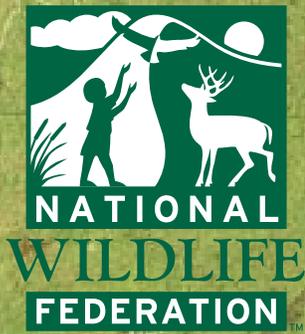


# THE CHESAPEAKE BAY AND GLOBAL WARMING

A PARADISE LOST FOR  
HUNTERS, ANGLERS,  
AND OUTDOOR ENTHUSIASTS?





## **The Chesapeake Bay and Global Warming:**

### **A Paradise Lost for Hunters, Anglers, and Outdoor Enthusiasts?**

September 2007

Prepared by:

Patty Glick, Senior Global Warming Specialist  
Amanda Staudt, Global Warming Scientist  
Doug Inkley, Senior Scientist

© 2007 by the National Wildlife Federation. All rights reserved.

Larry J. Schweiger  
President and Chief Executive Officer  
National Wildlife Federation

#### Acknowledgments

This report is the culmination of the efforts of numerous professionals without whom it could not have been completed.

At the National Wildlife Federation we especially thank Sue Brown, Christine Dorsey, John Kostyack, Jim Lyon, Sarah Gannon Nagle, Thuy Senser, Julie Sibbing, Felice Stadler, Tim Warman, and Dan Wrinn for their many valuable contributions.

We also appreciate the constructive assistance of Paul Massicot and George Chmael of the EcoLogix Group; Ray Najjar, Pennsylvania State University; Dru Schmidt-Perkins, 1000 Friends of Maryland; Skip Stiles, Wetlands Watch; Jeff Plummer, Maryland Waterfowlers Association; David Burke, Burke Environmental Associates; Bill Goldsborough and Beth McGee of the Chesapeake Bay Foundation; Eric Schwaab and Matthew Fleming of the Maryland Department of Natural Resources; Jack Travelstead, Virginia Marine Resources Commission; Chris Burkett and David Whitehurst of the Virginia Department of Game and Inland Fisheries; and Khristi Wilkins, U.S. Fish and Wildlife Service.

Thanks to Tom Waldron and the Hatcher Group for their editing services.

The National Wildlife Federation is grateful to the Keith Campbell Foundation for the Environment for its generous support of this project.

NATIONAL WILDLIFE FEDERATION  
11100 WILDLIFE CENTER DRIVE  
RESTON, VA 20190  
703-438-6000  
[www.nwf.org](http://www.nwf.org)



# Table of Contents

MESSAGE FROM THE CEO ..... 2

EXECUTIVE SUMMARY ..... 3

I. INTRODUCTION ..... 6

II. GLOBAL WARMING THREATENS AN ALREADY BELEAGUERED CHESAPEAKE BAY ..... 8

III. A TRIPLE THREAT TO WATERFOWL HUNTING.....10

IV. “GONE FISHING” OR FISHING GONE? .....14

V. CHANGING THE FORECAST FOR THE CHESAPEAKE BAY: A PLAN OF ACTION .....18

VI. CONCLUSION .....30

ENDNOTES .....31

NWF’s mission is  
 to **INSPIRE** Americans  
 to **PROTECT**  
**WILDLIFE** for our  
**CHILDREN’S**  
**FUTURE**

FRONT COVER: U.S. FISH AND WILDLIFE SERVICE (USFWS); MAP, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA); LEFT, U.S. GEOLOGICAL SURVEY (USGS); TOP RIGHT USFWS

## Message From The CEO



I have fond memories of trolling the lower Potomac on foggy autumn mornings, while nearby watermen “tonged” for oysters and gulls swarmed the skiffs. The Chesapeake Bay has long held a special place in my heart. From a home we enjoyed on Maryland’s Kent Island, I have developed a deep appreciation for the natural beauty and outstanding recreational opportunities offered by the bay. I have fished and hunted there for more than thirty years.

My personal devotion to the Chesapeake Bay has motivated professional efforts to protect this national treasure. Beginning in the late 1970s, I assisted in the most comprehensive assessment of the bay to date. During the 1980s, I served on the board of the Citizen’s Program for the Chesapeake and chaired a Point Source Working Group that helped develop an “action agenda” advancing measures to restore the Chesapeake Bay. Later working at the National Wildlife Federation, we organized a major conference, “Chesapeake Bay—A Pennsylvania Connection,” which encouraged the Chesapeake Bay Foundation to launch its Pennsylvania office focused on watershed restoration. In 1995, I joined the staff of the Chesapeake Bay Foundation, where we initiated an effort to better manage the blue crab and protect its deep water corridors. As CEO of the Western Pennsylvania Conservancy, I proposed that

the Commonwealth launch a conservation bond fund that evolved into “Growing Greener,” a program to fund watershed restoration along Pennsylvania’s many waterways. Growing Greener continues to pump tens of millions of dollars annually into various river and stream clean-up projects.

My deep concern about the future of the Chesapeake Bay continues to guide me from my post at the National Wildlife Federation. I also have an abiding respect for the many professionals who have spent their entire careers restoring the bay. I understand the importance of broad collaboration at this critical moment. Like it or not, global warming will be the defining issue of the 21st century. In its wake, the things I love most about the bay will be in jeopardy. Unless we address the root causes of global warming, rising sea levels will wash away islands, destroy critical wetlands, and render current shorelines unrecognizable. More-intense storms will increase sediment and nutrient runoff. Warmer water will change the entire ecology of the bay, pushing out cold-water species and allowing an influx of warm-water and invasive species. Without decisive action to address global warming, all the hard-fought progress made by so many to restore the bay could be lost.

The challenge is significant. Fortunately, we can minimize the impacts of global warming on the Chesapeake Bay. We can steer clear of the worst impacts by taking action now to reduce our global warming pollution by just 2 percent per year. And, we can take steps to help humans, along with the fish and wildlife of the Chesapeake Bay, cope with those climate changes that are inevitable. We don’t have time to waste. And, it will require the action of all of us. *The Chesapeake Bay and Global Warming: A Paradise Lost for Hunters, Anglers and Outdoor Enthusiasts?* offers a plan of action that can help restore the bay to its full splendor. It is my fervent hope and belief that we will be successful. Our children and grandchildren are counting on us.

Sincerely,

Larry Schweiger  
*President & Chief Executive Officer*

# Global Warming Jeopardizes Cherished Outdoor Traditions in the Chesapeake Bay Region

Global warming is causing major changes to natural systems today. Around the world, countries and communities are feeling the effects and searching for the right responses. This report by the National Wildlife Federation focuses on the very real threat that global warming poses for fish and wildlife in the Chesapeake Bay region. The report synthesizes recent scientific studies and observations from the field to offer a blueprint for action to overcome the problems spawned by global warming.

Fish and wildlife in the Chesapeake Bay region will be directly affected by several climate changes that are already underway:

- **Warmer air and water in the Chesapeake Bay region** will alter the composition of species that can live in the bay, contribute to worsening dead zones and harmful algal blooms, enhance marine diseases, and encourage expansion of harmful invasive species such as nutria.
- **Rapidly rising sea levels** will inundate coastal marshes and other important habitats that are important for fish and waterfowl and make coastal property more vulnerable.
- **More-extreme weather events, including floods, storms, droughts, and heat waves** will lead to more polluted runoff into the Chesapeake Bay, hurt water quality, and make the outdoor experience increasingly unacceptable for people.
- **Changing climate across North America** will affect breeding grounds and migration patterns for waterfowl, such that fewer birds make their way to Chesapeake Bay each year.

The bottom line is that these changes to natural habitats in the Chesapeake Bay region put treasured outdoor traditions—from sportfishing and waterfowl hunting to clamming and lazy days on the beach—at great risk.

## The Major Investments in Chesapeake Bay Restoration Could Be Lost Due to Global Warming

Over the past quarter century, billions of dollars have been invested in restoring the Chesapeake Bay watershed. Sportsmen and women in particular have been strong supporters of responsible land use, wildlife, and fisheries management, helping to restore populations of popular fish and wildlife species. But, global warming puts new stresses on the bay's habitats, in some cases making it harder to reach conservation goals.

Many efforts currently underway to restore and protect the Chesapeake Bay's habitats—such as reducing nutrient pollution to managing coastal development—may also help fish and wildlife deal with global warming. To be successful, these conservation programs will need to consider the additional stressor of global warming, and in some cases, new initiatives will be required.

## Solutions Are Available

The problem of global warming is daunting. Fortunately, solutions are at hand. The time for

# Executive Summary



action is now. Many of the decisions we make today—from where and how we build our homes, businesses, and highways, to how much and what kinds of energy we use—will have a significant impact on our resources, land use, and even our climate for many decades to come. This report makes the following summary recommendations, focusing on priority actions for the federal government, regional entities, and state and local governments in Maryland and Virginia, which share the majority of coastline habitats that will be affected by global warming. (More detailed recommendations are found in section V.)

## Reduce Global Warming Pollution

Reducing global warming pollution at a rate of 2 percent per year from current levels will significantly improve the forecast for wildlife. Taking bold steps today, using a combination of actions to reduce our dependence on fossil fuels, is essential to achieving this important goal. The federal government, as well as states, localities, and individuals, will need to step up to meet this challenge.

- The U.S. Congress and the administration should place mandatory limits on the nation's global warming pollution to ensure we meet the target of an 80 percent reduction by 2050.

## Provide Adequate, Dedicated Funding for Conservation

Even if we successfully reduce global warming pollution, fish and wildlife in Chesapeake Bay will face changes in climate and habitat conditions, creating an unprecedented conservation challenge for wildlife managers. The state and federal agencies charged with addressing this challenge were under-funded before global warming emerged as a problem. Today, they need a significant increase in funding to effectively carry out their mission of conserving wildlife for future generations.

- The U.S. Congress and the administration should pass a nationwide cap-and-trade bill to reduce global warming pollution, with roughly 10 percent of the revenue (from an auction of 100 percent of the permits) allocated for fish and wildlife conservation. The funding should supplement, not supplant, existing budgets for natural resource management, recognizing the new threat to fish and wildlife posed by global warming.
- Legislatures in Virginia and Maryland should ensure that conservation agencies receive adequate, dedicated funding each year to meet existing conservation goals and to address the new challenge posed by global warming. The legislatures also should reduce reliance on the annual appropriations process by providing long-term budgetary certainty.

