities change over time requires baseline information to assess vulnerability and resilience historically and into the future. This effort requires collaborative efforts between local community, State, and Federal governments to determine past conditions, current trends, and future projections. Thus, accurate observations, mapping, and ecosystem condition data must be available for modeling and analyses across the entire coastal area.⁹⁵ This baseline information leads to a better understanding and measure of community vulnerability and resilience.

Whether it be a coastal city planner developing a new 50-year infrastructure plan, or a fisherman preparing for the next season, individuals and communities are often presented with a myriad of choices, some which reduce risk and some which augment risk. Understanding the economic or social drivers that lead to support, opposition, or indifference to specific risk-reduction strategies or community enhancement actions could lead to increased effectiveness and reduced cost for local economies and response entities.

Priorities

- Examine community-driven resilience planning that uses the experience, concerns, and needs of industry and stakeholders, and incorporates their perspectives in conjunction with conventional science-supported, public-sector planning efforts.
- Identify and document baseline conditions (*e.g.*, biophysical, economic, ecological, social, and cultural) for use in assessments of environmental and natural hazards, catastrophic events, cumulative effects, and community vulnerability and resilience.
- Examine how environmental hazards, including a changing climate and rising sea level, along our coasts are affecting American communities (*e.g.*, economic, ecological, social, and cultural) at varied scales, resulting in questions concerning financial and social vulnerabilities to certain populations.
- Understand, describe, and quantify where possible, social vulnerability and the factors that contribute to the resilience of communities that depend upon and engage with coastal and marine resources.
- Assess how future conditions and changes to the environment could interact with hazards and catastrophic events, and affect community vulnerability, resilience, and continuity.
- Describe and evaluate effects of key drivers on community and economic resilience (*e.g.*, presence/absence, application, consistency, compliance, and effectiveness of planning and construction laws, regulations, ordinances, codes, and practices; barriers and effectiveness of incentive mechanisms, and existing socio-economic conditions of populations).
- Research the risks of ocean acidification and other ocean changes as they relate to at-risk populations, food security, and the implications for humanitarian crises.

Empower Local and Regional Decision-Making

For a coastal community to be resilient, it must build capacity to respond to disturbances. This requires a better understanding of the particular characteristics of the community and industries, as well as information to support dynamic risk assessment and cost-benefit analysis of local and regional trade-offs. There is no “one size fits all” to understanding, measuring, or developing capacity for community resilience. Rather, developing capacity is context and location specific and depends on a community’s physical, social, economic, and cultural characteristics, which vary from place to place, by region, and through time. Access to local and regional spe-

⁹⁵ Interagency Arctic Research Policy Committee. (2016) Arctic Research Plan FY2017–2021. 8.4 Improve observations, mapping, and charting to support research across the coastal interface. Washington D.C. 46–47. <https://www.iarpcollaborations.org/plan/objective/8.4> (accessed April 17, 2018).

cific data and data tools is key to effective decision-making when planning for the future of coastal communities.⁹⁶

The Organization for Economic Cooperation and Development (OECD) defines capacity development as the “process by which individuals, groups, organizations, institutions and societies increase their abilities to: (1) perform core functions, solve problems, define and achieve objectives; and (2) understand and deal with their development needs in a broad context and in a sustainable manner.” In alignment with the other national initiatives (*e.g.*, National Preparedness Goal⁹⁷), research, technical assistance, and capacity development actions should be fostered to understand existing conditions and address deficiencies for coastal community and economic resilience across multiple scales.

The complex interconnections between humans and marine ecosystems require a better understanding of their spatial and temporal scales. Research that considers all the drivers influencing a resource is better equipped to provide government, industry, nonprofits, and academia a more accurate understanding of marine resource-based economies and their challenges and opportunities for growth. Such greater understanding will provide more realistic situational awareness of our coastal and marine resources so that coastal communities and marine industries can appropriately prepare for and adapt to changes. Capacity building depends on incorporating stakeholders who are dependent on marine resources into resilience planning.

Incentive programs can aid in the acceptance of program requirements by offsetting real or perceived costs, but may not be adopted for reasons that are still not understood. Applied economics, psychology, and decision science can help determine what makes something acceptable and why, how opinions are formed and influenced by others, and ultimately which decision made by an individual or a community is refused or adopted.

Priorities

- Examine incentives and successful adoption of specific programs or concepts across segments of a community (*e.g.*, by population characteristics, such as age, gender, profession, income, and education). Identify and inform decision-makers of specific incentives and disincentives related to actions to further improve community recovery and adaptation capabilities.
- Assess and evaluate existing and potential community-level adaptations to environmental variability and change to understand what elements are most effective in mitigating impacts and what factors are most important in adoption of those adaptation measures.
- Develop capacity to deliver research results and culturally relevant products to all communities at risk (*e.g.*, translating scientific jargon, evaluating and communicating risk).
- Determine methods and incentives for increasing capacity for communities to effectively evaluate and improve their resilience in alignment with their own specific needs and objectives.
- Develop observation and monitoring systems, tools, and delivery mechanisms to evaluate scenarios, and to enable better decisions, in terms of social, ecological, cultural, and economic health and well-being taking into consideration the probabilities of the scenarios.

MOVING FORWARD

This document establishes a vision for the Federal ocean S&T enterprise, in partnership with the broader ocean community, for the coming 2018–2028 decade. The outlined priorities are intended to guide the development of future Federal ocean research implementation plans within each agency. It also will inform Federal agencies’ collaboration with State and local governments, academia, private industry, and nongovernmental organizations to leverage non-Federal resources and support related non-Federal efforts. Its success will require an engaged, informed, and coordinated ocean community, as a concerted effort is essential to advancing ocean S&T and improving application of that understanding for the benefit of the Nation.

⁹⁶Such local and regional data, tools, and technical support is available through integrated marine information systems such the Digital Coast Partnership (<https://coast.noaa.gov/digitalcoast/>), the Marine Cadastre (<https://marinecadastre.gov/>), and Regional Ocean Partnership (ROP) portals (*e.g.*, the Northeast Ocean Data Portal, <https://www.northeastocean.data.org/>) (accessed June 11, 2018).

⁹⁷FEMA. (2018) National Preparedness Goal. <https://www.fema.gov/national-preparedness-goal> (accessed April 17, 2018).

This document does not prescribe metrics and agency-specific tasks. Instead, it offers shaped directions in the form of priorities. These were designed to promote research that contributes to greater understanding of ocean issues and variability, addresses relevant needs of resource managers and mandates of governing entities, encourages partnerships to expand the Nation’s capabilities, and positively impacts national and economic security.

Advancing national ocean R&D priorities requires a coast-to-coast effort. These priorities vary across regions, as do the ways in which different regional organizations address them. This Plan acts as a guide to identify areas requiring national attention, while recognizing the need for flexibility.

Learning from the Last Decade

This 2018 vision for U.S. ocean S&T builds off the 2007 Plan, aiming to advance the achievements and progress developed during the past 10 years. For example, the 2007 Plan identified the need to forecast ocean and ocean-influenced processes and phenomena to produce better decision-making tools. This 2018 document advances such efforts to strengthen decision-making processes by incorporating socioeconomic data and regionally specific data. A significant area of growth since the 2007 plan is the establishment of a coordinated national and international network of observations⁹⁸ with associated data transmission, data management and communications (DMAC), and data analyses and modeling capabilities. We have collected an enormous amount of data about our ocean and coasts, and this 2018 document addresses the need to obtain, analyze, and manage such Big Data.

Some identified research priorities in the previous Plan remain as continued objectives, while many of the priorities are even more relevant today. For example, the 2007 Plan called for advancing modeling capabilities to improve “understanding and forecasting the response of natural and constructed landscapes and ecosystems to extreme weather events, natural disasters, and changing ocean conditions to inform hazard mitigation and response plans, support navigation safety.” In light of 2017’s hurricanes Harvey, Irma, and Maria, their aftermath, as well as the continued rise in Presidential Federal Emergency Management Agency (FEMA) Disaster Declarations in response to extreme weather and hazardous events, this 2007 priority remains just as crucial to continue the momentum toward improved predictions and proactive measures such as expedited warning and response time.

Balance Short-Term Imperatives and Long-Term Investments

Managing ocean S&T innovation is a long-term pursuit. There is, however, a need for balancing short-term research to address immediate needs or current perceived threats, with long-term R&D efforts to understand the fundamental ocean system and inform major challenges and decision-making. As technologies advance and research priorities shift, it is important to ensure that a balanced approach is taken between longer-term goals and areas of immediate opportunity. It is even more crucial to approach the next decade with a determined yet adaptable mindset, balancing resources needed for immediate action and applying enough science-based foresight to plan for what lies ahead.

