THE IMPACTS OF CLIMATE CHANGE ON THE CHESAPEAKE BAY

JOINT OVERSIGHT FIELD HEARING

BEFORE THE

SUBCOMMITTEE ON INSULAR AFFAIRS, OCEANS AND WILDLIFE

JOINT WITH THE

SUBCOMMITTEE ON NATIONAL PARKS, FORESTS AND PUBLIC LANDS

OF THE

COMMITTEE ON NATURAL RESOURCES
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OVERSIGHT FIELD HEARING ON "THE IMPACTS OF CLIMATE CHANGE ON THE CHESAPEAKE BAY"

Tuesday, June 23, 2009
U.S. House of Representatives
Subcommittee on Insular Affairs, Oceans and Wildlife,
joint with the
Subcommittee on National Parks, Forests & Public Lands
Committee on Natural Resources
Edgewater, Maryland

The Subcommittee met, pursuant to call, at 10:00 a.m., at the Smithsonian Environmental Research Center, 647 Contees Wharf Road, Edgewater, Maryland, Hon. Raúl M. Grijalva [Chairman of the Subcommittee on National Parks, Forests and Public Lands] and Hon. Madeleine Z. Bordallo [Chairwoman of the Subcommittee on Insular Affairs, Oceans and Wildlife] co-presiding.

Present from the Subcommittee on National Parks, Forests and Public Lands: Representatives Grijalva and Sarbanes.

Present from the Subcommittee on Insular Affairs, Oceans and Wildlife: Representatives Bordallo and Kratovil.

STATEMENT OF THE HONORABLE RAÚL M. GRIJALVA, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF ARIZONA

Mr. GRIJALVA. Thank you very much. Let me call the joint hearing of the Subcommittee on National Parks, Forests and Public Lands and the Subcommittee on Insular Affairs, Oceans, and Wildlife to order. Thank you very much for being here. This oversight hearing is on the impacts of climate change on the Chesapeake Bay.

I have an opening statement that I will submit for the record but suffice it to say that the issue of climate change has dominated some of the work of the Subcommittee that I have the privilege of chairing, the Subcommittee on National Parks, Forests and Public Lands. This will be our third hearing. I know that Chairwoman Bordallo has conducted similar hearings.

I feel there is an important impact on the public lands, that there is a role for the public lands in the adaptation of climate change and in lessening its very, very negative effects. It is a reality that is shaping all of us. One of the points that lags behind is the shaping of public policy to respond to this. This is what we are looking at. Not only the issue of public policy but the very direct effects upon the people and the areas where climate change is having some of its more devastating effects.

We visited an area that is primarily desert and saw what it is doing to those public lands and those communities. We are here on the Eastern Shore to talk about the Chesapeake Bay, the impacts of climate change, and the necessity and the urgency with which we need to deal with this reality.

I want to welcome all of you. I want to thank the Smithsonian for their hospitality and for hosting this meeting. With that, let me turn to my esteemed colleague, Chairwoman Bordallo, from the Subcommittee on Insular Affairs for her opening comments. Madam Chair.

[The prepared statement of Chairman Grijalva follows:]

Statement of The Honorable Raúl M. Grijalva, Chairman, Subcommittee on National Parks, Forests and Public Lands

I want to thank you all for coming today and thank you for warmly welcoming all of us this morning to this beautiful spot along side this most celebrated estuary.

The Chesapeake Bay has been a home to people for thousands of years. Drawn by the verdant landscape and bountiful waters, many tribes settled along its shores. The rich land and waters also drew English colonists, setting the stage for this region to become the birthplace of our nation.

But today we reflect upon that past knowing that the future of the Bay is beset by challenges: from years of pollution brought about by agricultural runoff and unchecked development and now by climate change, which is further threatening this fragile ecosystem.

We are here to listen. To hear from you, the experts—the people who love, know, and depend upon this storied Bay—about what is happening here. And more importantly, what has to be done.

And we look not only to the changes we are seeing to the natural environment, but to the cultural landscape as well.

People of the Chesapeake already know that their land, water and island communities are threatened by storms and rising waters brought about by the changing climate. But sadly, this Bay bears witness to threats to the fabric of our history as well—the monuments, treasures, records and places that tell the stories of who we are. And the stories yet untold too.

Keys to our history may disappear before they can be revealed by researchers who are desperately trying to save them. With storm surges, and rising sea levels our history could literally be washed away.

Many of the Chesapeake's rich cultural and historical assets are managed by the National Park Service. For the NPS sites along the Bay, and in the watershed—such as Jamestown, Fort McHenry, the birthplace of George Washington, and our own National Mall—climate change challenges the very foundation of their existence.

As the National Park Service enters into its second century of safeguarding and interpreting our natural and cultural treasures, in places along the Chesapeake Bay—and in sites around the country—the question, in the face of climate change, is: can the National Park Service uphold its mandate, to preserve and protect our nation's natural and cultural treasures, UNIMPAIRED, for future generations?

I believe the impact of climate change is the biggest challenge that the Park Service has ever faced—both from a preservation standpoint, but also a financial one. I look forward to hearing from the Administration about what plans they have to tackle this complex challenge.

And with the literal sinking of the land, comes the sinking of the local economies and communities as well. During the hearing, you will see several gripping images of the changing Chesapeake Bay generously provided by Mr. Dave Harp. His photo of a lone house—abandoned, and surrounded by water—standing stoically on Holland Island is a haunting illustration of just how fragile life is on the Bay.

We will hear today from scientists and experts on the Bay who will show us that the Bay is already being impacted by climate change. And we will hear from waterman Tommy Leggett, about the reality of life on the Chesapeake, and the drastic changes that the people here struggle with daily to maintain their livelihoods. While Historian Stuart Parnes will attest to the fact that with the decline of these communities comes the loss of a unique American culture. And Mayor Bojokles will talk about the financial burdens of climate change on small communities in the region, reminding us of the economic costs of inaction.

So, as we tackle climate change legislation in Washington DC, we need only look right here, into our own backyard, to see the urgent need for action. And to recognize the need to protect not only our precious natural icons and historic places, but our culture and our communities as well. This is not JUST an environmental issue.

I look forward to hearing from ALL of our witnesses today. And I thank all of them for taking the time to travel here today to be with us. I want to especially thank the Smithsonian Environmental Research Center staff for hosting us today.

I would now like to turn to my colleague Ms. Bordallo, Chairwoman of the Subcommittee on Insular Affairs, Oceans and Wildlife, for any opening statement she may have.

STATEMENT OF THE HONORABLE MADELEINE Z. BORDALLO, A DELEGATE IN CONGRESS FROM GUAM

Ms. BORDALLO. Thank you very much, Chairman Grijalva. It is indeed a pleasure to join you this morning in co-chairing this important joint Subcommittee hearing concerning climate change and the impacts on the Chesapeake Bay. I would like to also welcome my colleagues who are here.

I would also like to acknowledge, as I said earlier, Congressman John Sarbanes and Congressman Frank Kratovil and thank both of them for their leadership and their contributions to the work of the Natural Resources Committee.

I would also like to thank the Director of the Smithsonian Environmental Research Center, Dr. Anson Hines, and his outstanding staff for their gracious hospitality in hosting this hearing this morning. We are honored to be here and sincerely appreciate all of your efforts.

Today's hearing will mark the fourth time that I have convened a meeting of the Subcommittee on Insular Affairs, Oceans and Wildlife to discuss some aspect of climate change. Whether the topic is increased ocean acidification, disruption of bird migrations or the sharp decline in pollinators, evidence to date suggests that climate change, or I would say climate disruption, represents a challenge to our civilization and life on this planet like nothing before it.

In reviewing the testimony from the witnesses, it is clear that the Chesapeake Bay and the communities that have defined their existence by the historic abundance of the Bay's bountiful resources stand at a tenuous crossroads with little but uncertainty in the future.

I represent the island territory of Guam in the western Pacific Ocean about as far away from the Chesapeake Bay as you can possibly be, but I want to say to our witnesses that I understand the stark reality that emerges from your testimonies. You see, just as Smith and Tangier Islands and their communities are literally washing away into a rising Chesapeake Bay, so too are entire low-lying island nations in the Pacific Basin.

When high tides begin to flood your home, whether you are in Kiribati or Tangier Island, climate change quickly becomes a reality to be dealt with and not just a theory. With that thought in mind, I look forward to hearing from this morning's witnesses to better learn how we might act to both preserve our natural resources of the Chesapeake Bay, and its communities and culture, while we have time to limit the consequences. I thank you, Mr. Chairman.

Mr. GRIJALVA. Thank you, Madam Chair.

Let me now turn to my good friend and colleague, Mr. Sarbanes. Any comments?

STATEMENT OF THE HONORABLE JOHN P. SARBANES, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF MARYLAND

Mr. SARBANES. Thank you, Mr. Chairman. Thank you Chairwoman Bordallo for calling this hearing. This is a critical discussion that we're going to have today. I'm looking forward to this wonderful panel that we have assembled, the two panels that are going to address the topic today.

I want to welcome you again to Maryland. We did a field hearing in the last session if you remember, Patuxent National Wildlife Refuge, No Child Left Inside, which is, of course, very related to this topic in terms of raising awareness about the Chesapeake Bay and the environment at large. I do want to salute again SERC for hosting us here. This is a terrific facility and resource, not just for this region but for the country.

The reason this kind of hearing we are having today is so critical is because one of the challenges we have in responding to climate change as a matter of public policy is that it can be a very abstract concept. Humans aren't particularly good sometimes in absorbing those kinds of abstractions and taking concrete steps to address them.

The testimony today is going to illustrate very powerfully that there is nothing abstract or theoretical about climate change and climate disruption. There are very, very measurable effects that we are seeing every single day, particularly for those of us who care so deeply about the Chesapeake Bay—regarded as one of this country's treasures—and we consider ourselves its prime stewards.

The effects on the Chesapeake Bay of rising sea levels and other effects of climate change are things that are very measurable and apparent. The testimony today is going to, I think, really drive that home. I want to thank you again, Chairwoman Bordallo and Chairman Grijalva, for convening this very, very important hearing and I look forward to the testimony from the panels.

Mr. GRIJALVA. Thank you. We now ask our colleague for any comments he may have.

Mr. Kratovil.

STATEMENT OF THE HONORABLE FRANK KRATOVIL, JR., A REPRESENTATIVE IN CONGRESS FROM THE STATE OF MARYLAND

Mr. KRATOVIL. Thank you very much. Mr. Chairman, Madam Chairman, thank you for holding this very important field hearing on the impacts of climate change on the Chesapeake Bay. I'm obviously also very pleased to be with my colleague, John Sarbanes, who many of you know has been a leader on environmental issues throughout the State of Maryland for quite some time now.

I also want to thank the expert witnesses, many that I know quite well. I particularly want to recognize Senator Bernie Fowler, who is a close friend and has been a leader on environmental issues for many, many years.

As you all know, the Chesapeake Bay is a national treasure and home to rich, natural habitat and wildlife. As North America's largest estuary, the Chesapeake Bay provides recreational and economic opportunities that have created a way of life for generations of Marylanders.

The wetlands of Blackwater National Wildlife Refuge and the creeks and rivers that feed the Chesapeake provide breathtaking scenery and valued biodiversity. We have broken environmental and economic responsibility to protect this irreplaceable resource to ensure future generations will have the opportunity to enjoy all it has to offer.

As I expect the testimony will make clear, the low-lying communities that dot the Chesapeake Bay are especially at risk due to climate change. In fact, 13 islands in the Chesapeake Bay have disappeared since Europeans first mapped the area. Now more than ever much of the Eastern Shore is vulnerable due to the resulting temperature increase, sea level rise, and storm surge events that could lead to even more erosion, flooding, and the eventual loss of vital lands.

Climate change could also have lasting impacts on water quality and cause additional harm to an already delicate habitat for blue crabs, oysters, and other species. Climate change also poses a significant economic impact to the Chesapeake Bay and the State of Maryland. According to a 2006 report by the State, tourist spending was at $11.72 billion statewide supporting 116,000 jobs and generating $920 million in state and local tax revenue.

Much of this data can be directly attributed to the beaches and forest destinations on the shore that could be devastated by the effects of climate change. Furthermore, the commercial fishing industry, which generated $207 million to Maryland in 2007 could be irreparably harmed by these changes to the natural habitat.

We must undertake a smart scientific-based approach that carefully balances the needs of the agricultural community, which represents, obviously, a key piece of the heritage of the Eastern Shore and the very real threats of climate change to develop an effective strategy.

Many Maryland farmers have taken great strides to operate their farms in a more sustainable manner. The agricultural community's critical role in conservation must be recognized and it must have the opportunity to participate and benefit from new climate change proposals moving forward.

The Chesapeake Bay watershed is home to well over 16 million people and a destination for thousands of others who enjoy vacationing, hunting, fishing, and wildlife watching in its incomparably beautiful surroundings. Because of this it is also an economic engine that provides employment opportunities for thousands of Marylanders.

Unfortunately, because of the degradation of water quality over time, many of those opportunities have been lost. We cannot afford to risk further damage to this fragile habitat and to those who depend on it. This hearing is a vital step in helping us chart a course for protecting the Chesapeake Bay from the damages of climate change. Thank you. I'm happy to be with you today.

Mr. GRIJALVA. Thank you, sir.

And let me just remind the witnesses that your written statements and any other extraneous information that you would like to submit will all be made part of the record. I would hope that you would limit your comments to five minutes so that those of us on the Committee would have the opportunity to engage in some questions and answers.

A point of great concern, I think, to all of us and to me personally is the issue of the potential loss of cultural and historic resources in the region and other parts that are being affected by climate change. I hope that you are able to comment on those as well.

With that, let me now turn to Mr. Marvin Moriarty, Regional Director, U.S. Fish and Wildlife Service. Let me indicate that we invited the Department of the Interior as well to give a presentation. They are not here and I would hope to remind Interior that climate change is not agency specific, that it involves all of us. Hopefully their engagement will intensify as we go forward, not only with legislation but with additional hearings and reports that will emanate from both Subcommittees. Thank you.

Sir.

[The prepared statement of Mr. Kratovil follows:]

Statement of The Honorable Frank Kratovil, Jr., a Representative in Congress from the State of Maryland

Thank you Madame Chair Bordallo and Chairman Grijalva for holding this important field hearing on the impacts of climate change on the Chesapeake Bay. I am also pleased to be here today with my colleague from Maryland, Mr. Sarbanes.

I would also like to thank today's expert witnesses, some of who are my constituents. I look forward to your testimony.

The Chesapeake Bay is a national treasure and home to a rich natural wildlife and habitat. As North America's largest estuary, the Chesapeake Bay provides recreational and economic opportunities that have created a way of life for generations of Marylanders. The wetlands of Blackwater National Wildlife Refuge and the creeks and rivers that feed the Chesapeake provide breathtaking scenery and valued biodiversity. We have both an environmental and economic responsibility to protect this irreplaceable resource to ensure future generations will have the opportunity to enjoy all it has to offer.

As I expect that your testimony will make clear, the low lying communities that dot the Chesapeake Bay are especially at risk due to climate change. In fact, thirteen islands in the Chesapeake Bay have disappeared since Europeans first mapped the area. Now, more than ever, much of the Eastern Shore is vulnerable due to the resulting temperature increase, sea-level rise, and storm surge events that could lead to even more erosion, flooding and the eventual loss of vital lands. Climate change could also have lasting impacts on water quality and cause additional harm to an already delicate habitat for blue crabs, oysters, and other species.

Climate change also poses a significant economic impact to the Chesapeake Bay and the State of Maryland. According to a 2006 report by the State, tourist spending was at $11.72 billion statewide, supporting 116,000 jobs and generating $920 million in state and local tax revenue. Much of this data can be directly attributed to the beaches and tourist destinations on the Shore that could be devastated by the affects of climate change. Furthermore, the commercial fishing industry, which generated $207 million to Maryland in 2007, could be irreparably harmed by these changes to the natural habitat.

We must undertake a smart, scientific based approach that carefully balances the needs of agricultural community, who represent a key piece of the heritage of the Eastern Shore, and the very real threats of climate change to develop an effective strategy. Many Maryland farmers have taken great strides to operate their farms in a more sustainable manner. The agriculture community's critical role in conservation must be recognized and it must have the opportunity to participate and benefit from new climate change proposals moving forward. The Chesapeake Bay watershed is home to well over 16 million people and destination for thousands of others who enjoy vacationing, hunting, fishing, and wildlife watching in its incomparably beautiful surroundings. Because of this, it is also an economic engine that provides em-

ployment opportunities for thousands of Marylanders. Unfortunately, because of degradation of water quality over time, many of those opportunities have been lost. We cannot afford to risk further damage to this fragile habitat and to those who depend on it. This hearing is a vital step in helping us chart a course for protecting the Chesapeake Bay from the damages of climate change.

Thank you.

STATEMENT OF MARVIN MORIARTY, REGIONAL DIRECTOR, U.S. FISH AND WILDLIFE SERVICE

Mr. MORIARTY. Thank you, Mr. Chairman. Chairman Grijalva, Chairwoman Bordallo, and members of the Subcommittees, I am Marvin Moriarty, Regional Director for the Northeast Region and acting Deputy Director for the Fish and Wildlife Service. I thank you for the opportunity to testify on behalf of the Department about the impacts of climate change on the Chesapeake Bay.

Climate change is the defining conservation challenge of our time and it drives many of the Department's priorities. Because of its cultural and natural resource significance the Department manages 14 National Wildlife Refuge units, numerous National Park Service units, and maintains facilities including 12 geological survey science centers and 13 other Fish and Wildlife Service offices in the Chesapeake Bay watershed.

According to a recently released Chesapeake Bay program scientific and technical committee report the Bay is now experiencing numerous significant challenges resulting from climate change and is likely to experience significant changes throughout the 21st century including increased carbon dioxide concentrations in its waters, relative sea level rising, increasing water temperatures, and changes in precipitation patterns.

The changes will result in increased erosion and runoff of sediments and nutrients further damaging submerged aquatic vegetation, benthic communities and wetlands. These changes are already being documented at Department facilities. For instance, over the last century Bay water levels rose by more than a foot contributing to the loss of thousands of acres of shoreline marshes including about 8,000 acres of wetlands at the Fish and Wildlife Service's Blackwater National Wildlife Refuge which was also accelerated by the invasion of nutria.

Rising water levels and associated storm surges in the Chesapeake Bay watershed pose significant risk to historic structures and cultural resources managed by the National Park Service such as the Colonial National Historical Park and George Washington's birthplace monument.

To address threats to the Chesapeake Bay resources from climate change the Department through the U.S. Geological Survey models, simulates, and monitors sea level rise to predict its impacts on Department lands and trust resources. Additionally, the survey through its climate effects network is developing the capability to provide climate science at scales such as the Chesapeake Bay watershed.

The Department through the National Park Service is undertaking vulnerability studies to assess the impacts of sea level rise on Park Service facilities. It is also conducting scenario planning

in pilot parks across the country to design appropriate adaptation projects to build resilience into park ecosystems.

The Park Service has also begun strategic communication effort to make park staff and the public aware of the possible impacts to park resources by climate change.

The Department through the Fish and Wildlife Service is working with others to plan, design, implement and monitor conservation actions at landscape scales to address species and habitat conservation priorities. The Service is also applying a new tool called the Sea Level Affecting Marshes Model, otherwise known as SLAMM, to help plan protection of coastal refuges and to communicate with the public about the impacts of sea level rise.

SLAMM is currently being used to guide long-range habitat management planning in the Chesapeake Marshlands National Wildlife Refuge Complex. As you know, President Obama recently signed an executive order on Chesapeake Bay restoration and protection which ushers in a new era of shared Federal leadership.

Specifically, we will work closely with the Environmental Protection Agency and the Department of Commerce as well as with the six watershed states to organize and conduct research and scientific assessments that support development of a strategy to adapt to climate change impacts. We will also identify and prioritize critical living resources in the Bay and conduct research and habitat protection activities to protect these resources.

Changes in ecosystems due to human impacts and climate change must be better understood, monitored, and forecast so that all the nation's resources can be effectively protected. We look forward to working with you to better understand and mitigate these impacts in the Chesapeake Bay watershed. I thank you for the opportunity to testify before you today and would be happy to answer any questions that you or the Committee members may have.

[The prepared statement of Mr. Moriarty follows:]

Statement of Marvin Moriarty, Regional Director, Northeast Region, U.S. Fish and Wildlife Service, U.S. Department of the Interior

Chairman Grijalva, Chairwoman Bordallo, and Members of the Subcommittees, I am Marvin Moriarty, Regional Director for the U.S. Fish and Wildlife Service's Northeast Region. I am currently acting as the bureau's Deputy Director. Thank you for the opportunity to testify on behalf of the Department of the Interior about the impacts of climate change on the Chesapeake Bay.

After a brief introduction, my statement will focus on the impacts of climate change on the Chesapeake Bay watershed that are being observed by the Department's bureaus working on Chesapeake Bay restoration, and what we are doing to anticipate and respond to these impacts. I also offer a brief discussion of Executive Order 13508, issued by President Obama on May 12, 2009, that calls for leadership and action by federal agencies to protect and restore the Chesapeake Bay.

I am joined here today by representatives from the National Park Service and the U.S. Geological Survey who are here to answer any questions you might have with respect to their activities here in the Chesapeake Bay.

Introduction

The Chesapeake Bay is the largest estuary in the United States and, due to the Bay's geography, water characteristics and hydrology, is one of the most biologically productive estuaries in the world. The 64,000 square mile watershed that supports the Chesapeake Bay is home to a myriad of native species whose abundance, in the early 17th Century, awed Captain John Smith and fellow explorers and settlers through the 18th and early 19th Century. The Bay is a national treasure enjoyed by millions of visitors each year.

The U.S. Fish and Wildlife Service (Service) and the National Park Service (NPS) within the Department manage nationally significant federal lands, parks, wildlife refuges, monuments and museums in the Chesapeake Bay and its watershed. The U.S. Geological Survey (USGS) provides scientific information to the Department, other agencies, and the public to describe, monitor and understand the Earth's response to climate change over time. The USGS supports the mission of the Service and NPS by delivering accurate, impartial, and timely scientific information and geospatial data and assisting in biological, water and other natural resource management

The scientific community studying the impacts of climate change on natural systems, like the Chesapeake Bay, has increasingly verified impacts on these treasured landscapes, including alteration of precipitation patterns that are affecting water supplies and impacts to wildlife and habitat through temperature changes.

The Chesapeake Bay, along with its immense watershed, thousands of miles of tributaries, and multitude of living and nonliving resources, is acutely vulnerable to the impacts of climate change. A recent report (Pyke and others, 2008) by the Chesapeake Bay Program Scientific and Technical Advisory Committee stated that significant warming and sea-level rise trends during the 20th century have been detected in the Chesapeake Bay. The report suggests the Bay region is likely to experience significant changes throughout the 21st century, including increased carbon dioxide concentrations in its waters; relative sea-level rising; increasing water temperatures; and changes in precipitation patterns.

The Chesapeake Bay ecosystem has already been severely degraded due to human population increases, resulting in poor water quality, loss of habitat, and declines in populations of biological communities (Phillips, et al., 2007). The additional impacts of climate change could have additional, profound derivative effects on water quantity, water quality, and the sustainability of numerous aquatic freshwater, and marine and terrestrial living resources, as well as on the quality of life and economic well-being of visitors to and residents of this iconic watershed. For example, changes in precipitation patterns and intensity will induce changes in streamflow and water temperature. This will drive changes in nutrient and sediment loads to the Bay. All of these changes will impact aquatic habitats in the Bay and its watershed.

Threats to Fish and Wildlife

The Chesapeake Bay is a flooded river delta, fed by the freshwater of the Susquehanna River to the north and major rivers on the Eastern Shore and Western Shore of the Bay, which is mixed with ocean water drawn from the Atlantic. The waters range from fresh to brackish to ocean water, increasing opportunity for a diversity of aquatic species. A shallow basin, the Bay retains warmth from the sun, which has historically maximized its ability to support plants, fish, and shellfish. It supports extensive salt marshes, as well as emergent freshwater wetlands and over 16 species of submerged aquatic grasses, which provide food for waterfowl, shelter for young fish and shellfish, dissolved oxygen, and water clarity. Without these grasses, the Bay's ecosystem would be extinguished. It is believed that the Bay once supported over 600,000 acres of these grasses, but in 2006, only 23,941 acres were accounted for in the annual Bay survey of submerged aquatic vegetation. (Virginia Institute of Marine Science).

About 350 fish species live in the fresh and brackish waters in the watershed, including commercially important oysters, blue crabs, and clams (Jung and Houde, Science Direct 2002). The Bay, along with Delaware Bay, also supports the largest concentrations of migrating shorebirds in the western hemisphere, as well as one of the most important resting and wintering areas for other migratory birds. Millions of waterfowl come to the Bay each year, along with song birds and other species which feed on the rich abundance of aquatic, plant, and other food sources in the watershed. The plants and animals in the Chesapeake Bay watershed have evolved to depend on one another. The complex interaction between the characteristics of the water as it cycles through the Bay and the Bay's native species are delicate and key considerations to effective Bay restoration efforts.

Climate change will bring added stress to this system, which is already experiencing significant threats from human activities. For example, an influx of nitrogen and phosphorus coming from agriculture and other land uses is a significant threat to this delicate balance. The Bay's food web has changed from an ecosystem dominated by zooplankton to one that is increasingly populated by phytoplankton, because of these excess nutrients. Increased presence of phytoplankton increases the prevalence of algal blooms. Algae covers the leaves of submerged aquatic grasses, cutting out the sunlight they need to grow.

The Smithsonian Environmental Research Center has identified over 200 non-native, invasive species in the watershed. In 2001, 46 of these were identified as "nuisance" species and six (the mute swan, nutria, phragmites, purple loosestrife, water chestnut, and zebra mussel) were identified by the EPA Chesapeake Bay Program as posing the greatest threat to the Bay. The increase in disease affecting native aquatic species, such as oysters, clams, and blue crabs, are due in part to decreasing water quality and the introduction of exotic species, and is adding to what may ultimately be an irreversible change in the Chesapeake Bay's biological community.

These impacts alone have driven the population of some species into steep decline, prompting petitions for their listing under the Endangered Species Act. These include the Virginia oyster, which is said by some fisheries biologists to be "commercially extinct" at about one percent of its historic density. Petitions have also been filed with the Fish and Wildlife Service for the American eel, and with the Service and NOAA fisheries for the Atlantic sturgeon.

Climate change threatens to increase the significance of existing challenges to restoration of the Chesapeake Bay and its fish and wildlife populations. The warming of the Chesapeake Bay—about 2 degrees since the 1960s—and its tributaries is contributing to the decline of eel grass, an important source of food for waterfowl and shelter for fish and shellfish. Warmer waters also support fish and shellfish diseases, such as Dermo and other diseases and parasites of shellfish, affecting migratory waterfowl which rely on these sources of food. In the last century, Bay water levels have risen by about a foot, eroding or destroying wetlands and many of the Bay's islands. The erosion of these islands and shorelines has removed important nesting habitat for colonial nesting waterbirds, like black skimmers, least terns, and royal terns in the Bay.

The open, loblolly pine forests found along the marshes of the lower Eastern Shore of the Delmarva Peninsula are important habitat for the endangered Delmarva fox squirrel, and this and other forest communities unique to this part of the East Coast are threatened by sea-level rise. If plant hardiness zones, established by the U.S. Department of Agriculture, are moving north, some bird species may also move north, away from the Chesapeake Bay. The Baltimore oriole, for instance, is observed nesting further north and may in time leave Maryland altogether. At the rate of current warming, the red spruce forests of the Shenandoah National Park could be replaced by southern pines and oaks in the next 30 to 80 years, greatly affecting the species living there (EPA, Climate Change and Virginia, 1998).

Impacts on National Wildlife Refuges

Climate change also threatens to increase challenges faced by National Wildlife Refuges in the Chesapeake Bay watershed. Among the many threats to fish and wildlife, the most profound in coastal habitats is sea level rise. At the Blackwater National Wildlife Refuge, which is part of the Chesapeake Marshlands National Wildlife Refuge Complex, thousands of acres of shoreline marshes have eroded away, subsided or been overcome by sea level rise, including about 8,000 acres of wetlands at the Blackwater National Wildlife Refuge (Chesapeake Marshlands NWR CCP, 2006). Invasive species, such as nutria, have also severely damaged these wetlands. Sea level rise related to climate change may inundate these wetlands; a recent USGS study that modeled sea level rise at Blackwater forecasts that most of the refuge will be in open water in approximately 50 years. These marshes are used by millions of waterfowl, shorebirds, bald eagles, and other bird species, and refuge managers are working to restore them where practicable and feasible while securing habitats further upland to plan for future marsh habitat needs.

The other refuges in the Chesapeake Marshlands National Wildlife Refuge Complex are Eastern Neck National Wildlife Refuge, Martin National Wildlife Refuge, and Susquehanna National Wildlife Refuge. These and the other refuges in the Chesapeake Bay watershed, including Eastern Virginia Rivers National Wildlife Refuge Complex, Patuxent National Research Refuge, and Potomac River National Wildlife Refuge Complex and all of these protected areas are facing climate change related challenges.

Impacts on National Park Units

Climate change is a far-reaching and consequential challenge to the National Park Service (NPS) mission and its ability to leave America's natural and cultural heritage unimpaired for future generations.