## Manage the Land in the Face of Global Warming

Across the Chesapeake Bay region, people increasingly recognize that protecting fish and wildlife requires protecting wetlands, forests, and other natural habitats from encroaching urban development while doing a better job of managing already developed areas and farmland. It is now critical for the bay region to consider global warming as part of these land-management efforts. Failing to do so will make it much more difficult, if not impossible, to meet our important conservation goals.

In particular, sea-level rise should be a major consideration in the region's coastal development plans because it impacts both habitats and human settlements. We can improve the ability of our coasts to withstand some sea-level rise by enhancing the natural defenses provided by wetlands, barrier islands, and reefs; supporting the natural replenishment of sediments from rivers and beaches; and protecting inland buffers to enable habitats to migrate.

- Federal, state, and local agencies that manage coastal resources should consider sea-level rise when amending their plans for coastal development, expanding open space, protecting wetlands, and other relevant activities. It

is essential to discourage new development and coastal “armoring” such as bulkheads in ecologically sensitive coastal areas.

Land conservation efforts are currently underway to restore and protect the Chesapeake Bay’s habitats and the species they support. These programs include the conservation provisions of the national Farm Bill, Maryland’s Program Open Space, and the Virginia Land Conservation Foundation. It is critically important for decision makers to explicitly account for global warming in prioritizing and developing meaningful land conservation and habitat protection and restoration strategies.

- Congress should significantly expand funding for the conservation provisions of the Farm Bill. Land conservation agencies and foundations in Maryland and Virginia should develop improved criteria for identifying ecologically critical lands and take more significant steps to preserve and expand open space.

Global warming is likely to lead to more extreme precipitation events, including heavier rainfall and the possibility of more-intense coastal storms. In response, improving storm-water management will be critical in meeting established goals for reducing dead zones in the Chesapeake Bay.

- Maryland and Virginia should increase support of non-structural approaches to storm-water management (i.e., preventive measures incorporated in land-use and development planning), require local agencies to consider the likelihood of an increase in extreme precipitation events when considering new projects, and discourage construction in or near coastal and stream riparian buffers, wetlands, and other sensitive areas.

## Governments and Individuals Must Take Action Now

There is no time to lose before we take action to address global warming and the stress it places on the Chesapeake Bay region’s fish and wildlife. Global warming’s broad effects will come on top of the many other problems, such as nutrient pollution, that already plague the bay. As outlined in this report, federal, state, and local governments have the opportunity to reduce global warming pollution and at the same time help ease the effect that habitat changes will have on fish and wildlife.

But the challenge presented here is not simply for government agencies and elected officials. Citizens of Maryland and Virginia who treasure the natural beauty and resources of the Chesapeake Bay can play a critical role in advancing meaningful solutions. Hunters, anglers, and outdoor enthusiasts should take action now to both restore the bay and reduce global greenhouse gas emissions. We can change the forecast for the Chesapeake Bay and ensure that the economic opportunities, ecological benefits, and outdoor traditions it provides will endure for generations to come.





## I. INTRODUCTION

### The Chesapeake Bay is a Paradise for Hunters, Anglers, and Outdoor Enthusiasts

Hunting, fishing, and other outdoor traditions have been an important part of life in the Chesapeake Bay region for generations. Whether it is the thrill of reeling in a prized rockfish off Smith Point, spending a weekend with friends hunting canvasbacks on Maryland's Eastern Shore, or digging for clams on a sandy beach, the Chesapeake Bay's habitats provide incalculable value to the region and nation.

For waterfowlers, the Chesapeake Bay is a cherished destination. Each year, more than one million ducks, geese, and swans come to the bay for stopover and wintering habitat, congregating in the coastal wetlands of protected areas such as the Blackwater National Wildlife Refuge in Maryland and the Saxis Wildlife Management Area in Virginia. In 2001, close to 100,000 people hunted waterfowl in Maryland and Virginia combined, contributing \$25.5 million to the regional economy.<sup>1</sup>

As home to more than a dozen species of game fish, the Chesapeake Bay is also a fishing paradise. In 2004, residents and visitors spent more than \$700 million on saltwater recreational fishing in Maryland and Virginia, including the waters of the bay.<sup>2</sup> The Susquehanna Flats, Tangier Sound, Smith Point, and many other bay areas are year-round destinations for saltwater anglers pursuing prized game fish.

And millions of people flock to the Chesapeake Bay each year to go clamming, crabbing, build a sandcastle, cruise the waters, and enjoy a host of other outdoor recreational opportunities.

Preserving the Chesapeake Bay's treasured outdoor traditions for future generations will depend on how well we address growing conservation challenges, including global warming.

### Trouble in Paradise: Multiple Threats to the Bay

Billions of dollars have been invested in the Chesapeake Bay watershed to restore and protect fish and wildlife habitat. The Clean Water Act, for example, has been a valuable tool for restricting wetland destruction and improving water quality. Federal farm programs such as Swampbuster, the Conservation Reserve Program, and the Wetlands Reserve Program have encouraged farmers to set aside wetlands and other important habitat for waterfowl.

The widespread decline of the bay led to the historic 1983 Chesapeake Bay Agreement in which Virginia, Maryland, Pennsylvania, the District of Columbia, and the U.S. Environmental Protection Agency established the Chesapeake Bay Program partnership to protect and restore the bay's ecosystem. Their initial focus was on toxic pollution, excess nutrient input to the bay, and declining seagrasses. Since then, the program has issued several plans with ambitious goals and timelines for bay restoration, and there have been important improvements in the health of the bay. The plan was revised most recently in 2000, when Delaware, New York, and West Virginia became more involved in the partnership.

Waterfowlers and anglers have helped expand protected areas through the duck stamp program, fishing licenses and other



means. And they have been strong voices in support of responsible land use, wildlife, and fisheries management. Combined, these actions have helped bring populations of popular Chesapeake Bay fish and wildlife species—such as rockfish and Canada geese—back to healthy numbers.

But the bay still faces many challenges.<sup>3</sup> The majority of its waters are highly degraded due to excessive nutrients, chemical contaminants, and sedimentation. Critical habitats such as seagrass beds and tidal wetlands have shrunk under continuing pressure from development and pollution. Populations of many of the bay's fish and wildlife species are declining as a result. Hunters and anglers are seeing firsthand the fallout from these problems, whether it's lesions on rockfish or waterfowl that now stop elsewhere instead of the bay.

Today we also face extraordinary challenges brought on by human-caused global warming, primarily generated by the rapidly accelerating use of fossil fuels. Global warming is not a distant threat. It is causing major changes to our natural systems today: warmer air and water, rising sea levels, more extreme weather, and changing climates. As the evidence makes clear, these changes pose a great risk to the treasured outdoor traditions that have shaped the region for generations.

## **BOX 1.**

### *Blackwater National Wildlife Refuge*

Among the many treasured natural places along the Chesapeake Bay, the Blackwater National Wildlife Refuge is a crown jewel. Located on Maryland's Eastern Shore, the refuge is home to a diverse and abundant collection of fish and wildlife. Thousands of migrating ducks, geese, and swans use the refuge as stopover and wintering areas, making it popular for hunting waterfowl. At the same time, the wetlands help to control flooding and maintain water quality.

Sea-level rise is a major threat to the future of the Blackwater National Wildlife Refuge. Since the late 1930s, sea-level rise and overgrazing by nutria have contributed to a loss of one-third of the refuge's coastal marshes. As sea-level rise accelerates, the future of the refuge is in jeopardy. Saving such Blackwater and other coastal habitats will require diligent action both to reduce global warming pollution and to plan for habitat change brought on by sea-level rise.





## II. GLOBAL WARMING THREATENS AN ALREADY BELEAGUERED CHESAPEAKE BAY

**TABLE 1.  
REPORT CARD FOR THE  
CHESAPEAKE BAY, 2006<sup>5</sup>**

<b>Pollution</b>	
Nitrogen/Phosphorus	F/D
Dissolved Oxygen	F
Water Clarity	F
Toxics	D
<b>Habitat</b>	
Forested Buffers	B+
Wetlands	C+
Underwater Grasses	F
Resource Lands	D
<b>Fisheries</b>	
Rockfish	A+
Blue Crabs	C
Oysters	F
Shad	F

The latest report card on the health of the bay, compiled by the Chesapeake Bay Foundation, provides a grim accounting (see Table 1).

Populations of shad, menhaden, blue crabs, native oysters, and hard clam species have declined dramatically due to pollution, habitat degradation, and other problems. Declines in wetland breeding habitats outside the region, as well as reductions in food sources in the Chesapeake Bay, have caused many duck populations in the region to decline. This is especially a problem among species that depend on submerged aquatic vegetation as a primary source of food, including northern pintails, redheads, and American wigeon.<sup>4</sup> In addition, marine diseases continue to plague the bay, and fish advisories warning of contamination from mercury and other toxic pollutants are routine.

To be sure, we already face daunting conservation challenges. Global warming will add significantly to those challenges.

### Global Warming is Affecting the Chesapeake Bay Region

There is irrefutable evidence that human activities, particularly the burning of fossil fuels, have been causing excessive amounts of carbon dioxide and other greenhouse gases to build up in the atmosphere.<sup>6</sup> As a result, the Earth's average surface temperature has already increased by 1.7 degrees Fahrenheit, and scientists project that it will rise by another 2 to 11.5 degrees before the end of this century if we continue to depend so extensively on fossil fuels.<sup>7</sup> This warming is disrupting the planet's entire climate system. Average water temperatures are increasing, precipitation patterns are changing, and extreme weather events such as droughts, floods, storms, and heat waves are becoming more severe.<sup>8</sup> At the same time, the thermal expansion of the oceans combined with rapidly melting glaciers and ice fields are causing the average global sea level to rise at an accelerating rate.