Areas of Immediate Opportunity

Five recurrent topics emerged from the goals and objectives described in this document that provide focus for initial research and technology opportunities. These areas surfaced from Federal agencies with interest and responsibilities linked to the ocean, and thus represent synergy across Federal agencies and immediate areas of coordination and collaboration. They are not exclusive of other efforts directed to the full suite of longer-term (decadal) research and technology activities. These areas resulted from criteria that include impact of the work, urgency of the research and technology, funds availability, and partnerships and collaborations across agencies and the broader scientific community.

1. Fully integrate Big Data approaches in Earth system science

Big Data is revolutionizing the way scientists and the public approach and study the ocean Earth system. However, scientific communities often use Big Data for research objectives and require their data to be in a specific format, or the data is not made publically available in due course. As a result, many long-term measurements and models are not accessible to non-academic institutions and businesses. Sources of ocean-related Big Data in ocean sciences include the large amounts of multi-dimensional measurements on a wide range of ocean variables collected by re-

⁹⁸Interagency Ocean Observation Committee. (2017) Integrated Ocean Observing System. <http://www.iooc.us/ocean-observations/integrated-ocean-observing-system/> (accessed April 17, 2018).

mote and *in situ* sensors across the globe. Big data can also include biological information in the form of genetics as well as high-resolution, ground-truthed model simulations of global, regional, and local ocean processes. Full accessibility and use of Big Data capabilities provides opportunities for new and strong collaborations between the observational, modeling, scientific, and technological communities, resulting in novel findings through deployment of cloud infrastructure, data-analytic tools, data-mining algorithms, and scalable workflow frameworks. For example, certain Big Data analyses can be used to combat illegal fishing by increasing enforcement efficiency through rapid identification of illegal vessels, and complementing concrete resources such as manpower, ships, and planes.⁹⁹

2. Advance monitoring and predictive modeling capabilities

Advances in understanding coupled and nonlinear ocean, atmosphere, land, and ice phenomena and variations are required to monitor the environment and predict future changes. These models are significantly enhanced by improving computational resources and enabling ensemble simulation approaches to forecasting. Recent hurricane events clearly illustrate that research efforts aimed at improving coupled ocean-coastal-hydrology models for total water and storm surge prediction capability is of high priority and critical to the preparedness of the Nation. A combination of existing and emergent technologies and modeling capabilities is required to further elucidate oceanographic systems, future trajectories and uncertainties, and the connections among Earth system components. For example, building a weather-ready Nation requires ports and open ocean transit systems to continuously include weather, water, climate, and environmental data and information into decision-making and planning to ensure safe, secure, and efficient maritime commerce. Unified efforts should target the establishment of common and interoperable frameworks that allow for efficient model execution on scalable computing systems, as well as interdisciplinary application and standardized interface with Earth system observations.

3. Improve data integration in decision support tools

Understanding and managing the interactions of the human dimensions within the Earth system needs to be enhanced in the coming decade. Decision-making pertaining to ocean use and conservation issues is challenged by increasing complexities of economic variability, ecosystem features, and community diversity. The situation is becoming more challenging as the number and types of ocean users increase, while interdependencies between the ocean's ecosystems and human well-being continue to grow.¹⁰⁰ Decisions will need to directly address the role of humans as shaping modern seascapes and coastal landscapes. For example, physical, biological, and socioeconomic models can be coupled with various Earth system models of potential impacts or benefits to people, industry, and the surrounding ecosystems to evaluate alternative management approaches.¹⁰¹ Science, research, and technology will be most useful for citizens if the results and the implications of those results are broadly understandable and communicated, and made easily accessible. Decision-support tools and allied approaches will help both individuals and their communities ensure their viability now and in the future.

4. Support ocean exploration and characterization

Advances in ocean S&T within the next decade will allow us to better explore our ocean and better understand our environment, such as improved seafloor mapping to better inform maritime transportation operations. The advent of molecular tools collectively referred to as omics, has the promise to revolutionize our ability to explore, sample, and characterize the ocean efficiently. Through omics it has been possible to characterize and quantify the distribution and function of several organisms in ocean ecosystems through space and time, and explore organisms for natural products discovery. The declining cost and rapid increase in omics technologies offer

⁹⁹Command, Control, and Interoperability Center for Advanced Data Analysis. (2013) Fisheries Enforcement: U.S. Coast Guard is Sharpening Enforcement Tools with Big-Data Help from CCICADA. <http://ccicada.org/2013/12/20/fisheries-enforcement-us-coast-guard-is-sharpening-enforcement-tools-with-big-data-help-from-ccicada/> (accessed April 23, 2018).

¹⁰⁰Levin, P.S., and M. Poe. (2017) Conservation for the Anthropocene Ocean. Academic Press. London. p. 530. <https://www.sciencedirect.com/science/book/9780128053751> (accessed June 15, 2018); Plagányi, E.E., and E.A. Fulton. (2017) The Future of Modeling to Support Conservation. 423–446. In: Levin P.S., and M. Poe (eds) Conservation for the Anthropocene Ocean. Academic Press. London. <https://eprints.utas.edu.au/25751/> (accessed June 15, 2018).

¹⁰¹Holsman, K., A. Hollowed, A. Haynie, S. Kasperski, J. Ianelli, K. Aydin, W. Cheng, A. Hermann, T. Kristiansen, and A. Punt. (2016) A stress test for fisheries management: using coupled physical-biological-socioeconomic models to evaluate alternative management approaches in Alaska. NOAA Fisheries. p. 42. <https://cpo.noaa.gov/sites/cpo/MAPP/Webinars/2017/11-21-16/Holsman.pdf> (accessed April 21, 2018).

new opportunities to address pressing needs in ocean science. Further development of eDNA and other omics approaches to interpret the marine environment are likely to provide a high return on investment. Although there are sampling and cyberinfrastructure challenges for the coming decade, it is currently possible to address critical questions from managers and stakeholders. One example is how omics data can be used and/or coupled with models to effectively monitor and predict ecosystem changes and their consequences, as well as to manage marine resources such as fisheries. eDNA is one technology that can help facilitate fine-scale geographic and temporal mapping of fish populations to assess fisheries management effectiveness.¹⁰² The discovery of natural products is essential for the development of new therapeutics, nutrients, energy, ecological processes, and other beneficial products and technologies derived from a variety of marine hosts. Exploration, discovery, and assessment of marine resources, processes, and ecosystem structure and function, are vital to capitalize on economic opportunities, human health, and environmental resilience, among others.

5. *Support ongoing research and technology partnerships*

The success of the effort to advance the Nation's ocean S&T enterprise described in this document requires effective collaboration of all organizations involved in ocean science. Participation of local, tribal, State, and regional governance entities will ensure that national ocean priorities incorporate the needs of specific areas or groups. Involvement of academic institutions provides scientific innovation and peer review, helps identify and address pressing research questions, and shapes society's interaction with the ocean by communicating ocean science directly to the public. Increasing partnerships across government, non-government, international, and the private sectors prevents duplicative efforts, strengthens resources and opportunities, helps prioritize ocean science, and promotes an ocean-literate public. For example, programs have successfully used partnerships with Federal agencies, academia, industry, State, local, and tribal governments, and non-governmental organizations to increase ocean-related knowledge for the purposes of promoting national security, advancing economic development, protecting the marine environment, enhancing quality of life, and strengthening science education and communication.¹⁰³

Senator BALDWIN. And I do that so that we can all have context for what I'm about to discuss.

In your presentation to the departmental leadership last month, you proposed that the NOAA mission statement and vision either be amended or otherwise reconsidered. And specifically, the presentation included two columns, one labeled "Past" and one labeled "Present." The "Past" column included references to studying climate in order to realize resilient ecosystems, communities, and economies. The "Present" column does not even use the words "climate" or "resilience." And I think both of these are very important priorities for NOAA.

In the Great Lakes, higher-than-average temperatures and a less predictable climate have the potential to shorten the season for recreational activities, increase the rate and severity of storm and flooding events—and we've seen some enormous extreme events of late—impact shipping routes, threaten certain coldwater species, and impact our agriculture, tourism, and maritime industries.

Admiral Gallaudet, you said, in response, that—and I quote—"This presentation is a simplified draft for discussion. It was not intended to create change in the NOAA mission or policy from what it was before," end quote. So, what, then, do these columns, "Past" and "Present," aim to represent? And why are they labeled "Past" and "Present"?