Rising water levels and associated storm-surge tides in the Chesapeake Bay watershed pose significant potential risk to the associated historic and cultural landscape. Bank erosion results in the loss of land and the associated cultural properties, and also indirectly impacts the natural resources of the area. For example,

at Fort McHenry National Monument and Historic Shrine, foundations of historic structures at risk include the 1814 and 1912 Water Battery fortifications and the Married Soldiers' Quarters and Gunshed. The 2,900 linear feet of seawall, constructed in 1816-1897, and 2,000 linear feet of adjacent seawall trail (also a contributing feature and high-priority asset) are especially vulnerable. The bank erosion and rising water levels at George Washington's Birthplace National Historic Site have meant the loss of native sea grass beds, the nurseries for many of the fish, crabs, and especially oysters that are critical to the health of the bay, in addition to being the prey base for breeding birds such as bald eagles and osprey.

Historic structures and landscapes are affected by static water inundation, higher ground water tables, saturated soils, and damage from tidal water surges resulting from major storm events. The proposed Harriet Tubman National Historical Park and the surrounding nationally significant landscape, located in Caroline, Dorchester and Talbot Counties, Maryland, is vulnerable to these threats, and could result in the loss of historic sites.

Unlike plants and animals that are capable of adapting to new circumstances through migration, cultural resources are typically fixed in place on the landscape. Most cannot be moved without considerable cost and with the threat of incurring severe damage and loss of integrity. In addition, cultural resources are unique; they do not reproduce when conditions improve and once they are lost, they are lost forever. The combination of being geographically fixed and unique limits the range of appropriate responses in dealing with the effects of climate change on cultural resources.

Rising waters in the Chesapeake Bay watershed, which, it is noted below, is predicted to increase during the next century in the Bay region, will likely have significant consequences for units of the National Trail System and NPS partners in the region due to their geographic location—many NPS and partner resources in the watershed are located along or near the shoreline of the Chesapeake Bay or its tributaries—and low elevations, which increases their susceptibility to inundation due to relative sea level rise and storm surge. Increasing sea levels will threaten the landscapes, archeological sites, places important to Native American communities, and other resources significant to the Captain John Smith Chesapeake National Historic Trail. From the north of the trail at Garrett Island to the south at Historic Jamestowne, trail resources and public access sites will be impacted, as will the Star-Spangled Banner National Historic Trail and the NPS partners that make up the Chesapeake Bay Gateways and Watertrails Network.

Among the greatest areas of uncertainty for future scenarios of the natural environment of Assateague Island National Seashore is frequency and intensity of storm surges and the rate at which sea level rise is occurring. Whether storms become more frequent is less well understood. Should storms become more frequent, it is expected that erosional processes associated with storm events would challenge the system's ability to "keep pace" and it may not recover as well as the current dynamics allow. Hence, the dune system may become less stable under climate change projections that project more storms. Driven by increasing rates of sea level rise, more intense and possibly more frequent storms, the island is subject to an increased likelihood for erosion, overwash, inlet breaching, shoreline retreat, and island narrowing. This could in turn impact the spawning habitat for blue crabs and migratory overwintering sites for shorebirds and marine mammals such as right whales. Should the highest rates of projected sea level rise occur, the island may exceed stability thresholds, resulting in rapid migration landward, segmentation, and possibly disintegration.

Significant loss of salt marsh will decrease primary productivity and reduce habitat availability for both terrestrial and aquatic species; some of which are important to regional commercial fisheries. Habitat diversity is expected to decrease with a trend towards plant species and communities able to tolerate greater and more frequent disturbances from stressors such as sediment movement and saltwater inundation. Those community types requiring more stable conditions, such as the island's maritime forests, are likely to decline.

The effects of climate change could threaten to challenge the ability of the NPS to provide recreational access and opportunities for Assateague's visitors in traditional ways, too. Rapid rates of shore retreat and storm driven overwash will make fixed location infrastructure such as roads, parking lots and visitor-use facilities increasingly more difficult and costly to maintain. Some adaptive measures currently being demonstrated at Assateague include low-impact road and parking lot construction techniques and mobile visitor-use facilities that can be easily removed from harm's way prior to storms.

Colonial National Historical Park includes two of the nation's most significant historic sites, Historic Jamestowne and Yorktown Battlefield, as well as the Colonial

Parkway. They are located on the James and York Rivers, tributaries of the Chesapeake Bay. Over the years, damage from rising sea levels, erosion, and an increase in violent storms have done extensive damage to buildings such as the park's visitor center, bridges on the tour roads, roadways and archeological sites along the routes, campsites and historic buildings (Moore House). For example, the storm surge associated with Hurricane Isabel caused extensive damage to the collection at the visitor center, requiring $3.5 million to recover, stabilize and preserve the artifacts. Wind-driven wave forces also cause moderate to severe shoreline erosion, as does boat traffic and rising sea levels.

As discussed above, parks are already experiencing some dramatic impacts that may be the result of a changing climate. While some impacts are already measurable, the long-range effects of climate disruption on park natural and cultural resources, infrastructure, and visitor experience are just beginning to be understood.

Executive Order: Chesapeake Bay Protection and Restoration and Departmental Initiatives

On May 12, 2009, President Barack Obama signed Executive Order 13508, launching a "new era" of shared federal leadership and action to protect and restore the Chesapeake Bay. The order pronounces that the Bay is a "national treasure" and calls for the development of a Federal Leadership Committee, made up of relevant agencies including the Department of the Interior and led by the U.S. Environmental Protection Agency. The Committee is to manage the development of a new strategy to restore the Bay, assigning specific tasks to each of the major federal agencies involved and to coordinate restoration activities, including data management and reporting. The Executive Order specifically calls on the Committee to "assess the impacts of a changing climate on the Chesapeake Bay and develop a strategy for adapting natural resource programs and public infrastructure to the impacts of a changing climate on water quality and living resources of the Chesapeake Bay watershed." The Department of the Interior and the Department of Commerce share the lead on this task and will provide a report and recommendations to the President addressing it by the end of the summer.

The Department of the Interior, through its bureaus, is a national leader in climate science and in developing a framework for effectively addressing the impacts of climate change on all of our trust resources, including those in the Chesapeake Bay watershed. The U.S. Geological Survey has expertise in geological, hydrological, and biological science that is needed to better understand the impacts related to climate change. Relying on data and information from the U.S. Geological Survey and their own research and monitoring data, the U.S. Fish and Wildlife Service and the National Park Service can identify and test potential adaptation and management strategies for managing our natural resources and vital ecosystems in the face of these changes. Research and monitoring in all three bureaus provides data and information that guides the Department's land management decisions and local and regional adaption strategies to address climate impacts in the Chesapeake Bay watershed.

To effectively respond to the Executive Order, the Department is:

- Continuing research on relative sea-level rise, long-term changes in climate, and near-term changes in land use on the Bay estuary and National Wildlife Refuges and other DOI land and water resources.
- Beginning study of the impacts of climate change on streamflow in the Bay watershed and potential changes in nutrient and sediment loads to the Bay.
- Identifying additional opportunities to address the impacts of climate change on fish and wildlife populations and their habitats, and establishing associated monitoring programs, through the National Climate Change and Wildlife Science Center and through implementation of the USGS Climate Effects Network.
- Conducting research with U.S. Forest Service and other partners on the potential changes in forest conditions and their ability to provide water quality and habitat benefits.
- Conducting these activities based on the strong foundation of existing USGS research and monitoring in the Bay and its watershed.
- Continuing to work closely with the U.S. Environmental Protection Agency through the Chesapeake Bay Program.

The USGS has provided critical projections of the impacts of sea-level rise on vital marshes in the Blackwater National Wildlife Refuge (BNWR). The rate of sea-level rise is predicted to increase two- to four-fold during the next century in the Bay region. To determine what impact this sea-level change would have on wetland resources, and to improve land-use planning within the immediate vicinity of the BNWR for the next century, USGS scientists developed a digital elevation model

(DEM) showing BNWR land surfaces data collected in March 2002 (Larsen et. al., 2004). DEM simulations using current sea-level rise rates reveal that high marsh will convert to low marsh and low marsh will continue to convert to open water for the next century, assuming 2002 surface elevations remain unchanged. Marsh loss rates will be higher, and the area impacted greater, for predicted future rates of sea-level rise. The Service has used these results to plan wetland mitigation projects.

The USGS has demonstrated that rapid climatic and sea-level change influences water quality, temperature, and biota in the Chesapeake Bay. Research by USGS scientists and colleagues has focused on reconstruction of dissolved oxygen trends in the Chesapeake Bay during the past 2,500 years (Cronin and Vann, 2003; Willard and others, 2003). Data gathered from this study, together with earlier research, clearly indicate much more severe and extensive zones of oxygen depletion in the Chesapeake Bay and its tributaries during the past four decades than at any time in the past 500-2,500 years. The findings were used to help set new dissolved oxygen standards for the Chesapeake Bay.

The Fish and Wildlife Service has a long and distinguished history of supporting Service trust species and their habitats in the Chesapeake Bay. These trust species include threatened and endangered species, interjurisdictional fish, and migratory birds. In Fiscal Year 2007, 27 Service offices spent over $11 million contributing to the conservation and management of these trust species and their habitats. Service offices have worked collectively to: (1) Identify 11 priority fish and wildlife species, ranging from oysters and blue crabs to striped bass, black ducks, bog turtles and Delmarva fox squirrel; (2) identify priority habitats; and (3) in cases where the science is available, set species population goals necessary to achieve sustainable biological outcomes. The Service is now well positioned, through improved governance, shared performance measures for priority species, and shared performance measures for habitat conservation on and off Service lands, to contribute effectively to the goals and objectives of the Executive Order.

Because sea level rise is an immediate threat to our coastal resources, including the fish and wildlife in the Chesapeake Bay, the U.S. Fish and Wildlife Service is applying a model to help us plan for the future and communicate directly with the public about the impacts of sea level rise. The Sea Level Affecting Marshes Model (SLAMM)-View is a web-based application that displays map pairs of an area, each depicting different sea levels. The strength of this tool is its ability to visually show the modeling of sea level rise predictions, allowing people to see the impacts in a more intuitive way. SLAMM is guiding long-range habitat management planning in the Chesapeake Marshlands National Wildlife Refuge Complex. The model helps managers determine where to protect uplands and to restore wetlands for the fish and wildlife protected on these coastal areas.

The Service's approach to addressing climate change focuses on monitoring, modeling, and addressing habitat and species populations changes at the landscape level, with conservation and management strategies that take into account inputs from landscapes that support native species. Considered as a whole, these actions—under the broad categories of adaptation, mitigation, and education and communication—will allow the Service to address the most pressing near-term climate change challenges to fish and wildlife. At the same time, these steps will help us lay a strong foundation for the Service's long-term response to climate change. These actions include: (1) increasing regional climate science and monitoring expertise, (2) acquiring biological planning and conservation design expertise, (3) conducting species and habitat vulnerability assessments, and (4) incorporating consideration of climate change and its impacts into all Service activities and decisions.

The Service is also working closely with a range of partners, including NOAA, the U.S. Forest Service and other federal agencies, state fish and wildlife agencies, local governments, academia, nonprofit conservation groups and other private stakeholders to help biologists and managers understand, model, and effectively address both the short and long-term impacts of climate change on fish and wildlife resources. The Service is developing Landscape Conservation Cooperatives, for instance, which will serve as regional hubs for collecting and disseminating relevant information to support responsive conservation and identifying priority research within the region. The Service's landscape conservation approach to anticipating and addressing the impacts of climate change on fish and wildlife will be applied to the Chesapeake Bay region and will be integrated into the agency's planning, programs and activities toward Chesapeake Bay restoration.

Addressing climate change and its impacts on fish and wildlife is a priority for the Service. Consequently, the Service plans to deploy its resources, creativity, and energy in a long-term campaign to reduce the bureau's emissions of greenhouse gases and safeguard the fish and wildlife, and their habitats, over which it has management responsibility.

The NPS has hired a full-time climate change coordinator, established a service-wide steering committee, and is developing a comprehensive framework for a strategic response to global climate change. The response includes the development of a service-wide climate change response office, implementation of additional climate change monitoring, and development and implementation of bio-regional adaptation units and strategies. Vulnerability studies related to sea level rise and scenario planning are underway in pilot parks across the country and adaptation projects are being formulated to build resilience in park ecosystems. In addition, the NPS has begun a strategic communication effort to make park staff and the public aware of the possible impacts to park resources by climate change.

As a major element of NPS response, scenario planning is currently being developed for use as a long-range planning tool for incorporating climate change into a range of park management processes and documents, including General Management Plans, Adaptation Plans, and Resource Stewardship Strategies. Scenario planning offers a tool for developing a science-based decision-making framework in the face of an uncertain future. Climate change scenario planning involves exploring qualitative as well as quantitative models in order to envision future outcomes under a variety of different decisions, policies, or societal pathways. In this way, park managers are able to evaluate potential management actions and implement those actions that will be most effective in protecting cultural resources and facilities and enhancing ecosystem resilience into the future.

Conclusion

There is a growing consensus that changes in the natural and human systems related to the effects of climate change must be better understood, monitored, and forecast so that all of the nation's resources can be effectively managed and protected. The Department is in an important position to evaluate and develop proactive strategies for the impacts that we are observing and cataloging on the natural, historical, and cultural resources in the Chesapeake Bay and its watershed. We look forward to working with you to better understand and mitigate these impacts.

Thank you for the opportunity to testify before you today. I would be happy to answer any questions that you or the committee members might have.

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Mr. GRIJALVA. Thank you very much, sir.

Let me now ask Dr. Robert Wood, Director of the Cooperative Oxford Laboratory for your comments, sir.

STATEMENT OF ROBERT WOOD, PH.D., DIRECTOR, NOAA COOPERATIVE OXFORD LABORATORY

Dr. WOOD. Good morning, Chairman Grijalva, Chairwoman Bordallo, Mr. Sarbanes and Mr. Kratovil. Thank you for inviting me to testify before you today. I'm Robert Wood, Director of the Cooperative Oxford Lab. This NOAA administered lab brings together the combined missions and resources of the Maryland Department of Natural Resources, NOAA, and the U.S. Coast Guard in assessing the trends and factors affecting the ecosystem health of the Chesapeake Bay.

I also recently served as co-author of the Chesapeake Bay Program Scientific and Technical Advisory Committee reported entitled, "Climate Change and the Chesapeake Bay: State-of-the-Science Review and Recommendations." Many of the points I will make in this testimony are covered in greater detail both in that report and in my written testimony which I have submitted for the record.

Change in the global climate will have significant ramifications for the Bay's regional climate and will in turn affect the Bay's organisms, their habitats and, therefore, valuable ecosystem services the Bay provides to its coastal communities and to the nation.

However, we cannot provide a detailed forecast for when or exactly how the Bay may change. There are three primary reasons for this. First, there are uncertainties exactly how the Bay's regional climate will respond to global climate changes. Second, our knowledge of the Bay's ecosystem dynamics is incomplete. Third, the net effect of future climate change on ecosystems will depend on upon how humans prepare for, mitigate and respond to these changes.

Despite these challenges, it is critically important to use the best available science to answer the question of what are some important changes that might occur to alter the Chesapeake Bay and affect its coastal communities. Although global climate models are relatively close in agreement, differences emerge when comparing their forecast at smaller regional scales. This impacts our ability to precisely predict how the Bay's climate will change.

However, climate change models agree that atmosphere, carbon dioxide, temperature, and sea level will increase over time. Further, climate models suggest winter and spring stream flow, summertime heat waves, and precipitation intensity are all likely to increase in the future. It should be noted that relative sea level rise and rise of the Bay water has already been well documented.

Ecosystem models predict that future climate changes will likely alter the biogeochemistry of the Bay through changes in nutrient, sediment, and salinity levels. Because the Chesapeake Bay currently straddles the boundaries of temperate and subtropical climate boundaries, it is currently subject to pronounced climate variability. Therefore, it is true that native Bay plants and animals here have already developed strategies to cope with strong fluctuations and temperature.

However, over time warming, higher sea level and changes in salinity and circulation, especially if they occur rapidly, are expected to exceed the capability of some Bay organisms to adjust. Such changes would have far-reaching effects on a wide variety of

important processes, organisms, and habitats through the Bay ecosystem.

While the exact response of the Bay to future climate change remains unresolved, some changes are more likely than others. Nine likely changes include:

(1) A rise in sea level increasing the likelihood of coastal flooding, submergence of estuarine wetlands, and shoreline erosion.
(2) An increase of harmful algal blooms.
(3) Larger, more prevalent low-oxygen zones, also known as dead zones, limiting the available habitat for many important Bay species like oysters and striped bass.
(4) Reduced prevalence of eelgrass, the dominant submerged aquatic vegetation in the Bay and also an important habitat for the living resources in the Bay.
(5) Changes in the shifts in the seasonal timing of migration and reproduction.
(6) Food web shifts.
(7) Perhaps an increase in invasive species because the warming will likely also alter the relative abundance of individual fish and shellfish species in the Bay which, in turn, could alter predator-prey dynamics.
(8) Increase in invasive species could also occur because changes in the Bay salinity and temperature are likely to enhance the probability that species not currently found in the Bay may gain a foothold.
(9) And an increase in disease is possible because increased runoff, increased nutrient loading events and warming together are likely to increase exposure of humans, fish, and shellfish to disease-causing micro-organisms in the Bay.

This testimony has focused on changes that scientists have the most confidence in projecting. However, our insights are limited by our current understanding of the processes that shape the contemporary Bay. It is entirely possible the changes in climate may lead to changes in ecosystem dynamics that we cannot now predict.

Given the potential alterations of the Bay ecosystem there is great need for enhanced ecosystem research and observation. Further, because human response to these changes will help determine their overall impacts on the ecosystem and its coastal communities, it is imperative to identify changes in human behavior both within the watershed and on the water that will help restore a resilient Chesapeake Bay and protect the surrounding community. Thank you.

[The prepared statement of Dr. Wood follows:]

Statement of Dr. Robert J. Wood, Director of the Cooperative Oxford Laboratory, National Ocean Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce

INTRODUCTION

Good morning, Chairwoman Bordallo and members of the Committee. I am Robert Wood, Director of the Cooperative Oxford Laboratory, a cooperative scientific research laboratory, administered by the National Oceanic and Atmospheric Administration (NOAA). The Cooperative Oxford Laboratory brings together the combined missions and resources of the Maryland Department of Natural Resources, NOAA, and the U.S. Coast Guard in assessing the trends and factors affecting the ecosystem health of Chesapeake Bay. I also recently served as a co-author on the

Chesapeake Bay Program's Scientific and Technical Advisory Committee report entitled, Climate Change and the Chesapeake Bay: State-of-the-Science Review and Recommendations. Many of the points I will make in this testimony are covered in greater detail in that report, and I have submitted a copy of that report with my testimony for the record.

Thank you for inviting me to testify on the consequences of climate change for the Chesapeake Bay. I will provide background on the topic, address some potential consequences of climate change within the Bay, and discuss current and upcoming federal government action.

LOCAL-SCALE CLIMATE CHANGE IN CHESAPEAKE BAY

By the end of this century, based on a range of carbon dioxide (CO_2) emissions scenarios, global carbon CO_2 concentrations will be 50 to 160 percent higher than they are today. CO_2 is one of a number of "radiatively active" (a.k.a. "greenhouse") atmospheric gases (methane, for example is another) that traps heat within the earth's atmosphere. Accordingly, there is scientific consensus that the trend in increasing atmospheric CO_2 will warm the planet, influence global atmospheric and oceanic circulation, and alter the hydrological cycle (evaporation, precipitation, river flow, and related processes). These changes in the global climate will have ramifications for the Bay's regional climate and will, in turn, affect the Bay's organisms, their habitats, and therefore, the valuable and important ecosystem services that the Bay provides to coastal communities and the nation as a whole. However, we cannot provide a detailed forecast for when and exactly how the Bay may change. There are uncertainties in exactly how the Bay's regional climate will respond to global changes. In addition, the net effect of future climate change scenarios will depend upon how humans prepare for and respond to these changes, as well as how organisms respond.

CHANGES THAT MAY OCCUR

In order to prepare for changes in organisms, habitats and services, it is first important to understand how the Bay is likely to change in order to determine how those resources are likely to respond. Scientists typically approach this problem by linking studies of how the Bay's ecosystem (including humans) has responded to historic and contemporary climate variability and change, including sea level rise. Often this means that scientists use coupled atmosphere-ocean models to provide a projection of future climate conditions. Using a variety of methods, scientists translate these projections into potential changes that may occur within the waters and watershed of the Bay. Then, using specialized studies that focus on critical physical, chemical, and biological processes, scientists can evaluate how these changes may relate to the Bay's ability to sustainably deliver ecosystem goods and services, including safe recreational opportunities, productive fisheries, and safe commercial navigation.

What are some important changes that might occur to alter Chesapeake Bay and affect its coastal communities?

Projected Climate Changes

Although the climate models typically used to project future global climate change scenarios are in relatively close agreement, differences emerge when comparing their forecasts at smaller, regional scales. Our inability to precisely predict how the Bay's climate will change is impacted by differences in the projections of these models for the Chesapeake Bay region, especially with respect to storminess, precipitation, and streamflow. However, it seems likely that winter and spring streamflow will increase, and that summertime heat waves and precipitation intensity are likely to increase. The models also agree that atmospheric CO_2, water temperature and sea level will all increase over time. In fact, long term relative sea level rise and warming of Bay waters has already been well documented.

Likely Ecosystem Responses

Being a coastal estuary, the Bay's ecosystem is fundamentally shaped by the dynamic mixing of freshwater river flow and runoff from its watershed with oceanic waters. This means that plants, animals, sediments, and contaminants carried within these two differing sources of water also mix. Because the Chesapeake is a shallow estuary, its volume is relatively small compared to the volume of freshwater that enters the Bay as runoff from its large watershed. Accordingly, the Chesapeake is highly responsive to changes in precipitation and temperature.

Model projections predict climate changes will likely alter the biogeochemistry of the Bay through changes in nutrient, sediment, and salinity levels. Because the Chesapeake Bay currently straddles the boundaries of temperate mid-latitude and

sub-tropical climate boundaries, it is currently subject to pronounced climate variability. As such, the plants and animals that occupy the Bay have already developed some strategies to cope with an environment that is subject to large changes in salinity and temperature. Therefore, determining exactly when changes will exceed what we have come to accept as "natural variability" of the Bay is difficult. However, over time, warming, higher sea level, and changes in salinity and circulation are expected to have far-reaching impacts on a wide variety of important processes, organisms, and habitats throughout the Bay ecosystem, including erosion rates, phytoplankton, submerged aquatic vegetation, wetlands, bacteria, zooplankton, fish, and shellfish.

While the exact response of the Bay ecosystem to future climate changes remains unresolved, some changes are more likely than others. Likely changes include:

(1) Sea Level Rise—sea level within the Bay will rise (and its variability will increase), thereby increasing the likelihood of coastal flooding, submergence of estuarine wetlands, and shoreline erosion;
(2) Harmful algal blooms—warming and higher levels of atmospheric CO_2 are conditions that are favored by algae species that are harmful for humans, fish, and shellfish;
(3) Dead zones—warming and increased winter-spring stream flow will reduce the amount of dissolved oxygen in the Bay, limiting the available habitat for many important Bay species like oysters and striped bass;
(4) Seagrasses—warming will reduce the prevalence of eelgrass, the dominant submerged aquatic vegetation in the Bay;
(5) Shifts in Species Ranges—warming would likely shift the range of species in the Bay, favoring expanding ranges and abundances of plants and animals that are able to tolerate warmer temperatures. For species whose southernmost distribution limits occur within the Chesapeake, like the soft clam Mya arenaria, warming waters could dramatically reduce their occurrence or eliminate their presence from the Bay;
(6) Changes in the seasonal timing of migration and reproduction—warming will influence the growth rate, age of sexual maturity, and timing of spawning for many Bay organisms. Production of some species, especially spring spawning fish and shellfish could be inhibited by resulting mismatches that could occur between the age-sensitive dietary needs of developing fish and shellfish and the abundance of their prey;
(7) Food Web Shifts—warming will likely alter the relative abundance of fish and shellfish species in the Bay, which, in turn, could lead to large shifts in the Bay's overall food web as predator and prey dynamics shift;
(8) Invasive Species—changes in Bay salinity and temperature are likely to enhance the probability that invasive species may gain a foothold within the Bay (because some species will be able to expand their range, see (5)) and further disturb the ecosystem; and
(9) Diseases—warming and increased nutrient loading events are likely to increase the abundance of pathogenic bacteria capable of causing disease in fish, shellfish, and humans.

So What does this all mean? The Striped Bass Example

Although charting the course of the Chesapeake's response to future climate changes is difficult, we can better resolve the question at hand by simply asking, how are the most probable effects of climate change likely to affect key Bay species? The striped bass is one of the most ecologically and economically important species of the Bay and coastal area. To illustrate, let us analyze the potential effects on this particular species.

Striped bass spawn each spring in the upper tidal reaches of the Bay and its tributaries. Young striped bass depend upon the shallow shoreline areas for shelter and access to abundant prey. As sea levels rise, shoreline residents are likely to take protective measures to save their land from erosion. Armoring shorelines with sea walls and similar structures would replace valuable marshland habitats with an unvegetated stony shoreline that is unlikely to offer the necessary resources for the fish.

As sea levels rise, it is also likely that late winter and early spring conditions will be wetter and warmer. It has been established that cool, high flow conditions are associated with years of high striped bass production. While river flow is likely to be enhanced, warm conditions could cause shifts in the zooplankton community, thereby depriving the young fish of their preferred zooplankton prey species. In addition, the occurrence of large blooms of algae that may be inedible or even harmful to striped bass could further compromise production of these fish.

Warmer conditions could also cause disruptive shifts to occur in the Bay food web. In the past, striped bass spawning has occurred around the same time as the spring phytoplankton bloom. If the spring bloom does not occur at the same time spawning occurs, due to these climate changes, the traditional food of very young striped bass may not be available in the appropriate amount. Reduced food availability at early life stages would be expected to dramatically affect survival of these young fish and therefore could reduce striped bass production and abundance in the Bay.

In the main stem and lower tributaries of the Bay, important habitat for larger juvenile and adult striped bass is also likely to be reduced. As warmer, nutrient rich, turbid waters reduce seagrasses due the combined effects of shading and physiological stress, juvenile and adult striped bass will lose valuable foraging habitat. Seagrass beds are very productive habitats for juvenile blue crabs and small forage fish.

With warm and wet springtime conditions, phytoplankton may reach such high levels that many of the organisms could sink into deep waters before they could be eaten by other organisms. In the deeper waters in the main stem of the Bay, this mass of phytoplankton would be consumed by bacteria, and as a result, oxygen in these deep waters would be consumed faster than it could be replenished. The resulting low-oxygen zones (or dead zones) created would prevent juvenile and adult striped bass from occupying these areas. With these same projected climate changes, the Bay's surface waters could become too warm to allow for effective foraging by striped bass on important surface-feeding prey like Atlantic menhaden. This combination of warm surface waters and low oxygen deep waters would create a "habitat squeeze" that could force striped bass into a relatively narrow depth zone where prey may not be readily available. Another threat could emerge as these fish, stressed by prolonged periods of warm, low oxygen waters, may also be exposed to an increased abundance of pathogenic bacteria, which would likely cause disease to increase in the Bay's striped bass population.

Unfortunately, the processes and pressures described above are already observable in today's Bay. Relative sea level rise (including land subsidence) and population growth over past decades has accelerated the development of sea walls and other hardened shorelines and has eliminated some of the Bay's productive shoreline habitats. In addition, land use practices and development have led to enhanced runoff and nutrient enriched waters, especially in years when the weather is warm and wet. Climate changes, especially if coupled with human responses that may exacerbate, rather than mitigate, stress on the ecosystem may lead to an undesirable "drift" in the average conditions in the Bay so that, for example, years of high stress on the striped bass, which now occur intermittently, could become the average condition in future years.

NOAA's Role in Assessing and Adapting to Climate Change

NOAA, through development and delivery of climate information and services, implementation of a global observing system, and focused research and modeling to understand key climate processes, works to help society understand, plan for, and respond to climate variability and change. The NOAA climate mission is an end-to-end endeavor focused on providing a predictive understanding of the global climate system to allow the public to incorporate the information and products into their decision-making. Across the agency, scientists and technical experts are assisting local communities in studying, predicting, and responding to these potential changes. Just this month, the U.S. Global Change Research Program, which NOAA is a part of, released a new report titled Global Climate Change Impacts in the United States, which addresses the broad impacts of climate change in the U.S. and in regions such as the Chesapeake Bay.

NOAA and partners work to restore the natural buffers (e.g., near-shore oyster reefs and seagrass beds) that reduce wave damage and protect coastal property from erosion. Protection and restoration of these coastal resources can help protect coastal communities against the onslaught of coastal hazards, sea level rise, and other effects of climate change, and will enhance the ecosystem's resilience. NOAA also works with communities to restore eroding shorelines with natural vegetation rather than sea walls and other hardened shorelines which present barriers to the migration of habitat inland as sea level rises.

NOAA has a wide range of programs and tools to assist localities in planning for climate change. NOAA Sea Grant engages a network of the Chesapeake Bay area's top universities in conducting scientific research, education, training and extension projects designed to foster science-based decisions about the use and conservation of aquatic resources. Sea Grant's extension and education activities help inform policy, law and regulation, and management practices for industry and government agencies. The Chesapeake Inundation Prediction System can predict street-level in-

undation from coastal storms and sea level rise to assist local planners. NOAA's Chesapeake Network for Educating Municipal Officials helps communities to foster well-planned growth, preserve water quality, and protect natural areas in the Chesapeake watershed. Chesapeake Bay National Estuarine Research Reserve System's Coastal Training Program links local planners with new tools and available expertise. Through a series of workshops, planners and other officials are invited to participate in forums such as how to plan for climate change impacts, and adaptation and shoreline management.