We can feel the effects of global warming in the Chesapeake Bay watershed. Average air temperatures in the region have increased by 1.4 degrees Fahrenheit along the coastal margins of the Chesapeake Bay through Maine over the past century, and much of the region has seen about a 10 percent increase in average precipitation, with greater precipitation extremes.<sup>9</sup> The period between the first and last dates with snow on the ground has decreased seven days over the past 50 years.<sup>10</sup> The average



water temperatures in the bay also rose about 1.4 to 2 degrees Fahrenheit from the 1950s to 2000.<sup>11</sup>

At the same time, average sea levels in the Chesapeake Bay have been rising. Many places along the bay have seen a one-foot increase in relative sea-level rise over the 20th century, six inches due to global warming and another six inches due to naturally-subsiding coastal lands—a factor that places the Chesapeake Bay region at particular risk. Already, many of the bay’s coastal marshes and small islands have been inundated. At least 13 islands in the bay have disappeared entirely, and many more are at risk of being lost soon.<sup>12</sup>

## Failure to Combat Global Warming Means Even Greater Changes in the Decades to Come

As global warming pollution continues, these trends will worsen. Air temperatures in the Chesapeake Bay region will continue to increase, as much as 4 to 14 degrees Fahrenheit by the end of the century.<sup>13</sup> Waters in the bay will also continue to warm, with direct implications for aquatic plants and animals.

Recent studies also point to a greater likelihood of increased precipitation in the Chesapeake Bay region. By the end of the 21st century, the region could see an 8 to 15 percent increase in average precipitation compared to 2000.<sup>14</sup> In particular, climate models suggest that winter and spring precipitation will increase.<sup>15</sup> Because the extent of summertime plankton blooms and stratification

is partly determined by runoff into the bay during winter and spring, increases in precipitation during these seasons could be especially problematic.<sup>16</sup>

In addition, relative sea-level rise in the Chesapeake Bay region could reach 17 to 28 inches above 1990 levels by 2095.<sup>17</sup> This increase is significantly greater than the global average sea-level rise of 7 to 23 inches projected by the Intergovernmental Panel on Climate Change (IPCC)—again due to land subsidence.<sup>18</sup> If the melting of the Antarctic and Greenland ice sheets accelerates during the coming decades, as new studies suggest, sea-level rise in the Chesapeake Bay could be considerably greater.<sup>19</sup>



TOP LEFT, NOAA; TOP RIGHT, IAN; RIGHT, VIRGINIA DEPARTMENT OF EMERGENCY MANAGEMENT



### III. A TRIPLE THREAT TO WATERFOWL HUNTING

The Chesapeake Bay has long been one of the most important areas in North America for wintering waterfowl and has a tradition of excellent waterfowl hunting. The nation's largest collection of wooden duck decoys is housed at the Havre de Grace Decoy Museum, while the annual Waterfowl Festival in Easton attracts thousands of waterfowl enthusiasts from across the country.

Unfortunately, it has become clear that global warming poses a triple threat to waterfowl hunting in the Chesapeake Bay region. First, the breeding grounds for many of the bay's wintering ducks, the Prairie Pothole Region in the upper Great Plains, is expected to become much drier and produce fewer ducks because of global warming. Second, some migrating waterfowl are already stopping in ice-free areas farther north and west as winters become warmer, and the trend is expected to continue. Finally, waterfowl that do migrate all the way to Chesapeake Bay are likely to find a loss of shallow-water wintering habitat as sea levels increase.

With the impacts of global warming already affecting the bay, waterfowl hunters can't afford to wait to take actions that would slow the detrimental impacts of climate change. Quality days in the marshes and fields across the bay are already declining, jeopardizing the Chesapeake's long-term waterfowl heritage.

#### Declines in Prairie Pothole Wetlands

Global warming in regions far from the Chesapeake Bay will also affect the bay's wintering waterfowl populations. The Prairie Pothole Region of south-central Canada and the north-central United States, so-called for its abundance of small and shallow pothole-like wetlands, is the single most important breeding ground for North America's migratory ducks. About 50 percent of the nation's annual duck production is from the Prairie Potholes, which is especially important for mallards, gadwall, blue-winged teal, northern pintails, canvasbacks, and redheads. The majority of canvasbacks wintering in Chesapeake Bay are produced in the Prairie Potholes (see Box 2).

As the climate warms and evaporation and transpiration by plants increase, Prairie Pothole wetlands are expected to either dry up or remain wet for shorter periods, making them less suitable for duck breeding. Average March-to-May temperatures in the region increased in the latter half of the 20th century, and continued warming would be expected to raise evaporation rates and reduce soil moisture by 25 percent by the middle to the end of this century, particularly in summer months.<sup>20</sup> Models of future drought conditions in the region due to global warming indicate declines of up to 91 percent of Prairie Pothole wet-



lands by the 2080s, which could lead to a reduction of as much as 69 percent in the population of ducks breeding in the Prairie Potholes.<sup>21</sup>

## Short-Stopping: Where Have All the Ducks Gone?

Milder winters are already hurting waterfowl hunting as waterfowl delay migration due to the later onset of fall, or stop short of their usual wintering grounds when they find suitable wintering areas farther north. Lakes and rivers throughout the northern hemisphere are now freezing an average of six days later than they did 100 years ago.<sup>22</sup> And in some areas, lakes that tended to freeze completely in the winter now often remain at least partially open. For example, from 1850-1949, Lake Champlain completely froze over 95 percent of the time. But, from 1950 to 1999 Lake Champlain froze over only 54 percent of the time. As global warming continues, lakes will increasingly freeze later or not at all some winters.

During mild winters, waterfowl do not need to migrate as far south or as early as usual because they can find open water much more readily in more northerly areas. There are many reported incidents of this so-called short-stopping. For example, in the unusually mild winter of 2005-2006, Canada geese were observed for the first time spending the winter as far north as Prince Edward Island, on the Atlantic coast north of Nova Scotia. Tundra swans have wintered on open rivers in Canada and

canvasbacks are also short-stopping due to milder weather (see Box 2).

As this trend continues, waterfowl enthusiasts in the Chesapeake Bay and other places in the southern parts of the country can expect poorer hunting seasons. Delayed migration of waterfowl brought on by warming winters may force government officials to delay the opening of the annual waterfowl season.

Even then, waterfowl hunters in the marshes will likely see fewer and fewer ducks.

## Habitat Loss

Challenged by declining wetlands for breeding and short-stopping as winters become milder, waterfowl that do reach the Chesapeake Bay face a con-



*"I have hunted all over Chesapeake Bay during the last 20 years, and the number of quality hunting days has declined steadily. The biggest factor has been the weather. It simply doesn't get as cold, as early, as often in the bay. Large numbers of mallards and black ducks that we would typically get into around Thanksgiving aren't showing up in the Chesapeake until Christmas, if even then. And the last couple years we are lucky if the canvasbacks come at all. Weather drives duck hunting, and with more and more fall and winter days in the 70 degree range, more and more waterfowlers are hanging up their waders and calls. This threatens the future of waterfowling in the bay...."*

Steve Huettner  
Past President, Maryland Sportsman's Association

TOP LEFT, USFWS



tinuing loss of habitat that is expected to worsen with global warming. Sea-level rise will inundate coastal marshes, while both sea-level rise and warmer waters will place added strain on submerged aquatic vegetation, a critical food source for many ducks and geese. In addition, higher average air temperatures will likely encourage the expansion of invasive species, such as habitat-destroying nutria.

Of great concern is sea-level rise. Because coastal lands in the bay are subsiding, relative sea-level rise is occurring much faster than in other regions, with vast expanses of the bay's coastal marshes being inundated. While marshes may be able to accommodate moderate changes in sea level through natural sedimentation and marsh accretion (the build-up of organic matter), studies have shown that the rates of sedimentation and accretion for most Chesapeake Bay marshes are failing to keep pace with the rate of sea-level rise.<sup>23</sup> This disparity is expected to worsen as the rate of sea-level rise accelerates with global warming.

Furthermore, as sea-level rise floods low-lying areas, the introduction of miles of seawalls, bulkheads, and other armoring of coastlines precludes the natural creation of new coastal habitat. With an 18-to-24-inch rise in relative sea level, well within the projections for the 21st century, it is not far-fetched to envision the bay being surrounded not by



beaches and marshes, but by bulkeads and seawalls.<sup>24</sup>

Sea-level rise also is expected to have a direct impact on the distribution and composition of seagrass by increasing the water depth and thereby reducing the sunlight that seagrass needs for photosynthesis.<sup>25</sup> Seagrasses, or submerged aquatic vegetation, are a critical resource that provide food and habitat for a wide range of bay species, including crabs, fish, and waterfowl. Seagrasses also protect shorelines from erosion, remove nutrients from the water, and trap sediments that cloud bay waters. Rapid sea-level rise would undermine the current efforts to restore seagrass beds throughout much of bay, which would have a significant impact on species that depend on the seagrasses for food, including redheads, northern pintails,

American wigeon, American black ducks, ruddy ducks, and canvasbacks.

Higher water temperatures, meanwhile, have contributed to the decline of eelgrass in the bay over the past ten years.<sup>26</sup> Eelgrass, which is the primary nursery habitat for juvenile blue crabs, grows best in areas of cool water with high salinity. Too-warm water over an extended period kills eelgrass, especially in combination with turbidity and low-light conditions. Although eelgrass beds can often recover when conditions become more favorable, scientists are concerned that the trend toward more heat waves in the region will significantly reduce eelgrass coverage in the bay, where it is near the southern end of its range.