¹⁰²Stoeckle, M.Y., L. Soboleva, and Z. Charlop-Powers. (2017) Aquatic environmental DNA detects seasonal fish abundance and habitat preference in an urban estuary. *PLoS ONE* 12(4):e0175186. <https://doi.org/10.1371/journal.pone.0175186> (accessed June 15, 2018).

¹⁰³An example of such collaborative programs is the National Oceanographic Partnership Program (NOPP). More information can be found at: <http://www.nopp.org/> (accessed June 1, 2018).

Admiral GALLAUDET. Thanks for your question, Senator Baldwin. The presentation was deliberative. It had not been cleared through the Department. And the purpose of the slide deck and the slides you're talking about, in terms of mission, were merely to foster discussion on how NOAA is aligning under the Department's strategic plan. And so, there were elements, like aquaculture and weather forecasting, which were singularly present in the strategic plan, and that was the purpose behind the language.

Senator BALDWIN. The Decadal Ocean Vision document that I also entered into the record identifies goals to advance U.S. ocean science over the next 10 years. Remarkably, even though citations that include titles of study in the footnotes throughout the document use the term "climate change," the plan itself never once uses the phrase. How does NOAA intend and plan to continue to study and address the threats of climate change? And maybe a more difficult question, How will you make sure that what appears to be glaring omissions of the term "climate change" don't yield a subtext in which NOAA's internal culture—that science, conservation, and management of natural resources are not valued or, worse, should be censored in this administration?

Admiral GALLAUDET. Thank you for your question, Senator Baldwin.

The—as Secretary Ross and I stated publicly after the document hit the press, it was that we are committed to NOAA's climate and conservation elements of our mission. And you can see, today, in FY18, we have \$100 million dedicated—or nearly so—to climate research and we're continuing to perform climate services through our Climate Program Office and Climate Prediction Center. So, we are committed to continuing that element of our mission.

Senator SULLIVAN. Senator Nelson.

Senator NELSON. Admiral, you retired from the Navy as the Chief Oceanographer of the Navy. Is that correct?

Admiral GALLAUDET. Yes, Senator.

Senator NELSON. And what is that? Is that a Rear Admiral?

Admiral GALLAUDET. I was a Rear Admiral when I retired, yes, sir.

Senator NELSON. Two star.

Admiral GALLAUDET. I was a one star, sir.

Senator NELSON. Well, your long and distinguished record is certainly admirable, and we appreciate it. And personally, I'm very glad, with your background, that you are where you are.

Now, you answered the question of the Chairman's about fishing research, when he asked about a 17 percent cut—you answered it, "We are committed to fishing research, but we think we can be more efficient." When Senator Baldwin asked you about climate change and the lack of use of the term "climate change," you, basically, answered that we are committed to studying the climate. And yet, the President's budget has a \$50 million cut in climate change research. How do you square that?

Admiral GALLAUDET. In the President's budget, Senator, of course, we had to make tough priority calls, and the President elected to prioritize national security funding, and that—therefore, Commerce and NOAA saw reduced levels in the proposed budget. I will answer to you, though, that we're committed to our climate

support and research and advancement through the subseasonal-to-seasonal forecasting capability, or element of it, that's called out in the Weather Act.

Senator NELSON. Well, you just answered that, that the priorities of national security sometimes trump the other parts of the budget. The specific question here is about climate change. And you are a retired Navy admiral. Does the effects of climate change have any effects on national security?

Admiral GALLAUDET. Senator, yes, sir. I saw that in my career, and I've spoken about the effects of climate change on national security. But, in fact, though—I would say, though, that there are many interagency efforts to assess those impacts. And therefore, again, I don't believe that reductions in funding toward that in NOAA are significant in that. The Navy is also committed to studying climate and climate effects on national security, as is the Department of Energy, as is NASA.

Senator NELSON. I appreciate that, and I'm not going to throw you softballs. I'm going to throw you harder pitches. Give me an example of where climate change would have a direct impact on the United States military with regard to our national security.

Admiral GALLAUDET. I think the thing that I saw that was most obvious was the effects of sea level rise in Norfolk Naval Station, for example, which is experiencing increased levels of high tide flooding, which impact the infrastructure at the base, the airfields, and the piers, and just the accessibility by the sailors to get to the—their work every day.

Senator NELSON. Well, with that, I'm going to back off the hardballs, because I think you've answered the question about why it ought to be all-hands-on-deck, to use a Navy term, about the issue of climate change, not just the U.S. military, but the very agency that is tasked with studying the climate. And that's your agency: NOAA.

Thank you, Mr. Chairman.

Senator SULLIVAN. Senator Schatz.

**STATEMENT OF HON. BRIAN SCHATZ,
U.S. SENATOR FROM HAWAII**

Senator SCHATZ. Thank you.

Admiral Gallaudet, thank you for being here. Thank you for your service.

I want to talk about coastal resilience. As you know, the 2017 hurricane season—Harvey, Irma, Maria—showed incredible damage and resilience activities. Regardless of what we think the cause is, and the conversation about weather versus climate, and all the rest of it, it just simply makes sense to build more resilient coastal infrastructure. I'm wondering what you're doing in that space.

Admiral GALLAUDET. We're doing quite a bit, Senator. And thank you for the question.

You know, our fisheries has an Office of Habitat Restoration. And so, the—I've seen restored marshland in Louisiana, for example. I've stood on areas that—a restored marsh that was under water for decades. And that is now serving as an effective storm barrier for New Orleans.

Senator SCHATZ. So, I want to stop you right there, because this actually gets to my second question. And again, there's a kind of way you can talk about this that's going to freak people out if they don't self-identify as environmentalists, but here's the way I would describe it. We like to call it ecosystem services, but the other way to look at it is: If you destroy coastal ecosystems, then what you end up having to do, as a city or a town, is essentially levy taxes to reconstitute those services that the ecosystem provides: fresh water, flood abatement, even parks and recreation. You get rid of it, and then you end up building it back, but it doesn't work as well, and it costs you a heck of a lot more. Is that consistent with NOAA's view of ecosystem management?

Admiral GALLAUDET. Senator, yes, sir, it is. And our National Ocean Service, I believe, has performed a study about the economic contributions and gains made by investments in coastal resilience.

Senator SCHATZ. I want to ask you about a 2016 study by the Department of Commerce which valued the gross sales and receipts from recreational fishing and boating at around \$38 billion. And if we could count the indirect effects, like jobs, tourism, travel, the figure would be even higher. This is a significant and growing part of the Blue Economy. I think more people enjoying and appreciating our oceans and coasts is a good thing, because people are willing to take care of the things that they love and that they enjoy. What are you doing to support this growing industry? I know there has been a lot of talk about extractive industries—fisheries and minerals and other natural resources—less talk about recreational boating and fishing. I'd like you to talk about what you're doing in that space.

Admiral GALLAUDET. Yes, Senator, thank you very much.

That's something I'm—personally am interested in. I have a—I'm a recreational boater and fisherman, and I live on the coast, in the Chesapeake Bay. And so, NOAA's doing great work to support tourism and recreation. For example, we have our National Marine Sanctuaries, which provide for \$8 billion of economic activity every year. And that—you see in our sanctuaries much activity devoted towards fishing, recreation, scuba diving, and just enjoying the coastlines.

We also have great programs, like our Marine Debris Program, working to remove marine debris, plastics, not only offshore, but onshore, on beaches and coastlines, just because the citizens don't want to recreate in trashy areas. And so, that program, I think, is doing great things in that area, as well.

And I'd say, also, our weather forecasting through the National Weather Service is also supporting the safe conduct of recreation and tourism in our coasts.

Senator SCHATZ. Let's talk a little bit about surf forecasts. They're important for safety, they're also important for recreation. *Forbes* magazine is projecting around a \$13 billion value for the international surf industry. We can't find any specific data for just the United States. But, I want you to talk a little bit about getting better fidelity on surf reports, and the surf industry, more generally.

Admiral GALLAUDET. Yes, sir, Senator. I'll be glad to.

In fact, I've been really pleased to look at the improvements made in our coastal models. We have large-scale global ocean models and wave models, and then we, what they call, nest down into very localized, high-resolution coastal models. And we have them for regions all around the country. The latest one, the newest one we established was for the Gulf of Maine, and—but, that—we're making great improvements through science and technology advancements, through modeling improvements. And what we're encouraged to do is—as you cite, is share that technology with the private sector and encourage the growth of those kinds of industries, like surf line and—as we have done already with the private weather enterprise.

Senator SCHATZ. Thank you.