Executive Order 13508, Chesapeake Bay Protection and Restoration

On May 12, 2009, President Obama issued Executive Order (EO) 13508, Chesapeake Bay Protection and Restoration, calling for a greater federal role and accountability for Bay protection and restoration. The EO requires seven reports to be completed within 120 days (i.e., by September 15, 2009) and a coordinated federal strategy to be disseminated for public review at 180 days (i.e., by November 13, 2009). NOAA is helping to co-lead the production of 3 of these 7 reports with our interagency partners.

As part of the reports on climate change, the EO requires agencies to "develop a strategy for adapting—to the impacts of a changing climate on water quality and living resources of the Chesapeake Bay watershed." Efforts to address these changes will be integrated into all of the reports called for in the EO, as well as the overarching federal strategy for the protection and restoration of the Chesapeake Bay. The reports will build on existing capabilities and planning efforts, such as those related to the impacts of sea level rise and storm surge on coastal communities, predictive modeling of inundation and sea level rise, community resilience assessments and adaptive strategies, research on the impacts of climate change on living resources, and development of innovative practical applications (such as living shorelines) to protect coastal communities and resources.

CONCLUSION

This testimony has focused on those changes that scientists have the most confidence in projecting. However, it is important to note that our insights are limited by our current understanding of the processes that shape the contemporary Bay, under contemporary or historic climatic conditions. Even if we were blessed with a perfect understanding of today's Bay, it is entirely possible that changes in climate may lead to changes in ecosystem dynamics that we cannot predict.

Given the looming specter of climate change-induced alterations of the Bay ecosystem, there is great need for enhanced ecosystem research and observation designed to identify and better predict the nature and magnitude of these changes. Further, because the human response to these changes will help determine their overall impact on the ecosystem and its coastal communities, it is also imperative to identify changes in human behavior, both within the watershed and on the water, that will help restore a resilient Chesapeake Bay and protect the surrounding communities.

Mr. GRIJALVA. Thank you.

Let me now introduce The Honorable Michael Bojokles, Mayor, Town of North Beach.

Mr. Mayor, your comments.

STATEMENT OF THE HONORABLE MICHAEL BOJOKLES, MAYOR, TOWN OF NORTH BEACH

Mr. BOJOKLES. Good morning and thank you for this opportunity.

My name is Michael Bojokles, Mayor of the Town of North Beach. We are about 20 miles south of where we sit today. The Chesapeake Bay is North America's largest estuary with over 11,000 miles of shoreline and its watershed encompassing six states and Washington, D.C. It is a national treasure that belongs to each and every one of us.

North Beach is a small municipality located on the Western shore of the Chesapeake Bay in Southern Maryland. With a population of 2,000 we are less than an hour away from Capitol Hill. We take pride in our stewardship of the Bay and work very hard

in managing our water front. Along with a small public beach we also enjoy a 535 foot fishing pier and a half mile-long boardwalk that runs the length of town. We are also doing our part to improve water quality within the Bay watershed by growing oysters underneath our fishing pier. Once mature the oysters are then transported to reefs in rivers throughout Southern Maryland.

There are only a few remaining public beaches along the entire shore of the Chesapeake Bay and we are one of them. Public access is very important as many of the access points along the Bay have disappeared or are private. Keeping North Beach public is absolutely necessary for the enjoyment of all. Rising sea levels along the Bay have made it quite difficult to preserve what little beach we have left. In the last century, we have lost close to 1,000 feet of shoreline. The average annual rate of erosion is over five feet per year and increasing.

Beach erosion is causing additional problems along our water front. I am concerned that erosion will start to undermine the boardwalk superstructure and the adjoining street that runs along the waterfront. Private homes and businesses will be affected by increased incidence of flooding and decreasing property values.

In 2002, North Beach—along with the Maryland Department of Natural Resources—constructed offshore breakwaters to help curb erosion along our beach. While this has helped, it has certainly not eliminated erosion. I estimate within a decade at the beach at the current rate of erosion will be gone or the next strong nor'easter will definitely take it away.

With an annual budget of $2.2 million and limited resources North Beach cannot battle this problem alone. The economy of North Beach is dependent on the Bay and its natural resources. Incorporated in 1910 the beach created the town. A hundred years later we are on the verge of losing what we have. Tourists and dollars are the lifeblood of our local businesses.

Breakwaters and bulkheads are not the answer. Beach replenishment is the only way to save our beach. We need help and we need it today. The annual cost of replenishment is between $25,00 and $50,000. This is not a large amount of money compared to the value of losing our beach and continuing to have public access to this precious natural resource.

Again, with limited financial resources North Beach cannot manage this alone. We need awareness, assistance, commitment and cooperation from all levels of government to help us build a coast-smart community is our goal moving into the next decade and beyond.

One area that needs to be researched and discussed is that, with today's environmental controls, being stewards of our waterfront is extremely prohibitive. I currently have an administrative staff of three people and could easily create a full-time job for someone just to travel through the maze of bureaucracy. Being an elected official, I am accountable for what I do and I do not do.

There are times when accountability does not exist with those who are in charge of this process. At this time we are in need of five different permits to do work along our waterfront. This would include beach replenishment, storm water out-fall maintenance, breakwater stabilization and rehabilitation, boat slip dredging and

tidal tributary maintenance. An additional project that goes along with tidal tributary maintenance is wetland restoration.

We have a tidal tributary at the north end of town that is the only source of tidal flushing for a 440-acre wetland.

The tributary silts in with sand which prevents tidal flushing of the wetland causing a slow death of a crucial environmental gem. The town's public works department has been cleaning this channel since the mid-1980s as regular maintenance. Now permits are needed for offsite disposal. A common sense approach is needed for some of these maintenance items.

The process is daunting for us. Working with the different agencies can sometimes be frustrating and confusing. Getting a status of permit applications can be impossible, no accountability or cooperation. This process takes so long and sometimes the original staff member who is assigned to help us has either retired or moved on and no one knows what the status is.

I recommend that the process be streamlined in some way, either through a clearinghouse of some kind or a tracking system. In North Beach, we are developing our own tracking system for permits. When a permit applicant calls the town hall, we will be able to give them a status of where the permit is in the process, what needs to be done next, and when the permit will be issued.

North Beach is the jewel of the Chesapeake and it is our mission to pass it on to our children and our children's children. It will take the effort of all of us here today to make this happen. We must act today. Through fiscal responsibility and assistance, commitment and cooperation we can restore our beach for all to enjoy for the decades to come. Thank you.

[The prepared statement of Mr. Bojokles follows:]

Statement of The Honorable Michael Bojokles, Mayor, Town of North Beach

The Chesapeake Bay is North America's largest estuary with over 11,000 miles of shoreline and its watershed encompassing six states and Washington DC. It is a national treasure that belongs to each and every one of us.

North Beach is a small municipality located on the Western shore of the Chesapeake Bay in Southern Maryland. With a population of 2000, we are less than an hour away from Capitol Hill. We take pride in our stewardship of the Bay and work very hard in managing our waterfront. Along with a small public beach we also enjoy a 535 foot fishing pier and a half mile-long boardwalk that runs the length of town. We are also doing our part to improve water quality within the Bay Watershed by growing oysters in baskets underneath our fishing pier. Once mature, the oysters are then transported to reefs in rivers throughout Southern Maryland.

There are only a few remaining public beaches along the entire shore of the Chesapeake Bay and North Beach is one of them. Public access is very important as many of the access points along the Bay have disappeared or are private. Keeping North Beach public is absolutely necessary for the enjoyment of all. Rising sea levels along the Bay have made it quite difficult to preserve what little beach we have left. Since 1847, we have lost close to 1000 feet of shoreline. The average annual rate of erosion is over 5 feet per year, and increasing.

Beach erosion is causing additional problems along our waterfront. I am concerned that erosion will start to undermine the boardwalk superstructure and the adjoining street that runs along the waterfront. Private homes and businesses will be affected by increased incidences of flooding and decreasing property values.

In 2002, North Beach, along with the Maryland Department of Natural Resources constructed off shore breakwaters to help curb erosion along our beach. While this has helped it has certainly not eliminated erosion. I estimate within a decade with the current rate of erosion we will lose our beach. With an annual budget of $2.2 million, and limited resources, North Beach, cannot battle this problem alone. The economy of North Beach is dependent on the bay, and its natural resources. Incor-

porated in 1910 the beach created the town. Now 100 years later, we are on the verge of losing what we have. Tourism dollars are the lifeblood of our local businesses.

Breakwaters and bulkheads are not the answer; beach replenishment is the only way to save our beach. We need help, and we need it today. The annual cost of replenishment is between $25,000 and $50,000. This is not a large amount of money compared to the value of losing our beach and continuing to have public access to this precious natural resource. Again, with limited financial resources North Beach, cannot manage this alone. We need awareness, assistance, commitment and cooperation from all levels of government. Building a coast-smart community is our goal moving into the next decade and beyond.

One area that needs to be researched and discussed is the permitting process. With today's environmental controls being stewards of our waterfront is extremely prohibitive. I currently have an administrative staff of three people and could easily create a full-time job for someone just to travel through the maze of bureaucracy. Being an elected public official, I am accountable for what I do and do not do. There are times when accountability does not exist with those who are in charge of this process. At this time, we are in need of five different permits to do work along our waterfront. This would include beach replenishment, storm water outfall maintenance, breakwater stabilization and rehabilitation, boat slip dredging and tidal tributary maintenance. An additional project that goes along with tidal tributary maintenance is wetland restoration.

Storm water outfall maintenance: this outfall empties out into the Chesapeake Bay and needs regular monthly cleaning of sand buildup to prevent flooding. In the past maintenance on this outfall was quite simple. We would take a backhoe and scoop the sand out from in front of the outfall and throw it onto the beach. This would take the public works department about an hour to do once a month. Now things are quite different. What used to be regular maintenance is now considered dredging. The sand that is taken out must be loaded onto watertight dump trucks and disposed of at an approved disposal site after obtaining a permit. This is not a common sense approach and is very costly to the town.

Beach replenishment: the permit application for this work is now into its third year. The process to obtain this permit is taking way too long. The bureaucracy involved in obtaining this permit is frustrating. No less than seven different state and federal agencies must sign off on this permit application. We made this application in my first year in office in 2006 and I'm hoping to have it in my hands before my term is over four years later. In the meantime we watch as our beach gets thinner and thinner disappearing into the Chesapeake Bay.

Tidal tributary maintenance: there is a tidal tributary at the north end of town that is the only source of tidal flushing for a 440 acre wetland. This tributary silts in with sand which prevents tidal flushing of the wetland causing a slow death of a crucial environmental gem. Clearing this channel also reduces flooding of residential areas on the north side of town. The town's public works department has been cleaning this channel since the mid-1980s as regular maintenance. The sand that was removed was just simply put back onto the beach. Now permits are needed with an off-site disposal site. Again, a common sense approach is needed.

Wetland restoration: a feasibility study for this project was started by the Army Corps of Engineers and discontinued in 2001 due to the lack of funding. Upon taking office in 2006, I have worked side-by-side with our federal delegation in trying to resurrect this project. To date we have not been able to obtain funding to restart the feasibility study. This wetland is one of the few natural areas remaining along the shoreline near North Beach and represents critical aquatic habitat for 73 different species of breeding birds. This wetland represents one of the most substantial black duck breeding habitats in Calvert County and the Western shore of the Chesapeake Bay. This particular wetland is also amongst the largest contiguous segments of tidal marsh on the western shore providing the necessary acreage to support the breeding population of this species. The clogged drainage channel effectively serves as a fish blockage and limits access by species such as striped bass, yellow perch, summer flounder, winter flounder, shad, alewife and blueback herring. The whole marsh is experiencing degradation from many factors. This loss must be seen in conjunction with the overall loss of wetlands on the Chesapeake Bay, where, based on studies by the EPA's Chesapeake Bay Program, an estimated 75 percent of the bay wetlands have been lost in the past century. One solution to restoration that has been proposed is to create additional channels to allow tidal flushing at more points. If no action is taken to reclaim this area, the wetland will continue to degrade. The town of North Beach has made wetland conservation a key issue, and without restoration activities, the citizens of North Beach and the state of Maryland will be denied the positive environmental, educational, recreational, and

economic benefits that could be realized by improved habitat quality. In addition, it is likely that nuisance flooding will continue and the wetland will slowly decrease in size and quality.

As explained in the examples above the process is daunting. Working with the different agencies can sometimes be frustrating and confusing. Getting a status of permit applications can be impossible. No accountability or cooperation. The process takes so long that sometimes the original staff member who was assigned to help you has either retired or moved on and no one quite knows what the status is. I recommend that the process be streamlined in some way either through a clearinghouse of some kind or a tracking system. In North Beach we are developing our own tracking system for permits. When a permit applicant calls Town Hall we will be able to give them a status of where the permit is in the process what needs to be done next and when the permit will be issued.

North Beach is the "Jewel of the Chesapeake" and it is our mission to pass it on to our children and our children's children. It will take the effort of all of us here today to make this happen. But we must act now. Through fiscal responsibility and assistance, commitment and cooperation we can restore our beach for all to enjoy for decades to come.

Mr. GRIJALVA. Thank you, Mayor.

Dr. Donald Boesch, President, Center for Environmental Science. Thank you, sir.

STATEMENT OF DONALD F. BOESCH, PH.D., PRESIDENT, CENTER FOR ENVIRONMENTAL SCIENCE

Dr. BOESCH. Yes. Chairman Grijalva and Chairwoman Bordallo, it is a pleasure to be here with you and the other members of the Committee, our excellent Maryland Representatives on the Committee. I would like to talk about the effects on the Chesapeake Bay. A lot of it has been covered but I want to point you to these two very important reports from which I'll draw my testimony.

First is the report that we produced last year called "Global Warming and the Free State," which is a comprehensive assessment of the climate change impacts on Maryland that we did for Governor O'Malley's Climate Change Commission, which he established and reported out last year.

Just last week the White House released this report that I was an author for, Global Climate Change Impacts in the United States, which talked about impacts throughout the United States. As Mr. Sarbanes indicated, what we tried to do in both of these reports is to basically bring it home to where people live and care about. We talked about the kinds of impacts that people are experiencing now and will be experiencing into the future in this country. Hopefully you use these reports and I will use them to summarize my testimony.

As pointed out, climate change is something not just in the Chesapeake Bay's future but it's here today. We have seen major changes already. We have seen, for example, long-term temperature records of Bay water of this century have shown that the Bay is warmed about 2° Fahrenheit since the 1960s. It's a trend which seems to be continuing.

Depending upon our emissions trajectory—what we do about emitting heat-trapping gases—we may see in this region an average air temperature increase of 5° to 9° Fahrenheit that sort of translates and affects the Bay's temperature. As pointed out by the previous witness, this will affect the kinds of organisms that will

live here both in terms of the species that are so critically important for the Bay.

Field grass was mentioned, a submerged grass which provides critical habitat for crabs and fish. It's at the southern end of its range and as the Bay warms it is likely to be lost from the Bay. As also pointed out, the warming of the Bay opens the door to these hitchhikers, these invasive species which come in on our ships. I'm sure Dr. Hines will talk about this since he is at the center of research on that subject.

It is also one of this country's most sensitive regions with respect to sea level rise. Think of the recent centuries here in which Europeans have lived along the shores of the Bay and had relative sea level rise because the land has been sinking slowly, about a millimeter and a half a year. That caused the change of the shoreline and the landscape and loss of some of the islands.

In the last century, we've seen a doubling of that rate of sea level rise because, of course, the ocean is warming and the ice is melting and building up the volume of the ocean, adding this human component on the impact of relative sea level rise. As we project that based upon the best science we have now and emerging science, we see a contrast that depends on what we do, as was pointed out.

If we have business as usual and do not deal with the growth of our greenhouse gas emissions, the models suggest that we will actually may well experience something in excess of four feet of sea level rise this century in this region. If we actually take steps to reduce those emissions quickly, we can probably go back to something in the neighborhood of two feet, still double what we had last century but not nearly as serious as what we see in the future that has enormous consequences to our natural resources and Blackwater Refuge and all of our other tidal marshes that were mentioned are ery much in jeopardy.

Not only that, so are the places where people live. Then add on top of that sea level rise and storm surge, such as we experienced here in Hurricane Isabel a few years ago where we had nine feet of storm surge. We will see, of course, that build up and have an even greater effect.

The stakes are indeed very large and it requires that we take action in a number of respects. It needs to be factored into the way we manage and restore the Chesapeake Bay but, in addition to that, you folks needs to take action in Congress. In Maryland, as a result of the Governor's commission, we passed legislation this last session that is going to be set as the state goal to reducing our greenhouse gas emissions by 25 percent by the year 2020.

We need to do more than that and it requires several actions, including the legislation before you, the cap-and-trade legislation. You must in some fashion pass it soon, hopefully this year, in order to make a difference not only within this country but internationally.

There are many implications for the Chesapeake Bay in order to avoid this serious climate change. One of them is taking those actions quickly. The other, of course, is adapting to the changes that take place. We have under the commission a plan of action to deal with adapting the relative sea level rise but we need, of course, more information about how our climate is actually changing.

We need to have the best observations and the best assessments, scientific assessments, possible to inform those decisions. In that regard, I am very pleased about the legislation that Chairwoman Bordallo has submitted on the National Climate Enterprise Act to create a climate change service headed by NOAA. It also very broadly would involve other Federal agencies, who not only would contribute to this climate information database that countries urgently need, but also use it in their decisionmaking. Thank you for the opportunity.

[The prepared statement of Dr. Boesch follows:]

Statement of Dr. Donald F. Boesch, Professor and President, University of Maryland Center for Environmental Science, Cambridge, Maryland

Chairman Grijalva and Chairwoman Bordallo and members of the subcommittees, I am Donald F. Boesch and am pleased to appear before you today to address the impacts of climate change on the Chesapeake Bay, likely future effects, and what can be done to mitigate and adapt to these impacts.

I have conducted or directed research on the Chesapeake Bay for 30 years and have, specific to the topic of this hearing, been engaged in several relevant assessments of the impacts of climate change. Notably, these include: the report Global Warming and the Free State: Comprehensive Assessment of the Impacts of Climate Change in Maryland, done as a component of the Action Plan of the Maryland Commission on Climate Change; a National Research Council report Ecological Impacts of Climate Change, released earlier this year; and the report issued just last week by the White House, Global Climate Change Impacts in the United States. By the way, this last national assessment used the same model projection methodology that we used in the Maryland assessment. I am also a member of the Scientific and Technical Advisory Committee of the Chesapeake Bay Program which last year released the report Climate Change and the Chesapeake Bay. My testimony will draw on these reports. Finally, I should note that I am a member of National Academies Committee on America's Climate Choices, mandated by Congressional appropriations language and scheduled to release its wide-ranging report early next year.

A Warming Bay

Global climate change is not just something in the Chesapeake Bay's future. Evidence is building that it has already resulted in changes in the Bay environment over the last several decades. Based on long-term records from the piers at the Chesapeake's two historic marine laboratories—extending back to 1938 at my Center's Chesapeake Biological Laboratory on Solomons Island, Maryland, and to 1948 at the Virginia Institute of Marine Science at Gloucester Point—it is clear that the Bay has been warming (Exhibit 1). While annual Bay water temperatures have varied in relation to large-scale climate cycles, there has been a superimposed warming trend of 2°F since the 1960s. This is, by the way, consistent with the observed increases in air temperature over much of the Bay region during that same time period.

Because of the close connection of monthly average air temperature and the temperature of Bay waters, the models used to project future climate conditions as a function of increasing greenhouse gases provide some insight into further changes in temperature in the Bay. Depending on the emission scenarios, these models suggest a 5 to 9°F increase in annual mean temperature by the end of this century. These increases in air temperature may be modulated somewhat as water temperatures respond, but even if we act today to dramatically reduce greenhouse gas emissions around the world, the Chesapeake Bay is still very likely to experience significant additional warming.

The much warmer waters during the summer and much milder temperatures during the winter would have substantial consequences for the organisms that live in the Bay and how this ecosystem works. Species that are already stressed by high summer temperatures, such as the eelgrass that provides important habitats in the lower Bay, may be greatly reduced or eliminated. Milder winter temperatures are likely to open the back door to invaders from warm temperate areas around the world who hitchhike into the Bay in ships' ballast waters. With earlier spring warming the critical timing of spawning of species such as striped bass and blue crabs will adjust, potentially out of phase with other processes, such as food production, that are critical to the success of their young.

Inundation

The Chesapeake Bay region is one of the areas of the country most sensitive to the effects of sea-level rise because of its 8,000 miles of shoreline and extensive, low lying areas, particularly on the Eastern Shore (Exhibit 2). Sea level has been rising in the Bay for a long time, initially as a result of the melting of glaciers at the end of the last ice age. In fact the Bay itself is a series of drowned river valleys, inundated by the rise in the ocean levels of over 300 feet 7,000 to 12,000 years ago. Sea level has been rather stable in recent centuries, however, rising only slowly as a result of the sinking of the land—a slow subsidence of the Earth's crust that had bulged upward under the weight of glaciers to the north. Still this has been enough to cause the abandonment and, in some cases, disappearance of several islands that had human habitation in the 19th and early 20th centuries.

During the 20th century the Bay level rose a little over one foot relative to the land over most areas of the Bay (Exhibit 3). Accurate tide gauge records at six locations in the Bay showed this relative sea-level rise to range from 2.7 mm per year in Washington, DC to 4.5 mm per year in Hampton Roads, Virginia, with the difference apparently related to differences in subsidence rates. The rise in the surface level of the ocean during the 20th century averaged 1.7 mm per year, but, based on satellite measurements, was observed to have increased to 3.1 mm per year around the turn of the century.

The Intergovernmental Panel on Climate Change projected average global rise in sea level through the 21st century for different greenhouse gas emission scenarios. If one adds to their rates the average regional subsidence rates for the Chesapeake Bay of 1.8 mm per year, the projections equate to relative sea level rises by the 2090-2100 time period of 1.2 to 1.8 feet assuming emissions are eventually reduced and 1.4 to 2.5 feet if emissions continue to grow. However, there are several reasons to believe that these estimates might be too low. First, as mentioned earlier, satellite evidence indicates that the rise of the global ocean level during 1993-2003 was already much faster than the low emissions estimate. Secondly, the IPCC projections excluded acceleration of the melting of polar ice sheets and evidence is mounting that the melting of the Greenland ice sheet has accelerated. Recently published empirical projections suggest that relative sea level rise—including the effects of regional subsidence—could range from 2.1 to 4.8 feet by the end of this century.

While there remains uncertainty, not only as related to behavior of the climate, but also of the level of accumulated greenhouse gases, it appears likely that relative sea level in the Chesapeake Bay will rise at least twice as much during this century than it did in the previous century and could rise three or more times as much. This rise would probably be measured in several feet, rather than the catastrophic sea level rise of 20 feet or more associated with the complete melting of Greenland as depicted in some popular animations. Still, it is important to keep in mind that sea level would not simply reach a plateau in 2100 but will continue to rise under almost any emission assumption. Furthermore, a rise in Bay water level of just a foot or two will place into jeopardy extensive intertidal wetlands, many of which are already showing deterioration due to inundation, and additional low lying islands. Sea level rise will have profound, but poorly understood effects on the Bay itself. For example, the deepening of the Bay will allow saline ocean water to extend farther up the estuary. Already, this effect seems to be evident in the slight increase in salinity when one factors out the effects of freshwater inflow variations and hydrodynamic models project shifts in salinity significant enough to allow oyster diseases to penetrate deeper into the estuary.

But the effects will be felt in the built environment as well, as roads, utilities, sewerage and drainage systems are threatened with inundation and erosion of developed shorelines and saltwater intrusion into aquifers progress, not only on the Eastern Shore and the imperiled communities on Smith and Tangier Islands, but also in part of the cities of Hampton Roads, Baltimore, Annapolis, Alexandria and the Nation's Capital itself.

These effects will be experienced not just through the slow encroachment of mean sea level but during the extremes, when storm surges build on top of the inexorably slowly rising Bay. For example, in 2003 Hurricane Isabel resulted in storm surges up to 9 feet, typically exceeding the maximum recorded levels of a 1933 hurricane, which had a very similar trajectory and intensity, by about one foot. This is the approximate increase in relative sea level over that 70 year interlude. Add to this the potential for increased frequency and intensity of tropical cyclones as result of warmer ocean waters and there emerges the considerable likelihood of significantly increased vulnerability of the Chesapeake Bay's coastal communities and environments as a result of global climate change.

What Happens on Land Matters

As a large, but shallow estuary with limited exchange with the ocean, the Chesapeake Bay is particularly affected by what drains into it from its 64,000 square mile watershed. Greatly increased inputs of sediments and nitrogen and phosphorus nutrients as a result of land uses, agricultural inputs and atmospheric fallout are the root cause of the deterioration of the Bay during the latter half of the 20th century. And, reducing those nutrient and sediment inputs are the main focus of the Chesapeake Bay restoration program.

Climate change could affect the runoff of nutrients and sediments in a number of ways that interact, making prediction of future conditions somewhat difficult. The wild card is how climate change will affect precipitation and ultimately river runoff. Model projections for precipitation in the Mid-Atlantic region do not have the same level of consistency as those for temperature. However, there is considerable agreement for increased precipitation during the winter and spring. This would likely mean the flushing out of more nutrients through river flow to the Bay during the critical January-May time period, exacerbating water quality problems in the Bay, particularly summertime oxygen depletion of the deep waters of the Bay or the so-called "dead zone." On the other hand, models have less agreement in summer precipitation, with most predicting little or no overall increase but with most rain delivered during intense events that punctuate dry spells. Keeping in mind that warmer temperatures mean more evaporation and plant transpiration this would suggest significantly less river discharge during the summer, which could further allow the salt-water intrusion into the Bay discussed in the context of sea-level rise. Compounding these physical phenomena are the human responses, particularly in agriculture, to changing energy costs, temperature, soil moisture and water availability. These, as well as the still needed pollution abatement practices, will affect the inputs of nutrients in the first place.

Restoring the Chesapeake

Substantial public investments have been made and individual actions taken to restore the Chesapeake Bay. Approximately $5 billion has been spent on that effort since 1995 and it has been estimated that an additional $15 billion will be required to achieve the water quality objectives of the Chesapeake 2000 Agreement. While some of the changes in the regional climate that are anticipated over the remaining century might actually result in improvements in environmental quality, the tally sheet of reasonable expectations is heavily tilted toward the detrimental in terms of ecosystem recovery. For example, higher winter-spring runoff will require even more efforts to control non-point source pollution in order to receive the same water quality goal for the Bay. The loss of tidal wetlands will reduce their natural cleansing capabilities, and so on.

There are two corollary implications for Bay restoration. First, the impacts of climate change must be factored into restoration goals and actions. No longer should this be put off as too hypothetical, too political or too daunting. Second, mitigating the causes of climate change to avoid dangerous extreme changes should become part of the Bay restoration agenda.

Seeking Common Solutions

Integrating climate change mitigation and adaptation with Chesapeake Bay restoration requires the search for common solutions. If considered with an open mind, there are opportunities and savings rather than additional costs to be realized. The Maryland Commission on Climate Change established by Governor Martin O'Malley recommended a Plan of Action for mitigating and adapting to climate change. This led to the adoption of a state statute setting the goal of a 25% reduction in Maryland's net greenhouse gas emissions by 2020. The Commission found that as practical strategies to reduce the emissions of greenhouse gases are developed there can be significant net economic benefits, although initial investments are usually required to achieve them. Energy conservation and emphasizing transportation options that get many of the single-occupancy vehicles off the roads both favor smart growth and reduce impacts to the Bay. At the same time, we need to avoid apparent solutions to the fossil fuel dependence that could result in additional degradation of the Bay. In that vein, the rapid increase in growing corn, which has high fertilizer requirements and concomitant nutrient losses, to produce ethanol is particularly troublesome, particularly when, on careful inspection, this seems to produce few if any net reductions in greenhouse gas emissions.

Sound Scientific Guidance

To accomplish this integrated approach to Bay restoration and climate change mitigation and adaptation will require innovative and rigorous science to under-

stand both the synergistic as well as the antagonistic interconnections. While the Chesapeake Bay has a robust scientific community actively engaged in supporting Bay restoration, there is a critical need to build capacity in research, monitoring and assessment related to the consequences of regional climate change. This is largely because the federal science agencies have not invested much in this area. In a 2007 review of the U.S. Climate Change Science Program, the National Research Council concluded that:

Discovery science and understanding of the climate system are proceeding well, but use of that knowledge to support decision making and to manage risks and opportunities of climate change is proceeding slowly.

- Progress in understanding and predicting climate change has improved more at global, continental, and ocean basin scales than at regional and local scales.
- Our understanding of the impact of climate changes on human well-being and vulnerabilities is much less developed than our understanding of the natural climate system.

The Chesapeake Bay Program's Scientific and Technical Advisory Committee has prepared a review and agenda to support the practical understanding of regional climate change that could serve as a blueprint for the needed federal investments. However, we are not in this predicament alone—other regions of the country face similarly daunting challenges in assessing and responding to their climate future.