Furthermore, warmer conditions are likely to allow invasive species to become a greater presence in the bay area, potentially harming native species by out-competing them for habitat and food. One invasive species that could benefit from warmer winters in the region is the South American nutria, a highly destructive rodent that was introduced into Maryland's Eastern Shore in 1943 to support the fur trade.<sup>29</sup> Foraging nutria have caused significant local damage to marshes in the region, including destroying more than 7,000 acres in Blackwater National Wildlife Refuge. The nutria has been limited in its northward range due to intolerance for harsh winter conditions. But as winters in the region become milder, conditions will be more favorable for nutria to move northward.<sup>30</sup>



## BOX 2.

### *Canvasbacks*

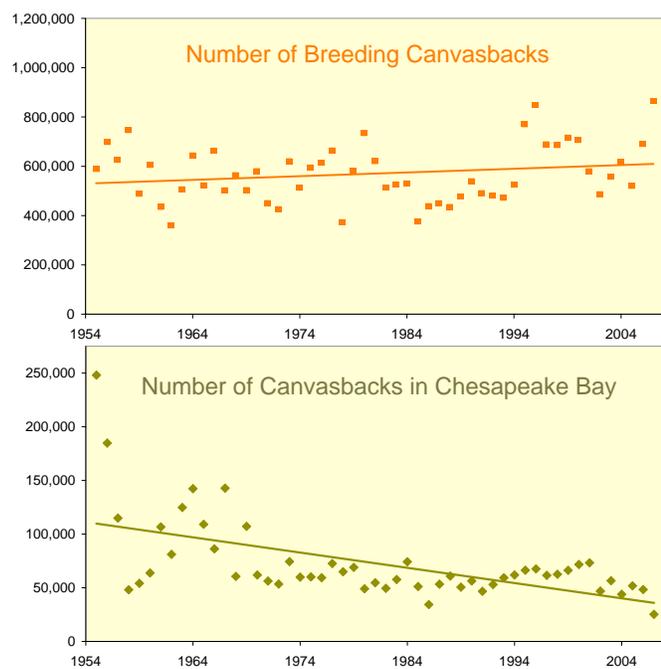
The largest of the diving ducks, the canvasback is popular among waterfowl hunters. While overall canvasback populations for the past 50 years have been stable, the number of wintering canvasbacks in the Chesapeake Bay has declined from a high of nearly a quarter million birds in the mid-20th century to an average of just over 30,000 birds in the last five years (see figure to the right).

Long-term observations indicate that canvasbacks have virtually abandoned the bay due to a loss of submerged aquatic vegetation. The loss of this essential vegetation is associated with water degradation, including nutrient over-loading from runoff, which leads to algal blooms and less sunlight.

Short-stopping due to milder winters is also a factor in the decline of the canvasbacks, many of which migrate from their breeding ground in the Prairie Potholes through the Great Lakes to the Chesapeake Bay. In the spring of 2007, the number of breeding canvasbacks was the highest ever reported in the annual Waterfowl Breeding Population Survey.<sup>27</sup> But only six months earlier, a record-low 13,800 canvasbacks were observed in Chesapeake Bay in the January 2007 Mid-winter Waterfowl Survey.<sup>28</sup> The “missing” canvasbacks were observed in unusually high numbers in the Great Lakes, which remained largely unfrozen in the winter of 2006-7 due to the unusually mild and late winter.

As winters become even milder due to global warming, canvasbacks may have little reason to migrate to the bay and could winter primarily in the Great Lakes instead.

#### SURVEY OF CANVASBACK POPULATION LEVELS IN UPPER MIDWEST BREEDING GROUNDS AND CHESAPEAKE BAY WINTERING AREAS





## IV. "GONE FISHING" OR FISHING GONE?

The Chesapeake Bay has been known historically for both its commercial fisheries and outstanding sport fishing. In recent decades, the bay's fishing reputation has been marred by declining catches and intermittent bans on rockfish, blue crabs, oysters, and other species. Contributing factors to these problems include over-fishing, excessive nutrients, sedimentation, disease, water pollution, loss of submerged aquatic vegetation, and shoreline development. Now, on top of these factors, global warming is having a profound effect on the entire Chesapeake Bay aquatic ecosystem by increasing water temperatures, raising sea levels, and changing freshwater inflow. Although the bay's complexity makes precise projections of future conditions challenging, it is certain that these changes will affect fish populations and fishing opportunities.

### BOX 3.

#### *Rockfish*

Rockfish, also known as striped bass or stripers, are a prized species in the Chesapeake Bay and the Atlantic Ocean. The health of the bay is critical for this species, because a majority of Atlantic Coast rockfish are spawned in the bay and its tributaries. Since a ban on rockfish fishing in the 1980s allowed the species to repopulate, fishing seasons have been opened again.

In recent years, though, fishermen and scientists have observed an increase in the number of malnourished and diseased rockfish. Significant declines in menhaden, a species harvested commercially and a primary rockfish food source, appear to be contributing to rockfish's declining health. Another factor may be increased disease transmission as rockfish are confined in denser populations within smaller areas to avoid hypoxic waters.<sup>43</sup>

Rockfish will likely be further stressed by a number of conditions associated with global warming, including warmer waters, enhanced growth of mycobacteria, and an increase in eutrophication and hypoxic conditions.

Such hypoxic conditions also will hurt menhaden, an important prey species for rockfish. As menhaden are forced to find new habitats to avoid hypoxic areas, rockfish will again be affected. It is clear that maintaining the rockfish population will require careful monitoring and management of the entire bay ecosystem rather than a focus only on rockfish.

### Warmer Water

Anglers are well aware of the sensitivity of fish to temperature and often refer to sea-surface temperature maps to determine where a particular species might be. As global warming increases air temperatures, bay water temperature will also rise. Assuming other habitat conditions are suitable, higher temperatures are expected to favor increasing populations of such warm-water species as brown shrimp, black drum, spotted seatrout, grouper, and southern flounder.<sup>31</sup>

On the other hand, increasing temperatures are a threat to such species as rockfish (sometimes called "striped bass"), Atlantic sturgeon, soft-shelled clams, and winter flounder, which thrive in relatively cool water. As temperatures increase, these species are stressed by both increased energy needs and lower oxygen supplies. When stressed, fish decline in overall health and become more susceptible to disease.

### Marine Diseases Spreading

In marine ecosystems around the world, new diseases and more frequent epidemics

have been causing mass mortality in important marine species, such as corals and marine mammals, with strong links to global warming.<sup>32</sup> Chesapeake Bay fisheries are not immune to this trend.

A new species of mycobacterium recently infected rockfish, and mycobacterial infections have increased in other bay fish species, including menhaden.<sup>33</sup> A wide variety of factors is likely responsible, including declining water quality, pollution, habitat degradation, and global warming.<sup>34</sup> Warmer water may enhance mycobacterial growth and infection, but it also stresses species that prefer cooler water, making them more vulnerable to infection.

Native oysters, once estimated at only about 1 percent of historic levels, have been devastated by the deadly oyster diseases MSX and Dermo. MSX appears to be less active and less infectious at lower temperatures. Dermo is also limited by colder conditions, and winter temperatures typically limit its range, but it had a rapid expansion of oyster infection and mortality northward up the Atlantic Coast from Delaware Bay during a period of especially warm winters starting in 1990.<sup>35</sup> With cold winters becoming rarer as the climate warms, MSX and Dermo are likely to continue to flourish as water warms earlier in the spring and stays warm later in the fall.

## Dead Zones to Expand

Eutrophication is a major problem, if not the major problem, for fish in the Chesapeake Bay, and it is likely to be exacerbated by global warming. Eutrophication is caused by an increase in nutrients, including nitrogen and phosphorus, in coastal waters. This leads to excessive phytoplankton growth that contributes to a depletion of oxygen in affected waters. Large areas of oxygen-depleted water can lead to significant fish kills among coastal species, particularly smaller, schooling fish such as menhaden. In August 2005, a record dead zone covered more than 40 percent of the bay.

River flow, which carries nutrients from agricultural fields and other sources into the Chesapeake Bay, is a major factor in hypoxia (low oxygen) and anoxia (no oxygen) events.<sup>36</sup> Heavier precipitation flushes greater amounts of nutrients and other pollutants into the bay, contributing to eutrophication and oxygen depletion.<sup>37</sup> Heavy runoff also decreases water mixing as less dense fresher water rides over the top of the denser saltier water, inhibiting the mixing of water and inhibiting the replenishment of oxygen in deep waters.

**TABLE 2. POTENTIAL IMPACTS OF GLOBAL WARMING ON CHESAPEAKE BAY FISHERIES**

-  Potential loss of species altogether in the Chesapeake Bay
-  Likely decline in species range or viability in the Chesapeake Bay
-  Likely expansion of species range or viability in the Chesapeake Bay

SPECIES	LIKELY TREND	CLIMATE CHANGE IMPACTS IN CHESAPEAKE BAY
Winter flounder		Water temperatures could exceed habitable range.
Soft-shelled clam		Water temperatures could exceed habitable range.
Rockfish		Water temperatures could reach near the upper limit of habitable range and also conducive to outbreaks of mycobacterial infections.
Atlantic sturgeon		Water temperatures could reach near the upper limit of habitable range.
Blue crab		Declining eelgrass habitat with rising sea level and exacerbated eutrophication.
Atlantic menhaden		Warmer water more conducive to mycobacterial infections.
Eastern oyster		Warmer water more conducive to Dermo and MSX.
Brown shrimp		Warmer water more favorable.
Southern flounder		Warmer water more favorable.
Black drum		Warmer water more favorable.
Grouper		Warmer water more favorable.
Spotted seatrout		Warmer water more favorable.

*Note: These probable effects were identified based on available information, but significant changes in key parameters such as temperature and salinity are likely to have wide-ranging unpredictable effects on life cycles and food webs.*



*“While the rockfish fishing is better today than when I was a kid in the 1980s, I’m growing more concerned about how good it will be for my kids. Warmer summer water temperatures seem to be concentrating the fish in smaller and smaller areas each year and harming their overall health. I worry about climate change’s long-term impact on the health of the fishery.”*

Christopher Conner  
Director of Communications and Marketing  
University of Maryland Center for Environmental Science  
and an avid fisherman

Water temperatures also affect oxygen levels because warm water holds less dissolved oxygen than cooler water does. For each degree Fahrenheit in temperature increase, the water’s ability to dissolve oxygen decreases by about 1 percent.<sup>38</sup> Higher water temperatures also accelerate the bacterial decay of organic matter present in the water, thereby consuming oxygen and exacerbating hypoxia.<sup>39</sup>

Waters without oxygen are essentially uninhabitable for marine life. High water temperatures and resulting loss of oxygen were identified as the leading cause of major fish kills among 22 coastal states between 1980 and 1989.<sup>40</sup> Furthermore, higher average sea temperatures and eutrophication are considered to be a factor in the growing number and severity of harmful algal blooms, such as “red tides,” “brown tides,” and “mahogany tides,” throughout the nation’s coastal waters, including the Chesapeake Bay.<sup>41</sup>

The urgent battle against bay eutrophication will become more difficult as global warming continues. Although different models show varying results, there is

agreement that precipitation will increase in late winter and early spring.<sup>42</sup> Increases in the spring flow of the Susquehanna River have been associated with increases in anoxia in the Chesapeake Bay during the summer.