Senator SULLIVAN. Senator Peters.

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

Senator PETERS. Thank you, Mr. Chairman, Ranking Member. Thank you for calling this important meeting. Particularly related to the Great Lakes, thank you very much. Appreciate that.

Admiral Gallaudet, I understand that, on your trip around the country as you're visiting various locations, you're going to have the opportunity to—at least planning to do some scuba diving in the Thunder Bay National Marine Sanctuary in Michigan in mid-August. And I appreciate your kind invitation for me to join you. I'm not going to be able to join you on this trip, although just—I guess it was about two years ago, I had the opportunity to be with our friends in NOAA and dive on some incredible wrecks. As you know, the Great Lakes and its fresh water just perfectly preserves these wrecks, so we have over 100 wrecks in the sanctuary. It is some of the most incredible scuba diving you'll do anywhere. So, folks who are listening to this, please come to Michigan and visit us, because it's part of the Blue Economy to come there to be able to experience that.

And I think my friends in Alpina will tell you what this sanctuary has meant for the area. It has been an incredible driver for the economy as people have not only come to dive, but on the glass-bottom boats, there is a Visitor Center that NOAA has that is world-class, that explains the heritage, the shipping, the nautical heritage, maritime heritage over the Great Lakes that built America as it—so, it's a very important part of the Blue Economy.

And that's why I'm—I—my question to you, sir, is, Why has NOAA proposed to reduce the budget for sanctuaries and marine protected areas in fiscal 2019? And, specifically, what kind of impact is this going to have on Thunder Bay and other marine sanctuaries?

Admiral GALLAUDET. Well, Senator, thank you for your question.

And my goal is to decorate my office with underwater photos, just like yours, in Thunder Bay. We think the impacts to the sanctuaries of those budget cuts are going to be minimal, and that we're able to absorb them and still manage our sanctuaries in a fine way, as we have been for years, over two decades. And, in fact, we are seeking to secure, potentially, expansions in our sanctuary system, as well as two, possibly, new sanctuaries over the next

coming period. One is in Malloys Bay, in the Potomac. And we're working with the State of Maryland on that. And I think that's a great example of how each sanctuary is sort of tailored to each local economy and community's interests and—so as to foster the great things that you've seen in Alpena through Thunder Bay.

Senator PETERS. Well, still, these cuts will have an impact, and especially when you look at zeroing out coastal zone management grants, sea grant programs. This is cumulative. We know these are economic drivers. These grants are important. And the growth continues. In fact, in the Thunder Bay example, we're—or they are undergoing research that they believe will find another 100 wrecks. This will continue to be an economic boom. These cutbacks have an impact, particularly in conjunction with these other programs, don't you agree?

Admiral GALLAUDET. I agree, they have an impact, Senator. And I'm—we understand that the—the work funded by the—or done at the sanctuaries in the coastal zone management programs is important. Again, our prioritization in the 2019 budget was to—for government services. And so, external grants to states and local entities were at a lower priority. It's important work, and, I mean—and we are happy—in FY18, for example, we did see appropriations for coastal zone management, and we've been able to do good work in executing, I think, \$75 million of funding toward those efforts this year.

Senator PETERS. I'd also like to follow up on a longstanding concern for our state and region, and that's the administration's proposed review of all sanctuaries and maritime national monuments. A straightforward question for you. Do you support maintaining the existing boundaries of the Thunder Bay National Marine Sanctuary?

Admiral GALLAUDET. Sir, I know that the administration has sought, through—to explore and examine the expansions that have occurred over the last few years. And I agree that we need to assess continuously how well and to what purposes our existing sanctuaries and monument systems serve the public, as well as the economic contributions they make.

Senator PETERS. Well, I hope you have a lot of discussion, when you're up in Alpena, with folks about the importance of those boundaries and how that is part of the Blue Economy in that part of northern Michigan. To keep that is going to be critically important. I hope you have that discussion.

I'd also like to ask you a bit about NOAA's oil-spill prevention-and-response efforts. As you know, NOAA is tasked with updating environmental sensitivity index maps, which help summarize the coastal resources that are a risk of oil spills. We had a very large oil spill in Michigan—in fact, the largest pipeline break in history, a few years ago. We have a lot of concerns related to line 5, which is in the Straits of Mackinac. In fact, a recent report came out to show it would be a multibillion-dollar effort to clean up that kind of spill, should it occur.

And, while the maps in the East, West, and Gulf Coasts have been updated within the last 5 years, it has been over 20 years—20 years—since NOAA maps were updated in the Great Lakes.

Why has NOAA not updated the environmental sensitivity maps in the Great Lakes for so long?

Admiral GALLAUDET. Senator, I'll have to take that for the record. I don't know the reason for being slow on the Great Lakes and not so in existing areas.

[Information follows:]

Admiral GALLAUDET. I can comment and say, though, that we have a Restoration and Response Office in our National Ocean Service, which does fantastic work responding to spills every week. And they're all around the country, in the Great Lakes as well as every coast, doing very good work. And I'm proud of their efforts.

Senator PETERS. Well, I'd like to enlist your efforts to make sure we get these maps done, particularly with the concern that we have related to a pipeline now that exists in what the University of Michigan has characterized as the most dangerous place anywhere in the Great Lakes Basin for an oil spill. And so, having sensitivity maps will be incredibly important as we try to work through issues related to that.

I've introduced, actually, legislation with Senator Young, who's a Member of this Committee, to require that NOAA update the Great Lakes coastal maps at least once every 7 years, which I think is appropriate. And our goal is to provide better, more actual information. I hope to get your support as we move that bill forward.

Admiral GALLAUDET. Well, thank you, Senator. We'll look hard at that. And, as I said, I'll get back to you on the—explaining why the delay.

Senator PETERS. I appreciate that. Thank you.

Senator SULLIVAN. Senator Markey.

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

Senator MARKEY. Thank you, Mr. Chairman.

Admiral, welcome.

The United States imports over 90 percent of all the seafood that we eat. And that amounts to a huge trade deficit. This seafood largely comes from countries who do not have laws like the United States that create sustainability, managed fisheries, such as Thailand. Many Americans understand that they can support local sustainable fisheries by buying from American fishermen, but seafood fraud, the fraudulent labeling of fish products, undermines these efforts and contributes to our seafood trade deficit. This isn't just a case of one fish or two fish marketed as a redfish or bluefish. There have been multiple investigations finding systemic seafood fraud. In 2011, the *Boston Globe* did an investigation and collected fish from 134 restaurants, grocery stores, and seafood markets. After conducting DNA testing, they found that 48 percent of fish were sold with the wrong species name. More recently, in 2018, we've learned, from Associated Press investigations, that companies continue to label farmed seafood as wild-caught and sell fish that is out of season and illegal to catch.

NOAA, in its Office of Law Enforcement, is responsible for monitoring fisheries and protecting the public by prosecuting seafood fraud. Admiral Gallaudet, let me give you the numbers. In June, I requested information from NOAA, and this morning I received

an answer. In the last 5 years, NOAA's Office of Law Enforcement has initiated 114 investigations related to seafood fraud, 24 of which were referred for prosecution. There are currently 30 active investigations. Do you believe that NOAA has enough resources for its Office of Law Enforcement in order to do this job, given the pervasive nature of fraudulent seafood being sold in the United States?

Admiral GALLAUDET. Senator Markey, thank you for your question.

And the answer is, yes, I do. I believe that our Office of Law Enforcement, who are all fine public servants, by the way, do great work and can handle the work by partnerships with State entities as well as foreign partners and interagency partners, such as the Navy and Coast Guard.

Senator MARKEY. So, you think you have adequate resources in order to detect and prosecute—

Admiral GALLAUDET. Yes, Senator, I do.

Senator MARKEY. Well, we have to encourage the purchase of domestically caught wild fish over fish from foreign fish farms. And that's why I am keeping a close eye on the Office of Law Enforcement and the progress of NOAA's new Seafood Import Monitoring Program. Senator Wicker and I worked with NOAA to create this program, which provides transparency and traceability for certain imported seafood products to prevent illegal, unreported, and unregulated seafood from entering the U.S.

Administrator Gallaudet, can you give us an update on how the implementation of NOAA's traceability rule is going?

Admiral GALLAUDET. Yes, Senator, I can.

And, in fact, the Seafood Import and Monitoring Program has been active since the beginning of the year. And we're currently executing those activities on a little over a dozen species. And we've added to—the FY18 omnibus added abalone and shrimp to that, which will double the amount of seafood that we are currently—that we have been monitoring and inspecting. And that will be in place by the end of the year.