Since I first became involved in assessing impacts of climate change about ten years ago, we as a nation have done far too little to reduce the extent of climate change and begin to adapt to its impacts. This was a critical period of time when one considers the pace of climate change and the immediacy of decisions that are required. I urge Congress to make up for this lost time by adopting legislation to reduce our greenhouse gas emissions and establish a national climate services enterprise to support the studies of regional climate dynamics and ecosystem and social responses that are needed to manage our future wisely.

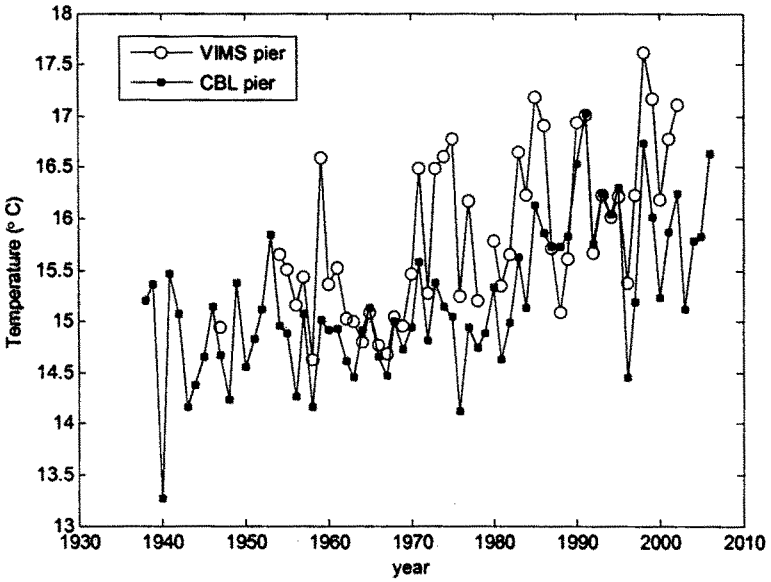


Exhibit 1. Mean annual water temperature at the Chesapeake Biological Laboratory (mid-bay) and the Virginia Institute of Marine Science (lower-bay).

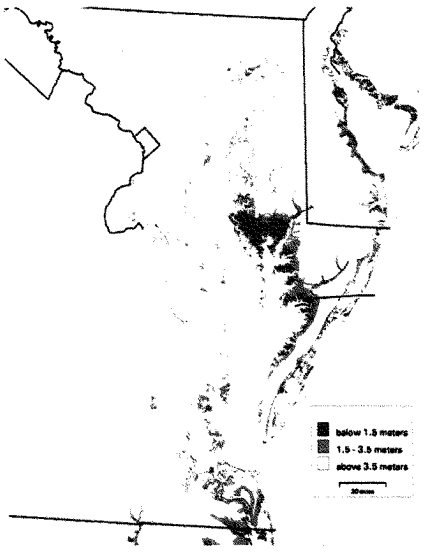


Exhibit 2. Land areas estimated to be less than 3.5 meters above mean sea level in 2000.

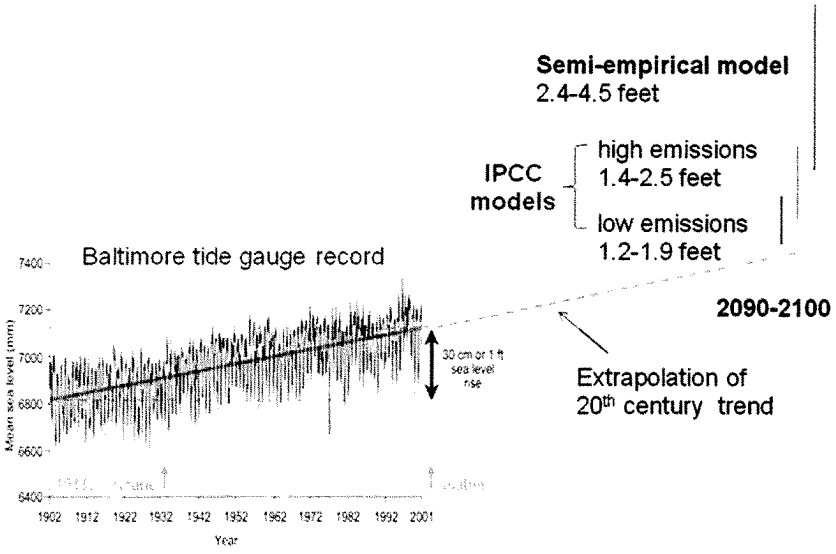
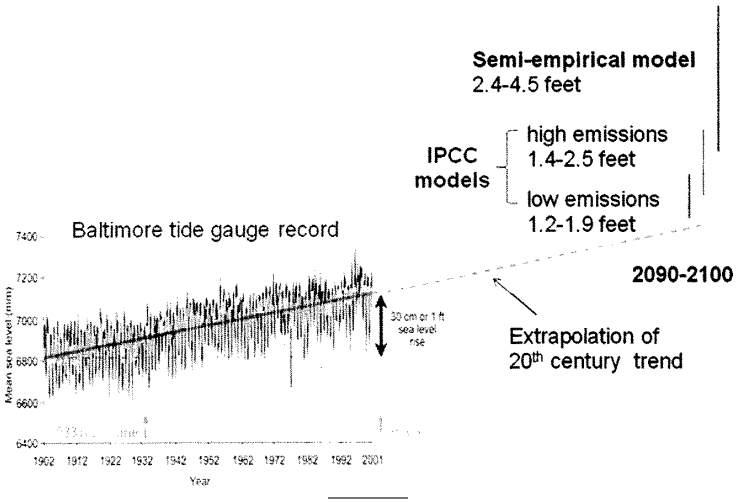


Exhibit 3. Baltimore tide gauge record for the 20th century and sea level rise projections for the 21st century.



Mr. GRIJALVA. Thank you, Doctor.

Let me know ask Dr. Anson Hines, Director, Smithsonian Environmental Research Center.

Dr. Hines, thank you for your hospitality here at the Center and your comments, sir.

STATEMENT OF ANSON H. HINES, PH.D., DIRECTOR, SMITHSONIAN ENVIRONMENTAL RESEARCH CENTER.

Dr. HINES. Thank you, Mr. Chairman, Madam Chairwoman Bordallo and members of the distinguished Committee. I've worked here in the Chesapeake Bay and conducted research for 30 years and have been the director leading programs here for the last 22 years. I am very pleased to host the field hearings on impacts of climate change on the Chesapeake Bay.

From its inception in 1965 SERC was established to track and understand the effects of climate change on coastal ecosystems of the Chesapeake Bay. SERC's primary study system now encompasses 2,650 acres of land and 16 miles of shoreline on a sub-estuary of the Chesapeake Bay. These resources include unique archeological resources spanning the human history of utilization of these natural resources as well. From its beginning we focused on ecosystem responses to what ecologists call forcing factors of the weather, the warm climate.

For more than four decades now SERC scientists have been developing unique long-term dataset models and experiments to try to understand the effects of climate change that would impact the Chesapeake Bay and the surrounding region. Without that long-term sustained effort we would not be able to really identify and assess the changes that are occurring in the environment that are so pervasive today.

In the 45 years since SERC began, we have seen a 2.5 degree rise in temperature in the Bay, warmer winters, hotter summers, a 15 percent increase in carbon dioxide concentration at this site, a four-inch rise in sea level, and fluctuating patterns of rainfall and

storms. While these factors track the global trends in climate change that we read about daily in our literature and the newspapers, the responses of ecosystems like Chesapeake Bay are not very certain.

The reason is that the mechanisms of ecological response to these forcing factors are not adequately understood, especially when we consider the complex interactions of many other human activities overlaid on climate change, factors such as land use change, fishery management, shipping and ballast water and pollution controls. Our goal here at SERC is to understand the mechanisms of these ecosystem responses to reduce that uncertainty.

Let me just mention briefly two or three examples of SERC's climate change research. The first example is the world's longest running experiment on the effects of rising CO_2 on natural plant communities which is being conducted for the past 24 years on the salt marsh here on the Rhode River. SERC scientists are using experimental chambers to test the effect of doubling of CO_2 concentrations in the atmosphere which are predicted in this century.

Those tests are reflected in the responses of two dominant plant species here. One, a sedge, has responded very positively with increased growth rates in response to rising CO_2. The other, a salt marsh hay, shows no significant response. This rising CO_2 could have effects on shifting species composition of salt marshes and probably other plant communities. This long-term experiment is also yielding unique insight into effects of rainfall, nutrients, and rising sea level.

The second, we've been tracking forest dynamics for 30 years, mapping tens of thousands of trees and 50 different species. Some of these species, especially tulip poplar and sweet gum, are responding vigorously to rising CO_2 and temperatures, while others like oaks are showing a decrease. These have big consequences for the carbon balance of the watershed and the effects of water balance on the watershed as well since evapotranspiration of trees can send as much as 60 or 70 percent of rainfall back into the atmosphere.

Third, and last, I would mention invasive species. Dr. Boesch mentioned SERC as the national center for the study of marine invasive species and home of the National Ballast Information Clearinghouse, which tracks ballast water discharges by all commercial ships. SERC's national database documents more than 160 species invading the Chesapeake Bay, and our research indicates that warming temperatures in winter and early spring can facilitate invasions from the South into the Mid-Atlantic region.

In conclusion, I would say that while climate change is already upon Chesapeake Bay and the rate of change is accelerating globally, ecosystem responses to climatic factors are highly uncertain and much more environmental research is needed to understand and predict those changes. The Smithsonian Institution will utilize its substantial scientific capabilities for monitoring, understanding, and predicting those effects.

Second, environmental research should include the key long-term data analyses that SERC and other research communities of the Bay program have developed to interpret that change and are critical to our predictions of the future. Last, the immense scale and

complexity of the climate change problem requires team work and partnerships at many levels of scientific and management organization.

SERC and other parts of the Smithsonian intend to continue to play a major role in collaboration with academic institutions, state and Federal government partners and non-government organizations to address these critical needs. Thank you very much.

[The prepared statement of Dr. Hines follows:]

Statement of Anson H. Hines, Director,
Smithsonian Environmental Research Center

Introduction

Thank you Chairwoman Bordallo and Chairman Grijalva and distinguished members of the Subcommittees for the opportunity to provide testimony today. My name is Anson Hines. I am the Director at the Smithsonian Environmental Research Center located here in Edgewater, Maryland. I hold an advanced degree in Zoology. I have led Smithsonian's environmental research programs on Chesapeake Bay for more than 22 years and have served on the Smithsonian's steering committee for its Marine Science Network of coastal research facilities that extend from Chesapeake Bay to Florida, Belize and Panama for 15 years. I have conducted intensive long-term research on the ecosystems, species composition and population dynamics of estuarine organisms in Chesapeake Bay for 30 years. I am very pleased that the Smithsonian Environmental Research Center is hosting the joint subcommittees' field hearing on impacts of climate change on Chesapeake Bay.

The greatest challenges to our environment today are in the coastal zone where 70 percent of the world's population lives, works, and plays. The ecosystems at the land-sea interface are also among the most biologically productive, and their health and sustainability is critical for the survival of both ocean and terrestrial environments, and the wide range of services they provide. These are the ecosystems that will be the most affected by climate change in the United States. There can be no better focus for impacts of climate change in the coastal zone than the Chesapeake Bay, the nation's largest and historically most productive estuary.

The Smithsonian Environmental Research Center (SERC) is one of the world's leading research centers for environmental studies of the coastal zone. The Smithsonian Institution established SERC in 1965 to track and understand effects of human interactions in coastal ecosystems, using Chesapeake Bay as its primary study system and a model for the nation. SERC science and education focus on key environmental issues facing this nation and the world. SERC works with government agencies, academic institutions, and the public to incorporate rigorous science into resource management and stewardship decisions.

My purpose today is to summarize the main themes and results of SERC's world-class research on climate change. From its inception, SERC was established to track and understand the effects of climate change on coastal ecosystems of Chesapeake Bay. SERC's primary study system now encompasses 2,650 acres of land and 16 miles of shoreline surrounding a subestuary of the Bay, providing a unique opportunity for intensive monitoring and controlled experiments on linked ecosystems of watershed and estuary. From its beginning, this research has focused on analyses and long-term measures of the ecosystem responses to what ecologists call "forcing factors" of weather—the seasonal and annual fluctuations in temperature, rainfall, and storm events. For more than four decades, SERC scientists have been developing unique long-term data sets, models, and experiments on ecosystem responses to climate change that extend out to the large Chesapeake region. I cannot emphasize enough the importance of the Smithsonian's commitment to long-term research. Without this sustained effort and these unique data sets, we would not be able to identify and assess changes occurring in the environment. Moreover, SERC's commitment to understanding the mechanisms of complex—often interactive—ecosystem responses allows us to provide sound advice to resource management and policy.

Atmospheric Change, Climate Change and Environmental Change

Since SERC began its long-term studies on Chesapeake Bay, our scientists have measured many environmental changes associated with climate change in studies conducted over time periods of 20 to 40 years. These variables are the "forcing factors" of the environment that drive the ecological responses in the Bay's ecosystems.

Much of the rise in atmospheric CO_2 has occurred in the past half century, which is the time period since SERC was established. SERC monitoring at Chesapeake Bay show that the concentration of atmospheric CO_2 has risen by 40 parts per million (ppm) or 14% since 1987, when it was measured at 340 ppm and it is now about 387 ppm.

Due to changes in composition of gases in the upper atmosphere, characteristics of solar radiation—particularly the ultraviolet (UVB) portion—reaching the surface of the Earth have changed. As part of a national and international monitoring network, SERC scientists have developed the longest running data set in the world for this portion of the sun's energy, and these data show that the UVB level (as average midday sunburn radiation) at Chesapeake Bay has increased by 15% in the past 36 years.

During SERC's 45-year history of research on Chesapeake Bay, we have witnessed much warmer temperatures, with a record number of hot summers and also milder winters. Water temperature of the Bay has increased by about 2.5oF (1.3oC). Most of these temperature changes have occurred in the past two decades.

Patterns of rainfall are much more varied and lack clear trends, but climate models generally predict greater rainfall overall for the Chesapeake Bay watershed, with precipitation likely to be more episodic and dispersed among drought periods. These changes could have large impacts on watershed discharges into the Bay. SERC scientists have documented the frequency and intensity of storm events and of droughts at its long-term study site on the Rhode River subestuary and watershed in relation to the broader regional variations in precipitation and consequences of the Bay's water balance and water quality. These records include a full spectrum of storm intensity from Hurricane Agnes in 1972 and Isabel in 2003 to localized thunderstorms.

Sea level has risen approximately four inches (10 cm) over the course of SERC's long-term research. The present rate of rise at 3mm per year appears to be accelerating globally and may be exacerbated in the Chesapeake region by coastal subsidence and by changes in off-shore currents that can push water up into the Bay. Rising sea level may have major impacts on the marshes and other shoreline ecosystems of the Bay.

Chemical changes in the Bay are occurring as a result of, and interacting with, climate change. Clearly, the large problem of nutrient loading (nitrogen and phosphorus) running off the watershed and into the Bay is not only a problem of managing land use, but it is also related to the quantity and timing of precipitation effects on stream discharges. One third of all anthropogenic CO_2 emitted into the atmosphere has been absorbed by the oceans, reducing pH by about 0.1 of a unit and significantly altering their carbonate chemistry. There is widespread concern that these changes are altering marine habitats severely, but little or no attention has been given to the biota of brackish and fresh waters, which have less pH buffering capacity than the ocean. The amount of mercury falling from the atmosphere into ecosystems has tripled over the past 200 years as a result of burning of fossil fuels since the Industrial Revolution.

Responses of Chesapeake Ecosystems to Climate Changes

The pervasive and accelerating rates of these climate changes are becoming ever more evident. However, responses of the Bay's and the Earth's biological systems to these forcing factors are a major source of uncertainty in predicting effects of climate change. The complex and interactive aspects of the Bay's responses to climate change require detailed studies of mechanisms of ecosystem controls across the coastal landscape.

Salt Marshes. Salt marshes and other wetlands are important ecosystems providing nursery habitats for fish and shellfish and other animals, sources of carbon into the Bay's food web, modifiers of water quality, and regulators of key chemical compounds including nitrogen, sulphur, carbon dioxide, methane, and mercury in the Bay. Salt marshes are also relevant models for the responses of plant communities to rising atmospheric CO_2, because they are include common species that are representative of the two major biochemical pathways of photosynthesis in plants. Termed C3 and C4, the two types of plants are hypothesized to respond differently to rising CO_2.

For 24 years (1985-2009) SERC scientists have conducted the worlds' longest running experiment on effects of rising CO_2 concentrations on natural plant communities at a salt marsh ecosystem of Chesapeake Bay. Funding from the Department of Energy allowed these scientists to test the effect of doubling of CO_2 levels on two major plant species of the marsh. The experiment showed that growth and biomass production of marsh communities dominated by one species—Scirpus olyneyi, a sedge representative of C3 plants—is markedly enhanced by rising CO_2. By con-

trast, marsh communities dominated by another species—Spartina patens, a salt marsh hay representive of C4 species—shows no significant response. These results suggest that rising CO_2 could cause shifts in species composition of salt marshes and probably other plant communities, with decreasing grasses (C4) and increasing sedges (C3) species. SERC's long-term marsh experiment shows changes in species composition in response to the interactions of both more modest rises in CO_2 and variations in other factors.

This long-term experiment yielded unique insights into the effects of environmental variability on CO_2 impacts, especially the importance of rainfall affecting water availability and salt stress in the marsh. Because rising CO_2 enhances water-use efficiency of plants, low rainfall and drought markedly enhances the effects of CO_2 impacts on plants. Importantly, this unique on-going experiment allows SERC scientists to track the long-term ecosystem responses to the complete array of climate change variables with controls for the effects of rising CO_2.

The salt marsh project has been supplemented in recent years by funding from the National Science Foundation and U.S. Geological Survey to SERC scientists to address carbon storage in peat of marsh soils of Chesapeake Bay. This aspect of the project is focused on interactive effects of nutrient (nitrogen) enrichment and rising sea level—two key confounding factors in coastal systems. Initial results indicate that carbon sequestration enhanced by rising CO_2 resulting in peat accumulation in salt marshes is keeping up with sea level rise in Chesapeake Bay. However, increased nitrogen loading—a major problem for the Bay—can inhibit or divert belowground carbon storage, preventing peat accumulation from keeping up with sea level rise. This confounding effect of nutrient pollution and rising CO_2, coupled with the probability of acceleration in sea level rise, could cause inundation of the Bay's salt marshes and other wetland, with serious losses of ecosystem function for the health of the Bay.

Forests. Forest ecosystems play crucial roles in regulating water run off in the Chesapeake watershed. They also play a major role in carbon sequestration that mitigates the CO_2 inputs into the atmosphere from fossil fuels. For the past 30 years, SERC scientists have been tracking long-term changes in species survival and growth in carefully mapped plots of tens of thousands of trees at the Rhode River site, which has the highest biodiversity of tree species in the region. Tracking 50 species, this research allows SERC forests scientists to measure and model tree growth in response to climate variation. Some species are responding vigorously to CO_2 and temperature, especially tulip poplar and sweet gum, while other species such as oaks appear to be declining in growth rates. This suggests that climate change will promote significant changes in species composition of forests of the watershed, which will in turn affect rates of carbon sequestration, leaf litter decomposition and nutrient cycling. Forests also have major effects on water processing and transfers across the landscape, because evapotranspiration by trees can send as much as 60-70% of rainfall back into the atmosphere, reducing run-off and modifying rising temperatures. Thus, forests play a key role in regulating stream discharges and nutrient pollution into the Bay.

Additionally, SERC and other science research units of the Smithsonian are engaged in partnerships linked to national and global networks for tracking forest responses to climate change. SERC's detailed forest studies are now being integrated into both the emerging National Ecological Observatory Network (NEON) of the National Science Foundation and the Smithsonian Institution Global Ecological Observatory (SIGEO) initiative. SIGEO is a multi-institutional global network of 34 forest research plots. NEON has proposed that the Smithsonian's Conservation and Research Center in Front Royal, Virginia, serve as the permanent monitoring site for the mid-Atlantic "domain" (region) of the nation; and SERC has been proposed as one of the initial "re-locatable sites" for the region. NEON seeks to provide additional research infrastructure and instrumentation to track long-term environmental change within and among regions of the country in response to climate change and other factors. SIGEO will link these Chesapeake forest studies to a network of mapped forests in the tropics around the world and to several additional mapped forests in the temperate zone of North America. SERC scientists will be using these networks to set up instrumentation that measures the ecosystem fluxes of carbon dioxide, water, and energy through forests in response to climate change and forestry management. Variation in these fluxes, and the factors that control them in forests, account for much of the uncertainty of climate change predictions in the Chesapeake Bay watershed, with important ramifications for Bay waters proper.

Chesapeake Watershed Dynamics: Stream Discharges

As climate change affects the quantity and timing of precipitation, it will affect watershed dynamics and stream discharges that are critical to managing water quality and health of Chesapeake Bay. SERC's watershed studies measure and model stream discharges of water, sediment and nutrients as a function of precipitation, land use, and geological features. SERC's watershed models have significantly improved predictions of nutrient loading into the Bay. One of the important uncertainties of watershed dynamics is understanding the effects of variation in evapotranspiration by forests on stream discharges. SERC's expanding analysis of factors affecting water balance in forests will contribute new insights in this area. Long-term measures of storm events on the Rhode River watershed also provide measures of sediment transfers and fluxes of toxic chemicals such as mercury. SERC data, like data from other regions, clearly show that these large storm events caused major disturbance and influxes of water-borne sediment and chemicals. This means predictions of increased frequency and intensity of storms associated with climate change will have negative impacts on Chesapeake Bay.

Bay Water Quality, Plankton Production, and Oxygen Levels

Watershed discharges of nutrients into the Bay affect water quality and fuel phytoplankton production, which in turn affect oxygen levels. SERC researchers have tracked the sources of nutrient discharges that stimulate plankton dynamics and harmful algal blooms in the Rhode River as a model system for the upper Bay. These studies suggest that the spring plankton bloom may be occurring earlier with advanced seasonal discharges from the Susquehanna River. SERC's long-term research shows that summer-time turbidity is increasing in the Rhode River and upper Bay, much of which appears related to re-suspension of sediments rather than to plankton blooms. This indicates that factors other than watershed discharges also affect water quality, adding further uncertainty about the effects of climate change and watershed discharge into the Bay. The seasonal timing and intensity of plankton production affects light penetration into the Bay's waters, and SERC research and models show how these factors affect light needed for growth and restoration of submerged aquatic vegetation, which forms important habitat that has declined drastically during the past 40 years.

Fishery Production

Climate change can have both positive and negative affects on fishery species of the Bay. SERC scientists have conducted extensive studies of blue crabs, as the major fishery in Chesapeake Bay. As a species of tropical origin, blue crabs are likely to be favored by warming. SERC research on the life history and demography of blue crabs indicate that their reproductive output will increase, growth will speed up, and time to reach maturity will shorten as the warm season lengthens in Chesapeake Bay. SERC research indicates that mortality of small juvenile and adult female crabs during harsh winters may be reduced by climate warming that makes for milder winters. While this will have positive effects on population dynamics, a number of other factors may have negative effects on blue crabs. For example, rising temperatures cause losses of sea grass beds in the lower Bay, which is important habitat for newly settling juvenile crabs. SERC research shows that warming temperatures will also increase predation rates on juvenile crabs, and may increase the abundance and species of crab predators from southern latitudes.

Oysters require calcium carbonate for shell growth, and restoration of this ecologically and economically valuable species may be affected by acidification of Bay waters due to rising CO_2, just as ocean acidification may have adverse impacts on coral reefs. Current research by SERC scientists show that acidification of estuarine water has negative impacts on shell growth of larval oysters as higher levels of CO_2 cause shifts in the chemical balance of carbonate deposition calcium in their shells. Larvae of native oysters (Crassostrea virginica) experienced a 16% decrease in shell area and a 42% reduction in calcium content when comparing treatments of CO_2 levels projected from pre-industrial time periods and the end of 21st century.

Invasive Species

SERC is a national center for study of marine invasive species and the home of the National Ballast Information Clearinghouse, which tracks ballast water discharges by all commercial ships arriving to all U.S. ports—the major source of introduced species in coastal waters. SERC researchers are analyzing the patterns of invasions in Chesapeake Bay in comparison to other parts of the U.S. coastal system. SERC's national data base documents more than 160 invasive species in Chesapeake Bay. Increasing temperatures can facilitate invasive species spreading from the south into the mid-Atlantic region. SERC research shows that such range ex-

pansions often result from warmer winter temperatures and earlier springs, rather than from hotter summers. Other invasive species such as the southern marsh reed Phragmites australis are spreading very rapidly across Chesapeake salt marshes, appear to respond very positively to rising CO_2, and are likely to out-compete the native plants that are already under stress from rising sea level and nitrogen pollution. Terrestrial invasive species also affect the Bay's responses to climate change. For example, SERC research on earthworms—most are invasive species introduced long ago from Europe—have major effects on carbon processing and sequestration of leaf litter in forest soils. These effects facilitate shifts in species composition of trees in the forests, again with important consequences for water movement through the watershed. SERC's research show that still other species, such as mitten crabs and snakehead fish from Asia, may become established and spread in the region through complex factors interacting with climate and a range of other disturbance factors.

Complex Interactions: Mercury in Seafood as an Example

The environmental forcing factors of climate change interact with many effects of other human activities that are impacting Chesapeake ecosystems (such as land-use change, fishery management, shipping and ballast water, pollution controls). These interactions are likely to have complex and indirect consequences for Chesapeake Bay that may be just as important as the direct effects of climate change. This complexity contributes much of the uncertainty in predictions about ecosystem responses to climate change. These complex interactions are a major focus of SERC's research on the mechanisms of ecosystem responses to climate change.

For example, new SERC research and elsewhere indicates that mercury is a major toxic contaminant that can accumulate in seafood. Mercury is an atmospheric pollutant that often results from burning of coal in power plants, and is transferred into the food chain by a series of steps. As mercury falls from the atmosphere into coastal ecosystems, it is converted into methylmercury by bacteria that reside in wet, low-oxygen soils and sediments. This bacteria-processed methylmercury is what is picked up by organisms and concentrated up the food chain into seafood. Recent and on-going SERC research shows that once mercury falls into salt marshes and other wetlands, it is transformed and released into the Bay's food web. New SERC research and elsewhere indicates that methylmercury is also forming in coastal groundwater, which is released into the Bay in wet spring periods, which are predicted by the Science and Technology Advisory Committee of the Chesapeake Bay Program to be enhanced by climate change in the mid-Atlantic region. Thus, SERC research on mercury contamination illustrates how climate change may indirectly affect the environment and human health.

Conclusions

1. While climate change is already upon the Chesapeake Bay, and the rate of change is accelerating globally, the responses of ecosystems to the changing environmental forcing factors are highly uncertain. Much of this uncertainty is due to the complex ecological interactions with many other factors that are changing simultaneously across the coastal landscape with population increase. To reduce this uncertainty, much more environmental research is urgently needed to determine the mechanisms of ecosystem response to climate change. The Smithsonian Institution will utilize its substantial scientific capabilities towards monitoring, understanding and predicting effects of climate change in Chesapeake Bay.
2. Environmental research should utilize the key long-term data and analyses that are already in place and are critical to interpreting future change. The Smithsonian's commitment to environmental research on Chesapeake Bay clearly shows the value of these data, and the importance of the scientific efforts needed to sustain them.
3. The immense scale and complexity of the climate change problems require teamwork and partnerships at many levels of scientific and management organization. The Smithsonian Environmental Research Center intends to continue to play a major role in collaboration with academic institutions, State and Federal governmental partners, and non-governmental organizations to address these critical needs.

Thank you for the opportunity to testify today and I look forward to answering any questions you may have.

Mr. GRIJALVA. Thank you.

We will now ask if Chairwoman Bordallo has some questions. Thank you.

Ms. BORDALLO. Thank you, Mr. Chairman. I do have a few questions. First for Mr. Moriarty. How is the sea level rise affecting refuges within the Chesapeake Marshlands National Wildlife Refuge complex, especially at the Blackwater and the Susquehanna National Wildlife Refuge?

Mr. MORIARTY. Chairwoman Bordallo, let me first apologize for the apparent miscommunication by the Department about my role here for the hearing. I hope my testimony showed that I am actually representing all three agencies and I have representatives from each of the agencies here with me in case I'm not able to answer the question thoroughly so I apologize for that.

Ms. BORDALLO. So you are in the hot seat today.

Mr. MORIARTY. I am. Thank you. And how is the sea level rise affecting these marshes. Primarily as the water level rises we are seeing loss of wetlands due to increased erosive forces on the edges of the wetlands. In the case of the Blackwater National Wildlife Refuge, we do have an additional factor going on there with the nutria that is an invasive species in the Bay.

The nutria is cutting channels into the marsh. As a result, the channels are allowing more erosive forces to occur within the marsh and it erodes more quickly. Hopefully we have that problem solved on the refuge per se although we still have to work on eradicating the nutria and the rest of the Delmarva Peninsula so it doesn't form as a source for additional impact to the refuge. But the water level is rising and increasing the erosive forces that are occurring on the wetlands and those wetlands are gradually going away.

Ms. BORDALLO. So it has an effect on the refuge.

Mr. MORIARTY. Very much so.

Ms. BORDALLO. I have another question for you. What is the most important far-reaching strategy that National Wildlife Refuges associated with the Chesapeake Bay can employ in light of the complexity of issues that we face as our climate changes?

