Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change

Phase II: Building societal, economic, and ecological resilience

REPORT OF THE MARYLAND COMMISSION ON CLIMATE CHANGE ADAPTATION AND RESPONSE AND SCIENTIFIC AND TECHNICAL WORKING GROUPS

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ACRONYMS

BMP	Best Management Practice
CDC	Center for Disease Control
COMAR	Code of Maryland Regulations
DBED	Department of Business and Economic Development
DGS	Department of General Services
DHCD	Department of Housing and Community Development
DHMH	Department of Health and Mental Hygiene
DNR	Department of Natural Resources
ESD	Environmental Site Design
FEMA	Federal Emergency Management Agency
GPS	Global Positioning Systems
HAB	Harmful Algae Blooms
ICPRB	Interstate Commission on the Potomac River Basin
IPM PIPE	Integrated Pest Management Pest Information Platform for Extension and Education
LID	Low Impact Development
MADE-CLEAR	Maryland and Delaware Climate Change Education, Assessment, and Research
MALPF	Maryland Agriculture Land Preservation Foundation
MARC	Maryland Area Regional Commuter
MDA	Maryland Department of Agriculture
MDE	Maryland Department of Environment
MDOT	Maryland Department of Transportation
MDP	Maryland Department of Planning
MEA	Maryland Energy Administration
MEMA	Maryland Emergency Management Agency
MS4	Municipal Separate Storm Sewer Systems
NASA	National Aeronautics and Space Administration
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
OSDS	On-Site Disposal System
PSC	Public Service Commission
SHA	State Highway Administration
TMDL	Total Maximum Daily Load
UME	University of Maryland Extension
USDA	United States Department of Agriculture
US DOI	United States Department of Interior
US EPA	United States Environmental Protection Agency
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WIP	Watershed Implementation Plan
WRE	Water Resources Element

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Jane Hawkey

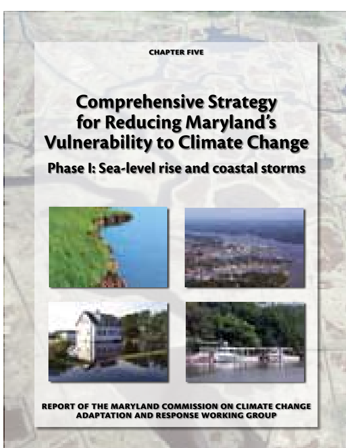
INTRODUCTION

On April 20, 2007, Governor Martin O'Malley signed an Executive Order establishing the Maryland Commission on Climate Change (MCCC) and charging them with developing an action plan to address the causes of climate change and prepare for the likely impacts. Three working groups carried out the work of the MCCC: the Scientific and Technical Working Group; the Greenhouse Gas and Carbon Mitigation Working Group; and the Adaptation and Response Working Group. These groups worked together to produce Maryland's Climate Action Plan within the following context:

- **Maryland's climate has, until recently, been variable but stable for several thousand years;**
- **Atmospheric concentrations of greenhouse gases have dramatically increased; and**
- **Global warming is unequivocal.**

The Climate Action Plan, released in 2008, addressed the impacts, mitigation and economic concerns and recommended a suite of adaptation strategies to reduce the Maryland's vulnerability to sea level rise and coastal storms. The Climate Action Plan also addressed the need to pursue the development of adaptation strategies to reduce vulnerability among other affected sectors, including agriculture, forestry, water resources, aquatic and terrestrial ecosystems, and human health. This work was begun in earnest in late 2009. Two key elements of the Climate Action Plan, the *Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change, Phase I: Sea Level Rise and Coastal Storms* and *Global Warming in the Free State*, laid the foundation and framework for the development of the sector-based adaptation strategies contained in this report.