Senator MARKEY. OK, thank you.

Back in April, ten of my Senate colleagues and myself, we sent a letter asking NOAA to do a comparability study of Canada and the United States marine mammal conservation standards. Our concern is obviously about the right whale. Could you commit to giving us the results of the comparability study by September 15 of this year?

Admiral GALLAUDET. Senator Markey, yes. As we discussed yesterday, we will get you the answers there of that study of comparability with Canada by September.

[Information follows:]

Senator MARKEY. OK, thank you. And that is very important.

Now, on the question of drilling off of the coastline of the United States, I have been very concerned about the, still, lack of full implementation of the *Deepwater Horizon* oil spill recommendations. The Department of Interior is proposing a rollback of offshore drilling safety rule. Secretary Zinke is actually moving forward on that.

My view—and this is right at the heart of this issue—is that, for New England, it really makes no sense for us to be talking about

drilling off of our coastline, when the fishing and tourism are the life's blood of our economy, and any oil spill would have devastating consequences already—on an already existing economy. What is the plan, from your perspective, that would be best in order to ensure that New England does not suffer from an oil drilling program that ultimately could result in a spill?

Admiral GALLAUDET. Well, from NOAA's perspective, Senator, I think the currently new National Ocean Policy that the President has put into effect through executive order provides the mechanisms, I think, to mitigate the unwanted consequences through the planning and data aspects that the policy provides for. So, ensuring that siting takes into account multiple uses or potentially competing uses, and being informed by the best science and data. And that's what the policy provides for. And I think that's something that we can use to mitigate the concerns you have, sir.

Senator MARKEY. Well, do you think it makes any sense to be rolling back the safety protections that were implemented after the accident down in the Gulf of Mexico?

Admiral GALLAUDET. Senator, I'm not sure what you mean by "safety protections," but we are committed to the things that we're responsible for, such as implementing the Marine Mammal Protection Act and Endangered Species Act.

Senator MARKEY. OK. So, you don't want to see them rolled back. Is that what you're saying?

Admiral GALLAUDET. I'd—I'm not sure what you're referring to, sir.

Senator MARKEY. Well, again, we're talking about comments made by Secretary Zinke with regard to rolling back—

Admiral GALLAUDET. I will state, though, sir, that we are supportive of the administration's desire to lead—be a leader in global energy.

Senator MARKEY. OK, good. I appreciate that. But, we—in New England, we're in a situation where we would run all the risks and get very little of the benefits. That is, we are not an oil or natural gas economy. We are a—we are an economy of tourism and fishing. So, that's the concern that we have, and we want to make sure that all the offshore drilling safety rules, the well-control rules, are all at the strongest possible level in order to protect our economy.

Thank you.

Senator SULLIVAN. Thank you, Senator Markey.

Admiral, I want to, actually, follow up on a line of questioning Senator Markey was just discussing with you on the topic of fisheries. And I applaud his focus on the issue of seafood fraud and how it impacts our fisheries negatively and adds to the trade deficit, which I know Secretary Ross has been very focused on. And we appreciate that. I understand that NOAA is working on an initiative to promote the production and competitiveness of U.S. seafood. I applaud this work. And I know it comes directly from the top. As I mentioned, Secretary of Commerce is very interested in that. Can you give us a little bit more information or details on this initiative that you are working on with the Secretary?

Admiral GALLAUDET. Yes, Chairman Sullivan, thank you.

The initiative and the efforts we're undergoing—undertaking today involve, as you said, addressing the \$16 billion seafood trade

deficit that exists. And so, one element is fostering the increase of domestic aquaculture industry in Federal waters and also providing support and science to aquaculture in state waters. So, promoting that industry is one element that we are underway with right now, and we intend to expand in, to some degree.

The other thing we're working with is to look for ways to expand market access for our seafood producers. And that's a pretty exciting element, I think, and has opportunity, especially as we are in the Department of Commerce.

And then—and last, it's optimizing our fisheries in sustainable fashion. And, as I mentioned earlier, we are improving our stock assessment models, as well as the data behind them, so that we can really maximize the sustainable yields of our commercial fishermen around the country.

And so, those three efforts, we're underway with, and we think we'll really be able to make a dent in the seafood trade deficit and really foster seafood competitiveness.

Senator SULLIVAN. Let me probe a little bit more, here. I know that NOAA's not a marketing agency, but making U.S. seafood competitive also means making it a priority choice of consumers. I think most consumers would agree that wild-caught salmon or wild-caught lobster is preferable to farm-raised. How can NOAA build and improve on the Fish Watch Program to help educate U.S. consumers on the benefits, the health, sustainability of U.S. seafood, particularly wild-caught seafood?

Admiral GALLAUDET. The Fish Watch Program is a—is an excellent one. And, in fact, what we're working with is the network of aquariums that exist around the country as an outreach vehicle to talk about seafood competitiveness within the country and, ultimately, abroad, in terms of exports.

Senator SULLIVAN. When you talk about exports, I do want to just mention, as Senator Nelson did, a growing concern that we have with regard to the potential for trade retaliation. As you know, Alaska's a major, major seafood exporter. I know that the President's goal, here, is certainly to open markets in China and in other countries, where he sees nonreciprocal trading treatment. I actually happen to agree with that, particularly as it relates to China. The economic and trade relationship is very nonreciprocal. It favors China. And we need to do something about that. I appreciate his efforts, although I have raised with him and with Secretary Ross the concerns I have about the retaliation hitting the major exporters in the seafood area. And that's, of course, a lot of Alaska fishermen.

Is NOAA doing anything to analyze the effects of this retaliation on U.S. seafood prices and exports and competitiveness, which, again, I know is a priority of the Secretary and yours? Are you doing anything in that area?

Admiral GALLAUDET. Well, thank you, Chairman Sullivan.

We do continually study exports and—of our—of the seafood industry, as well as imports and their effectiveness. And, in fact, encouragingly, we did see an increase of about 4.7 percent over the last year of our seafood exports, and actually more than double that, 10.7 percent, of the value of U.S. seafood exports. So, we do track that. I don't have any data now on—in terms of the impacts

of the tariffs, but I will say we support the administration's agenda with respect to trade, because our competitors have outclassed us and had an advantage in the past by not being free and fair in their trade policies.

Senator SULLIVAN. Let me end with a topic I touched on. And I know it's part of the Blue Economy Initiative, but it goes to hydrographic surveying. Senator Peters raised it as an issue with regard to the Great Lakes. And so, you see it as a concern, not just for tourism and commercial activity, but for preventing ships from running aground. As I mentioned in my opening comments, in the Arctic we are woefully inadequate, in terms of the maps, surveys. Senator Peters mentioned being surveyed once every 6 or 7 years in the Great Lakes. As I mentioned, there are parts of Alaska that have never been surveyed, ever. And some of the other areas haven't been surveyed in over 100 years, where, let's face it, the technology wasn't very cutting-edge back then. What are you doing to prioritize updating nautical charts in the Arctic, particularly given the vast expansion of commercial activity in transportation and fishing in that part of the world and that part of America?

Admiral GALLAUDET. Thank you, Chairman Sullivan.

We're doing great work in our Office of Coast Survey in Alaska and across the country, in terms of trying to map our—and chart our—perform hydrographic surveys of our EEZ, and with the goal to complete that by 2030. And, in Alaska specifically, we're both using our ships, the Fairweather, and also the unmanned technology I talked about before. And we are using these unmanned surface drones, for example, for the first time to collect bathymetric information. So, we're—we have a plan, a National Arctic—or, pardon me, Charting Plan. And we're executing that.

Senator SULLIVAN. So, your strategies at NOAA to pursue the data gaps in Alaska are covering what? Give me a sense, a little bit more of the specifics of the strategy.

Admiral GALLAUDET. Well, again, our goal is to get to the whole U.S. EEZ, including Alaska, by 2030.

Senator SULLIVAN. So, specifics.

Admiral GALLAUDET. In Alaska and in the Gulf Coast and every coast.

Senator SULLIVAN. But, I mean, how are you doing that? Ships? You mentioned—

Admiral GALLAUDET. Oh, you—yes—

Senator SULLIVAN.—doing these—

Admiral GALLAUDET. Yes, sir, ships and using unmanned surface drones.

Senator SULLIVAN.—and do you have the funding to do that?

Admiral GALLAUDET. Yes, sir, we are funded for that.

Senator SULLIVAN. OK.

Senator Cantwell.