Mr. MORIARTY. Thank you for that question. I think that is a very good question because it's one that speaks to the need for looking at the system as a larger whole rather than each refuge responding to it individually and what they think they know best. It's best that they all get together and look at the Chesapeake Bay watershed and the landscape that they exist in, what are all the forces that are working there.

So that is why we work very closely with the U.S. Geological Survey and the National Park Service to look at the systems as a whole at a landscape scale. We bring in the science that the U.S. Geological Survey provides. We bring any answers to questions that the Park Service is able to provide to its ecosystem approach, and we integrate them into our planning for the future.

Right now we are at the very beginning stages of that but we're still learning all of these impacts about climate change on our Bay. This conversation, however, will be to the design of approaches toward implementation of protective measures for the refuges or adaptation measures for the refuges as sea level rises.

It will also lead to implementation of those measures and then we'll be monitoring them with the Geological Survey to assure whether they work or not and if another approach would need to

be taken. I would say the best approach is to look at it more holistically at the landscape scale and design your way forward from there.

Ms. BORDALLO. Thank you very much.

Dr. Wood, I have a couple of questions for you. What kind of services is NOAA providing in the Chesapeake Bay region to help communities adapt to climate change and what types of services can NOAA provide?

Dr. WOOD. Thank you, Chairwoman Bordallo.

NOAA offers a wide range of tool, policy, advice and training to states and local communities. NOAA works with the states through a number of programs including the Chesapeake Network for Education and Municipal Officials, otherwise known as CNEMO. CNEMO provides education and training to these officials to help community planners understand and communicate the challenges of climate change to its citizens.

NOAA helps provide core capabilities, technological and science capabilities including LIDAR mapping. LIDAR is a technology like radar but uses light instead. LIDAR is capable of very high detail, high resolution topographical mapping of shorelines. Using LIDAR you can map the changes in the shorelines and understand where erosion rates are the worst and where sea level rise could pose the most significant problems.

Combining this with geographic information system technology that NOAA has, we can layer those threat maps, if you will, on top of layers of other maps that map out where resources that are very valuable, for example, habitats or hard structures, highways that are low-lying areas and are subject to threat by sea level rise and coastal storm inundation.

NOAA is also partnering with the community to develop a Chesapeake Inundation Prediction System. This system is an interesting map-based system which allows individual users—it's a web-based system—you can access it through the web—to chart storm surge. For example, if a tropical cyclone was coming to the Bay, a tropical storm or hurricane, where sea level rise might strike the communities, they actually get resolution on a block-by-block location of their community and they can, again, overlay that with resources they might need in case of emergencies to better prepare them for climate changes.

Ms. BORDALLO. In addition to that, how is the Coastal Zone Management Program helping to support efforts?

Dr. WOOD. The coastal states and the Chesapeake Bay watershed have elevated climate change assessment and planning to a very high priority. CZMA funds have been used by state coastal programs to ensure adaptation planning conducted both at the state and local levels. Activities include formulation of new policies and programs, assistance to localities, and land acquisition. Wherever possible, new programs are providing technological support to these state and local programs.

Ms. BORDALLO. Thank you very much. Dr. Boesch, I have a question for you. You recommend that the Congress adopt legislation to reduce greenhouse gas emissions and to establish a national climate enterprise to support the studies of regional climate dynamics and ecosystems and social responses.

I want to thank you for raising my legislation H.R. 2685 that would authorize a national climate enterprise. Would my bill provide a framework for Federal and nonFederal coordination to fulfill all of your recommendations for better science and better information on the impacts of climate change?

Mr. KRATOVIL. Just a one-word answer, please.

Dr. BOESCH. Yes, Chairman Bordallo, but let me tell you why. As you know, there are many proposals out there.

Ms. BORDALLO. Yes.

Dr. BOESCH. The administration also wants a National Climate Service. I have read your legislation and many other dozens assigned to the community. I think it has a number of advantages over alternatives. They include a mechanism, a framework to involve inner agencies, obviously with no one to lead but involving the other agencies in a very meaningful way and a very high level.

Second, reliance on the capacity that we have already built within this country for regional impact assessment so we bring those together. We think this can be done and your legislation, I think, does that very well and hope that it will pass and be included in the comprehensive legislation.

Ms. BORDALLO. So, as a word to my colleagues, I guess my legislation is pretty good.

Mr. KRATOVIL. The message was subtle.

Ms. BORDALLO. Dr. Hines, I noted with interest when you mentioned that rising CO_2 could cause shifts in the plant species compositions of salt marshes and probably other plant community around the Chesapeake Bay. What are the implications of our efforts to restore and recover wetland habitats today?

Dr. HINES. Well, we've seen clear responses of major plants here at this site to increased CO_2 on an experimental basis. We've also been looking at the interaction with rising sea level and rainfall water availability. What we can see in wetlands, for example, is that the increased growth of these salt marsh plants is being stored in the root system of the plants in the peat system of these marshes. At the moment in the most recent years the rate of that accumulation of peat here at this site is actually just keeping up with sea level rise.

If sea level rise increases, it may have serious impacts and overwhelm the ability of those plants to respond to that inundation problem. But those plants represent the true basic processes, biochemical processes of photosynthesis in the plant kingdom, so it suggests that the complex interactions among plant species will depend on those biochemical pathways and how the two different mechanisms respond.

One is favored and one remains the same. It's an indication of how complex these responses will be and how difficult it is to project exactly what will happen at this point and it is the reason why we are conducting the research here.

Ms. BORDALLO. Thank you. Thank you very much, Dr.

I have a question for the Mayor. Mayor, I am very sympathetic to your situation, you know. I hope someday this doesn't happen to the U.S. territory of Guam, the issues that you brought up about the need for beach renourishment in your town. However, considering that increased sea level and greater frequency of severe

storms is projected to increase erosion rates across the Chesapeake Bay, does beach renourishment make practical sense over the long term?

Mr. BOJOKLES. It may not and that is a good question. Time will tell us what we need to do there. I think not doing something is not a good idea either.

Ms. BORDALLO. Well, that's true.

Mr. BOJOKLES. Yeah. I think in our case we have lost over 1,000—since the early 1900s, we've lost a thousand feet of depth in the shoreline. So now we are down in areas along the beachfront. It could be 50 feet, 30 feet, depending on the tides of the day. I think smarter people than me can tell you that bulkheading and these sorts of efforts don't work either, so I don't think there is a solution.

Ms. BORDALLO. Do you have any idea what the cost is?

Mr. BOJOKLES. For us we have estimated the cost and we actually budget for it every year which is about $25,000 to $50,000 a year depending on how much Mother Nature takes away from us on an annual basis.

Ms. BORDALLO. Right.

Mr. BOJOKLES. We usually try to do that work in early spring or late winter when the tides are very, very low. The problem I'm having now is more of—a funding issue is not for me today. It's more of——

Ms. BORDALLO. It's a long term.

Mr. BOJOKLES. It's the process to get the permits needed to be able to do this. The permit that we have applied for to do the beach replenishment program is in year three. I was elected in 2006 and I'm thinking now I'll be lucky to have that permit in my hands before my term is over.

Ms. BORDALLO. I read that in your testimony.

Mr. BOJOKLES. That is just as frustrating as it can be because we sit there every day and watch it erode every day and it gets thinner and thinner.

Ms. BORDALLO. We have frustrating moments in Congress, too. Would anyone else like to comment on that? Yes.

Mr. MORIARTY. If I might, Chairwoman Bordallo. I think the town of North Beach is in a very difficult situation and I really appreciate their view toward hardening of shorelines because that really isn't the answer. They are in a particular difficult situation because where you find the source of material to provide the beach erosion is an issue. Are you taking it from some other place that it might have to be going.

Ms. BORDALLO. That's right.

Mr. MORIARTY. So the difficulty will get greater and greater every year. I think that is going to raise some very, very difficult questions for the town as it goes forward.

Ms. BORDALLO. Anyone else? Yes.

Dr. BOESCH. Not exactly on that issue but related to this problem of the things washing away. Much mention was made of our salt marshes and how they seem to be disappearing. I think it is important for you folks to understand it's not a simple matter. It's not intuitively obvious the way these work.

I think Dr. Hines mentioned that salt marshes can build their own soil so they have the potential to keep up with rising sea levels, you know, to grow upward by laying down peat from the plant material produced and also by trapping sediments, fine sediments, silts and clays. The problem we are experiencing is that they are not building soil fast enough to keep up in some places like Blackwater with the rise in sea level.

We have another issue which has long been considered a problem in the Chesapeake Bay which is really a resource management issue. We spend lots of effort, the Federal government spends effort, dredging our channels, taking the sediment from the bottom of the Bay and placing it somewhere so we have some options to use this resource, not a waste product, the sediments that we dredge from the Bay to maintain our shipping channels to nourish those wetlands, to allow them to continue to survive over time.

That is another issue. I think the Blackwater refuge is interested and active in considering that and I think we need to think more widely of how to use our resources in a comprehensive way to deal with this problem.

Ms. BORDALLO. Thank you. We also have this problem in the Pacific Islands. You know, a lot of erosion. In Guam, in fact, we had almost a fourth of a park entirely washed away after a typhoon so I sympathize with you and certainly I hope you get those permits before the end of your term.

Thank you, Mr. Chairman.

Mr. GRIJALVA. Thank you.

Mr. Moriarty, this is part question and part comment, I think. The National Park Service units are under a very important mandate and that is to preserve and protect our nation's cultural and natural resources unimpaired for future generations. Based on the predictions we've heard not only here but in other places, climate change is threatening that mandate and in a very serious way. What will it take for the National Park Service to be able to meet its mandate? What kind of resources? What kind of policy if you could explain.

Mr. MORIARTY. Let me first say that opposed to natural resources like fish and wildlife and plants, aquacultural resources don't move very well, and they don't reproduce so they are where they are, by and large. They are the only ones we do have. The question then becomes, how do we protect them in light of these rising storm surges and other rising water levels that increase foundation damage and damage to artifacts kept in basements and things like that? That is a very tough question for the Park Service to answer and they are devoting their resources to that answer right now.

If I might, I would like to turn it over to Mr. Carl Zimmerman who is the natural resources manager at Assateague National Seashore for some additional information on that.

Mr. GRIJALVA. OK. If you wouldn't mind, sir, just your name for the record.

Mr. ZIMMERMAN. Certainly. My name is Carl Zimmerman. I am a resource manager at Assateague Island National Seashore.

Mr. GRIJALVA. Thank you.

Mr. ZIMMERMAN. Not to contradict but I do have responsibilities for both the natural and the cultural resources at Assateague Is-

land. The initial discussion there is certainly true. We face some significant challenges and the National Park Service is trying to protect this nation and their special places.

The cultural resources in particular are particularly vulnerable because, as noted, they are fixed in place. They cannot move in those circumstances. They are unique. Once lost they cannot be recovered. Basically the National Park Service is pursuing a three-prong strategy in response to sea level rise. The first of those is mitigation, attempting to manage our own house and reduce our own emissions of greenhouse gases and be as sustainable as we possibly can in park operations.

The second prong is adaptation and that is directed in three primary areas. First, toward the natural systems that are managed by the National Park Service. Second, toward cultural resources. Third, toward our infrastructure. Many of the parks and areas here in the Chesapeake Bay provide a good example of that. They are located along the water's edge and are vulnerable, making it increasingly difficult to maintain access to some of these resources by the visiting public.

The third prong of our overall response strategy is communication and that is both internal and external. The National Park Service has what I think is a unique opportunity to communicate with the public with 275 million visitors a year all of whom are coming to places that are particularly meaningful for them. We have a great opportunity to speak with them in terms that others do not when speaking to the public about some place that they love when we can articulate the concerns and the specific issues and threats of individual units.

Mr. GRIJALVA. If I may, a specific question, Jamestown just celebrated 400 years last year and excavation has continued since the '90s there. Has the Park Service done a risk analysis of George Washington's birthplace—that particular area? If so, is there a mitigation plan associated with it?

Mr. ZIMMERMAN. The direct answer to your first two questions is no, we have not done risk or vulnerability assessments at those two areas. We are, however, in the process of developing a strategy, a framework strategy, for addressing cultural resource impacts in the parks. There are really several components of that which are being developed, and I caution you to note that this is a work in progress.

Mr. GRIJALVA. I know.

Mr. ZIMMERMAN. First, the components were being cranked up on a service-wide basis to develop comprehensive maps in a GIS environment, the physical location of all of our assets, all our cultural resources. Second is looking at it from a physiographic region perspective to try to identify the threats by physiographic regions on those resources and combining the two to develop a threat assessment methodology. In other words, what resources are in areas that are very vulnerable.

The second part of that is to develop specific criteria to evaluate the opportunities for intervention. Potential criteria will likely be things like severity of threat, the significance of the resource, its uniqueness, the relationship of the resource to the park purpose. Last, feasibility of intervention. I expect very much that we will

end up in a triage situation where we will have to make hard decisions about what gets——

Mr. GRIJALVA. Do you have the authority now under current law to deal with the situation in the question that I asked you or is that authority needed?

Mr. ZIMMERMAN. I believe that we do have the authorities that are needed. It is a matter of developing a prioritized list of those resources. We have opportunities to intervene and then seeking the resource to do that both internally and collaboratively with our partners.

Mr. GRIJALVA. That particular asset resource that you are addressing now, does it have the priority within the department——

Mr. ZIMMERMAN. I believe that——

Mr. GRIJALVA.—given the authority?

Mr. ZIMMERMAN. The service is vigorously approaching this question of how to protect its cultural resources.

Mr. GRIJALVA. Thank you.

Mr. ZIMMERMAN. Certainly.

Mr. GRIJALVA. Dr. Boesch, we've heard testimony in other hearings that a healthy ecosystem is much more resilient and can better adapt to climate change than one that is under stress. First of all, do you concur with that assessment? Doesn't that mean to some extent that ongoing restoration efforts have greater importance and urgency now given the discussion we're having?

Dr. BOESCH. Yes. I think that is a fair characterization. Take the Chesapeake Bay and our effort to try to restore it. There are fundamental problems that are causing widespread degradation in the Bay and the loss of its characteristics, its ecological characteristics, that are so important, as the excessive amount of nutrients that are running off into the land or being discharged into the Bay.

As climate changes, there are a number of things that are likely to change to make that problem worse. For example, models suggest that we will experience more rainfall in the winter and spring to wash the nutrients, the fertilizers and so on, off the land into the Bay.

It means that we need to emphasize taking care of these problems early before it becomes very difficult or impossible to deal with. That is just one example but it means there is some sense of urgency in destroying the ecosystem so they can to the degree possible withstand and adapt to the changes that are before us with changing climate.

Mr. GRIJALVA. Thank you. Dr. Wood, your testimony highlights a number of areas in which NOAA is assisting local and landowners and planners and communities to adapt to climate change. Are there critical areas in which NOAA or its partners need more resources for those efforts? Do we need more resources to do more?

Dr. WOOD. Thank you, Chairman Grijalva. That is a very insightful question. I can't ask—I can't answer on a very specific note because as a scientific expert I'm not prepared in some of these policy matters and can give you an answer for the record.

However, I will say as your insightful question indicated and Don Boesch's solid answer provided, it is very important to continue our efforts to restore the Chesapeake Bay and also to support the local community efforts at the state and local levels, the people

who know their localities best and those assets they want to preserve the most. It's very important to continue to fund programs that provide those training and technical opportunities that can help facilitate the best decisions being made to safeguard our resources.

Mr. GRIJALVA. Thank you. Mr. Sarbanes.

Mr. SARBANES. Thank you, Mr. Chairman. I want to apologize. I'm probably going to have to scoot after I ask questions because we've got a healthcare hearing going on. I'm particularly distressed at this because I wanted to hear Bernie Fowler on the next panel but I'll get the notes from folks.

I have a random assortment of questions. Many of the topics I wanted to address have been touched on but I wanted to come back, Don, to this question about how much harder the job of restoring the Chesapeake Bay that we are already embarked on is going to be as a result of climate change? Many of us are excited because we feel like there is a new level of commitment to cleaning up the Bay and also that we have at our fingertips much better data and information to allow us to do that, particularly sort of at the tributary level, farming, citizens to take ownership of that responsibility right in their own backyard.

We are all gung ho about that. The President has signaled a high level of commitment to the health of the Chesapeake Bay and we are kind of ready to go and then here comes climate change to complicate the whole situation.

I don't know if you can quantify it but maybe you can roughly. How much extra burden is climate change placing on this kind of original responsibility we have undertaken to clean up the Bay through the various means that have been outlined over time? Tackle that one more time because I'm particularly intrigued by that issue.

Dr. BOESCH. Sure. A very challenging question. Let's see if I can try to address it shortly but positively. The Bay that we want to achieve isn't the Bay we can achieve. Let's put it this way—isn't Senator Fowler's Bay because the world is changing and the climate is changing but we can achieve some of the characteristics, some of the vitality of that ecosystem in a changing world understanding that the target is always going to be moving to some degree and outside of our direct control.

This notion of achieving tipping points where the ecosystem restores itself to the point that it can regulate itself and restore its basic positive qualities and its productivity is something that we are now trying to direct the goals here for Maryland's restoration efforts.

Rather than a challenge, I actually see climate change as providing an opportunity to deal with Bay restoration. Why is that so? Well, if we think about the changes that we have to put in place that deal with climate change, energy conservation, a reduced footprint on the landscape, smarter growth, better transportation systems, all of those kinds of things can actually be positive forces to correct some of the problems that are causing problems within this Bay's watershed. We really need to look how these work together.

A good example would be when you are considering legislation now on climate change we need to think about how we can have

win/wins so that, for example, if we also try to deal with the problems of agriculture on the landscape, can they be part of the climate change solution with respect to carbon capture sequestration? Can they get credits and benefits for that at the same time they are doing practices that help reduce nutrient runoff in the Bay. That is just one example of the kind of accountability that we need to seek for as we try to solve both of these challenges together.

Mr. SARBANES. I guess what you are saying is that here we are trying to deal with the Bay, clean up the Bay, institute best practices at all levels with respect to the Bay under this threshold charge we have to try to restore its health. Then here comes climate change to raise our awareness to another level and begin to push the public policy that will put a larger framework in place and will lead to the kinds of practices and actions that will also benefit the Bay.

That is kind of a positive slant that you can put on that. Of course, that is premised on the notion that we will take those larger framework actions with respect to climate change. As you have all pointed out, that legislation is moving along right now having set some targets on emissions and many other goals that hopefully are going to have a positive effect.

Again, try to provide some quantification here for a moment. The mayor spoke about needing to replenish the beachfront there at the cost of $25,000 to $50,000 a year. Let's say climate change got no worse from this point forward. How many years more of each replenishment recognizing, as you all have, that may not be the ultimate answer but let's just go with that for a moment.

I mean, do you assume for your model that he's going to have to be replenishing that beach based on what is going on right now for 20 years, 30 years, 50 years, or do we get a tipping point sooner rather than later based on the actions that we take?

Dr. BOESCH. Sea level rise is a very challenging force in that regard because it is a slow responder so even if we tomorrow stopped increasing the greenhouse gas emissions, even reduced them to the 80 percent reduction targets that we are talking about down the road, sea level would continue to rise as a result of the inertia from the change in the system, picking up heat, the ice is melting, so on.

It's going to be with us. The point I make is that we have a choice to make. We can deal with the problem and reduce our emissions and probably have something like twice as much sea level rise as we had last century this century or we cannot deal with the problem and have four times as much sea level rise as we had last century. My best effort to try to characterize the nature of the differences and how dealing with sea level and dealing with greenhouse gas emissions will affect the challenges we have to face.

Obviously I think the mayor would have a far different problem. You're not still going to be in office in 2090 but your successor if he sees that very dramatic rise in sea level, you cannot maintain a beach in a static position under those circumstances.

Mr. SARBANES. Thank you. I don't have anymore questions. I have used for myself as a way of understanding this the metaphor or analogy, I guess, of a levee that we are worried about breaching. I guess I understand that even after the rain stops the river can

continue to rise for a period of time before it stabilizes and begins to recede.

That is the lens I kind of use when I think about the climate change, what we don't know. Would you agree with this that we don't know yet whether the levee will be breached? In other words, whether we have gone past when this climate change is to the point of no return?

Dr. BOESCH. The climate is changed. The forces that cause climate change that are acting in place basically do not allow us to return to some past. The best we can hope for is to stabilize the change so that it won't change so much in the future. This is particularly challenging for sea level rise because those are long-term responses.

If by the end of this century we have not stabilized the greenhouse gas concentrations, the scientific evidence suggest that we will probably be approaching an unstoppable meltdown of the polar ice sheets. Then we will be looking at not in this century but in subsequent centuries a sea level rise of 20 to 30 feet. At that point we can't do anything about it to stop it. It's already over the hill and it's melting down and we can't turn back the clock.

It's that kind of a levee level that we are talking about. Most of the scientific assessments suggest that we have to try to control the greenhouse gas concentrations so that we don't exceed an average increase in world temperature of about 2 degrees Celsius so that is the target that you folks are considering in Congress in terms of trying to reach something like an 80 percent reduction of our emissions by 2050 are all conditioned to.

If we don't do it, don't do it in the first half of this century, it's too late. In terms of those kinds of levee breeches, that is what we need to think of, 2050 reducing it by something like 70 to 80 percent or face a future which is much more drastic than the one we have outlined in the subsequent centuries.

Mr. SARBANES. Thank you.

Mr. GRIJALVA. Mr. Kratovil, questions?

Mr. KRATOVIL. Yes. Thank you. I wanted to start off with a more general question, Dr. Boesch. You mentioned that you are hoping that at some point in this year we may get to this energy bill. It appears we may get to this energy bill this week. As you may know, I'm on the Ag and on the Natural Resources Committee which gives me a very unique perspective to hear about the benefits and criticisms of a lot of this legislation moving forward on environmental issues.

My question is I'm wondering whether each of you have reviewed the energy bill as proposed and, if not, if you haven't specifically reviewed it, in terms of what you do know about it what your overall impression of it is in terms of dealing with the issues that you so much care about. Two, what do you see as the primary strengths or weaknesses with the legislation in dealing with climate change. That goes to all of you.

Dr. BOESCH. Well, I don't know if anyone has read the energy bill. I haven't read it but I have kept abreast of the coverage and the debates about the bill. I'm not an expert on a lot of the economic policies or energy generation policies. Let me just speak to some of the things that I know about.

If this is going to be successful, it's going to have to be—we are going to have to have a bill that allows us and provides incentives for conserving energy in an enormous way. That is the low-hanging fruit. There is an enormous opportunity by just conserving our energy use.

Second, it has to provide an ability incentives for switching to renewable sources of energy. In the long run, we need to think about whether we can capture carbon from burning fossil fuel. That is a long-term R&D challenge. We need to find incentives to reduce renewal energies.

The third part, which I think people don't necessarily understand which is very important, is land use. Of course, the landscape is involved in the dynamics of carbon dioxide as Dr. Hines mentioned. Plants take up CO_2. They sequester it in their roots and trees and soil and the like so we need to have a bill which makes sure that we are managing land uses in a way that maximizes the opportunity for capturing carbon.

As I mentioned in my answer to the question earlier, for example, I think part of the debate with respect to the Committee on Agriculture is this issue for Agriculture to participate in this part of the program with respect to carbon sequestration in soils, for example. I think we need to find ways to do it.

I think it needs to be married with the other kinds of challenges, just as I mentioned earlier in dealing with the Bay. If we have a problem with dealing with agricultural non-point source pollution and if we have some practices that can actually prove that problem and also allow us to capture more carbon in the soil, we ought to provide incentives for that rather than not allow that because of some rules that don't include those sort of practices just for an example, Mr. Kratovil.

Mr. KRATOVIL. Thank you.

Anybody else?

Mr. MORIARTY. The Department of the Interior is releasing a statement of policy on the bill today. However, I am not able to speak about it until it's out.

Mr. KRATOVIL. Fair enough.

Mr. MORIARTY. We can e-mail that to you right away if you would like.

Dr. WOOD. Again, as a scientific expert on climate change I am not an expert on that bill but I can say that the administration supports cap-and-trade and clean energy policies that can continue to make a difference here.

Mr. KRATOVIL. Dr. Boesch, one of the concerns that was raised to me by some of the Maryland folks was given sort of Maryland's leadership in many ways on a lot of these issues given the nature of Maryland and the Bay and so forth concerns that the National standards may not be as tough as Maryland. Any concerns in that regard?

Dr. BOESCH. I am not aware of any such specific concerns. Maryland has taken action under the Governor's climate change commission and has enacted several pieces of legislation that would, for example, require clean cars, California standard cars that EPA is going to reverse the decision made in the previous administration that will allow that to take hold.

We are participating in the regional greenhouse gas initiative for a cap-and-trade program for electricity generation in the Northeast already. I think that will continue and be built on. In addition to that, of course, there is the legislation that would set a state policy on reduction of greenhouse gas emissions by 25 percent by the year 2020.

That is just the down payment on the long-term goal. To meet the long-term goal it can't be done without Federal assistance and Federal involvement over the long-run. I don't see any real problem with what I have seen in the Federal legislation that would diminish the efforts here in Maryland. In fact, quite the contrary. I think it would give us additional incentives and opportunity to meet the state goals.

Mr. KRATOVIL. What role do you see that Ag can play in dealing with the climate change issue? Specifically what can the Ag industry be doing to help with this problem?

Dr. BOESCH. I think what I mentioned was to see how well they can play in capturing carbon. We have a general problem in this country of diminishing quality of soils because of the way we farm and that has reduced the carbon resources of those sediments. We can turn that around and provide incentives for practices that do it related to tillage and a number of other practices, but also the kinds of crops that are grown.

Second, there is the big issue, of course, of biofuels and the role agriculture will play in producing alternative sources of energy. I think the challenge there is to do that in a way that is full cost accounting of how we produce the biofuels. I think you are aware of the criticisms of corn-based ethanol of not really benefitting in terms of greenhouse gas emissions having a lot of side effects.

I think if we think about other kinds of biofuels and develop the R&D to use those, Agriculture could play a very important part.

Mr. KRATOVIL. Based on that you think it would be significant to allow Ag to participate in that offset program?

Dr. BOESCH. I do, particularly when we are accomplishing some regional goals like restoring the Bay and also sequestering carbon. I mean, it's a win/win situation.

Mr. KRATOVIL. OK. Let me go back to a question that was already asked dealing with Blackwater and the problems we are seeing at Blackwater. Specifically what are we looking at in terms of mitigation of the consequences of that?

Mr. MORIARTY. In terms of mitigation, we are looking at—with the Corps of Engineers there is a very serious look at how we can use the dredge that was mentioned earlier to augment the self-building of the marsh. How that has formalized I am not fully aware. I could ask Leo Miranda, my field supervisor from the Chesapeake Bay field office if he could fill us in on that.

Mr. MIRANDA. Yes, Leo Miranda, Chesapeake Bay Field Office. Together with the Army Corps of Engineers and the U.S. Geological Survey and other agencies we have been in discussions how to mitigate for sea level rising in Blackwater National Water Refuge, the restoration of Barren Island and also some areas within the mainland refuge itself are being right now discussed and designed to try to mitigate for those.

The other thing that we are trying to accomplish through this partnership is to restore private lands around the Blackwater National Wildlife Refuge to basically in a strategic way to mitigate for sea level rise and plant change issues.

Mr. KRATOVIL. And the measures that you have taken at Poplar Island, as an example, have those been successful in your view?

Mr. MIRANDA. We have learned a lot from Poplar on how to establish and protect these sites. Looking into the future we are looking at more like these and using win/win situations.

Mr. KRATOVIL. One more just to follow up to Congressman Sarbanes' question. He asked generally the continuing impact of global warming on our efforts to restore the Bay. Let me take that a little more specifically. Specifically how does that impact our ability to specifically restore our oyster and crab populations?

Dr. HINES. Well, the issues are trying to manage the fisheries and restoration of these systems. The whole Bay ecosystem is responsible for that productivity so the increasing emphasis on an integrated ecosystem management approach rather than trying to manage individual species by species fisheries is a much more scientifically sustainable approach but there are complications of that.

In the case of crabs, the increase in salinity and increase in warming temperatures may favor crabs, for example, since it is a species that evolved in tropical systems. On the other hand, it may also impact some of the habitats that we know crabs need, such as eelgrass systems in the lower Bay which are at the southern end of their range and are harmed by hot summer temperatures.

It's a complicated system and the multiple stressors that we see in the system are confounded by the magnitude and rate of climate change to make it difficult for scientists to predict exactly what will happen for any single species. As a whole, we need to be taking a much more integrated approach trying to manage the multiple species of fisheries and the supporting species with them if we are going to be successful. If we continue on the path that we have been doing species by species, it's clear that we will not succeed and the history is not a very good one in the Chesapeake Bay or elsewhere.

Dr. WOOD. I think that is an important question because after 25 years of efforts to restore the Chesapeake Bay we realize that there is still frustration regarding a perceived lack of impact to the degree that people would like to see. One of the problems in demonstrating impact is that climate variability from year to year masks some of the changes we can make in best management practices in that the amount of nutrients that is contributed during a wet year, for example, is much higher than anything we can change incrementally from year to year.

Climate change is predicted to bring higher spring and late winter runoff events to the Bay. That is likely to contribute to more nutrients in terms of the effect on the Bay. We will be concerned as scientists and most people on this panel will probably agree that might exacerbate the problem we see in low oxygen or dead zones.