## Drowning our Fishing Heritage

Coastal wetlands of the Chesapeake Bay are already disappearing due to sea-level rise, and will continue to do so as global warming increases. While some new wetlands are likely to be created in low-lying upland coastal zones, efforts to minimize land loss and protect roads, buildings, and other structures will likely lead to more “armoring” of shorelines, precluding the development of new wetlands in these areas.

Unless major efforts are implemented to ensure the development of new wetlands as the sea level rises, the loss of coastal



wetlands will have a significant impact on bay life. Tidal wetlands serve as filters of bay waters and stabilizers of shallow water and inter-tidal zones. Many game fish and other species depend on coastal marshes and seagrass beds for spawning, feeding, and protection. At risk from the loss of these important coastal habitats are rockfish, flounder, bluefish, menhaden, and other species. Wetland loss will also reduce essential habitat for important prey species, such as shrimp, crabs, and smaller fish, which would have ripple effects throughout the bay's food chain.

Furthermore, sea-level rise makes the coasts more vulnerable to erosion from storm surges and wave action. The depth of water in estuaries has a significant influence on wave action during storms—the deeper the water, the larger and more destructive the waves.<sup>44</sup> This is of a special concern because hurricanes and other storms will likely be stronger in the coming decades (see Box 4).

#### **BOX 4.**

### *Hurricanes – A Growing Menace*

Hurricanes are infrequent in the Chesapeake Bay area, but they can have major impacts on the region as demonstrated by Hurricane Agnes (1972) and Hurricane Isabel (2003). Global warming will likely bring an increase in hurricane intensity. So, while scientists do not expect there to be more hurricanes in the future, the hurricanes that do form will likely be stronger.<sup>45</sup> At the same time, sea-level rise will also lead to bigger storm surges, which do great harm to marine life and coastal wetlands. These two factors together mean that future hurricanes that visit the Chesapeake Bay will bring increased rainfall and flooding.

In June 1972 the remnants of Hurricane Agnes combined with another low-pressure system, dumping heavy rains over Northeastern Pennsylvania. In addition to large-scale property damage, the subsequent flooding had a major impact on the Chesapeake Bay ecosystem. Despite being a relatively weak hurricane, Agnes sent an enormous amount of freshwater into the bay. The dramatic reduction in salinity had a drastic effect on many species,<sup>46</sup> and it was years before many marine fisheries recovered.

The extremely heavy sediment load of some 30 million tons washed into the bay by Hurricane Agnes alone was equivalent to the sediment deposited over about seven years during normal flows.<sup>47</sup> Many seagrass beds in the bay were dealt a devastating blow by the sediment, which carried a heavy nutrient load, blocked out sunlight due to suspended particles, and buried seagrass beds, or both.

More recently, Hurricane Isabel in 2003 also had a marked effect on the Chesapeake Bay. The relatively deeper waters of the Chesapeake Bay, which were due in part to sea-level rise, were likely a factor in the near-record storm surge and damaging waves that Isabel generated in the region.<sup>48</sup>



## V. CHANGING THE FORECAST FOR THE CHESAPEAKE BAY: A PLAN OF ACTION

Even though the problems posed by global warming seem daunting, practical solutions are available. By reducing global warming pollution while taking steps to help wildlife cope with some of the inevitable changes, we can ensure that the Chesapeake Bay's treasured natural heritage and sporting legacy will endure.

Effectively managing the land in the face of global warming is a major challenge for the next decade and beyond. Across the Chesapeake Bay region, officials have recognized the importance of protecting wetlands, forests, and other natural habitats from encroaching urban development and better managing already-developed and agricultural lands. Sound land use is one of the primary goals of the Chesapeake 2000 Bay Agreement. However, failure to explicitly consider global warming as part of these efforts will make it much more difficult, if not impossible, to meet conservation goals.

The time for action is now, because many of the decisions we make today—from where and how we build our homes, businesses, and highways, to how much and what kinds of energy we use—will have a significant impact on the Chesapeake Bay and its fish and wildlife for decades to come.

Policy makers in Washington, along with the governments and citizens of Maryland and Virginia, can play a critical role in advancing meaningful solutions to change the forecast for the Chesapeake Bay. This section makes recommendations in seven broad areas to accomplish that.

### 1. Reduce Global Warming Pollution and Provide New Funding for Wildlife

To help fish and wildlife in the Chesapeake Bay, we need a two-pronged approach. First, we must curb global warming pollution, thereby limiting the magnitude of changes to the climate and ecosystems. Reducing global warming pollution at a rate of 2 percent per year from current levels will significantly improve the forecast for fish and wildlife (see Box 5). This will require action by the federal government, as well as states, localities, and individuals.

But, even if we successfully reduce global warming pollution, fish and wildlife in the bay will inevitably face some impacts of global warming. There will still be some warming over the next century from greenhouse gases that are already in the atmo-



sphere and those that we will continue to emit while transitioning to new energy sources. New and enhanced restoration and adaptation strategies will be needed. To develop those effectively, fish and wildlife agencies must be given a permanent, stable, and new funding source.

For years, sportsmen have helped sustain fish and wildlife populations through the purchase of licenses and permits, as well as special excise taxes on hunting and fishing equipment. The U.S. Congress has provided some additional funding for state fish and wildlife agencies (\$61 million in 2005), but it is far short of what is needed to sustain fish and wildlife populations affected by global warming.

Programs to reduce global warming pollution should be designed to provide funds to sustain wildlife habitat and populations during the period when global warming threatens these critical resources. The leading proposals in Congress for controlling global warming pollution create a new system of permits for major emitters, often referred to as a “cap-and-trade” system. Under such a proposal, the government would auction off annual permits that allow industry to emit a certain amount of carbon dioxide and other greenhouse gases. At the end of the year, each industrial source would be required to hold permits to cover its emissions for the year. As such a system is put in place, it is critical that a portion of proceeds from the auction of emission permits be set aside to fund conservation of fish and wildlife.

Such a cap-and-trade system for regulating global warming pollution can provide a double benefit for fish and wildlife. It will help reduce the impacts of global warming and it will provide new funding for resource managers to help fish and wildlife cope with those climate changes that are inevitable. In an added benefit for the Chesapeake Bay, many of the measures that reduce global warming pollution will also reduce nitrogen emissions that are ultimately deposited in the bay.

Dedicated conservation funding will be crucial to help states develop strategies for protecting fish and wildlife from global warming, integrate fish and wildlife adaptation strategies into existing resource management plans, and carry out conservation actions. Indeed this funding could help support many of the activities recommended in this report.

#### Federal actions:

- The U.S. Congress and the administration should place mandatory limits on the nation’s global warming pollution to ensure we meet the necessary target of 80 percent reduction by 2050.
- The U.S. Congress and the administration should pass a nationwide

### **BOX 5.** *Avoiding the Worst-case Scenario*

As many as one-third of species worldwide are at risk of extinction if global temperatures reach more than 2 to 3 degrees Fahrenheit above present levels.<sup>52</sup> These extinctions will be accompanied by major changes in the structure and function of ecosystems. The only way to keep temperatures from increasing more than 2 degrees Fahrenheit in the next century is to begin taking steps immediately to reduce global warming pollution.

To have a reasonable chance of staying below 2 degrees of warming, greenhouse gases in the atmosphere need to stay below about 400-450 parts per million of carbon dioxide equivalent.<sup>53</sup> To meet this goal, the United States must reduce current carbon dioxide and other greenhouse gas emissions by about 80 percent by 2050.<sup>54</sup> Experts have concluded that this target is achievable with technologies either available or under development.



cap-and-trade bill to reduce global warming pollution, with roughly 10 percent of the revenue (from an auction of 100 percent of the permits) allocated for fish and wildlife conservation. The funding should supplement, not supplant, existing budgets for natural resource management, recognizing the new threat to fish and wildlife posed by global warming.

Maryland has taken some important steps to address global warming pollution. It joined the northeastern states' Regional-Greenhouse Gas Initiative, with a commitment to reduce carbon dioxide emissions from the state's utility companies by about 10 percent from current levels by 2019. It passed a renewable energy standard, which requires electric utilities to generate 7.5 percent of their electricity from renewable sources like solar, wind, and biomass by 2019. Recently, Maryland adopted a requirement to reduce carbon dioxide emissions from new cars sold in the state, and adopted more stringent efficiency standards for new appliances.<sup>55</sup> While much progress has been made in Maryland, more needs to be done. Virginia lawmakers have yet to act.

### State Actions

- Maryland and Virginia should adopt a stringent carbon dioxide reduction goal of 2 percent per year, or 20 percent per decade, to achieve the necessary 80 percent reduction target by 2050.
- Maryland should strengthen its renewable energy standard to require utilities to generate at least 20 percent of electricity from renewable sources by 2020. Virginia should adopt a similar standard.





- Maryland should adopt more stringent building codes for government-owned buildings to require all new and renovated buildings to be carbon neutral by 2030. Virginia should adopt a similar standard.
- Virginia should adopt a “clean cars” bill and join the 10-state Regional Greenhouse Gas Initiative to work with neighboring states to achieve reduction in carbon dioxide emissions from power plants.

## 2. Expand State Wildlife Action Plans to Address Global Warming

In 2000, the U.S. Congress charged each state and territory with developing a wildlife conservation strategy. These Wildlife Action Plans identify at-risk species and habitats and outline the actions necessary to protect them, ultimately leading to cost-effective, proactive conservation strategies. To date, few of the plans include specific strategies to help wildlife cope with climate change.

Congress provided funding for creating and implementing these plans through the State and Tribal Wildlife Grants Program. Funds appropriated under this program are allocated according to a formula based on each state’s size and human population. The average grant in 2007 was just over \$1 million.

The Virginia Wildlife Action Plan mentions global warming as a threat to wildlife. Specifically, the plan lists the Blue Ridge Mountains and the biologically diverse Northern Ridge and Valley regions as particularly susceptible to change brought on by climate change. Several rare species and habitat types would likely be lost, including high-elevation forests, home to the endangered Carolina Northern Flying Squirrel. The current Virginia plan calls for more research, but does not include specific conservation actions that address global warming.