**STATEMENT OF HON. MARIA CANTWELL,
U.S. SENATOR FROM WASHINGTON**

Senator CANTWELL. Thank you, Mr. Chairman. And thank you for holding this important hearing. I know our subject, here, is pretty broad, but obviously, as a region of the country that is great-

ly affected by our oceans economy, I appreciate the fact that we're having this hearing to talk about how critically important it is.

I know the Chair also mentioned stock assessments. I want to definitely go back to that subject. Our fisheries management is so dependent upon stock assessments. Do you have adequate budget to do the stock assessments that are critical for us to continue to grow this part of our economy?

Admiral GALLAUDET. Yes, Senator, I believe we do have an adequate budget to perform the stock assessments for—to sustainably manage our fisheries.

Senator CANTWELL. You can manage all our fisheries under the current level of funding that you have.

Admiral GALLAUDET. Yes, Senator.

Senator CANTWELL. OK. I find that surprising, because most of the things that we've been talking about are issues of not being able to accurately manage the fisheries, based on the fact that we haven't done the stock assessments. If you haven't done the stock assessments for a lot of these fisheries, how can we do the science behind the management strategy?

Admiral GALLAUDET. Well, I've seen—I've visited our Fishery Science Centers in your State, for example, and I've talked to our scientists who are doing this, and we've improved our models, and we've improved our observational capabilities to do these.

Senator CANTWELL. OK. Senator Risch and I have introduced legislation dealing with the Columbia River. Are you in support of that legislation?

Admiral GALLAUDET. Ma'am, I'm not familiar with it. I've been to the Columbia River. I've talked to the pilots. I don't—not familiar—is the sea lion legislation?

Senator CANTWELL. Yes.

Admiral GALLAUDET. Oh, I am familiar with it, ma'am, and our staff has worked with both the House and is now working with the Senate.

Senator CANTWELL. In support of the legislation or——

Admiral GALLAUDET. To assist with it, yes, ma'am.

Senator CANTWELL. OK. Well, if you'd give us a solid answer, on that legislation, that would be so helpful.

What else do we need to do in the continuation of policies that are going to help us with both our orca population and salmon population? What other additional things should NOAA be doing?

Admiral GALLAUDET. I think it's what you pointed to with stock assessments, ma'am. It's improving our observation technology and the study and science behind it through the Fishery Science Centers in your State.

Senator CANTWELL. OK.

Thank you, Mr. Chairman.

Senator SULLIVAN. Senator Baldwin.

Senator BALDWIN. So, I am a member of the Senate Great Lakes Task Force. And we work very hard to share—to protect our shared resource. It's a very strong bipartisan task force. I noted earlier that these lakes provide drinking water for 35 million people. They also contribute billions of dollars in tourism each year and support over a million jobs across our region. And they're home to myriad ecosystems. We've discussed a number of issues that could really

harm the Great Lakes Basin, from pollution that can follow the drinking water, to invasive species that could threaten our fisheries, an oil spill when the lakes are iced over, or harmful algal blooms that plague our beaches in the summer.

Admiral Gallaudet, your Vision Setting Summit presentation includes a proposal to implement 50 deregulatory actions. I am all for cutting red tape and letting our homegrown businesses get to work, but many of these are—many of these environmental protections actually support the Blue Economy. The Clean Water Act, the Oil Pollution Act, the Endangered Species Act, and others, protect the resources that support Wisconsin industry. So, Admiral, how will you ensure that you aren't rolling back important and commonsense environmental protections when you go about this process?

Admiral GALLAUDET. Senator Baldwin, thank you for your concern. I think that's absolutely valid and important. We are committed to meeting the statutory obligations of the Endangered Species Act and the Marine Mammal Protection Act and all the others that we are required to do. The deregulatory actions referred to in that brief are more so along the lines of fisheries management. In fact, one example will be—I think is in the FY18 omnibus, Fish—Critical Fish Habitat Amendment—pardon me—Amendment is the right term—which will—is a deregulatory fisheries management action which will save about \$70 million for New England fishermen this year. So, there's—that's an example of the actions we're talking about. It's not to meet the mandates of the environmental protection statutes.

Senator BALDWIN. Quick question about shipping. According to a 2011 study, maritime commerce in the Great Lakes Saint Lawrence Seaway supported 227,000 jobs and \$33.5 billion in annual business revenue. Specifically, Wisconsin ports support 8,777 direct jobs—direct and indirect jobs—and \$1.4 billion in business revenue, handling over 30 million tons of cargo valued at \$2.4 billion. Admiral Gallaudet, do your plans to promote efficient seaports capitalize on the ports and maritime commerce resources of Wisconsin?

Admiral GALLAUDET. That's a great question, Senator. I will have to find out for you if any Wisconsin ports is—are included. I know that we have 90 ports around the country, including Great Lake ports like Toledo, which we'll be installing sensor systems next month. So, we'll find out for you about Wisconsin. And I hope to give that answer to you by the time I visit, September 12.

[Information follows:]

Senator BALDWIN. Great. Thank you.

Admiral GALLAUDET. Part of the listening tour.

Senator BALDWIN. Wonderful. Thank you.

Senator SULLIVAN. Admiral, I'm going to ask a few more questions. You've been an outstanding witness here.

Senator Cantwell mentioned the issue in her community, in the Columbia River, on sea lions. One of the issues that I wanted to raise with you is a continuing concern—it's really a concern that's gone on for years with my—many of my coastal communities and constituents, about the negative consequences related to restrictive measures in place with regard to the western Stellar sea lion population that, as you know, was listed under the ESA, but has had

an enormously big recovery. And so, there are a number of Alaskans who have been working with your agency, conducting a five-year review of that stock's status, which I think everybody recognizes has dramatically increased. I know you don't have the status of that review off the top of your head today, but, at least, can you commit to me that you will complete the review in an expeditious matter incorporating the data from many of Alaskans involved in this, including a lot of our biologists and scientists, so we have a way to look at the possibility of resolving this issue in the future? And this is an issue that I think—it's not just Alaska, but I know senior officials in Washington and Oregon have also raised similar concerns about this stock assessment and what to do, going forward.

Admiral GALLAUDET. Yes, Chairman Sullivan, we will commit to an expeditious review of the Stellar sea lions.

Senator SULLIVAN. Western Stellar sea lions.

Admiral GALLAUDET. Western Stellar sea lions, sir.

Senator SULLIVAN. It's different from the eastern. It's important, that's important distinction, actually.

Let me end with two final questions with regard to the Blue Economy Initiative. Obviously, if we're talking about the economy, we, obviously, are talking about the private sector. What does NOAA plan to do, either through existing partnership programs or new ones, to help build those relationships between NOAA and the private sector to help have a much more robust and successful Blue Economy Initiative? And do you need any type of funding for that?

Admiral GALLAUDET. Thank you very much, Chairman Sullivan.

We think the most opportunity lies in what the National Ocean Policy highlights, and that's the current National Oceanographic Partnership Program, which is a terrific vehicle to bring together the private sector, academia, and the government, in terms—and to conduct ocean-related research, which will directly benefit the Blue Economy. And so, we think that's the one vehicle that we would like to see leveraged more in the future.

Senator SULLIVAN. So, that's collaboration with other research institutes, essentially?

Admiral GALLAUDET. Yes, and yes, including industry and academia, as well as our Federal partners.

Senator SULLIVAN. Great.

Admiral GALLAUDET. The Navy runs the program.

Senator SULLIVAN. And then, finally, how can this Committee work with NOAA on the potential Blue Economy Initiative and legislation to advance our mutual priorities and goals? I believe there is a strong potential for bipartisan legislation that supports many of the goals that NOAA is setting out in your initiative. And I think you saw that demonstrated by the number of Senators who participated today, and their questions.

Admiral GALLAUDET. Thank you, Chairman.

I believe that this Committee could do great things for us in advancing the work I described with respect to fisheries, aquaculture, and seafood competitiveness, as well as tourism and recreation, ocean—and ocean exploration and maritime commerce, all of which were discussed, I think, well and solidly in this hearing.

Senator SULLIVAN. Great. Well, we look forward to working with you on potential legislation as it relates to the Blue Economy, an area where, again, I think there's bipartisan support and enormous potential to benefit my State, Wisconsin, and our citizens and constituents throughout the country.

So, thank you again, Admiral. You did a fine job today, I thought. And your team, thank you.

And this hearing record will be open for the next two weeks. So, if there are additional questions from any other Senators, we would ask that you and your team expeditiously respond to those.

And again, we appreciate the hard work you're doing.

This hearing is now adjourned.

[Whereupon, at 11:20 a.m., the hearing was adjourned.]