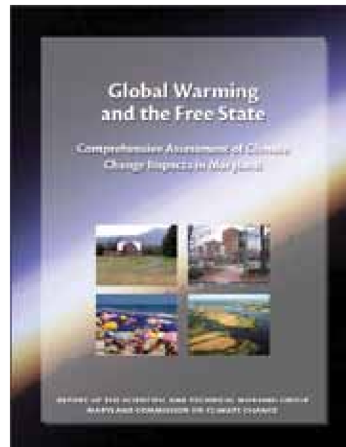
Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change *Phase I:* Sea Level Rise and Coastal Storms



The Phase I Adaptation Strategy, produced by the MCCC's Adaptation and Response Working Group, provided recommendations for reducing risk associated with sea level rise and coastal storms. To protect Maryland's future economic wellbeing, environmental heritage, and public safety, the Strategy recommends a suite of 18 legislative and policy actions aimed at:

- **Promoting programs and policies aimed at the avoidance or reduction of impact to the existing-built environment, as well as to future growth and development in vulnerable coastal areas;**
- **Shifting to sustainable economies and investments; and, avoiding assumption of the financial risk of development and redevelopment in highly hazardous coastal areas;**
- **Enhancing preparedness and planning efforts to protect human health, safety and welfare; and**
- **Protecting and restoring Maryland's natural shoreline and its resources, including its tidal wetlands and marshes, vegetated buffers, and Bay Islands, that inherently shield Maryland's shoreline and interior.**

Global Warming and the Free State



The report of the Scientific and Technical Working Group provided an initial assessment of the vulnerability of Maryland's various sectors to climate change and was based on extensive literature review and existing climate model projections. The recent and likely climate changes in Maryland that provide the basis of the climate information for the current report are as follows:

- **Climate regimes will continue to differ across Maryland;**
- **Temperature is projected to increase substantially, especially under higher emissions; and**
- **Precipitation is projected to increase during the winter, but become more episodic.**

The report highlighted that changes in climate will likely affect the baselines upon which ecosystems, population growth and infrastructure, health systems, agriculture and water resources are planned and managed. The sector-based impact and issue assessments provided by the Scientific and Technical Working Group served as the basis for the evaluation and formulation of the adaptation strategies contained in this report.

Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change
Phase II: Building societal, economic, and ecological resilience

The Scientific and Technical and Adaptation and Response Working Groups worked collaboratively to develop the Phase II Adaptation Strategy. This Strategy is the product of over 80 experts from the governmental, non-profit, and private sectors that held a series of meetings to synthesize the most recent climate change literature, to evaluate adaptation options and recommend adaptation strategies to reduce the Maryland's overall vulnerability to climate change. The Strategy outlines adaptation strategies to reduce the impacts of climate change, including sea level rise, increased temperature and changes in precipitation within the following sectors: Human Health; Agriculture; Forest and Terrestrial Ecosystems; Bay and Aquatic Environments; Water Resources; and Population Growth and Infrastructure. The Phase II Strategy provides the basis for guiding and prioritizing state-level activities with respect to both climate science and adaptation policy within short to medium-term timeframes.

Key Recommendations

Human Health

Conduct vulnerability assessments to gain a better understanding of risks and inform preventative responses.
Assess potential health threats and the sufficiency of Maryland's response capacity. Evaluate impacts to food safety and availability. Assess the vulnerability of Maryland's populations and communities to changing health threats. Identify potential barriers to effective emergency response.

Integrate impact reduction strategies into State and local planning practices.
Improve response capacity through the development of new or expanded programs. Address climate-related health risks in hazard mitigation and emergency response plans. Support community engagement in planning and emergency response decisions. Pursue opportunities to enhance protection of Maryland's "green infrastructure".

Streamline and revise data collection and information dissemination channels.
Improve the resolution and availability of health and population data. Analyze health and population data along with other spatially explicit information (e.g., land use, air quality, water quality).

Agriculture

Increase crop diversity, protect against pests and disease, and intensify water management.
Promote diversification of crop species and varieties. Intensify water management and conservation through research, funding and incentives. Protect against incoming pests, weeds and disease. Support innovative solutions that foster adaptation and also reduce energy costs and carbon footprints.

Strengthen applied research, risk communication and technical support.
Enhance dissemination channels to improve the relay of climate information. Identify opportunities to support the transition of farm and agricultural practices. Enhance emergency response and risk management.

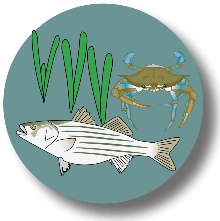
Enhance existing Best Management Practices (BMPs) and land conservation targets.
Evaluate the effectiveness of BMPs under future climate change scenarios. Assess and revise targets for agricultural land preservation.