The Maryland Wildlife Action Plan, formally known as the Maryland Wildlife Diversity Conservation Plan, lists global warming and sea-level rise as statewide threats to wildlife. In particular, sea-level rise has contributed to the decline of the extremely rare type of floodplain forest, called a sea-level fen; the plan calls for restoring these wetlands by reintroducing northern conifers to the landscape and protecting them from ditching, draining, and water withdrawal. The Maryland plan also identifies sea-level rise as a threat to several types of coastal habitats: beaches, dunes, mudflats, and coastal plain freshwater streams. The plan calls for conserving these habitats by protecting and restoring riparian buffers, improving storm-water management systems, developing shoreline erosion control practices, and restoring native dune vegetation.

Maryland has taken an important first step to better account for global warming in its wildlife action plan. In April 2007, Governor O’Malley created the Governor’s Climate Change Commission, charged with developing a strategy to reduce the sources and impacts of global warming. The Adaptation and Response Working Group of the Commission is developing state-based adaptation measures, with an initial focus on sea-level rise. Maryland could be one of the first states in the nation to develop a state-based adaptation plan.

### State actions:

- In Maryland, continue efforts through the Governor’s Climate Change Commission to develop a wildlife adaptation strategy that identifies fish, wildlife, and habitats threatened by climate change and outlines actions to protect them.



- In Virginia, develop a wildlife adaptation strategy that identifies fish, wildlife, and habitats threatened by climate change and outlines actions to protect them.
- In both states, incorporate adaptation measures related to climate change in the State Wildlife Action Plan.

### 3. Expand State-Based Funding for Maryland and Virginia Conservation Activities

Despite more than three decades of conservation and restoration activities, the Chesapeake Bay ecosystem is still stressed due to pollution, over-fishing, and coastal development. Moving ahead, global warming could significantly alter the bay's habi-

#### **BOX 6.** *Blue Crab*

Crabbing is a popular recreational activity and the Chesapeake Bay's single largest commercial fishery, with more than 50 percent of the nation's annual blue crab harvest coming from the bay.<sup>49</sup>

As with other species, determining how climate change will impact the blue crab population is a complex puzzle. Because blue crab growth is inhibited by cold winter weather in the Chesapeake Bay region—forcing crabs to burrow in the bay's mud until warmer weather returns—warmer winters could actually extend the growing season and lead to population increases.<sup>50</sup>

But, other global warming factors are likely to inhibit the blue crab population in the bay. For example, eelgrass, which provides juvenile blue crabs with important habitat, would face significant danger if water temperatures exceed its tolerance levels.<sup>51</sup> Without suitable nursery habitat, the Chesapeake Bay blue crab population would be expected to decline even in the face of more favorable warmer winters.

As global warming affects the Chesapeake Bay ecosystem it will be important that the blue crab population be carefully studied and harvest levels adjusted as conditions dictate.





tats, further disrupting its ability to support the fish and wildlife for which it is best known.

Reducing environmental stressors like nutrient overload, habitat loss, and fragmentation will make the system healthier and help wildlife survive the impacts of global warming. At the same time, new efforts are required to specifically address the habitat changes that global warming is likely to bring. These new activities will require new funding.

Conservation activities in both Maryland and Virginia are supported by a combination of special revenues—mostly from the sale of hunting and fishing licenses and taxes on sales of watercraft and equipment used in hunting and fishing—state general fund appropriations, and federal support. However, the funds available to the Maryland and Virginia agencies that handle conservation, fisheries, environment, and planning are insufficient to meet the current conservation challenges, much less the new challenges posed by global warming.

Furthermore agencies in both states face budgetary uncertainty from year to year. It is not uncommon that the special revenues supposedly dedicated for fish and wildlife conservation are redirected to other unrelated efforts. In Maryland, for example, funds dedicated for land acquisition in Program Open Space have often been redirected to other uses, hampering the effectiveness of the program. Such funding uncertainty will constrain agencies from pursuing new programs to address global warming.

Finally, the states should provide more accountability for their conservation spending to assure the public that such spending is effective. To that end, Maryland has recently begun the BayStat initiative to track Chesapeake Bay restoration activities.<sup>56</sup> BayStat will help ensure that existing and new funding is well spent.

**State actions:**

- Legislatures in Virginia and Maryland should ensure that conservation agencies receive adequate, dedicated funding each year to meet existing conservation goals and to address the new challenge of global warming. The legislatures also should reduce reliance on the annual appropriations process and provide more long-term budgeting certainty.



## 4. Adapt Waterfowl and Fish Management Practices

Waterfowl and fish migration patterns are shifting, and populations are changing in response to global warming, affecting which species frequent the Chesapeake Bay and when they are present. Indeed, global warming will have broad, interconnected impacts on entire marine ecosystems. Effective management will mean addressing the health of the habitat as a whole, rather than one species at a time. Yet, most fisheries management plans focus on single-species management and do not consider the inter-related impacts of climate change. An ecosystem management approach would be more effective and allow for better consideration of long-term changes such as those brought on by global warming.

If we fail to address global warming, shifts in waterfowl and fish migration patterns and declines in some species may also force resource managers to consider making adjustments to hunting and fishing seasons to ensure the long-term viability of species. The management approach will need to take into consideration year-to-year conditions as well as longer-term climate trends. For example, the delayed migration of waterfowl due to warming winters may force government officials to delay the opening of the annual waterfowl season.

### State and Regional Actions:

- The Atlantic States Marine Fisheries Commission, the Mid-Atlantic Fisheries Management Council, the Virginia Marine Resources Commission, the Maryland Fisheries Service, and the Chesapeake Bay Program should move towards an ecosystem approach for managing fisheries in Chesapeake Bay. State and regional marine fisheries management plans should consider how climate change will affect fisheries.
- As species populations shift in response to global warming, fisheries managers should consider adjusting fishing regulations.
- The delayed migration of waterfowl due to warming winters may force government officials to delay the opening of the annual waterfowl hunting season.



## 5. Discourage Extensive Coastal Development and Armoring of Shorelines

Sea-level rise should be a major consideration in the region's coastal development plans. Maryland has taken an important first step by establishing a state-wide Sea-level Rise Response Strategy, which has laid out a number of recommended actions.<sup>57</sup> To be successful, however, actions should be coordinated throughout the region.

The best ways to improve the ability of our coasts to withstand sea-level rise are to enhance the natural defenses provided by wetlands, barrier islands, and reefs; support the natural replenishment of sediments from rivers and beaches; and protect inland buffers to enable habitats to migrate. Whenever possible, resource managers and land-use planners should steer away from structural approaches such as seawalls and bulkheads for coastal protection. Coastal armoring hinders the ability of habitats to migrate inland as sea levels rise, preventing coastal wetlands from replenishing themselves through sediment buildup.

In addition, the region should discourage development in vulnerable areas. For example, both Maryland and Virginia currently designate that new development can not take place within a 100-foot buffer surrounding ecologically critical areas. This size buffer may not be sufficient as erosion and inundation rates accelerate due to sea-level rise, threatening habitats farther inland.<sup>58</sup>

### Federal Actions:

- The U.S. Congress should reauthorize the Coastal Zone Management Act to require relevant state agencies to consider sea-level rise in coastal management plans to qualify for federal funding; prohibit federal subsidization of infrastructure development and coastal armoring in ecologically sensitive areas; and encourage public and private land acquisition of coastal habitats and upland buffers.
- The Federal Emergency Management Agency should remap potential hazard areas in coastal zones to reflect anticipated sea-level rise, taking into account potential storm surge impacts, and establish policies to reduce or eliminate federal flood insurance for new construction and rebuilding in high-risk areas.





- The U.S. Congress should expand the Coastal Barrier Resources system to discourage new development in areas needed to buffer natural resources and existing development from sea-level rise. Such areas should be denied federal subsidies such as federal flood insurance, disaster relief, and loans for sewer, water, and highway construction.

#### State and Local Actions:

- Maryland and Virginia should enact new legislation requiring local governments to consider sea-level rise when amending their plans for coastal land use, open space, wetland protection policies, and other relevant activities.
- The Virginia Marine Resources Commission and the Maryland Department of Natural Resources in conjunction with the Maryland Department of the Environment should develop state tidal wetlands conservation and restoration plans that promote designation of wetland migration corridors and remove and discourage use of hard shoreline erosion structures in coastal marsh environments.



- The Maryland Department of Natural Resources should expand Maryland's Critical Area buffer designation and the Virginia Department of Conservation and Recreation should expand Virginia's Resources Protection Area buffer designations beyond the current 100-foot requirement to accommodate impacts of sea-level rise. States should also expand enforcement of current regulations and prevent any attempts to weaken these provisions in relevant legislation.
- State and local agencies should establish policies such as rolling easements or mandatory setbacks to discourage new development in vulnerable coastal areas.



## 6. Account for Global Warming in Land Conservation and Habitat Protection Efforts

Numerous land conservation efforts are currently underway to restore and protect the Chesapeake Bay's habitats and the species they support. Bay-protection efforts have included limiting suburban sprawl, reflecting the fact that such development contributes to habitat fragmentation and destruction, air pollution, and water quality degradation. Many of these efforts will also make the region's coastal wetlands and other natural habitats more resistant to the effects of global warming. For example, habitat restoration and de-fragmentation along with open-space protection will allow wildlife to move more easily to new locations as climate shifts push them out of their current homes.

But it is also critically important for decision makers to explicitly account for global warming as they develop strategies for land conservation, habitat protection, and restoration. For example, while both Maryland and Virginia have a number of state-based land conservation programs—including Maryland's Program Open Space, the Virginia Land Conservation Foundation, and the Virginia Outdoors Foundation—neither state currently considers the impacts of global warming when assessing ecologically critical habitats for possible acquisition. Nor do the states' current land-use planning measures adequately consider the longer-term threats from global warming in their habitat-protection requirements. Maryland's Green Infrastructure criteria are a step in the right direction, but future revisions will need to consider global warming explicitly.