A P P E N D I X

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. ROGER WICKER TO
RDML TIMOTHY GALLAUDET, PH.D.

Question 1. What do you see as the biggest barrier to growth of the marine aquaculture industry in the United States?

Answer. NOAA supports U.S. aquaculture to promote domestic seafood production and create jobs. Consistent with the Department of Commerce's 2018–2022 Strategic Plan, NOAA is working to reduce regulatory burdens and drive aquaculture research to ensure the continued growth of this industry.

One of the biggest impediments to expanding aquaculture in Federal waters is an uncertain regulatory environment. Senators Wicker and Rubio introduced S. 3138—the “Advancing the Quality and Understanding of American Aquaculture Act.” This bill would authorize a NOAA-issued aquaculture permit and better coordinate other Federal regulatory requirements.

To further reduce regulatory burdens, NOAA is working with other Federal agencies and coastal states to streamline Federal marine aquaculture permitting. In addition, NOAA invests in regulatory efficiency measures and public-private partnerships to jump-start production. Last year, NOAA led a six-agency Memorandum of Understanding to streamline regulatory processes for aquaculture operations in the Gulf of Mexico.

Question 2. How would NOAA ensure that marine aquaculture is conducted in an environmentally sustainable way, using existing authorities?

Answer. U.S. marine aquaculture operators must abide by a comprehensive suite of environmental regulations, which differ depending on the type of operation. Major environmental statutes include, but are not limited to, the Endangered Species Act, Marine Mammal Protection Act, Clean Water Act, and National Environmental Policy Act.

To help ensure the statutory requirements listed above are effectively implemented, NOAA and our partners conduct research to inform our coastal managers about how to predict and avoid potential negative impacts. One key way to do this is through proper siting. Others include developing science-based tools to predict and avoid impact on, among other things, water quality, benthic habitats, and fish and other wild populations. For example, NOAA collaborates with researchers at USDA and elsewhere to develop new feed ingredients (*e.g.*, soy, algae) that reduce the need for fish meal and fish oil in commercial fish diets. NOAA also conducts research to assess the potential interactions between farmed fish and wild populations and their habitats and has developed the Offshore Mariculture Escapes Genetics Assessment (OMEGA) model to identify and evaluate genetic risks and inform development of management strategies.

Question 3. How would NOAA ensure that marine aquaculture is compatible with other sectors of the blue economy?

Answer. NOAA is committed to ensuring that marine aquaculture development is compatible with other sectors of the blue economy. For instance, the U.S. Army Corps of Engineers (USACE) may require an alternatives analysis pursuant to the National Environmental Policy Act (NEPA), and the permit evaluation would include a Public Interest Review process. The Corps decision to issue a permit is based on an evaluation of the probable impacts, including cumulative impacts, of the proposed activity and its intended use on the public interest, which includes the evaluation of 21 different factors. Accordingly, NOAA analyzes spatial use patterns and solicits stakeholder input prior to and during the permitting process, to ensure that marine aquaculture development is compatible with other ocean uses, including but not limited to oil and gas development, and commercial and recreational fishing. The NEPA process similarly mandates alternatives analyses.

Question 4. What are other regions and industries that would benefit from increased marine aquaculture production in the United States?

Answer. Aquaculture could play an expanded role in food security and economic development in every region of the country. U.S. aquaculture production (freshwater and marine) is valued at \$1.4 billion per year and supports other industries including seafood processing, feed, equipment manufacturing, and food services. Expansion of the industry to Federal waters, generally from 3–200 nautical miles offshore, would unlock enormous economic growth potential. There are additional opportunities to expand production in state waters, as well as on land, in tank-based production systems.

By one estimate¹, doubling U.S. aquaculture production to about 1 million tons would create an additional 50,000 jobs. These jobs could provide stable, year-round employment opportunities in coastal and fishing communities where commercial fishing opportunities are often seasonally dependent. These economic benefits would not be limited to coastal areas. Agricultural regions where aquaculture feed ingredients, such as soy, are produced or where land-based fish hatcheries are located, could also benefit.

Question 5. How would NOAA law enforcement oversee marine aquaculture development in Federal waters?

Answer. NOAA's Office of Law Enforcement (OLE) would be responsible for promoting compliance with, and the enforcement of, any applicable laws and regulations within NOAA's jurisdiction governing aquaculture in Federal waters. However, current Federal laws and regulations do not specifically define OLE's authorities and responsibilities with respect to aquaculture.

Question 6. What are NOAA's research priorities for marine aquaculture?

Answer. To drive aquaculture research, NOAA works in collaboration with industry to support research that advances commercial-scale marine aquaculture production. Aquaculture research funding addresses issues identified by industry and the public such as feeds development, hatchery technologies, and siting tools to reduce conflicts with other coastal users.

Other research priorities that have been identified in the *NOAA Marine Aquaculture Strategic Plan* and the *Sea Grant 10-Year Aquaculture Vision* include ensuring seafood safety, minimizing environmental impacts, and conducting socioeconomic and job impact analysis to support the domestic aquaculture industry.

Question 7. How would marine aquaculture in Federal waters interact with a state's Coastal Zone Management plan?

Answer. The Coastal Zone Management Act (CZMA) "federal consistency" provision authorizes state review of projects located in Federal waters, including aquaculture projects, proposed by non-federal applicants that require Federal licenses or permits. The state coastal management program must meet the requirements of NOAA CZMA regulations. If NOAA regulations authorize a state to review an aquaculture project in Federal waters, then the applicant provides the state coastal management program with a CZMA consistency certification.

The state has six months to review an applicant's consistency certification. During the state CZMA review there is opportunity for public input into the state's CZMA decision and for the state and applicant to work out any issues. The state bases its CZMA Federal consistency decision on whether the project will be consistent with the "enforceable policies" of the state's coastal management program. State enforceable policies are state laws, regulations, and other standards that are legally binding under state law and that NOAA has approved as enforceable policies of a state's coastal management program. For an offshore aquaculture project, these enforceable policies would likely include policies related to: effects to commercial and recreational fishing access; fish and fish habitat; native fisheries impacts from escape of non-native species; water quality impacts; navigation related impacts. State concurrence with an applicant's consistency certification is presumed if the state does not respond within the CZMA six-month review period. Any required Department of the Army authorization would also require the activity to be consistent with state CZMA standards.

Question 8. What aspects of a marine aquaculture permit, as proposed in S. 3138, would give businesses and investors the confidence to invest in marine aquaculture in Federal waters?

Answer. S. 3138 includes several provisions that might serve as first steps towards providing investors with increased certainty in the offshore aquaculture in-

¹ Knapp, G. Economic potential for U.S. offshore aquaculture: An analytical approach, 15–50. In: *Offshore Aquaculture in the United States: Economic Considerations, Implications and Opportunities* (Rubino, M. C., Ed.). NOAA Technical Memorandum NMFS F/SPO-103. Silver Spring, MD: Department of Commerce, National Oceanic and Atmospheric Administration (2008).

dustry. These include removing aquaculture from the definition of “fishing” under the Magnuson-Stevens Act and authorizing the Secretary of Commerce to issue 25-year offshore aquaculture permits that are both renewable and transferable, providing security of tenure for private sector investment in the offshore aquaculture industry. In addition, S. 3138 designates a lead Federal agency (NOAA) to coordinate Federal review and permitting processes, establishes specific timelines for decisions on offshore aquaculture permit applications, and consolidates National Environmental Policy Act (NEPA) and public comment processes for all Federal agencies to the extent practicable.

Finally, S. 3138 requires the Secretary of Commerce to identify and complete programmatic environmental impact statements (a form of NEPA analysis) for areas determined to be highly favorable for aquaculture and compatible with other uses. Programmatic evaluations would consider the potential impacts that would result from issuing permits for specific gear types and/or culture methods within a broad geographic area. Projects located within these areas could receive more timely reviews because the programmatic environmental impact statement would cover many or potentially all of the potential concerns that would need to be addressed for the specific project proposal. Programmatic NEPA reviews may result in higher investor confidence by supporting clearer and more transparent decision-making, as well as provide a better-defined and more expeditious path toward decisions on proposed actions.

Question 9. As an emerging sector of the blue economy, how would unmanned systems be used by NOAA to fulfill and support core mission requirements?

Answer. Nearly all of the sectors that constitute the blue economy can be advanced through research and monitoring activities ongoing at NOAA, and many of these activities have the potential to benefit from the strategic application of unmanned systems. Maritime shipping and transport, commercial fishing, aquaculture, and offshore resource extraction and tourism all stand to benefit from additional data gathered via unmanned systems.