Of course, since those are low oxygen zones at the bottom of the Bay they keep fish like striped bass from being able to access the cool waters they prefer and the resources, the worms and things, that they would otherwise feed on. Oysters since they can't move,

of course, are predisposed to problems of death as low oxygen zones invade their habitats.

Last, the work that we conducted with partnerships with the University of Maryland and others show that especially stream runoff events can contribute to the over abundance of disease-causing microorganisms in the Bay that affect both shellfish and humans so we would be concerned about that, too, in the context of continued efforts to restore the Bay.

Dr. HINES. Thank you.

Mr. GRIJALVA. Thank you and let me thank the panel. Thank you, gentlemen. It was very informative and very helpful. Thank you very much.

Let me know invite our next panel up, please.

Gentlemen, thank you very much and welcome. Let me begin with The Honorable Bernie Fowler, former Maryland State Senator. Welcome and looking forward to your comments.

STATEMENT OF THE HONORABLE BERNIE FOWLER, FORMER STATE SENATOR, MARYLAND STATE SENATE

Mr. FOWLER. Thank you very much, Mr. Chairman and Madam Chairman. I am truly honored and delighted to be here today. It's very infrequent that I get an opportunity to talk with some of the most powerful people in the world so I feel very humbled today and very honored to do so.

I want to say up front I am not an expert on global warming. What knowledge I have is common sense and listening very attentive to the scientific community, some of them very dear friends of mine.

May I say something informative before I go forward. Madam Chair, I had the very wonderful opportunity to visit Guam during the years of 1944 and '45. It was a little bit of a tenuous time but I can tell you that we enjoyed every moment which was too infrequent when we got back for a few days liberty on the beaches of Guam. Those are great memories that I shall always remember. We thank you indeed for your interest.

Most of my childhood and adult life has actually been spent either on or around the Patuxent River and the Chesapeake Bay. The Patuxent River—I'll use that quite a bit in my testimony—is really a microcosm of the Chesapeake Bay. We have all of the diversities in the Patuxent River that you will find in the Chesapeake Bay, the agricultural, the suburban, urban, residential runoff, power plants, 10 major waste water treatment plants, probably another 20 minor plants. What happens in the Patuxent River is really a mirror of what is happening in the Chesapeake Bay.

I remember the Great Depression. I'll give my age away, which I am not ashamed to admit. I was born in 1924 and the depression started in 1929 and lasted in Southern Maryland until about 1937, 1938. The Patuxent River at that time we were very, very dependent on it actually to supply the food and the income that we needed to sustain our way of life.

I well remember those years.

I also remember the abundance of aquatic life. On the island that I lived on we had about 150 homes and there were about 60 oyster boats, we called them work boats, that went over there every day

during the oyster season. We had 12 commercial seine crews with four people in a crew. The fish were very abundant then and it was a very stable way of making a living.

It was not uncommon for a family to catch eight to 10 dozen or so softshell crabs a day. In fact, we had one lady, her name was Dixie Buck, and she was the champion crabber in the area. She caught sometimes as high as 25 dozen softshell crabs in a day. That's crabbing both tides. She was great at it. As an aside, the price for softshell crabs then was 12 cents a dozen, one penny a piece. Quite a contrast from what they are today.

All of that is gone now. Dixie is gone and most of our seafood is gone. That way of life has pretty well been demolished. There are only a few watermen left because it's very, very difficult to earn a living on the water. It's almost impossible to do that. They have gone on to look for other ways to make a living and feed their family.

Early on we were ignorant. We didn't quite know what we were doing. The old adage in those days was that if you had something you wanted to get rid of, you just threw it in the river, and it would go out in the Bay and go out in the ocean and that would be the end of it. That was folly. We know differently now. We are no longer ignorant.

We know pretty much what is wrong with the Chesapeake Bay, the big ticket items. I'm sure you are probably as familiar with them as I am. The big piece of the pie is the stormwater runoff which includes residential, urban, suburban, agriculture, commercial runoff which carries off a lot of the nutrients and toxicity that really has been the demise of the Bay.

The other part of the pie, or one of the other parts of the pie, is a waste water treatment plant. In 1950, we had no waste water treatment plants going in the Patuxent River. Today as we speak there are 60 million gallons going into that river every day. While we have come a long way in terms of technology in treating that waste, we are still a long way from reducing the poundage of the tonnage that is going into that river.

What is happening in that river is happening in most rivers around. You remember that the Chesapeake Bay is really the recipient to six jurisdictions all together and each one of them has a very emerging way of contributing to the demise of the Chesapeake Bay.

Global warming has been covered very well and I certainly have great regard, respect, and admiration for the folks that testified here. I have known Don Boesch for a number of years and what he tells you, you can take it to the bank. He is very well informed about it, a man of great intellect. He also is a man with a great heart and dedication to the cause of trying to clean up the Chesapeake Bay.

We have a costly operation ahead. I don't have to tell you that. It won't come easy. It's going to be very expensive but to me it's absolutely a necessity. Not just from the standpoint of the abundance of seafood that it is able to provide but also the human health.

My granddaughter teaches elementary school in Southern Anne Arundel. She and I talked a few nights ago about this. I asked her,

I said, "Do any of the kids in your class have any inhalation problems?" She said, "Granddaddy, I have cabinets on my wall that hold the atomizers of 40 percent of the children in my class that have either asthma or inhalation problems, bronchitis or something."

These old eyes have seen it all. We are at a point in time what are we doing? What are we actually doing? I'm not being cynical about this. I'm certainly not trying to lay the blame on any one particular person but we have taken a resource that was so productive and so healthy and so expected. We thought it would last forever but it didn't. Now we are going to have to work—and work very, very hard—to see if we can salvage the Chesapeake Bay from the jaws of death because it is heading for death row. I can tell you that right now.

The testimony this morning on climate warming certainly didn't give me a great deal of encouragement. I long ago agreed there was one thing I would not allow to happen in my life. I will not falter in my optimism. I will not falter in my hope because for a country as rich as we are, with the kind of intelligence that we have leading our nation, there is no reason for me to give up.

Someone wrote one time and I don't know who it was. I quote these things all the time. I don't have the foggiest notion who wrote it but it goes like this. "The darkest part of the night is just before the dawn." This is, in my opinion, the dawn of new hope. We have a president who during his campaign I heard him say that, "When I'm elected President of the United States, we are going to clean the Chesapeake Bay up." As recently as three weeks ago, he signed an executive order putting in action the kind of things he said during the campaign.

We also have with him my dear friend and just a great public servant Steny Hoyer, the majority leader. You all know him well. He lives on the Patuxent River. Coupled with that we have a Governor in Maryland now, Martin O'Malley, who is absolutely committed. I hear him talk all the time. I watch his actions. I think in his heart and in his mind and in his soul he wants to get something done.

The Governor over in Virginia has also joined forces with him. We've got a long ways to go but you have to look on the horizon now at the kind of stars that are shining out there and the change that we hope to have. Don't let global warming dry up your hope and scare you off. We know what we need to do to clean up the Chesapeake Bay. I mentioned the big ticket items. We have to crack down on storm water. We've got to crack down on waste water treatment plants. We've got to crack down on air deposition. They are the three big targets that we need to make a change in the Patuxent River and the Chesapeake Bay.

I think the eyes of the world are watching us and if we are unable to succeed here we may fail everywhere else on the planet. That would be a very sad ending and would be a national disgrace and we are not going to let that happen. You are not going to let that happen. We are going to support you all the way.

I will close by saying that it is my hope and prayer that things will begin to happen, and I respect and appreciate what you are trying to do. Years ago, when I would be down a little bit because

I got a bad editorial because I was out in front on the Chesapeake Bay back in 1970, when people were tee-heeing me, one of my supporters used to tell me, "Commissioner Fowler, please keep on keeping on." We knew there was a difference. We knew things were happening. So I want to tell you today, "Keep on keeping on." God bless you and I wish you the very best of success. We can stand some at this time. Thank you all very much.

[The prepared statement of Mr. Fowler follows:]

Statement of Bernie Fowler, Former Maryland State Senator

Mr. Chairman, Madame Chair, thank you very much for deciding to have this hearing about climate change and the Chesapeake Bay and for making me a part of it.

Most of my childhood and adult life has been spent on or around the Patuxent River and the Chesapeake Bay. My home was located in Broomes Island in Calvert County Maryland, a peninsula county that juts out in the water like a banana with the Chesapeake Bay on one side and the Patuxent River on the other.

I well remember the Great Depression in the late 1920's and 1930's and how dependent we were on the Patuxent River to provide much of our food and income for the bare necessities to sustain our way of life. Broomes Island was a community of approximately one hundred and fifty homes and 90% of the residents were in the water industry. We had no electricity or indoor plumbing but we were happy and seldom in want.

The Patuxent River is the largest estuary located totally in the state of Maryland and the abundance of crabs, fish, oysters, and soft shell clams was astonishing. We had approximately sixty work boats from "the island" that tonged oysters daily during the regular season with two men catching 15-20 bushels of oysters each day. There were twelve commercial seine crew(4 men) netting fish for the market. Baited trot lines were very common and crabbers could catch 6-8 barrels of crabs in one day. Ten dozen softshell crabs in one day was not unusual. In fact we had a lady whose name was Dixie Buck who could net as many as twenty five dozen soft shell in a day crabbing both tides. This was occurring as recent as the early 1960's. Dixie Buck is gone and so is our seafood.

That's all gone now. The harvest has dwindled to almost nothing and so have the waterman. They can no longer make a decent living as they have taken other jobs.

There are only a few watermen left in the watershed because at present it is difficult to earn a living out of the Chesapeake Bay. Sad but true, a watershed that exported seafood all around the United States of America is now importing crabs and crabmeat from as far away as China and South America. In my opinion this is outrageous and a national disgrace.

The Chesapeake Bay was one of the most productive estuaries in the world giving bountifully of her aquatic life, a great protein factory is all but gone. What a shame that we as the richest nation in the world is making only minimal progress in improving our water quality as we watch this giant heading slowly towards death row. Why has this happened?

Early on we were ignorant and did not understand that the nutrients and toxic material would strangle our Chesapeake Bay. Ignorance is no longer an excuse. We know what is wrong. Urban, suburban, residential and agriculture runoff transporting nitrogen, phosphorous and toxic material into the watershed waste water treatment plants dumping hundreds of millions of gallons a day with the same reputation mimicking storm water runoff. Air deposition emanating from vehicular traffic and fossil fueled power plants are also partners in the demise of the Chesapeake Bay. Individual septic systems (quite numerous) in the watershed are also part of the cause.

Lastly global warning is looming and will not be advantageous to water quality in the bay. Additionally, I am advised by my scientific friends that an increase in water temperature by 2 degrees or greater in the spawning estuaries may abort the entire spawn of striped bass. Sounds scary? It is! More frequent storm activity coupled with an increase in rainfall will add to the damage already occurring.

We know what to do. It is costly but necessary to rescue the Chesapeake Bay and her tributaries from the jaws of death and bring her back to an estuary that will match the water quality of the 1950's. We will then enjoy our Chesapeake Bay and once again provide wholesome seafood without concern for consumption.

This is my hope, this is my prayer.

I am deeply grateful for this opportunity and greatly admire and respect what you are trying to do and wish you an abundance of success in your quest to do what is just, fair and critically necessary.

Thank you.

Mr. GRIJALVA. Mr. Skip Stiles, Executive Director of Wetlands Watch. Thank you, sir.

STATEMENT OF SKIP STILES, EXECUTIVE DIRECTOR, WETLANDS WATCH

Mr. STILES. Thank you. And thank you for inviting me to testify today. I am William A. Stiles, Jr., Skip Stiles to the rest of my family. I am Executive Director of Wetlands Watch. We are a small nonprofit working out of Norfolk. I also was a member of the Virginia Commission on Climate Change which issued its report in January of this year.

Wetlands Watch began working on climate change in late 2006 when we became aware of what was then predicted to be a minimum of two feet of sea level rise in our region. In the Bay where the tide range is .3 feet to 3 feet, if you run a couple of feet of sea level on top of it you've got some problems.

We tried to find out where the best estimates of the impacts were and found out there really weren't any good impact estimates then even though all of the states had agreed to look at climate change and its impact on the wetlands as part of the Chesapeake Bay 2000 agreement. So we set out on our own to try to find out. We ran into a number of hurdles.

The State of Virginia does not have high resolution LIDAR maps as was mentioned by the previous panel. These maps are what you really need to try to find a couple of feet of sea level rise. A few localities in Virginia have it but unlike Maryland and North Carolina, Virginia has not mapped any of its coastal plain in LIDAR in a comprehensive fashion.

Its natural resource inventories are out of date. The tidal wetlands inventory is 30 years old and consists of some data points that were taken from some tracings off of old topographic maps. We took a lot of bad data and a little bit of good bourbon and came up with an estimate that Virginia was going to lose between 50 and 80 percent of its tidal wetlands with two feet of sea level rise.

Subsequently, people smarter than us and apparently with better data have come up—I won't comment on the quality of their bourbon—have come up with figures that are within that ballpark. We wrote to Governor Kaine in May of 2007 with these findings asking that the state take action. Governor Kaine subsequently in 2008 appointed a Commission on Climate Change. In that commission report, we laid out an adaptation strategy.

There are only a few of the 30 or so states that have commissions on climate change that have laid out adaptation strategies. We had one and it was a fairly comprehensive look at all of the departments and agencies within the state. Relative to Chairman Grijalva's statement, one of the mandates was for the State Department of Historic Resources to look at all the historic resources in the State of Virginia and begin to look at what impacts would be had on those facilities with what we saw as a climate change endpoint that we laid out in the report.

At that time, the endpoints were estimated at 2.3 feet of sea level rise with 3 degrees Centigrade temperature increase and 11 percent increase in storm intensity. We had hoped that part of an adaptation strategy that we could get a list of those and a whole lot of other resources and begin an adaptation strategy in Virginia.

Unfortunately, Virginia has taken no action on those adaptation recommendations. In the face of increasing estimates of impacts on the State of Virginia, this inaction is inexcusable. Virginia will probably take it about as far as anyone along the Mid-Atlantic and we are just now starting to recognize the severity of the problem.

Wetlands Watch is not waiting for the state or Federal government to act began working at the local level with local governments to see if we could put adaptation strategies in place at a local level. We began to assemble a tool kit of state and Federal programs that would be of use. We began to identify some impediments to adaptation strategies in both state and Federal statute.

In the course of this work, as we have wandered up and down mostly the western shore of Virginia in the tidal region, we found a number of things going on at the local level that cause us to pause. I think it illustrates the fact that local governments in Virginia are being left on their own to cope with sea level rise and they are making a lot of decisions today that are probably going to cost us in the long run.

Most of the land-use decisions in the Bay are made at the local level. Eighty-five percent of the shoreline is privately owned. Nearly all of the shoreline decisions were made at the local level. As was mentioned by the last panel, the wetland can't keep up vertically. It tried to move inland. It colonizes the land behind it. If it runs into a bulkhead or shopping center or subdivision, it drowns in place. This is what led to our higher-end estimates of 80 percent wetland loss.

Right now, there are a number of examples I pointed to in my testimony where local governments are wandering around on their own on what we characterize as an increasingly dangerous terrain—sort of stumbling around blind and alone trying to find their way. There are counties with limited budgets being asked to raise roads with no maps, no set of line elevations, no inundation predictions. These are very costly endeavors.

Gloucester County is being asked to raise a half-mile road 10 inches because the residents were complaining about the increased flooding. $320,000 was the bill. The county doesn't know whether that is the right road to raise, how long a time they get out of 10 inches of elevation of that road or how many other roads there are in the county that need that same work.

Around the corner from me where I live in Norfolk, FEMA, state and local governments just spent hundreds of thousands of dollars elevating structures after Hurricane Isabel. Now the road in front of those houses is largely unusable twice a month because of the tides. People in that neighborhood move their cars on a full moon if the high tide is going to occur in the morning or they've got to put their boots on to go get to their car.

Now the city has to elevate that street. How high? How long a gain do they get? Again, there is very little information in Virginia especially. This makes the task of restoring the Chesapeake Bay

even more difficult because these decisions are being made bit by bit across the Bay and they are going to complicate things in the future.

There are plans out there. The climate change strategies in Virginia and Maryland are good plans. There was a plan at the back of the recent report that came out on sea level rise in the Mid-Atlantic so there are plans out there. All it takes is political will and a little bit of funding.

If I could digress for just a moment, Chairwoman Bordallo, your bill on climate enterprise I read. It's a very good bill. I used to be legislative director of the House Science Committee so I know what happens with jurisdictional battles between my old committee and your current committee but I think that your legislation is a very good piece of legislation.

I think the interagency approach is very good. I think that it's inclusion of stakeholders in the setting of the information that comes out is excellent. I'm one of those stakeholders. I can use better climate information. So can all the local governments. I think this climate enterprise is a much needed piece of legislation. With that I'll close. Thank you.

[The prepared statement of Mr. Stiles follows:]

Statement of William A. Stiles, Jr.,
Executive Director, Wetlands Watch

Chairman Grijalva, Chairwoman Bordallo, Ranking Members Bishop and Brown, members of the subcommittees. I appreciate the opportunity to appear before you today. My name is William A. Stiles, Jr. and I am the executive director of Wetlands Watch, an environmental group based in Norfolk, Virginia, working statewide to protect and conserve wetlands. I am also vice president of the Virginia Conservation Network, a statewide coalition of over 120 conservation groups in Virginia. Our group is a member of the newly formed Choose Clean Water Campaign in the Chesapeake Bay. Finally, I was a member of the Virginia Commission on Climate Change that met during 2008 and produced its final report in January of this year.

I feel somewhat out of place on this side of the microphone, having spent 22 years as a staffer in the House of Representatives, often working on hearings similar to this one. Today I toil at the other end of the policy continuum, at the local government level in Virginia, working on community-level adaptation strategies to address sea level rise.

Wetlands Watch's work on climate change began in 2007 when we became aware of estimates for a 2-foot relative sea level rise in the mid-Atlantic region of the United States over the next century. We were concerned about the potential impact of this accelerated rate of sea level rise on the coastal ecosystem and started looking for some factual analysis of how this change would affect the coastal environment of the Chesapeake Bay.

We hoped to find some data coming from the Chesapeake Bay 2000 Agreement, wherein the signatory governments committed to look at climate change impacts on wetlands when they agreed to: "Evaluate the potential impact of climate change on the Chesapeake Bay watershed, particularly with respect to its wetlands, and consider potential management options."

We discovered that Virginia had done no evaluations, nor could we find any of the signatory governments to the Chesapeake Bay 2000 Agreement who met this commitment.

We saw that in the Coastal Zone Management Act (CZMA) there is a provision at U.S.C. 33 § 1451(l) mandating sea level rise planning: "Because global warming may result in a substantial sea level rise with serious adverse effects in the coastal zone, coastal states must anticipate and plan for such an occurrence."

Again we found no activity in Virginia resulting from the CZMA mandate. Without available state or federal analyses, we had to undertake our own evaluation of climate change impacts on the coastal ecosystem, with the help of the Virginia Institute of Marine Sciences (VIMS) and others.

As we tried to estimate these impacts, we were immediately frustrated by the lack of data in Virginia. Unlike Maryland and North Carolina, Virginia does not have

digital LIDAR (light detection and ranging) maps to provide precise vertical elevations allowing inundation modeling to be done on flat coastal landscapes. This forces smaller, rural counties and towns in Virginia struggle with maps of fairly coarse resolution. In addition, Virginia's natural resources inventories are spotty at best: VIMS's tidal wetland inventory is 30 years old, plotted on hand-drawn tracings from topographic maps.

Tidal ranges in the Chesapeake Bay run from .3 to 3 feet, meaning a sea level rise of two feet could have significant impacts upon wetlands in the intertidal zone, adjacent beds of submerged aquatic vegetation (SAV), mudflats, and primary dunes along the Chesapeake Bay and Atlantic Ocean shorelines. Wetlands can accrete and move vertically to keep up with sea level rise, if the wetlands are healthy and have enough sediment. We looked at the few studies available on Chesapeake Bay wetlands and they showed many of our existing tidal vegetated wetlands would probably not keep up with a two foot sea level rise due to the compromised health and productivity of the wetlands and/or inadequate sediment in some ranges of the Bay.

We assumed that if vegetated tidal wetlands and adjacent ecosystems could not move vertically, they would have to move landward or "uphill" as sea level rose. We knew that about 85 percent of the Bay's shoreline is privately owned, and increasingly "hardened" with erosion control structures, development, roads, and other barriers blocking this landward migration. If wetlands cannot colonize the land at a higher elevation from their existing location, they will drown in place.

We read research showing that sea level rise of the magnitude expected could result in a 30 to 40 percent reduction in submerged aquatic vegetation (SAV) due to lower light penetration through the higher water column. We also learned that the Chesapeake Bay's key SAV species, eelgrass, is already under stress from warmer water temperatures, and the Bay will only get warmer with climate change.

We used this available information to make a rough estimate that the then-projected increase in the rate of sea level rise to 2 feet per century would eliminate between 50 and 80 percent of Virginia's remaining tidal wetlands and have significant impacts upon the rest of the coastal ecosystem.

The coastal ecosystem complex is the most productive in North America, rivaling the productivity of tropical rain forests. Threats to this ecosystem directly threaten the Chesapeake Bay and the economies and communities that depend upon a healthy Bay.

Estimates show that 70 to 90 percent of the finfish and shellfish in the Chesapeake Bay and mid-Atlantic coastal ocean use tidal wetlands and SAV beds for spawning, recruitment, food, or other habitat functions. Losses in these ecosystems would produce severe consequences for the Chesapeake Bay and Atlantic Ocean commercial and sport fishery and the communities and economies dependant upon that fishery.

In Virginia alone, the commercial fishery is worth $130 million a year, the saltwater sport fishing industry generates $1.2 billion and 9,000 jobs, waterfowl hunting is a $14 million sector, and wildlife watching—much of which takes place in coastal areas along the Atlantic flyway—generates $941 million a year and supports 23,000 jobs. One significant sector threatened by sea level rise is the hard shell clam aquaculture industry on the Eastern Shore of Virginia. This industry, located in the shallow coastal ecosystem, produces an economic output of $48.8 million a year and employs 620 people in coastal communities. If tidal wetlands and the coastal ecosystem are threatened by climate change, so is all of this economic activity.

In the course of our analysis, we also noted adverse impacts on the U.S. Fish and Wildlife Service's (USFWS) refuge system in the mid-Atlantic from climate change as we projected significant potential tidal wetland habitat loss in each of the refuges. Given that these impacts were occurring in each of the refuges simultaneously, we saw a potentially significant cumulative impact on the mid-Atlantic section of the Atlantic migratory bird flyway, from Cape May through Cedar Island National Wildlife Refuges. We spoke to USFWS refuge managers in Maryland, Virginia, and North Carolina all of whom had observed habitat losses occurring at their sites with current rates of sea level rise. Higher rates of sea level rise and temperature stress can be expected to accelerate this rate of habitat loss.

We then wrote Virginia's Governor Kaine in May of 2007 (Attachment I), asking that Virginia take steps to prepare Virginia for the sea level rise we were expecting. Specifically, we asked that the state live up to its commitment under the Chesapeake Bay 2000 Agreement to evaluate climate change, undertake LIDAR mapping in the coastal plain, provide updated natural resource inventories in the tidal regions, and then model climate change impacts upon those natural resources. Finally we pointed to the need to work with local governments to develop adaptation plans at the local level, where most land use and shoreline hardening decisions are made.

Governor Kaine soon thereafter appointed the Virginia Commission on Climate Change, on which I served along with 39 other citizens. We met during 2008 and delivered our report in January of 2009. Virginia joins 30 other states in having a state climate commission and is among a very small number that examined adaptation strategies as part of their commission.

Virginia's Commission on Climate Change looked extensively at what it would take for Virginia to adapt to the climate change impact end points expected by 2108, estimated in the report as: a 2.3 to 5.2 foot increase in sea level, a 3 degree Centigrade increase in temperature, and an 11 percent increase in storm intensity/precipitation intensity. We then developed a novel approach to formulating a state adaptation strategy, one that might serve as a model for development of government climate change adaptation strategies.

The strategic process envisioned by the adaptation work group of the Commission involved each state agency reviewing programs and regulations under their authority and judging the impacts of projected climate change end points on those operations. The agencies would then recommend adjustments to those programs and regulations to adapt to the projected end points.

So for example, the Virginia Secretary of Transportation, wanting to know the impacts of sea level rise on transportation structures, would ask the Virginia Department of Transportation for a list of all state-owned transportation segments in tidal flood plains whose centerlines are 3 feet or less above mean higher high water. Or Virginia's Secretary of Natural Resources, wanting to insure that habitat management accommodated these end points, would ask the Department of Game and Inland Fisheries what the impact of a 3 degree Centigrade rise in temperature would be upon brook trout habitat. Or the Virginia Secretary of Public Safety would ask the Department of Emergency Management what changes in emergency preparedness might be needed with an 11 percent increase in storm intensity and 2.3 feet of sea level rise.

The agency responses would either highlight gaps and omissions in current agency authorities and operations that hindered their ability to address climate change, or the agencies would begin to adjust their programs to accommodate these changes. In the case of gaps and omissions, we would then be able to adjust agency statutory or regulatory authorities as needed. The process would be repeated as new information about end points was obtained.

What we expected as a result of this process would be a growing awareness of how climate change needs to be taken into account in the daily conduct of government operations in Virginia. We hoped that as government "led by example" and went through adaptation planning, the private sector would as well. In the end, what we envisioned emerging from this process was a full adaptation strategy for Virginia.

Unfortunately, Virginia has not taken action on the adaptation proposals made by its Commission on Climate Change. With estimates of the threat to Virginia constantly increasing, this inaction is inexcusable. Just last week, the latest federal report on climate change impacts stated that a relative sea level rise of 2.9 feet was probable for the southern Chesapeake Bay in the coming century. This is up from the Climate Change Commission's estimate of just last year of a minimum of 2.3 feet, and up from Wetlands Watch's original starting point in 2007 that assumed "only" a two-foot relative sea level rise.

Others are taking notice, however. Recent decisions by private insurance companies to withdraw new coverage from coastal areas in Maryland and Virginia are a clear signal that businesses see an increasing risk from sea level rise. Over the last two years, a number of private insurance companies representing 55 percent of the insurance market in the mid-Atlantic have stopped writing policies on businesses and primary residences near the coast. Other companies have withdrawn new coverage on secondary residences.

These moves illustrate another negative impact from our lack of climate change planning in Virginia. Communities without sufficient information on climate change impacts and adaptation strategies are having their economic future affected by business decisions beyond their control.

The single largest barrier to putting an adaptation strategy in place in Virginia's is the lack of accurate maps of the coastal plain. At present, only a handful of localities have LIDAR maps, most of which were paid for by the local government themselves. The Virginia Commission on Climate Change set a "no regrets" priority for the mapping of the state's coastal plan with LIDAR, to provide individuals, businesses, and local governments in Virginia with a road map through the coming climate changes. This is a project that has been estimated by the Virginia Geographic Information Network to cost around $5 million. Unfortunately, there are no proposals pending to fund the generation of these maps.

We also stressed the need for inclusion of climate change impacts in numerous long range planning processes, for transportation and infrastructure at the state and regional level and in land use decisions at the local level. The hundreds of transportation and land use decisions made daily in scores of local governments throughout the Chesapeake Bay watershed combine and conspire to set the course for the health of the Bay.

Our failures to meet the goals of the Chesapeake Bay 2000 Agreement have been traced primarily to our inability to plan for and control growth and our failure to give localities the tools they need to make smart land use decisions—technical tools, legal tools, and financial tools. These local land use decisions loom even larger as we move into the future under the uncertain consequences of climate change. Every bulkhead, development, road, or other barrier allowed will cause incremental change today that, when aggregated and exacerbated by climate change over time, will result in consequential change to the Chesapeake Bay. Our actions must guarantee the resiliency of the Bay by keeping its shoreline open, thus keeping our climate change adaptation options open.

Without maps, models, wetlands inventories, and dozens of other bits of information, local governments are making decisions in the dark, encumbering the taxpayers and potentially endangering citizens. As Wetlands Watch works throughout tidewater Virginia helping local citizens and governments cope with climate change, we encounter examples of this daily. Let me walk you from my house in Norfolk, north along the Chesapeake Bay's western shoreline to look at a few of these examples we have run across.

In a neighborhood in Norfolk just two miles from my house, federal and state taxpayers spent hundreds of thousands of dollars raising houses in the Larchmont/Edgewater neighborhoods after Hurricane Isabel under a Federal Emergency Management Agency (FEMA) grant. However, this program apparently didn't account for the impact of sea level rise on the flooding of the adjacent roads, which are now inundated frequently on full and new moon tides.

People on these streets move their cars to higher ground on surrounding streets on a lunar cycle, to avoid having to put on their boots to slosh to their cars in the morning at high tide. To maintain the usefulness of the houses we just raised, the city of Norfolk proposes to spend countless thousands of dollars to raise the adjacent roads and infrastructure out of the zone of increased flooding. The park in front of these homes, formerly upland, is now a salt pan fringed by marsh grass and the city plans to convert it into a restoration wetland; an admission that sea level rise is here to stay.

Was the decision to raise these houses made strategically? Do we know how high the roads should be raised and what the projected rate of inundation plus subsidence is for this neighborhood? What is the long-term prospect for this neighborhood and when do we try to find out? These strategic questions need to be asked prior to making this next significant taxpayer investment.