Forests and Terrestrial Ecosystems

Expand land protection and restoration and revise targeting priorities.
Integrate climate data and models into existing resource assessments and spatial planning frameworks. Incorporate climate change adaptation strategies into state resource managmeent plans. Collaborate with federal partners to support regional and national adaptation planning efforts. Update existing land protection targeting programs and project evaluation protocols. Develop climate change adaptation guidance and technical tools suitable for local government planning.

Adjust management practices and reduce existing stressors.
Strengthen State and local programs to slow the loss and fragmentation of forest and terrestrial ecosystems to new development. Revise Maryland's best forestry management practices. Reinforce and incorporate strategies set forth by Maryland's Sustainable Forestry Act of 2009. Evaluate sustainable forestry certification programs for opportunities to enhance climate resilience. Reduce existing stressors.

Foster stewardship on private lands.
Develop new tools to guide adaptation stewardship activities on private lands. Incorporate adaptation concerns into existing programs. Develop new conservation easement mechanisms to promote adaptation stewardship activities on private lands.



Bay and Aquatic Ecosystems

Advance protection of at-risk species and habitats.

Revise state-level protection targeting programs to reflect climate change adaptation priorities. Develop new protection and conservation mechanisms to promote adaptation stewardship activities on private lands. Amend legal mechanisms to designate and protect temperature-sensitive streams. Implement an adaptive management approach.

Restore critical bay and aquatic habitats to enhance resilience.

Proactively pursue, design, and construct habitat restoration projects to enhance the resilience of bay and aquatic ecosystems. Conduct an audit of state-owned lands to identify habitat restoration potential for enhancing ecosystem resilience and increasing on-site carbon sequestration. Increase on-the-ground implementation of existing stream restoration practices.

Reduce existing stressors.

Remove barriers to habitat connectivity. Reduce impervious surface cover. Prepare for new or expanding ranges of invasive species.

Foster a collective response to climate change.

Adjust bay and watershed restoration priorities in light of a changing climate. Integrate both adaptation and mitigation reduction strategies into natural resource management plans and programs. Revise fishery and wildlife management to build climate resilient safeguards. Increase collaboration between federal, state, local and regional climate change adaptation partners.

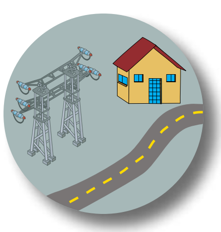
Water Resources

Ensure long-term safe and adequate water supply for humans and ecosystems.

Adopt and fund the recommendations of the 2008 "Wolman Committee" report. Manage water through the lens of future climate and population. Enhance planning and coordination within the water resource community. Encourage water suppliers to evaluate and improve their resilience. Promote demand management and water conservation practices. Assess, target and protect high-quality water recharge areas.

Reduce the impacts of flooding and stormwater.

Encourage the removal of vulnerable or high-hazard water supply and treatment infrastructure. Prevent inundation and overflow of on-site disposal systems. Revise Clean Water Revolving Fund criteria. Invest in an improved understanding and communication of flood probabilities and hazards.



Population Growth and Infrastructure

Ensure safety, clean water, clean air and sufficient infrastructure.

Address funding and revenue constraints to ensure adequate support for current and future infrastructure needs. Conduct a comprehensive analysis of the vulnerability of Maryland's infrastructure. Develop a "lead by example" investment policy to guide state investments. Reduce regional air quality impacts in Maryland.

Plan for precipitation-related weather extremes and increase resilience to rising temperatures.

Assess the economic costs resulting from severe weather events. Identify state investment needs to prepare for future weather emergencies. Accelerate use of improved stormwater management strategies and environmental site design (ESD). Enhance the preparedness of transportation system and utility providers. Develop operation contingency plans for critical infrastructure. Increase urban tree canopy. Strengthen building and infrastructure design standards.

Institutionalize consideration of climate change.

Promote integration of climate change adaptation strategies into state and local policies and programs. Integrate climate vulnerability data into state and local spatial planning frameworks. Consider climate change issues in combination with ongoing growth and development planning efforts. Explore incentives to promote sound planning practices. Investigate the impacts of climate change on future energy needs. Create a framework and standards for the placement and use of alternative energy.