Unmanned systems have already contributed to NOAA’s mission in several ways. For example, they have been used for seafloor mapping, identification of rare earth metals and critical minerals, characterization of the U.S. exclusive economic zone, ocean condition assessments to facilitate improved weather forecasting, information for improving fishery stock assessments, and study of protected fish and mammal species.

NOAA is assessing core mission requirements and how and where unmanned systems might allow NOAA to collect needed data more cost-effectively, freeing resources for other high priority activities.

Question 10. How would NOAA collaborate with the Navy, the private sector, and academic institutions to further the evaluation and implementation of unmanned systems and improve the blue economy?

Answer. NOAA values our partnerships with other Federal agencies, industry and non-federal partners in the use of unmanned systems. These partnerships help advance NOAA’s mission requirements and drive down life-cycle costs for unmanned systems, ultimately reducing the cost per observation, and providing critical information supporting expansion of the blue economy.

NOAA partners with universities around the country to use existing unmanned systems to develop tools and adapt existing technologies to meet NOAA’s mission. With regards to the blue economy, NOAA has partnered with the University of Michigan in helping to predict harmful algal blooms in the Great Lakes and with Mississippi State University in coral reef monitoring.

NOAA works closely with the U.S. Navy on unmanned maritime system applications relevant to both agencies’ missions. For example, NOAA has teamed up with the Naval Oceanographic Office to deploy gliders to get temperature and salinity data from as many as 40 Navy assets deployed throughout the Gulf of Mexico and Caribbean. Data from the gliders are being used by NOAA to evaluate model performance and are considered for use in the experimental data assimilation process being developed for our hurricane models. There is a NOAA-Navy unmanned systems working group specifically focused on buoyancy glider collaboration.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO
RADM TIMOTHY GALLAUDET, PH.D.

The day after President Trump issued his new Ocean Policy, you presented a proposal in a closed-door “vision-setting summit” to senior executives at the Department of Commerce. In that presentation, the slide deck shows dates by which NOAA intends to carry out certain priorities, including implementing the Weather Act. I

authored a provision that we included in the Weather Act to ensure reliable backup for our Hurricane Hunter aircraft. And last year, in the midst of one of the most devastating hurricane seasons on record, NOAA's Gulfstream jet was grounded for emergency maintenance several times. Yet your slide deck does not show a timeline for acquiring the required backup.

Question 1. Can you please provide us a status update on your progress in complying with the requirement to have backup?

Answer. NOAA is following the Federal acquisition process to acquire a new high-altitude aircraft pursuant to the FY 2018 appropriation that NOAA received to acquire this capability. NOAA estimates the new high-altitude jet aircraft would be in-service for the 2022 hurricane season. Until such time that NOAA procures its own backup aircraft, NOAA plans to use its existing interagency agreement for aircraft services with the National Science Foundation (NSF), if needed and if the NSF high-altitude jet is available.

You may have seen recent news reports about the harmful algae blooms (HABs) wrecking our state—and the economic impact that these events have. Right now, we've got both a blue-green algae outbreak in the freshwater of Lake Okeechobee that's spreading through the Caloosahatchee and St. Lucie Rivers to the coasts, and we've also got a record-breaking red tide event that's killed tarpon, goliath grouper, manatees, and maybe even a whale shark. That's why in 2014, I teamed up with Senator Portman of Ohio to reauthorize the joint program at EPA and NOAA to research and control Harmful Algal Blooms and Hypoxia. And that's why he and I have worked together yet again on a bipartisan reauthorization bill that passed the Senate unanimously last September. The House has failed to act. Representatives Hastings and Buchanan sent a letter last week urging House leadership to pass the reauthorization.

Question 2. If the House doesn't act, and the program is not reauthorized by the end of Fiscal Year 2018, what will happen to NOAA's activities to research and help mitigate these kinds of blooms?

Answer. The Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2017 was included in Public Law No: 115-423, which reauthorizes NOAA's harmful algal bloom and hypoxia activities and research. NOAA will implement the law as directed.

In this administration's trade war, Florida's fishing and boating industries could be among the hardest hit. Both industries are critical to jobs and economic growth in my state. As I mentioned earlier, I recently visited one of Central Florida's biggest boating companies, Correct Craft. They told me that the Trump administration's tariffs—which are increasing the cost of raw materials and shrinking markets for exports of boats and marine products—could cost them hundreds of jobs.

Question 3. How will NOAA be able to support and grow a sustainable domestic blue economy even as the Administration has other policies outside of NOAA that may undercut your initiatives?

Answer. First, the actions taken by the President under Section 232 to address a threatened impairment of national security are fully justified as a matter of U.S. law and international trade rules. Where other countries respond to these actions with unjustified and illegitimate retaliatory measures, the Administration will take all necessary actions to protect U.S. interests.

Second NOAA remains firmly committed to supporting a sustainable blue economy. NOAA's Blue Economy Initiative focuses on: (1) continuing to maximize commercial and recreational fishing opportunities; (2) pursuing expanded involvement in international seafood marketing and trade; and (3) promoting and expanding marine aquaculture. Specific initiatives include expanding commercial port use, undertaking better mapping of the U.S. Exclusive Economic Zone (EEZ), streamlining regulations and administrative practices (including in the area of aquaculture) to promote economic growth, and working through regional fisheries management organizations and using domestic legal tools to combat IUU fishing around the world.

Further information on the Blue Economy initiative is available at:

<https://www.fisheries.noaa.gov/leadership-message/blue-economy-initiative-means-seafood-future>

<https://www.commerce.senate.gov/public/cache/files/9efa9eeb-5b5f-439c-889d-0691cced64da/470C83787C26A3B381E35594BFF0DEFF.7.24.18-gallaudet-testimony.pdf>

<https://coast.noaa.gov/states/stories/blue-economy-initiative.html>

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. TOM UDALL TO
 RADM TIM GALLAUDET

NOAA's core missions are to understand and predict changes in the Earth's climate, weather, oceans and coasts; to share that knowledge and information with the public; and to conserve and manage our coastal and marine resources. Thus, the mission and portfolio of NOAA is incredibly broad and complex. In June, you gave a presentation at an internal meeting within the Department of Commerce where you altered the mission and vision statements for NOAA by removing climate, stewardship, and management from NOAA's overall mandate.

Question 1a. Will you commit to ensure that NOAA's overall mandate and established marine and coastal priorities will not be disrupted?

Answer. Yes. After the Department's meeting, Secretary of Commerce Wilbur Ross reiterated NOAA's mandate has not changed and NOAA is continuing to implement that mandate.

Question 1b. Will you commit to support NOAA's current mission "to understand and predict changes in climate, weather, oceans and coasts; to share that knowledge and information with others; and to conserve and manage coastal and marine ecosystems and resources"?

Answer. Yes, see answer to 1a.

Question 1c. Will you commit to continue to adhere to congressional mandates as it relates to NOAA's mission and vision?

Answer. Yes, see answer to 1a.

Question 2. Do you think that NOAA should continue to understand and address climate? Why or why not?

Answer. Yes. Understanding climate is important not only to inform decisions related to long-term planning and management of our natural resources and national security, but it also helps improve seasonal to sub-seasonal forecasts.

Question 3. What role do you think NOAA plays in the future to (a) understand and predict changes in the Earth's climate, weather, oceans and coasts, and (b) conserve and manage our coastal and marine resources?

Answer. NOAA will continue to be the world leader in our mission areas: to understand and predict changes in climate, weather, oceans and coasts; to share that knowledge and information with others; and to conserve and manage coastal and marine ecosystems and resources.

Question 4. What is your view on protected areas, such as the National Marine Sanctuaries and Marine National Monuments, as a tool for ocean conservation? Do you agree that our Nation's federally-designated ocean protected areas should remain protected?

Answer. Where locally supported, National Marine Sanctuaries are an effective tool for conservation and the sustainable management of natural resources and maritime heritage resources. There are currently 13 sanctuaries around the country that are managed by NOAA, each one governed by a management plan tailored to the needs of the site's unique resources and priorities of their respective communities. The majority of the National Marine Sanctuary System is composed of "working waters" that potentially support billions of dollars of commercial and recreational activity. Across all National Marine Sanctuaries, diverse activities—commercial fishing, research, recreational fishing and other recreation activities—enhance local coastal-and ocean-dependent economies. The result is that sanctuaries engender strong local support and significantly leverage Federal investments, averaging 123,000 volunteer hours each year, which is equivalent to \$3 million in salaries. As local priorities evolve, the management plans may be modified to reflect new priorities for conservation and resource management.