Moving north, on the other side of the James River, the Department of Defense is closing Fort Monroe and the state is determining its reuse. Virginia is studying the best use of the open space surrounding the Fort, land located on a low-lying barrier island. Proposals range from creating a new park to developing the land for residential and commercial use.

On the Virginia Commission on Climate Change, we were presented with a simulation showing this open space adjacent to Fort Monroe going underwater in 2108 with a category I storm surge. Yet state and local planners are still considering proposals to build residences and businesses on this increasingly dangerous landscape.

To the northwest a few miles is Poquoson, a city whose highest point is just seven feet above sea level. The city recently installed a new gravity-flow storm water system for around $20 million. The city engineer, who understands sea level rise, asked the contractor what it would take to make the system work with 2-3 feet of additional sea level rise. The answer was another $5 million to sleeve and pressurize the section of pipe and install a pump system. Without compelling data on climate change and financial support, the city installed the system as-is, effectively putting a $5 million taxpayer liability (in 2008 dollars) in the ground.

Across the York River from Poquoson, is Gloucester County, a low-lying locality changing from a rural to a more developed area. Residents recently complained about a road section that was now regularly flooded on a monthly tide cycle or by winds from the north. They wanted the road raised to fix the problem.

The County estimated that to raise the road 10 inches for a half mile would cost $320,000 in materials and labor, without including the expense of permits and environmental assessments. This represented 18% of the county's entire annual road maintenance budget to be spent for just one road section out of the many needing elevation in a low-lying and increasingly flood-prone locality. Without road ele-

vations, precise digital maps, models of flooding and inundation, and other information, Gloucester County is forced to make these decisions in a vacuum, as are all other localities in Virginia.

Just north of Gloucester County is Mathews County, the self-proclaimed "pearl of the Chesapeake Bay" and deserving of the title. Mathews has much low laying land that is threatened by sea level rise and also has the longest shoreline of any county in Virginia. The County is undergoing a revision of its long-range land use plan, with an eye on sea level rise and trying to decide what to do along its coastline.

Mathews is handicapped without data on transportation and public infrastructure elevations, it has no digital maps or geographic information system data, it lacks the funding to conduct build-out analyses of those low-lying areas of the county that may be threatened by sea level rise, and so on. The state is providing few resources to guide willing local planners and citizens find their way ahead. Mathews wants to do the right thing and there is even talk of making the county a "living laboratory" for climate change adaptation, but there is no funding to help them reach that goal.

On the other side of the coin, in Mathews County, we have seen an example of federal and state efforts working at the local level with the support being provided by Chesapeake Network for Education of Municipal Officials (NEMO). Chesapeake NEMO is a federal-state partnership that helps communities implement sound, natural resource-based planning. Chesapeake NEMO is providing support for Mathews as it works through its long-range plans and the staff from the National Oceanographic and Atmospheric Administration (NOAA) and the Virginia Department of Conservation and Recreation working with Mathews County deserve credit.

As well, NOAA has funded three regional planning efforts being run through the Coastal Zone Management Program in Virginia attempting to bring stakeholder groups together to address climate change on a regional and local level. This same effort has funded programs in Maryland at the community level. However, as good as these efforts are, they are inadequate to the task we face.

These bright spots need to be expanded because the stories just related of localities being abandoned in the face of sea level rise occur throughout the Virginia coastal region. They paint a clear picture of need for a significant expansion of state and federal work in support of local land use planning and decision-making processes in this changing environment.

Conclusion

Restoring the Chesapeake Bay is a difficult task. We've made too many shortsighted decisions—allowed too many people to do too many unsustainable things along our shoreline—to expect to get out of this situation without a lot of expense and disruption. For a while we did this out of ignorance. For a time after that we did it out of indifference or indecision.

Today, there is no longer any excuse for what we are allowing along our shorelines as we permit inappropriate and unsustainable development that is encumbering our grandchildren with a huge debt to be paid to restore the Chesapeake Bay. This debt is large enough today, without climate change figured in, and increases substantially when that calculation is made.

The failure by state and federal governments to develop climate change adaptation strategies leaves individuals, companies, and local governments to stumble blind and alone onto an increasingly dangerous terrain. At a minimum, this will produce costly consequences for taxpayers and shareholders, as decisions made without considering climate change impacts need to be corrected or reversed. At the other extreme, decisions being made today in Virginia's policy vacuum will limit our future adaptation options and are putting lives and livelihoods at risk

The absurdity of this situation is made worse by the fact that plans exist to begin the process of adapting to climate change. The federal government recently issued a report, "Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region," at the back of which is a list of suggested federal actions offered by the report's advisory committee (Attachment II). The Maryland and Virginia Climate Change Commission Reports contain dozens of sound recommendations that will get us started. Wetlands Watch has started work on a "tool kit" for local governments. Other reports from the private sector, professional organizations, and the like pile up daily.

We know enough to take action. All that remains is the political will and the funding to do something with the recommendations on the table.

Thank you for the opportunity to appear before you today. I welcome any questions you may have.

ATTACHMENT I TO TESTIMONY OF WILLIAM A. STILES, JR. June 23, 2009

May 31, 2007

Governor Tim Kaine
Office of the Governor
Patrick Henry Building, 3rd Floor
1111 East Broad Street
Richmond, VA 23219

Dear Governor Kaine:

We are writing regarding sea level rise and the ecological impact upon Virginia's coastal ecosystems. We have been reviewing existing information for the Chesapeake Bay and its tidal tributaries, the coastal bays of the Eastern Shore, and Virginia's southern rivers and bays in the Currituck Sound watershed.

With a relative sea level rise in the range currently predicted by federal agencies (1 1/2 to 2 feet in the next century), a "best guess" estimate indicates a loss of 50—80% of the remaining vegetated tidal wetlands in the tidal reaches of Virginia by 2107, absent efforts at mitigation. Adjacent shoreline features (mudflats, buffers, dunes, etc.) would also be adversely impacted.

Losses of this magnitude would, at the lowest predicted ranges, negate any progress made toward restoration of the Chesapeake Bay's ecosystem. Unmitigated losses of wetlands, buffers, and coastal dunes at the upper predicted ranges would trigger an ecosystem collapse throughout the Chesapeake Bay.

Sea level rise impacts are already being felt. A paper from University of Maryland states that, "coastal marshes are currently disappearing in the Chesapeake at rates as rapid as the more widely publicized losses in the Mississippi Delta."

The coming relative sea level rise will hit the mid-Atlantic Region hard, with Virginia being the most impacted region. In fact, Hampton Roads is the largest population center at greatest risk from sea level rise and storm surges outside of New Orleans.

In the mid-Atlantic, some states are in the process of initial analysis, some are conducting detailed mapping of coastal areas and running inundation models, and some have advanced to initial deliberations on a response and mitigation strategy. Virginia is currently the only state in the mid-Atlantic Region without a visible state reaction to the issue of sea level rise and its impacts on coastal ecosystems.

In the Chesapeake 2000 agreement, Virginia and all of the signatories agreed to, *"Evaluate the potential impact of climate change on the Chesapeake Bay watershed, particularly with respect to its wetlands, and consider potential management options."* Virginia has made no appreciable progress toward that goal since then-Governor Gilmore signed that agreement.

In addition, the Coastal Zone Management Act at U.S.C. 33 § 1451(l) finds that, *"Because global warming may result in a substantial sea level rise with serious adverse effects in the coastal zone, coastal states must anticipate and plan for such an occurrence."*

Wetlands Watch is beginning a campaign to raise awareness on this issue with a goal of making sea level rise a high priority issue in Virginia. We must do better than make a "best guess" at where inundation will occur and what the ecological impacts will be. We offer our assistance in improving the state response to sea level rise.

First, Virginia's flood map modernization effort needs to be adequately funded to allow precise mapping of coastal areas. Maryland and North Carolina provided state funding to augment the Federal Emergency Management Agency (FEMA) program to modernize flood zone maps. In coastal areas, those state funds have provided LIDAR data and are producing digitized maps with data density sufficient to predict relative sea level rise inundation areas.

In Virginia, inundation maps at this level of detail are only available if local governments pay for them, and as of today, few at-risk coastal communities have paid to get the data. And even for those few localities with detailed inundation mapping, there is no funding for ecological impact analysis or modeling.

This leaves these localities environmentally vulnerable. At the same time they are becoming economically vulnerable from decisions made by others with better information. Allstate has stopped writing new homeowner insurance policies in 19 Virginia coastal communities. State Farm and Nationwide are pulling new coverage from coastal areas as well. USAA will no longer offer unconditional coverage on second homes in Virginia.

These companies are reacting to greater risk from sea level rise and storm surge damage. Together they represent more than 55% of the private insurance market

in the mid-Atlantic. In addition, all insurance companies operating in Virginia have raised insurance rates and announced a doubling of the hurricane deductible to 5% on homeowner policies.

For the ecosystems and economies of Tidewater Virginia, sea level rise and storm surge risks are a major threat to which our state government needs to respond.

The second phase of a state action plan is an evaluation of the ecosystem services that will be lost as we identify those coastal features that will drown if they cannot move shoreward. For example, Maryland has estimated that it is currently losing around 150 acres of tidal vegetated wetlands a year and North Carolina has placed its loss from sea level rise and erosion at 780 acres of wetlands annually. Virginia has no estimate of its acreage losses nor the habitat, nutrient cycling, and other functions threatened by these losses. We do not know which functions will be in greatest demand as sea level rises and thus we have no plan for mitigating for the loss of those functions.

Third, the state, in partnership with local governments, needs to begin assembling a "tool box" of land use and other approaches for arranging the orderly retreat of people and ecosystems from the rising tides. What is needed is collaboration between state and local governments, landowners and land trusts, and business and non-profit organizations such as Wetlands Watch.

One focal point for the start of this collaboration is the planned release later this year of federal studies outlining regional tributary-level impacts of sea level rise in Virginia and the likely responses along the shoreline. These will be rough estimates and will need refinement by involved and interested citizens at all levels, but in the course of that work we can begin to move this issue to higher visibility and priority.

We realize that this is a significant undertaking and one that will require constant effort for decades to come. It is also an issue that has, in the past, only been dimly glimpsed. With more immediate needs, it is understandable why this work has been placed farther down the list of state government priorities.

However, now that we can begin to see the outlines of the problem, now that various economic sectors in Virginia have begun to react, now that the news is full of global change issues, now that the deadline looms on the commitments made under the Chesapeake 2000 agreement, we must make this matter one of our State's highest priorities.

Wetlands Watch stands ready to assist you in this effort and bring greater public attention to this pressing need.

Sincerely,

William A. Stiles, Jr.
Executive Director
Wetlands Watch

ATTACHMENT II TO TESTIMONY OF WILLIAM A. STILES, JR. June 23, 2009

From: "Report of the Coastal Elevations and Sea Level Rise Advisory Committee," in the U.S. Climate Change Science Program report, "Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region," October 2008.

6. Recommendations for the Future

In addition to the recommendations above for improvement of SAP 4.1, the committee would like to highlight several areas in which further research appears warranted. These include the following:

1. Efforts to better understand the impacts of extreme events upon coastal ecosystems should be supported as they will also contribute substantially to our understanding of the impacts of accelerated rates of SLR.
2. Many governmental programs maintain high quality shoreline and other coastal data: for land use analyses and associated decisions. It is important to ensure that these data are managed for maximum public accessibility.
3. There is a strong need for all levels of government to coordinate an integrated, comprehensive, high-resolution coastal mapping program (including shallow bathymetry as well as coastal topography). Such a program should provide for a minimum of a five-year re-mapping rate.
4. Work on coastal evolution models should be accelerated to better characterize the complex, punctuated dynamics of coastal ecosystems and SLR. This should include analysis of how physical stressors (e.g., salinity, pH, temperature, physical distance) impact biological processes that might also contribute to accretion and migration.

5. All public agencies should reexamine their current methods of cost effectiveness analysis, especially in light of conditions imposed by SLR associated with climate change.
6. Appropriate agencies should develop plans for replacement of coastal public lands (e.g., National Parks and Seashores, National Wildlife Refuges, National Estuarine Research Reserves) in the face of SLR.
7. There is a need to inventory efforts across all levels of government as to plans and strategies to address and/or adapt to accelerated rates of SLR as well as "lessons learned" and best management practices.
8. The committee recommends that appropriate agencies should develop a regional-scale resilience-ranking system based upon attributes such as climate sensitivity, societal and economic value of undeveloped vs. developed landscape, and elevational possibilities for wetland migration. Such a tool should enable assessment of the societal benefits of strategic acquisition and conservation actions.
9. Appropriate agencies should develop risk assessment approaches to inform strategic plans for coastal abandonment due to SLR. This effort should include detailed delineations of areas that warrant close scrutiny and explicitly assess the costs and impacts of not taking action.
10. Agencies should combine efforts to conduct a comprehensive assessment of opportunities for appropriate legislative responses to SLR: such as FEMA map modernization, Coastal Zone Management Act, Clean Water Act, Water Resources Development Act, Coastal Barrier Resources Act, and the Farm Bill. Tax code modifications and other appropriate mechanisms should be developed to provide incentives for more strategic landscape conservation practices as well as personal and community adaptation strategies. Climate change legislation needs to recognize that adaptation is an important step to initiate early on.
11. Agencies should develop executable mechanisms to assess the efficacy of publicly funded or operated infrastructure in high hazard coastal areas as an essential part of the public decision processes.
12. Appropriate agencies need to assess local capabilities and resources to respond to SLR, and ensure their ability to make use of high-resolution and other decision support tools.
13. There is a need to develop improved national estimates of U.S. coastal population subject to the effects of SLR. Improved demographic estimates combined with high resolution mapping of the coast would improve the ability to characterize high risk areas.
14. All water quality certifications (e.g., Clean Water Act Section 401) should incorporate evaluation of SLR impacts on the action reviewed to include consideration of both present and future compliance with water quality standards.
15. In the near-shore environment the USACE should adopt policies (e.g., Nationwide Permits) and procedures to discourage the placement or replacement (including following disasters) of bulkheads and other hard structures. In the event that protection is allowed, the use of soft protection techniques should be encouraged. There needs to be a comprehensive review and evaluation of federal laws, rules and practices in response to extreme events and coastal disasters to discourage the rebuilding of physical infrastructure in high hazard coastal areas (e.g., Coastal Barrier Resources Act).
16. Under next generation map modernization (RiskMAP), FEMA should include relevant information regarding SLR, coastal erosion, and/or projected coastal inundation. Implementation of this will be dependent on results obtained from a recently initiated study of the impact of climate change on the NFIP, and would require new legislative mandates.
17. Best sediment management practices should be implemented in the future. The USACE should be encouraged to accelerate its regional sediment management studies.
18. Human and other climate change impacts on watershed hydrology and soils should be taken into account in any discussion of the effects of SLR on coastal systems. This includes the impacts of SLR on non-coastal floodplains, e.g., the lower Roanoke River, NC.

Mr. GRIJALVA. Thank you.

Let me now recognize Mr. Stuart Parnes, President, Chesapeake Bay Maritime Museum. Sir.

STATEMENT OF STUART PARNES, PRESIDENT, CHESAPEAKE BAY MARITIME MUSEUM

Mr. PARNES. Thank you very much. Madam Chairman, Mr. Chairman, Representative Kratovil, I'm delighted to be here. I'm especially delighted to be here this morning because I'm not a scientist. I think we need a broader participation in this discussion to meet these challenges that goes beyond the scientific community alone.

I admit that I really don't lie awake at night worrying about TMDL's or dead zones. I cannot really predict the changes that are facing us or the impacts of those who are already feeling it. Of the 3,600 species of plants and animals that live along the Bay I'm really only concerned with one and that is the human animal. I'm a humanist. I worry about the Bay's people and particularly about the endangered communities in which they live.

I worry about the survival of the rich human culture that for centuries has defined what and who we are along this part of the world. These cultures would still survive along the Bay's edges and islands and threatened with inundation and if they disappear, our sense of place may disappear with them.

We may still be part of Maryland and part of America 100 years from now but both Maryland and America will have been diminished having lost some of the important folkways and traditions and culture and knowledge that has been routed in these waters for generations.

I've been involved in history museums for over 40 years, both in this country and abroad, and for most of that time the institutions that I've worked for have been focused on collecting and preserving works of art or artifacts from some ancient historic culture, lost civilizations or abandoned technologies.

I currently am the President of the Chesapeake Bay Maritime Museum right across the Bay from here in St. Michaels. In 2009, I see the mission of museum people in a very different way. We are a museum about an extraordinary place, a place of outstanding not only cultural but natural vitality and beauty and significance. Our museum tells the story of the Chesapeake Bay and her people which is a story of the interconnectedness of the water and the land and the nature and the communities and both science and history.

Of course we preserve and celebrate the rich heritage of the Bay's past but we are really attempting to do much more than that. Our goal now is to strengthen the link between today's past and its future that link these issues of science and humanities. Our mission is to inspire stewardship, plain and simple. We want to help our visitors and our members and the folks who experience our museum understand how important it is to preserve both the cultural and natural resources that make this place extraordinary.

I actually believe that looking into rear-view mirror of history from time to time can help us navigate the road to the future. I think that museums like ours and many others can help the scientific community by offering unique educational experiences and by sharing the perspectives that centuries of living in this place have provided to us.

I believe we can share our knowledge of the past and we can help our communities really appreciate how much of this region's culture has been shaped by the Bay and how much of that regional identity will be lost if we allow this culture to be simply washed away. The health and survival of this region's culture is now more than ever dependent on all of our decisions and actions, not just yours, not just the scientific community, but all of us.

I think educational institutions like my museum and others can and must help inform those decisions. We need to take lessons from the generations that came before us both in how to live in this place and how to not live in this place. This is not simply a challenge for the scientific community.

So many man-made pressures that my scientific colleagues this morning have mentioned, population explosion, accelerating development, increasing pollution, declining water quality, and the shift from a primarily agricultural and seafood harvesting economy to one that is now based on recreation and tourism and suburbanization. These are already threatening to change beyond recognition the place that we all love. Now climate change and sea level rise have been added to the list.

These islands and waters have always been in flux. The natural processes of erosion and subsidence are not new nor are they going to stop. Their impact has always been here and it continues to be here for at least three centuries. I want to point your attention if I can to a couple of photographs that my colleague there, David Harp, who is the most extraordinary photographer on the Chesapeake Bay, has brought along with us today.

For more than three centuries Holland Island, which is that image there, supported dozens of homes, farms, a huge fleet of fishing vessels. Today there is one house left. Residents of Smith Island have gradually moved from the southern end of that island as the properties have become slowly inundated.

The panorama of Hooper's Island that Dave can show you is an extraordinary example of just how thin the margin is between water and land in this amazing place and how we are literally hanging on the edge. As climate changes cause the water to rise more quickly, we are at real risk of a sudden loss of not only marshlands and meadows, not only of low-lying buildings and roadways, not only of peninsulas and islands, we are at risk of losing important chapters of our history, our culture, and our identity.

If 50 or 100 years from now our great grandchildren have to visit places like the Chesapeake Bay Maritime Museum to see the surviving relics of what was once a rich and varied coastal culture borne out of and nourished by the waters of this Bay, then I'm afraid we will all have failed.

The attention and the leadership of your committees to these issues is hugely encouraging to all of us here on the Bay. We live and work here and we care about this place. All I ask is that you please do not overlook the impact of climate change on the traditional communities that define the very character of this extraordinary place. The reason we should care about this issue is the people of the Bay. I'm a people person and I'm hoping that you are and that we can keep focused on the real goal here. Thank you very much.

[The prepared statement of Mr. Parnes follows:]

Statement of Stuart Parnes, President, Chesapeake Bay Maritime Museum, St. Michaels, Maryland

I am not a scientist. I admit that I don't lie awake at night worrying about TMDL's or dead zones. I cannot enlighten any of you to the true causes of climate change nor the remedy for the impacts likely to be felt along the Chesapeake Bay.

Of the 3600 species of plants and animals that live together in and around the Bay, I most concerned about just one. I am a humanist. I worry about the Bay's people, and the endangered communities in which they live. I worry about the survival of the rich human cultures that for centuries have defined what and who we are. These cultures, which still survive along the Bay's edges and islands are threatened with inundation, and if they disappear, our sense of place may disappear with them. We may still be part of Maryland and part of America, but both Maryland and America will have been diminished, having lost some of the folkways, traditions, culture and knowledge that has been rooted in these waters for generations.

For nearly 40 years, I have been involved with history museums in this country and abroad. For most of that time, the institutions were focused on the collection and preservation of works of art or artifacts of historic significance. We were the keepers of ancient treasures, lost civilizations, forgotten cultures, abandoned technologies.

I am currently the President of the Chesapeake Bay Maritime Museum, and in 2009 I see our mission in significantly different terms. We are a museum about an extraordinary place; a place of outstanding natural and cultural vitality, beauty, and significance. Our Museum tells the story of the Chesapeake Bay and her people—a story of the interconnectedness of water and land, of nature and communities. Of course we preserve and celebrate the rich heritage of the Bay's past, but we are attempting to do much more. Our goal is to strengthen the link between the Bay's past and its future. Our mission is to inspire stewardship of the bays cultural and natural resources. I actually believe that looking into the rear-view mirror from time to time can help us navigate the road that lies ahead.

I believe that museums like ours can offer unique educational experiences by sharing the perspectives that centuries of living in a place provides. I believe that by sharing our knowledge of the past, we can help our communities recognize how much this region's culture has been shaped by the Bay, and how much of our regional identity will be lost if we allow this culture to be washed away. The health and vitality of this region's culture is now more than ever dependent on human decisions and actions, and educational institutions like ours must help inform those decisions. This is no time for nostalgia or romance. We need to take lessons from the generations that have come before us, both how to live and how NOT to live.

Man-made pressures—population explosion, accelerating development, increasing pollution, declining water quality, and the shift from a primarily agricultural and seafood harvesting economy to one based on recreation, tourism, and suburbanization—are already threatening to change beyond recognition this place we all love. Now climate change and sea level rise have been added to the list.

The Bay's islands and waters have always been in flux. The natural processes of erosion and subsidence are not new, nor is their impact on the Bay's people. For at least three centuries, Holland Island supported dozens of homes, today, there is one left. Residents of Smith Island have gradually moved from the southern end of the Island as their properties have become slowly inundated. The crisis we face today is due the accelerating PACE of this change. As climate changes cause the waters to rise more quickly, we are at real risk of sudden loss of not only marshlands and meadows, not only low-lying buildings and roads, not only peninsulas and islands. We are at risk of losing important chapters of our history, our culture, our identity. If, 50 or 100 years from now, our great grandchildren have to visit places like the Chesapeake Bay Maritime Museum to see the surviving relics of what was once a rich and varied coastal culture born out of and nourished by the waters of the Bay, then we all will have failed.

Your attention to these issues is hugely encouraging to all of us who live and work along the Chesapeake Bay. All I ask is that you please do not overlook the impact of climate change on the traditional communities that define the character of this extraordinary place.

Mr. GRIJALVA. Thank you.

Mr. Tommy Leggett, waterman.

STATEMENT OF TOMMY LEGGETT, WATERMAN, WICOMICO, VIRGINIA

Mr. LEGGETT. Good morning, Mr. Chairman, Madam Chair, members of the Committee. Thank you for inviting me to speak. I've been a waterman for about 27 years but I'm a waterman of a different variety. I have a degree in Marine Science from the Virginia Institute of Marine Science but I did not pursue that career. I didn't really want to be tied to grant writing and research and funding and that sort of thing. I wanted to do the fun stuff so I taught myself to be a waterman.

I have no family in the commercial fishing business so I taught myself how to do it. I raised a family doing that. I'm a waterman that has evolved with a changing Chesapeake Bay. I have always been on the tale end of most all the fisheries jumping from one fishery as it declined to another. I've crab potted, oystered, gill netted for fish, I've shed soft crabs, and the last thing I did was patent tong for clams.

I got a captain's license thinking that I might want to take fishing parties, charter fishing parties. The last thing that I started doing was shellfish aquaculture. I'm still a commercial shellfish grower. Continuing to adapt I was offered a job at the Chesapeake Bay Foundation doing environmental education in 1998. From there I took on the role in the Virginia part of the Chesapeake Bay Foundation doing environmental restoration, mainly oyster restoration.

Just yesterday, or the last three days, my partner and I have planted nearly 2 million baby oysters in the Piankatank River. Last year we planted about 10 million. My day job is an oyster restoration scientist and I have a part-time business as a shellfish grower growing and harvesting about 100,000 oysters a year. I shell 1,000 to 2,000 oysters per week to local restaurants. That is who I am. Even though I have a day job as a restoration scientist, my identity is a waterman. It's who I have been for 27 years. That is what I think of myself.

I have seen some changes and I have no idea if they are related to climate change but there are things that are different. Our winters seem to be warmer. When I moved to Gloucester County, and I do live in Gloucester County in a place called Guinea Neck, my residence is eight feet above sea level. I live on the Parana River with a southeast view of the Chesapeake Bay and 25 miles beyond that view is the Atlantic Ocean.

When I first moved to Gloucester, the York River froze over in 1976 and 1977. I have yet to see the York River freeze over at the lower end since then. We have seen some episodes where the creeks freeze but, there again, they don't seem to freeze quite as often. I remember as a child it seemed to me it was colder, more snow. Just about seven years ago the creek that our oyster farm is located on we had three inches of ice. I just don't see those kind of events like we have seen in the past.

Another observation I think Don Boesch mentioned, eelgrass. In 2005, the summer temperatures rose to 80 degrees, and above 80 degrees Fahrenheit. Those temperatures are lethal for eelgrass. One of the areas that I traverse on a weekly basis to get to my oyster farm is a huge underwater grass, eelgrass meadow.

That essentially disappeared in 2005 as a result of the lethal summer temperatures. I suspect we will continue to see more and more of that as eelgrass—we are at the southern end of its range and that particular type of vegetation is vital to our blue crab population. We are seeing reductions in the blue crab fishery as a result of that and other things.

One of the things that concerns me the most, I mentioned that I've been at the tale end of most all these fisheries, is some of the possibilities that we are going to see affecting the shellfish industry and that is ocean acidification. This is something that I have really never thought about, something I learned in graduate school, but it is just starting to come home now. As CO_2 levels increase in the atmosphere, the ocean takes it up.

Trees take up CO_2 but as levels increase the oceans are going to become more and more acidic. CO_2 converts to carbonic acid. Carbonic acid can convert to bicarbonate ions or carbonate. Shellfish such as oysters, clams, coral reefs, and other micro-organisms need calcium carbonate to form their shells. As the oceans become more acidic, their ability to take up that carbonate, or the ability of the oceans to produce carbonate, is reduced. We run the risk of losing these calcium carbonate-producing organisms.

We saw last week a report from the Pacific Northwest on its huge shellfish aquaculture industry where they are suggesting that the oceanic waters, acidic waters, are up-welling into the bays on the West Coast. There has been essentially recruitment failure of some of their wild shellfisheries, and the suspect is ocean acidification.

Are we seeing this in the Chesapeake Bay? I don't know. We are seeing very slow progress in restoring our native oyster despite the efforts that we are putting into it. We may already be seeing that. We are also seeing little progress in maintaining and restoring our clam fisheries, wild clam fisheries.

The last thing I'll mention is just the impact on the cultural aspects. Our seafood industry depends on these coastal areas. That is where we have to be. That is where we tie our boats up. That is where we off load our catches and we are losing that aspect of our heritage not only to sea level rise but to the growth and development the pressure put on these areas for development.

I'm just here to tell you things that I see. I'm in and on the water virtually every day of my life. I work around the tides. I depend on the environment so I see these things. I certainly haven't been around as long as Mr. Fowler but I have seen a lot of this going on in my 27 years as a waterman. Thank you very much for having me.

[The prepared statement of Mr. Leggett follows:]

Statement of Tommy Leggett, Waterman and Shellfish Farmer

Chairman Grijalva, Madame Chair Bordallo, and members of the Natural Resources Committee, thank you for inviting me to participate in the joint field hearing on "The Impacts of Climate Change on the Chesapeake Bay". My name is Tommy Leggett. I am a resident of Gloucester County, Virginia, and I reside in a small fishing community known as Guinea Neck, at the confluence of the York River, Mobjack Bay, and the Chesapeake Bay. I have had the good fortune to live within two miles of a Virginia tributary of the Bay my entire life. It is fitting that this hearing is being held along the Chesapeake Bay in a coastal community that will be so severely impacted by sea level rise and climate change. What I will

present to you is applicable to this community and many others around the Chesapeake Bay, as well as to coastal communities worldwide.

By way of background, I am not a technical expert on climate change, but I do consider myself an expert on matters related the Chesapeake Bay, its fisheries, and its cultural heritage. I am a shellfish farmer and waterman. I grow native Eastern Oysters and hard clams on a small farm in the York River. I am not representing any group or organization here today, but like the thousands of individuals that reside and depend on the Chesapeake Bay for a livelihood, I have many concerns about the ability of future generations to make a living off the natural resources of the Bay as we face the effects of climate change. After receiving a bachelor of science degree in biology from Old Dominion University in 1977 and a masters degree in Marine Science from the Virginia Institute of Marine Science (VIMS) of the College of William and Mary in 1980, and being enrolled in the PhD program at VIMS for one year in 1981, I realized that academia and research was not for me and I taught myself how to make a living on the Chesapeake Bay as a waterman, or commercial fisherman. The term waterman is a carryover from British river workers who transferred passengers across and along the city center rivers in Britain prior to the settlement of North America. Today there are nearly 3,000 of us still working the Bay in Virginia and around 5,000 working the Bay in Maryland. I am one of only a handful of watermen in the Bay who have degrees in biology and marine science and it provides me a very unique perspective on the challenges we face in restoring the Bay and maintaining fisheries in the face of increasing pollution, population growth, use conflicts, and more recently, climate change.