CHAPTER 1

HUMAN HEALTH

Lead author: Joel Scheraga
Contributing authors: Sania Amr, Russell Dickerson, J. Morgan Grove, Clifford Mitchell, Kimberly Mitchell, Jonathan Sherwell, and Konstantin Vinnikov

KEY POINTS

- **Climate change will likely cause increases in heat stress, reduced air and water quality, and shifts in vector borne disease risk.** The impacts of climate change on human health will vary and depend on, among other factors, an individual's sensitivity and exposure to a given threat and capacity to adapt.
- **Reducing impacts should focus on integrating climate into decisions affecting health and increasing preventive measures.** Funding and planning efforts should be informed by the projected interactions between human health impacts, and the existing vulnerabilities of populations. The co-benefits of other management actions not exclusive to the health community (e.g., increasing urban canopy) are emphasized.
- **Preventive actions are dependent on Maryland's capacity to track current disease patterns and project future threats to human health.** Given the variability of potential impacts to human health statewide, there is a large need to collect and make health information available at a high spatial resolution.

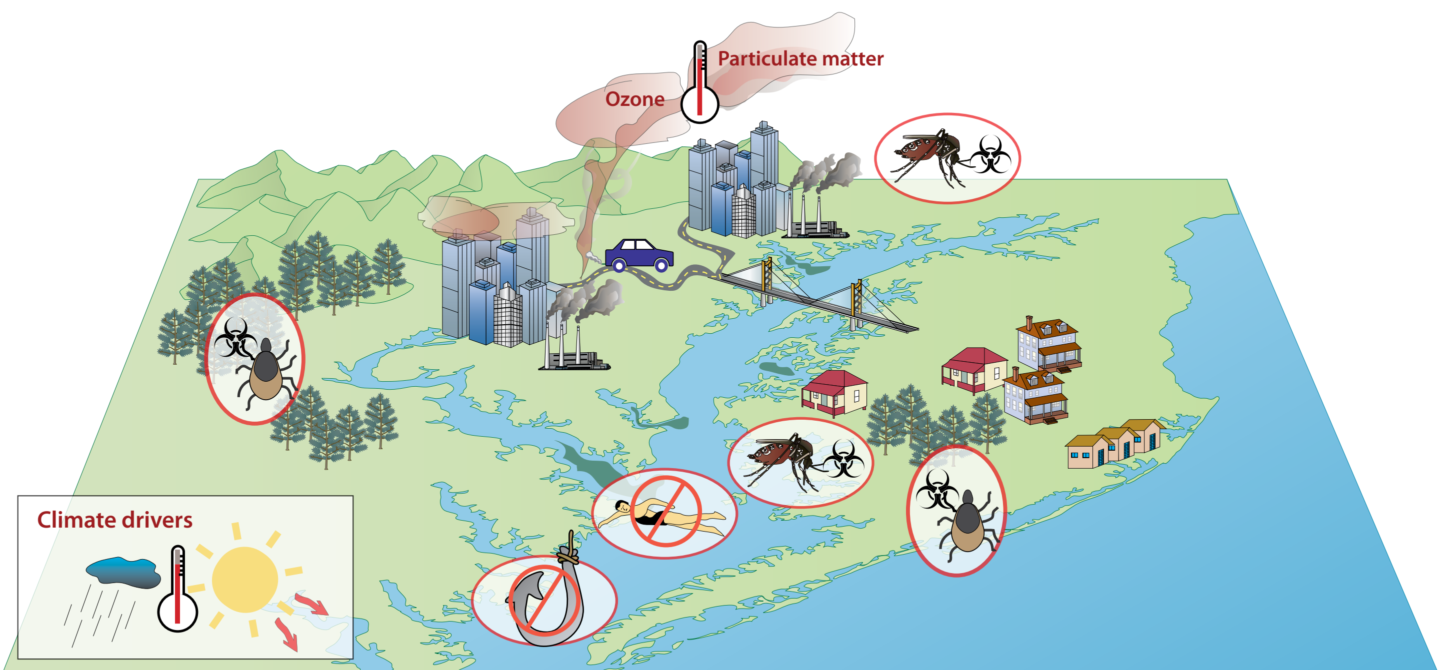


Figure 1.1: Climate drivers, such as temperature and precipitation, influence many health issues. Health issues are likely to change or become exacerbated. Among those health concerns occurring across the State are water contamination or harmful algal blooms , which prevent swimming and fishing . Increases in temperature and changes to precipitation patterns are likely to influence air quality , heat stress, and vector-borne diseases across the State.