Agricultural lands play an important role in providing habitat for some waterfowl species, such as mallards and Canada geese. Accordingly, sportsmen and women have worked closely with the agricultural community, helping pass initiatives in the federal Farm Bill that provide incentives for wetlands and associated upland habitat conservation (such as the Wetland Reserve Program and the Conservation Reserve Program). Ensuring that these habitats are available is even more important as the region continues to face added pressures on coastal wetlands, seagrass beds, and other natural habitats due to global warming. However, the Farm Bill conservation programs are currently under-funded. In Fiscal Year 2004, for example, three out of every four applications to participate in Farm Bill conservation programs administered by the Natural Resources Conservation Service were rejected due to lack of funds.<sup>59</sup> At the same time, the conservation rates paid to land owners are not always keeping pace with increasing land values.



#### Federal Actions:

- The U.S. Congress should significantly expand funding for the conservation provisions of the Farm Bill, including the Conservation Reserve Program, the Wetlands Reserve Program, the Conservation Security Program, the Grasslands Reserve Program, and the Wildlife Habitat Incentives Program. These provisions should include greater incentives for maintaining coastal and riparian buffers in response to increased runoff and sea-level rise.

#### State Actions:

- Land conservation agencies and foundations in Maryland and Virginia should develop improved criteria for identifying ecologically critical lands, in particular considering how sea-level rise and other climate changes will hurt habitats, and seek opportunities to acquire or better manage these lands.
- Maryland and Virginia should ensure that the Farm Bill conservation programs preserve existing commitments and encourage new enrollments. This may involve adjusting the rates paid to land owners or finding efficient ways to restore relatively small parcels, such as buffers along streams.

## 7. Redouble Efforts to Manage Storm-water Runoff into the Chesapeake Bay

As the region faces greater extremes in precipitation events, including heavier rainfall and the possibility of more-intense coastal storms, improving storm-water management will be critical to meeting important goals to reduce eutrophication in the Chesapeake Bay. This is particularly important as the region considers denser development and redevelopment projects in the interest of smart growth.

Significant efforts are being made in the region to improve storm-water and wastewater management, including new legislation in Maryland to develop more effective storm-water environmental site design. The state has also identified storm-water retrofits as a priority for funding under its Green Fund proposal. Similar efforts are warranted in Virginia, where current funding for the Virginia Water Quality Improvement Fund is inadequate.

In both states and across the region, however, storm-water managers must seriously consider the likelihood of heavier precipitation and more runoff problems due to global warming. For both new developments and redevelopment projects, it is critical to incorporate non-structural, preventive measures employed through land-use planning and educational programs, in addition to the structural fixes, such as water treatment systems for large point sources, that have been emphasized in the past. Promoting more flexible strategies and moving development away from sensitive areas can also help handle precipitation extremes. In addition, reducing runoff flows over impervious surfaces such as roads and parking lots can help moderate high water temperatures in tidal creeks and marshes, a problem that is likely to be exacerbated by global warming.<sup>60</sup>

The region must also establish runoff-reduction goals that account for greater extremes than are reflected in historic trends. For example, even where technological solutions to storm-water management are warranted (e.g., retrofitting culverts and storm drains), it will be prudent to consider expanding the capacity today rather than being faced with having to re-invest in further



retrofits in the coming decades. Several actions at the federal and state levels will help improve storm-water management in the region to more effectively deal with the added pressures from global warming.

#### Federal Actions:

- The U.S. Environmental Protection Agency should revise its storm-water management rules under the Clean Water Act to discourage construction in or near coastal and stream riparian buffers, wetlands, and other sensitive areas.

#### State and Local Actions:

- Virginia should develop a dedicated funding source for sewage and wastewater treatment upgrades and provide sufficient funding to the Virginia Water Quality Improvement Fund.
- Both Virginia and Maryland (through its Green Fund) should increase support of non-structural approaches to storm-water management (i.e., preventive measures incorporated in land-use and development planning rather than technological fixes of point-source pollution) and require consideration of greater extremes in precipitation events due to global warming.
- Both Virginia and Maryland should consider stricter storm-water permits to steer development away from coastal and stream buffer areas, wetlands, and other sensitive lands.





## VI. CONCLUSION

Global warming poses a significant threat to the fish and wildlife of the Chesapeake Bay. Left unchecked, global warming will lead to rising sea levels and coastal inundation and an increase in marine diseases and harmful algal blooms. It will place the region's people and wildlife at increasing risk from catastrophic storms and other extreme events. Warmer air and water, both locally and across the continent, will alter the composition of fish and wildlife species that make their home in the bay region. These effects will fall on top of the many other problems, such as eutrophication, that continue to plague the bay.

But it is not too late to act. It will take foresight, the right investments, and determination to reduce the risks rather than wait for the consequences. Hunters, anglers, and all those who cherish the beauty and recreational opportunities offered by the Chesapeake Bay can make a difference by letting elected officials at the federal, state, and local levels know that the time for action is now. And, we can all make changes in our day-to-day lives to reduce our contributions to global warming pollution (see Box 7) and to manage properties we own to minimize the negative impacts on fish and wildlife.

By taking action now to both restore the bay and reduce global greenhouse gas emissions, we can change the forecast for the Chesapeake Bay and ensure that its economic opportunities, ecological benefits, and outdoor traditions will endure for generations to come.

### BOX 7.

#### *What Can You Do to Reduce Global Warming Pollution?*

Individuals can make an important difference in reducing global warming pollution by changing how we use energy in our daily activities. There are many things you can do:

- Reduce energy consumption in your home by purchasing more energy-efficient lighting, such as compact fluorescent bulbs, and appliances with high-efficiency Energy Star ratings.
- When purchasing a new car or truck, buy the most fuel-efficient model that suits your needs.
- Install a programmable thermostat and set it warmer in the summer and cooler in the winter.
- Seek ways to use electricity generated from renewable sources.
- Make sure your boat motor is tuned up.
- Keep your vehicle's tires properly inflated.<sup>61</sup>
- Work in your local community to promote energy efficiency, recycle waste, plant trees, plan smart growth, or reduce traffic congestion.

# ENDNOTES

<sup>1</sup> U.S. Fish & Wildlife Service (FWS), *2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: Maryland* (Washington, D.C.: U.S. Department of the Interior, Revised March 2003); FWS, *2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: Virginia* (Washington, D.C.: U.S. Department of the Interior, Revised March 2003).

<sup>2</sup> Ibid.

<sup>3</sup> Chesapeake Bay Program, *Chesapeake Bay 2006 Health & Restoration Assessment, Part One: Ecosystem Health* (Annapolis, MD: Chesapeake Bay Program, 2007).

<sup>4</sup> A. Fisher, et al., *Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change: Mid-Atlantic Foundations, Chapter 7: Coastal Zones* (University Park, PA: Pennsylvania State University, 2000).

<sup>5</sup> Chesapeake Bay Foundation, *2006 State of the Bay* (Annapolis, MD: Chesapeake Bay Foundation, 2006).

<sup>6</sup> Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007: The Physical Science Basis, Summary for Policymakers* (Geneva: IPCC Secretariat, 2007a).

<sup>7</sup> Ibid.

<sup>8</sup> K.E. Trenberth, et al., "The Changing Character of Precipitation." *Bulletin of the American Meteorological Society* 84 (2003): 1205-1217; D.R. Easterling, et al., "Climate Extremes: Observations, Modeling, and Impacts." *Science* 289 (2000): 2068-74.

<sup>9</sup> K. Hayhoe, et al., "Past and Future Changes in Climate and Hydrological Indicators in the US Northeast." *Climate Dynamics* 28 (2007): 381-407; P.Y.

Groisman, et al., "Contemporary Changes of the Hydrological Cycle over the Contiguous United States: Trends Derived from In Situ Observations." *J. of Hydrometeorology* 5 (2004): 64-84.

<sup>10</sup> Hayhoe et al., 2007.

<sup>11</sup> B. L. Preston. "Observed Winter Warming of the Chesapeake Bay Estuary (1949-2002): Implications for Ecosystem Management." *Environmental Management* 34 (2004): 125-139; H. M. Austin, "Decadal Oscillations and Regime Shifts, a Characterization of the Chesapeake Bay Marine Climate." *American Fisheries Society Symposium* 32 (2002): 155-170.

<sup>12</sup> Environmental Protection Agency (EPA), "Climate Change, Wildlife, and Wildlands Case Study: Chesapeake Bay and Assateague Island." Available at: [http://www.epa.gov/climatechange/wycd/downloads/CS\\_Ches.pdf](http://www.epa.gov/climatechange/wycd/downloads/CS_Ches.pdf) (accessed September 17, 2007).

<sup>13</sup> R.G. Najjar, et al., "The Potential Impacts of Climate Change on the Mid-Atlantic Coastal Region." *Climate Research* 14 (2000): 219-33.

<sup>14</sup> Hayhoe et al., 2007.

<sup>15</sup> Najjar, Patterson, and Graham, 2007 (in preparation).

<sup>16</sup> W.M. Kemp, et al., "Eutrophication of Chesapeake Bay: Historical Trends and Ecological Interactions." *Marine Ecology Progress Series* 303 (2005): 1-29.

<sup>17</sup> R.G. Najjar, et al., 2000; S.Y. Wu, R.G. Najjar, and J. Siewert, "Sea-Level Rise Impacts: Potential Impacts of Sea-level Rise on the Mid- and Upper-Atlantic Region of the United States." (2007, submitted).

<sup>18</sup> IPCC, 2007a.

<sup>19</sup> J.L. Chen, C.R. Wilson, and B.D. Tapley, "Satellite Gravity Measurements Confirm Accelerated Melting of Greenland Ice Sheet." *Science* 313 (2006): 1958-60; B.L. Otto-Bliesner, et al., "Simulating Arctic Climate Warmth and Icefield Retreat in the Last Interglaciation." *Science* 311 (2006): 1747-50; J.T. Overpeck, et al., "Paleoclimatic Evidence for Future Ice-sheet Instability and Rapid Sea-level Rise." *Science* 311(2006): 1747-50; E. Rignot and P. Kana-garatnam, "Changes in the Velocity Structure of the Greenland Ice Sheet." *Science* 311 (2006): 986-90.

<sup>20</sup> M.G. Anderson and L.G. Sorenson, "Global Climate Change and Waterfowl: Adaptation in the Face of Uncertainty." *Transactions of the 66th North American Wildlife and Natural Resources Conference* (Washington, DC: Wildlife Management Institute, 2001): 300-319.