I worked the water commercially on a full time basis from 1982 until 1998, crabbing, fishing, clamming and oystering. I was able to raise my family as a sole proprietor with my own 40 foot work boat. In 1995 I realized that commercial fishing would not continue to be as profitable; I saw sweeping changes in the crab resource, decreasing abundance of hard clams, and the plight of the oyster fishery is all too familiar. I was desperate to continue working on the water, feeling far more comfortable carving a living out of the Bay as opposed to justifying my existence to funding agencies by writing grants and doing research in academia, so I began to explore other opportunities.

I received a Coast Guard Captain's license in 1995 that would allow me to carry passengers for hire on charter fishing boats and I started toying with the idea of farming clams and oysters. By the end of the year, I had a small quantity of both clams and oysters growing on leased oyster ground in the York River. I continued to work in the hard clam fishery, using a mechanical harvesting device know as patent tongs, while working my way into the aquaculture business. Of all the public fisheries that I participated in, clamming was by far the most gratifying to me. I worked my boat alone, with no dependence on a crew, and the profits were respectable, with low operating expenses. Unfortunately, the clam population began to plummet, clammers began to drop out of the fishery and take land jobs such as trucking, and I soon followed after being offered a job as an environmental educator/captain on one of the Chesapeake Bay Foundation's (CBF) education vessels in Virginia. I did environmental education for two years in Hampton Roads aboard the Baywatcher while maintaining my commercial fishing licenses and developing my shellfish aquaculture business, and in 2000 began working in CBFs Environmental Restoration and Protection Department as a fisheries scientist, doing oyster restoration.

I had come full circle at that point. Today, I am employed by CBF and produce millions of oysters annually for restoration projects and I still have my own clam and oyster farm, selling shellfish to restaurants. In addition, I still maintain my commercial fishing licenses and even though I am employed by CBF, I still consider myself a Chesapeake Bay waterman; it is who I have been for 27 years. My son Tom dabbled in commercial crabbing for a time but in 2001, he realized how difficult it would be to pursue the life of a Chesapeake Bay waterman, and joined the Coast Guard and is currently stationed at Coast Guard Station Sandy Hook, in New Jersey. There are very few watermen of Tom's generation entering the Chesapeake Bay fishery and I suspect this pattern is seen world wide. Adding climate change into the mix only exacerbates the problem of a shrinking population of watermen in Chesapeake Bay, and as daunting a task as improving the health of the Bay is, climate change can easily erase all of the progress made towards saving and restoring the Bay.

Effects of Climate Change on Fisheries and Natural Resources

I want to offer you some sense of what climate change is likely to do to the Chesapeake Bay, based on my own experience and the reading I have done. Much of what I present to you today can also be found in a publication by the National Wildlife

Federation entitled, "Sea-Level Rise and Coastal Habitats of the Chesapeake Bay".1 If possible, I would ask that you include this publication in today's hearing record.

Wetlands

Virtually all of the fisheries in Chesapeake Bay depend on wetlands as nursery areas. Wetlands vegetation is completely dependent on varying degrees of water inundation and saltwater intrusion. Each species of vegetation has its own tolerance of water, whether it is salt or fresh. Sea level rise resulting from climate change will ultimately flood wetlands and eliminate vital habitats that species such as crabs and many finfish require at some point in their life cycle. Many acres of wetlands have already been lost as a result of population growth and the development of coastal areas. If sea level rises as a result climate change the loss of wetlands will be the nail in the coffin for the Chesapeake Bay seafood industry. No wetlands, no seafood, it's as simple as that.

Wetlands and salt marshes also provide shoreline protection for coastal communities. My home in Guinea Neck is only 6-8 feet above sea level and my shore line is completely vegetated with salt mash species as is most of the creek where I live. Vegetated shorelines provide vital habitat for many estuarine species, reduce erosion and run off, and protect upland areas from the impacts of waves during severe storm events. Sea level rise will result in the loss of vegetated shorelines throughout the Chesapeake Bay and the result will be the eventual loss and inundation of coastal communities and the entire infrastructure associated with them such as roads and utilities, and more importantly, the cultural heritage of those communities that have fished the Chesapeake for many generations. The loss of coastal communities will also make inland areas more susceptible to storm surge as the incidence of tropical cyclones increases. One only has to look to the island chains of the Chesapeake Bay that terminate with Smith, Tangier and Fox Islands. Many of my island friends have described in detail the process by which their ancestors moved homes from one part of the island to the other as the land subsided and sea level crept up. Many of the once thriving island fishing communities such as Watts and Holland are now completely uninhabited. It is only a matter of time before we lose what is left of Tangier and Smith Islands, as the rate at which they are disappearing is increasing as the saga of sea level rise plays out.

Underwater Grasses (or SAV—Submerged Aquatic Vegetation)

Underwater grass beds also provide vital habitat for many commercially important seafood species; most notable is the blue crab. Eel grass in particular is crucial in the life of blue crabs, providing shelter to juvenile life stages of the crab as larvae and the first crab stage migrate into and up the Chesapeake Bay. The once-dense meadows of this underwater grass are only a fraction of what they were 100 years ago as a result of degradation of the Chesapeake Bay. The Chesapeake is at the southern geographic range for eel grass, meaning that areas south of the bay are too warm for it to thrive. As our climate warms and our oceans warm, eel grass will be completely removed from the southern portion of the Chesapeake. This was very obvious in 2005 when the lower Bay experienced water temperatures in excess of 80 degrees; temperatures which are lethal to eel grass. Vast meadows of the grass completely disappeared and are only now recovering after 4 years as summer water temperatures come back to near normal levels. Areas that I had to run my boat carefully through at low tide were completely devoid of eel grass for nearly two years. Crabbers in Tangier and Pocomoke Sounds, the epicenter of soft shell crab production in the Bay, reported huge die-offs of eel grass and corresponding reductions in their take of peeler crabs, or the crab stage that eventually results in a soft shelled crab.

Sea level rise will also affect meadows of underwater grass. The Bays underwater grass beds are primarily limited to very shallow areas because the Bay is too turbid, or cloudy, from algae blooms and suspended sediment for grasses to grow in water deeper than about 3 feet. The grasses are dependent on sunlight for photosynthesis. A two foot rise in sea level will virtually eliminate all of the underwater grasses in the lower Bay because sunlight only penetrates about three feet during summer months when algae blooms and suspended sediment are most abundant.

Grass beds also help control sediment transport. Just as grass and vegetation along a shoreline reduces runoff, underwater grass limits sediment movement in the Bay. This phenomenon is very obvious on my sandy bottom oyster ground lease. Patchy grass beds were once prevalent on my lease and sediment transport in those areas was limited. There are currently no underwater grass beds on my lease and I constantly contend with shifting sands around my oyster cages. Underwater grasses would tend to knock suspended sediment out of suspension.

Shellfish and Climate Change

Shellfish such as clams and oysters require calcium carbonate to form their shells. Even the free swimming larvae of these species have a shell, although it is transparent under a microscope. As CO_2 levels in the atmosphere increase from the burning of fossil fuels, the oceans take up more and more of the greenhouse gas and it is converted to carbonic acid, which converts to either carbonate or bicarbonate ions. More and more carbonic acid tips the scale to a more acidic level (ocean acidification) which creates more bicarbonate, and results in less carbonate for shellfish to form shells. Too much carbonic acid can even cause the erosion of existing shell. The larval stages of oysters and clams are particularly vulnerable to ocean acidification since their shell material is very susceptible to erosion at low pH levels.

Clammers in Virginia continue to see low recruitment of new clams into the fishery, even as take is reduced from the attrition of many clammers and restoration projects stockpile broodstock in sanctuaries to promote more successful reproduction. The number of patent tong clammers in Virginia has dropped from over 80 to around 24 since the 1990s. It is likely that the clam population in Chesapeake Bay remains depressed as a function of environmental factors, predation, pollution, or perhaps ocean acidification. Similarly, oyster restoration is proceeding slowly, but that is largely a result of disease, lack of adequate funding for restoration projects, and predation. However, recruitment is often sporadic and inconsistent in areas that historically recruited very well. Ocean acidification could already be having an effect on oyster restoration in Chesapeake Bay.

Just last week, news articles reminded us that the oyster fishery and aquaculture industry on the west coast of the United States has reported recruitment failure since 2005 and ocean acidification is suspect. There is a strong indication that cold acidic waters from the Pacific are upwelled into the estuaries of the west coast and the resulting corrosive waters are preventing oyster larvae from forming shells. Shellfish farmers and scientists expected that phenomenon would occur sometime in the future but it appears to be happening at the present.

Ocean Acidification and the Shells of Plankton

Microscopic planktonic, or free floating organisms, are at the base of the ocean and estuarine food chains. Many planktonic organisms, in particular certain protozoans called foraminifera (forams) that have calcium carbonate shells, are also at risk of shell loss from ocean acidification. Researchers have found that forams in southern ocean core samples that predate the industrial age have thicker shells than modern day forams. The researchers conclude that modern day foram shells are thinner due to their inability to extract calcium carbonate from ocean water as a result of ocean acidification.2 This alarming finding strikes at the heart of the oceans food web and threatens the balance of the entire oceanic and estuarine ecosystem.

Concluding Personal Observations

My watermen friends on Tangier Island are seeing more frequent flooding events on the island during typical northeasterly storms; storm events that are associated with low atmospheric pressure, north east winds, and more water moving into the bay and onto low lying coastal areas. Tangier Island is only five feet above sea level and they are situated in the center of the Bay, five miles south of the Maryland State line. The Bay water doesn't just go into marshes on the Island; it covers streets and rises up to some of the foundation of the homes. Reasons for this include subsidence of the island from freshwater withdrawal to supply the demands of an increasing population of people on the Delmarva Peninsula, or Eastern Shore, and tipping of the continental plates from melting glaciers to the north. As the glaciers melt, the weight on the continental plates decreases and the those to the south subside.

Just in my lifetime I have seen changes in the seasons. We seldom have heavy freezes and when we do, they are shorter than in the past. When I moved to Gloucester County in 1977, it was common place for many of the creeks and even the York River to freeze over periodically. I haven't seen significant ice on the lower York River in over 20 years. We haven't had single digit temperatures since the early 1980s. Several of the local ponds would freeze over every year and serve as a source of ice for ice companies in the 1800s and early 1900s. Ice would be cut out of the pond, carried by horse drawn cart and stored at ice plants in salt hay and insulation until it was needed in the summer. Ice is now manufactured at commercial ice plants, but Haynes Mill Pond in Gloucester has not frozen over enough to supply any quantity of ice that I can remember since living in Gloucester.

Our winters are starting later and are routinely milder. This is very evident in the Chesapeake Bay crab dredge fishery, which used to start December first, after

crabs had begun to burrow in the bottom of the Bay. When I was crab dredging in the 1990s, the month of December was rarely cold enough for crabs to burrow in the bottom and the dredge boats usually spent the first half of the month chasing migrating "schools" of crabs around the Bay until they settled down in January. It was typically warm enough that the crabs would scurry off the deck of the boat during the winter, when they should be nearly dormant.

Shorter and milder winters may have benefits in that a longer agricultural growing season occurs, but that comes at a price for another resource. Longer warm seasons and shorter winters were suspect in the ability of oysters to go through full maturation, or ripening, prior to spawning in 2008 at the VIMS shellfish hatchery, which led to their inability to produce oyster larvae and seed in sufficient quantities for research and production. Whether or not this is the beginning of a pattern is yet to be determined, but it is a sign of what is yet to come as our climate changes and marine and estuarine organisms respond.

Mr. and Madame Chairman and members of the committee, we humans have done a huge amount of damage to the Chesapeake Bay. Coastal communities of people dependent on the Bay for their livelihoods are engaged in a desperate struggle to restore the Bay and the bounty that lives in it. We are only now beginning to realize what we are also doing to the atmosphere and the oceans, and the effect that it will have on the Bay and other estuaries and coastal areas worldwide. On behalf of coastal people in communities around the globe, I urge you to do all you can to slow down the effects of climate change. Thank you.

References

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Mr. GRIJALVA. Thank you, sir.

I will now ask Chairwoman Bordallo for any questions she might have.

Ms. BORDALLO. Thank you, Mr. Chairman. First I want to complement Senator Fowler. I truly enjoyed your testimony. It was very genuine. You've been around to see it all. I also am an optimist myself so I like your optimism. I think that is the way to go. I think more people should hang onto that.

I was pleased that you mentioned Guam and you were there in the '40s during the war. I wish you could come back, Senator. You would be absolutely floored at what you will see today. We are a thriving community of about 175,000 people. We have 1.4 million tourists a year. It's our main industry. Currently we are moving 8,300 marines and their families from Okinawa to Guam and this will be a $14 billion military buildup. Of course, this comes at a very opportune time since we have the situation in North Korea and other areas in the Asia area.

We also have a Home Depot. We have a Macy's. We have a K-Mart. We have all the U.S. restaurant chains represented there and the hotels and the boutiques. Most recently we just opened a Hooters. Senator, I want you to come back to Guam. Thank you very much, Senator.

On a serious note, Mr. Stiles, I was surprised to hear that many communities in Virginia lack the necessary technical, legal, and financial tools to begin to plan for the projected impact of climate change. Could you please explain what factors have contributed to this situation and are the types of data or tools you recommend simply cost prohibitive for these communities to afford?

Mr. STILES. The sort of baseline tools that I think that every community needs are decent elevation maps. As I mentioned, there are about five or six localities in Virginia that have paid for these on their own but the state has not mapped the very flat coastal plain to give you the precise elevations you need.

The second piece of it is to do the modeling on inundation. Once you have the maps then you can go in and start saying, "OK, this block is going to go under faster than this block. And decisions like which road do I elevate, and I said it right this time. Which road do I elevate are made in a much more strategic fashion.

Virginia is sort of an odd state. We are what they call a Dillon Rule state and localities can only do what the state permits them to do. Maryland is a home rule state. Most places are. You can do what you want until the state says no. In Virginia, you've got to go to Richmond to get permission to change a lot of land use practices. Localities are pretty much handcuffed.

The financial tools, the kinds of things we are talking about in keeping development off of open land and in some cases taking development off of land that is increasingly inundated is expensive. This is going to be a major problem nationwide, Bay wide, especially Virginia. Local governments right now could use—the best thing they could use is the mapping and the modeling to be able to figure out just exactly should I allow that shopping center at the end of Guinea Neck of shouldn't I?

Should I allow development down there or not? Is that road going to go under in 30 years? Again, centerline elevations on roads in Virginia. I asked the other day an Assistant Secretary of Transportation if they could provide centerline elevations on roads to local governments and they at this point either cannot or don't have the data. It's those kinds of things that make the life of a local land use official a whole lot easier.

Ms. BORDALLO. I have a follow-up question. What is the best way to maintain economically viable coastal communities without creating new or compounding existing vulnerabilities to climate change? What is the appropriate time horizon for planning to ensure that large capital investments aren't a waste of taxpayer's money?

Mr. STILES. Well, the time to make those decisions is now because the decisions that we make today will have a long life. The average life of a residence is 100 years. Let me give you an example. Fort Monroe is being given back to the state under BRAC. It's being closed. It sits on a barrier island, very low lying. North of the fort is an open piece of land that, once they clear the ordnances off of it, will be developed.

If they develop that land, that is a commitment being made today that will be in place when a lot of these impacts come to be. Again, retail. You know, you build and tear down a shopping center about every 25 years. Commercial real estate, office real estate 60, 70 years. A house is a house is a house for about 100 years. All of these decisions we are making today are cluttering our coastline. They are impairing the resiliency of that coastline to respond to climate change and they are creating expensive investments today that we are going to have to roll off of the land in coming decades.

Ms. BORDALLO. Another one. I have another question for you, Mr. Stiles. Should the Coastal Zone Management Act be amended to specifically require coastal states to amend their existing approved programs to account for climate change?

Mr. STILES. I think that would be one of the best things that could be done. Anything at the Federal level, the planning for transportation that is done regionally, FEMA changes, all of those things need to be on the table but the CZMA reauthorization language needs to be strengthened in that regard.

Ms. BORDALLO. Thank you. My final question, Mr. Chairman, is I want to thank all of you for your testimony and it is clear from your statements that coastal communities around the Chesapeake Bay should expect tougher times ahead as climate change begins to more significantly alter the Bay's environment. Now, if you were to offer one or two recommendations for what we in Congress could do to better prepare coastal communities around the Bay to adopt and respond to climate change, what would they be? If you could just make it very short.

Yes, Mr. Parnes.

Mr. PARNES. I'm an educator and my interest goes back to educating not people our age but the next generation. I'm surprised frequently by how little contact, even those of us who live very near the Bay, really have with the Bay. How little we think about it, how little we think it affects our lives. I think there is a sense that it's your job to deal with this problem. It's not my job.

For institutions like ours we spent a lot of time educating not just children but adults both that it's all of our jobs to become part of the solution, to think hard about what it is about this place that is worth saving and that we need to agree if we are willing to sacrifice, willing to pay a few more tax pennies a year, willing to change what we do in order to make sure that the tradition of this place doesn't get erased.

I think there is a real danger that 50 years from now this place will look just like so many other places and that would be a terrible loss. I think for us we are working to educate folks that it's part of their role as citizens. It's not just up to you all. It's not just who we elect to go into office but it's all of our role, too, to work closely with that and become part of it. I think this effort that you're making is a great step forward. I think the leadership in the White House right now is what a lot of us have been waiting for, for many years.

Ms. BORDALLO. Thank you. So your recommendation then is to educate and get the community involved.

Mr. PARNES. I think in this region, at least right now, there is a great interest in education that tends to be science and math focused because of the challenges that we face. We are missing the opportunity also to educate folks about the cultural heritage and the richness of this place and what makes this place special. I think we don't want to lose that. To me that is a key piece.

Ms. BORDALLO. Thank you.

Mr. Leggett.

Mr. LEGGETT. I would have to agree education is critical, environmental education about how we can all be better environmental stewards, how we can better take care of our planet. In my case,

it's the Chesapeake Bay. More support from environmental restoration as was mentioned earlier.

A healthy ecosystem is more resilient. We need to continue all of our restoration activities to make a healthier Bay whether it's improving water quality, supporting oyster restoration or multi-species fisheries' management. Also education about our cultural heritage. I would say education and restoration is critical.

Ms. BORDALLO. Thank you.

Mr. Stiles, do you have anything to add to that?

Mr. STILES. I think a comprehensive review of Federal authorities would be of use to look at how agency and department operations and regulatory processes can or cannot accept and adapt to the climate endpoints that we now understand, for us the 2.3 feet of sea level rise, the 3 degree Centigrade and the 11 percent increase in intensity.

This is what we did at the state level. We said, "OK, state agencies, how do these endpoints affect what you do?"In the process, you either get a gap analysis where the statutes can't cover those changes or you get an adaptation within the agencies within their existing statutory and regulatory authorities to do what they are supposed to do. I think that kind of a mandate would be a very good first step.

Ms. BORDALLO. So the Federal government involvement.

Senator.

Mr. FOWLER. Thank you, Madam Chair. The Clean Water Act, I believe, was passed in 1972, 37 years ago. I don't want to suggest nothing has been done but it has been ignored for the patience creatures. I think one of the most important things, one of the key things early on if we had coincided with the intent of that bill an established total maximum daily loads for all of the tributaries. It doesn't mean to stop growing.

It simply means if you're going to grow and you want to grow and growth is a big problem, then you are going to have to meet certain qualifications. It's going to have to be purified a little more. Instead of three milligrams of nitrogen per liter of water, it may have to be two. The technology is here to do it. It's costly. That's very important.

Another thing that we have not done, and I'm partly to blame for that, we just have not been able to raise public awareness sufficiently enough. That bar needs to be raised high. People have to understand the personal consequences that are in store for us down the road. I mentioned the inhalation problems in the school my granddaughter teaches in. There is also a very, very high cancer rate in the Southern Maryland area.

I can't sit here today and tell you that is what's causing it but I can tell you I really think it's a big part of it. The air and the water, the environment we live in has a lot to do with our well being. Those are two things I would strongly recommend. Maybe we need to get on television. We need to get that Indian back on the television.

Let him shed some tears about the beer cans floating down the stream. That has all been taken away. We are all pumping our chests over what great things we're doing and it's time we looked at the world in reality. Let the public know that and demand that

the public become strong supporters and intervenors and supporting you so you can get the job done.

Ms. BORDALLO. Thank you. Thank you very much, Senator. Thank you to all the witnesses.

Mr. Chairman.

Mr. GRIJALVA. Thank you very much.

Mr. Kratovil.

Mr. KRATOVIL. Mr. Chairman, I don't have any questions. I'll just close by thanking all the members of the panel.

Senator Fowler, I do think there is reason to be optimistic. I mean, it was just a few years ago where everyone, and still there is obviously some debate although pretty minimal now, in terms of the concerns related to climate change. There is a much broader consensus now. Like many things in our country and across the world it takes some time for people to recognize sort of where we are going.

I think there is consensus now across this country. There are some who still criticize the scientific part of this but I think that is a relatively small number. Given the comments you made about our President, given what we see, just this week as we are moving forward on some very significant energy legislation I think there is very good reason to be optimistic and perhaps we are now finally getting it. Thank you all for being here.

Mr. FOWLER. We can do it.

Mr. GRIJALVA. Thank you very much. Just a couple of quick questions from me.

Mr. Stiles, one of the hearings we had we have been exploring the role of western public lands and mitigating climate change. Out in the west where I am from we have large tracts of public land and we have intact ecosystems.

To look at that corridor study, to look at how that plays a part with species and buffers I'm not saying it's easier but the planning is not as complex when you consider that in the area that we're talking about it's smaller tracts of public land, a lot of private land and obviously more densely populated. What role should the Federal government have in the public land, the Chesapeake Bay, and the watershed in combating that climate change?

Mr. STILES. Well, there are a number of large tracts in the Bay watershed. I think, again, elevating the awareness of this issue into the day-to-day operations of any agency, state or Federal, is going to help them begin to get their arms around what they need to do. I think managing the Federal lands with an eye toward increasing the sequestration of carbon is something that is important.

I think that also a lot of these public lands serve as corridors for wildlife to move from the places where they are now that are going to get increasingly inhospitable to places where they are going to have to move in the future over time. Managing wildlife corridors is something we have just started to look at.

It is something that a lot of the big land operations like Nature Conservancy and Trust for Public Lands are also looking at how you manage lands, how you manage public lands and also the allied lands to provide these wildlife corridors. Things like that would be very useful.

Mr. GRIJALVA. I think as a former county supervisor commissioner land use planning was the big deal in our county in relationship to conservation. That role is vital to the health of the Bay. Could you elaborate a little more on the land use part of dealing with climate change?

Mr. STILES. The challenges in the Bay, especially in the flat areas around Edgewater, the flat areas, Mathews and Gloucester, is that the land that you need to preserve is not necessarily the land that is under jurisdiction now for wetlands protection or even uphill from it the buffer protections in both Maryland and Virginia.

The land you are after is private land and it can be developed by right today but in these flat-lying counties that is where the wetlands or the shoreline is going to be in 40 or 50 years. The big problem is the conflict between property rights and also the property tax aspirations of the locality. If I'm a locality, I'm not going to put my most valuable land off the table.

What do I do with that land that is slightly uphill from what they call the jurisdictional lands? How do I deal with that? Is there some money on the table for me to buy those development rights out? Are there alliances that I can form with land trust? Is there favorable tracts treatment to where that land owner can get a fair return on some of the development value of that land but the public gets a promise that the land will remain open.

Mr. GRIJALVA. So zoning prerogatives and acquisition become tools.

Mr. STILES. Yes. And down-zoning. At some point you tip the balance between the property rights governing that land and what they call the public trust doctrine. That land remaining developed is actually harming land and taxpayers somewhere else. At some point there is going to be a tipping point in the legal argument about the property rights of this upland. It's very hard to do, though, because it's an asymmetric operation.

Mr. GRIJALVA. Yes.

Mr. STILES. The benefits come beyond the life of any current elected local politician.

Mr. GRIJALVA. In your testimony, you mentioned that we have done enough studying, published enough reports that we know that we need to take some action. What immediate action if you had to recommend to this Committee as a first step given our jurisdictions what would that be?

Mr. STILES. Well, I think, especially since you have jurisdiction over the CZMA, I think there are a lot of things that could be done with the Coastal Zone Management Act to really bolster the mandate for coastal states to begin this planning. Some states are already doing it. I think Maryland is doing a pretty good job. North Carolina has the maps and is moving ahead.

Then there are states that lag behind Virginia being the prime example that I know of because I live there but other states in the southeast are also experiencing a much slower pace of acceptance of the need to adapt. I think if there were a mandate that your CZMA money is dependent and your program is dependent upon some performance standard here on climate change would be useful.

Mr. GRIJALVA. Did you review or look at all at the adaptation section that is part of what the legislation will be dealing with this week?

Mr. STILES. I have looked at it in various iterations and I think this is going to be a very, very expensive operation. Again, you are going to have to freeze lands and somebody's financial aspirations if you really want to do the right thing on sea level rise, for example.

So it's going to take some money to put those adaptation programs in place and the only source of money that I can see is going to come from some of the auctioning and the generation of funding from that auctioning that is going to go on to the land. I think that probably the only way, I mean, the magnitude of the money we are after is probably the only way to effectively put adaptation in place.

Mr. GRIJALVA. Thank you.

Mr. Parnes, you mentioned in your testimony that we need to take lessons from the cultures and the generations that came before us. What are those lessons that you would suggest to help us deal with this enormous and urgent challenge of climate change?

Mr. PARNES. Well, there are a couple of specific ones I guess I could say. Over the last century or so the way that the resources of the Chesapeake Bay have been harvested by our forefathers was not always with much looking out to the future. I came to this area from living on the Connecticut coast and 100 years ago the fishermen on the Connecticut coast came down here and tried to catch every last oyster on the Bay.

There are lessons about over-harvesting. There are lessons about living on the land, which our ancestors did extremely well, much better than we have. They knew they wanted to live in communities where they could provide for each other and be close to each other and have what they needed in their communities.

Now we live in these sprawling suburban areas that we have to drive to get to school, we have to drive to get a quart of milk or whatever it is. We should have learned something from the way that our ancestors have lived here and we should have also learned something from the way they have kind of abused the privilege in a sense. So much abundance was here and so much abundance has been taken from this place that we need to balance that out.

I think there is no shame in looking back and saying, "Boy, if we could do it again, we would be smarter now." But there is also no shame in looking back and saying, "You know, they really knew what they were doing back then and they understood the sustainability of this place." Now in our intensive farming and our intensive development and our intensive suburbanization there is a certain capacity that the Chesapeake Bay is able to support.

I think we all feel if we haven't crossed that line we are getting mighty close. That is a terrible kind of decision to make. I think we have put up on the walls these sort of romantic views of the Chesapeake Bay and they have sort of become a little motif for all of us. We go to our seafood restaurant and there it is but we don't think about it.

Our ancestors actually were pretty smart the way they learned to live on this place and the way they understood that if they lived at the edge of the water they were going to have to pick up and

move someday. They knew that but they thought it through and I think we can learn a great deal and I think there is no shame in looking back and saying, "Gee, we didn't learn that lesson well. We really could have done it better."

Mr. GRIJALVA. Thank you.

Mr. Leggett. thank you very much for your testimony.

Senator, I had some questions I was going to ask you but after your opening comment and then your response to the Chairwoman's question they seem at best redundant right now so thank you very much for being here. I appreciate that very much.

Mr. FOWLER. Can I make a comment?

Mr. GRIJALVA. Absolutely.

Mr. FOWLER.—nephew was working back there with a great big wooden box and on it was "crab meat from Ecuador." When I was coming up as a youngster and even a young adult, we exported seafood all around the United States of America—fish, crabs, oysters, you name it. Today we are importing that to supply our need. That to me is really almost a national disgrace with the kind of ability we have in that Chesapeake Bay and the protein factor we have out there to import all this stuff to sustain our restaurants and people who love these delicacies.

Ms. BORDALLO. Good point.

Mr. FOWLER. Yet, we have the ability to do it. We just need to hunker down and crack down. I really think it will not get done. It will not get done unless there is a strong Federal oversight that has some mandatory authority there to get it done.

Mr. GRIJALVA. Thank you very much. Let me thank you, gentlemen. The information that has been provided at all these hearings, and certainly this one, and all of you are very privileged and fortunate to live in this beautiful part of the world but we all share a responsibility to try to maintain what is there for future generations.

I agree that the legislation before us on climate change is imperative and necessary. It needs to be strengthened in some areas. Thank you for that recommendation on the Coastal Land Management Act and putting some strength into the adaptation and the mandates, looking at our regulatory abilities and mandates now, and how to enforce them.

Part of it has disappeared from our agencies, and they are barely growing their teeth back right now. Over the last almost decade, we have lost all enforcement ability and all desire to enforce the regulations and the laws that exist—clean water being one of them. Those are all lessons that we take from this hearing. Thank you so much and we are very appreciative of your time and your expertise. Thanks a lot. Meeting adjourned.

[Whereupon, at 12:31 p.m., the Subcommittee was adjourned.]

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