<sup>21</sup> L.G. Sorenson, et al., "Potential Effects of Global Warming on Waterfowl Populations Breeding in the Northern Great Plains." *Climatic Change* 40 (1998): 343-69.

<sup>22</sup> J.J. Magnuson, et al., "Ice Cover Phenologies of Lakes and Rivers in the Northern Hemisphere and Climate Warming." *Science* 289 (2000): 1743-1746.

<sup>23</sup> R.M. Erwin, et al., "Surface Elevation Dynamics in Vegetated Spartina Marshes Versus Unvegetated Tidal Ponds Along the Mid-Atlantic Coast, USA, With Implications to Waterbirds." *Estuaries and Coasts* 29 (2006): 96-106.

<sup>24</sup> IPCC, 2007a.

<sup>25</sup> F.T. Short and S. Wyllie-Echeverria, "Global Seagrass Declines and Effect of Climate Change," in: C.R.C. Sheppard, ed., *Seas at the Millennium: An Environmental Evaluation, Vol. III* (Amsterdam: Pergamon, Elsevier, 2000): 10-11.

<sup>26</sup> K. Blankenship, "Underwater Grasses at the Tipping Point?" *Bay Journal* (Baltimore, MD: Alliance for the Chesapeake Bay, 2006).

<sup>27</sup> K. Wilkins, et al., *July 11, 2007 Administrative Report. Trends in Duck Breeding Populations, 1955-2007*. (Washington, D.C.: U.S. Fish and Wildlife Service, 2007).

<sup>28</sup> Maryland Department of Natural Resources, "Midwinter Waterfowl Survey Records Historic Low for Canvasbacks." Available at: <http://www.dnr.state.md.us/dnrnews/pressrelease2007/031507.html> (accessed September 10, 2007).

<sup>29</sup> Chesapeake Bay Nutria Working Group, "Nutria (*Myocastor coypus*) in the Chesapeake Bay: A Draft Bay-Wide Management Plan." Available at: [www.chesapeakebay.net/pubs/calendar/NISW\\_12-10-03\\_Report\\_5\\_5129.pdf](http://www.chesapeakebay.net/pubs/calendar/NISW_12-10-03_Report_5_5129.pdf) (accessed September 10, 2007).

<sup>30</sup> J.C. Stevenson, M.S. Kearney, and E.W. Koch, "Impacts of Sea Level Rise on Tidal Wetlands and Shallow Water Habitats: A Case Study from Chesapeake Bay." In N.A. McGinn, ed., *Fisheries in a Changing Climate* (Bethesda, MD: American Fisheries Society, 2002): 23-36.

<sup>31</sup> Fisher, et al., 2000.

<sup>32</sup> C.D. Harvell, et al., "Emerging Marine Diseases—Climate Links and Anthropogenic Factors." *Science* 285 (1999): 1505–10.

<sup>33</sup> R.A. Heckert, et al., "Detection of a New Mycobacterium Species in Wild Striped Bass in the Chesapeake Bay." *Clinical Microbiology* 39 (2001): 710-5;

M.W. Rhodes, et al., "A Unique Mycobacterium Species Isolated From an Epizootic of Striped Bass (*Morone saxatilis*)." *Emerging Infectious Diseases* 7 (2001): 896-9; A.S. Kane, et al., "Mycobacteria as Environmental Portent in Chesapeake Bay Fish Species." *Emerging Infectious Diseases* 13 (2007): Available at: <http://www.cdc.gov/EID/content/13/2/329.htm>.

- <sup>34</sup> J.O. Falkinham, et al., "Natural Ecology and Survival in Water of Mycobacteria of Potential Public Health Significance." In: J. Bartram, et al., editors. *Pathogenic Mycobacteria in Water: a Guide to Public Health Consequences, Monitoring and Management*. (London: IWA Publishing, 2004): 15–25.
- <sup>35</sup> J.W. Ewart and S.E. Ford. *Northeast Regional Aquaculture Center Fact Sheet No. 200* (1993); T. Cook, et al., "The Relationship Between Increasing Sea-surface Temperature and the Northward Spread of *Perkinsus marinus* (Derma) Disease Epizootics in Oysters." *Estuarine, Coastal and Shelf Science* 46 (1998): 587–597.
- <sup>36</sup> J.D. Hagy, et al., "Hypoxia in Chesapeake Bay, 1950–2001: Long-term Change in Relation to Nutrient Loading and River Flow." *Estuaries* 27 (2004): 634–658.
- <sup>37</sup> R.W. Howarth, et al., "The influence of climate on average nitrogen export from large watersheds in the Northeastern United States." *Biogeochemistry* 79 (2006): 163–186.
- <sup>38</sup> Najjar, et al., 2000.
- <sup>39</sup> J.C. Varekamp, et al., "The Paleo-environmental History of Long Island Sound as Traced by Organic Carbon, Biogenic Silica and Stable Isotope/ Trace Element Studies in Sediment Cores." *Proceedings of the 6th Biennial Long Island Sound Meeting, Groton, CT, October 2004*: 109–113.
- <sup>40</sup> A.J. Lowe, et al., *Fish Kills in Coastal Waters: 1980–1989* (Rockville, MD: National Ocean Service, NOAA, 1991).
- <sup>41</sup> Harvell, et al., 1999.
- <sup>42</sup> Hayhoe, et al. 2007; Najjar, Patterson, and Graham, 2007 (in preparation).
- <sup>43</sup> J.H. Uphoff, Jr., "Predator-prey Analysis of Striped Bass and Atlantic Menhaden in Upper Chesapeake Bay." *Fisheries Management and Ecology* 1 (2003): 313–322.
- <sup>44</sup> M.S. Kearney, "The Potential for Significant Impacts on Chesapeake Bay," *Scientific Symposium Presentation Abstracts, Washington Summit on Climate Stabilization, September 18–21, 2006* (Washington, D.C.: Climate Institute, 2006).
- <sup>45</sup> K. Emanuel, "Increasing Destructiveness of Tropical Cyclones Over the Past 30 Years," *Nature*. 436 (2005): 686–688; Webster, et al., "Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment," *Science* 309 (2005): 1844–1846.
- <sup>46</sup> J.D. Andrews, "Effects of Tropical Storm Agnes on Epifaunal Invertebrates in Virginia Estuaries." *Chesapeake Science* 14 (1973): 223–234.
- <sup>47</sup> U.S. Geological Survey (USGS), "A Summary Report of Sediment Processes in Chesapeake Bay and Watershed," *USGS Water-Resources Investigations Report 03-4123* (New Cumberland, Pennsylvania: USGS, 2003 draft). Available at: [http://www.chesapeakebay.net/temporary/nsc/sedwg/final\\_draft\\_sed\\_rpt\\_7-3-03.pdf](http://www.chesapeakebay.net/temporary/nsc/sedwg/final_draft_sed_rpt_7-3-03.pdf) (accessed September 10, 2007).
- <sup>48</sup> Kearney, 2006.
- <sup>49</sup> Maryland Department of Natural Resources, "Blue Crab." Available at: <http://www.dnr.state.md.us/fisheries/education/crab/bluecrabfacts.html> (accessed September 10, 2007).
- <sup>50</sup> G. Raymond, et al., "The potential impacts of climate change on the mid-Atlantic coastal region." *Climate Research* 14 (2000): 219–233.
- <sup>51</sup> Maryland Sea Grant, "Global Warming and the Bay," *Chesapeake Quarterly Online* 5 (2006).
- <sup>52</sup> IPCC, *Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability: Summary for Policymakers* (Geneva: IPCC Secretariat, 2007b).
- <sup>53</sup> M. Meinshausen, "On the Risk of Overshooting 2°C." Presented at a scientific symposium on "Avoiding Dangerous Climate Change," (Exeter: Met-Office, 2005).
- <sup>54</sup> IPCC, *Climate Change 2007: Mitigation of Climate Change: Summary for Policymakers* (Geneva: IPCC Secretariat, 2007c).
- <sup>55</sup> Environment Maryland, "Action by States Would Lead to Major Reduction in Global Warming Pollution," *Global Warming Campaign News* 5/21/2007. Available at: <http://www.environmentmaryland.org/newsroom/global-warming> (accessed September 10, 2007).
- <sup>56</sup> Maryland Office of the Governor, *Maryland Executive Order 01.01.2007.02*. Available at <http://www.gov.state.md.us/executiveorders/01.07.02Baystat.pdf> (accessed September 10, 2007).
- <sup>57</sup> Z.P. Johnson, *A Sea Level Rise Response Strategy for the State of Maryland* (Annapolis, MD: Maryland Department of Natural Resources, 2000).
- <sup>58</sup> J. Lerch, "Zoning, Subdivision and Site Planning: What Coastal Communities Can Do to Address Sea Level Rise." Presentation at the Virginia Institute of Marine Science Spring 2007 Workshop, *Sea Level Rise & Other Coastal Hazards: the Risks of Coastal Living*. Available at [http://ccrm.vims.edu/seminarpresentations/spring\\_2007/spring\\_2007\\_presentations.html](http://ccrm.vims.edu/seminarpresentations/spring_2007/spring_2007_presentations.html) (accessed September 10, 2007).
- <sup>59</sup> Agriculture and Wildlife Working Group, *Growing Conservaton in the Farm Bill* (Washington, DC: Theodore Roosevelt Conservation Partnership, 2007).
- <sup>60</sup> Galli, J., *Thermal Impacts Associated With Urbanization and Stormwater Management Best Management Practices* (Washington, D.C.: Metropolitan Washington Council of Governments, 1991).
- <sup>61</sup> Properly inflated tires require less energy to get rolling and to maintain speed, are safer, and last longer. Keeping your tires properly inflated can improve fuel economy by as much as 3 percent, reducing emissions of carbon dioxide by an average of 250 lbs per year and cutting fuel costs by as much as 10 cents per gallon. Source: <http://www.fueleconomy.gov>.





11100 WILDLIFE CENTER DRIVE  
RESTON, VA 20190  
703-438-6000



PRINTED ON 100% POST-CONSUMER CHLORINE-FREE PAPER THAT IS FOREST STEWARDSHIP COUNCIL CERTIFIED.  
PRINTED WITH SOY-BASED INKS.