INTRODUCTION

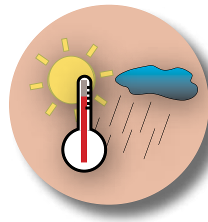
Climate change poses many health risks to people in Maryland, including heat-related stress and cardiovascular mortality and morbidity, respiratory illness, altered infectious disease patterns (both vector-borne and water-borne diseases), impacts to water supply and quality, and direct or mental harm from extreme storm events and flooding (Figure 1.1).[1] Through this century at least, the expected overall impacts of climate change on human health are expected to be small relative to the other major causes of mortality in the mid-Atlantic region, including heart disease, cancer, stroke, and lung disease, among others. However, changes in climate will likely exacerbate many existing stresses on human health, and in some cases pose new risks to the health of Maryland's citizens. The health impacts of climate change are expected to disproportionately affect certain populations, communities, and regions. Some of the impacts could be severe.

LIHL/Gary Hamilton

Individuals vulnerable to respiratory illness may be at an increased risk in Maryland's future climate.

There is a great opportunity to manage these preventable impacts, particularly in a system that historically has been able to adapt to and reduce the vulnerability of health risks. Without appropriate action, highly preventable mortality and health complications that are influenced by climate are likely to increase. The current capacity of Maryland's health community is equipped for the type, but not magnitude, of possible impacts.

CLIMATE VULNERABILITY



The health consequences of climate change are not novel, and climate change is not an explicit, single source health issue. Rather, climate change represents an overlying stressor that changes the environmental context of health, and disproportionately affects certain populations and communities. Health problems caused by increased heat, reduced air quality, severe storms, shifts in disease presence, are likely to occur. Many of these health issues will result from interactions between climate change, ecological changes, and the characteristics of existing infrastructure (e.g., lack of shade or air conditioning; old or unsuitable water supply and treatment facilities). Other impacts to nutrition and mental health may occur, though these are less certain, and include increased food-borne illness or psychological effects from extreme events. Harmful algal blooms (HABs) and water-borne diseases also may affect the health of Maryland's citizens. The vulnerability of Maryland's citizens to climate risks is shaped by the degree to which they are exposed to these influences and also by a number of factors affecting their sensitivity and adaptive capacity (Figure 1.2-1.3).

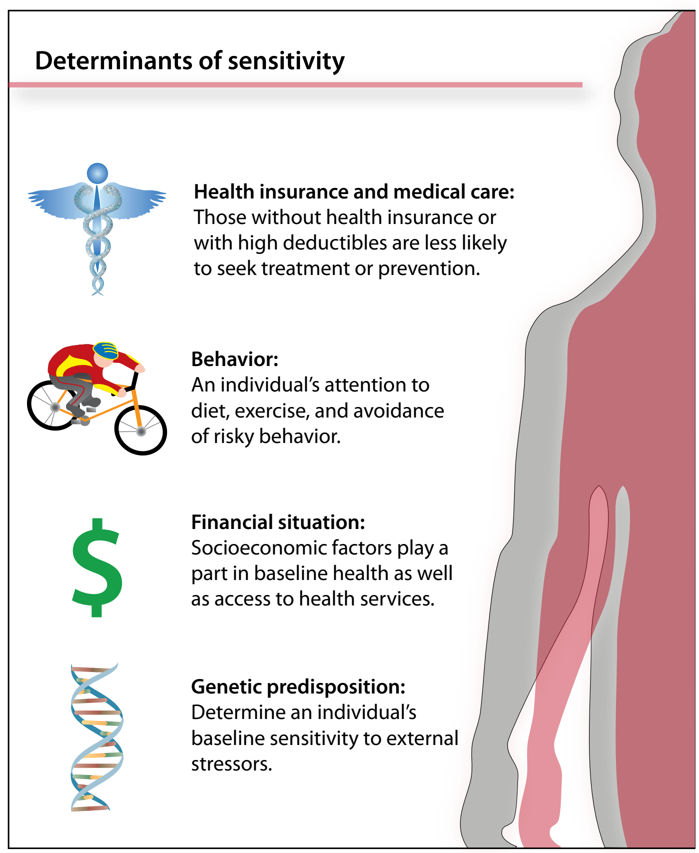
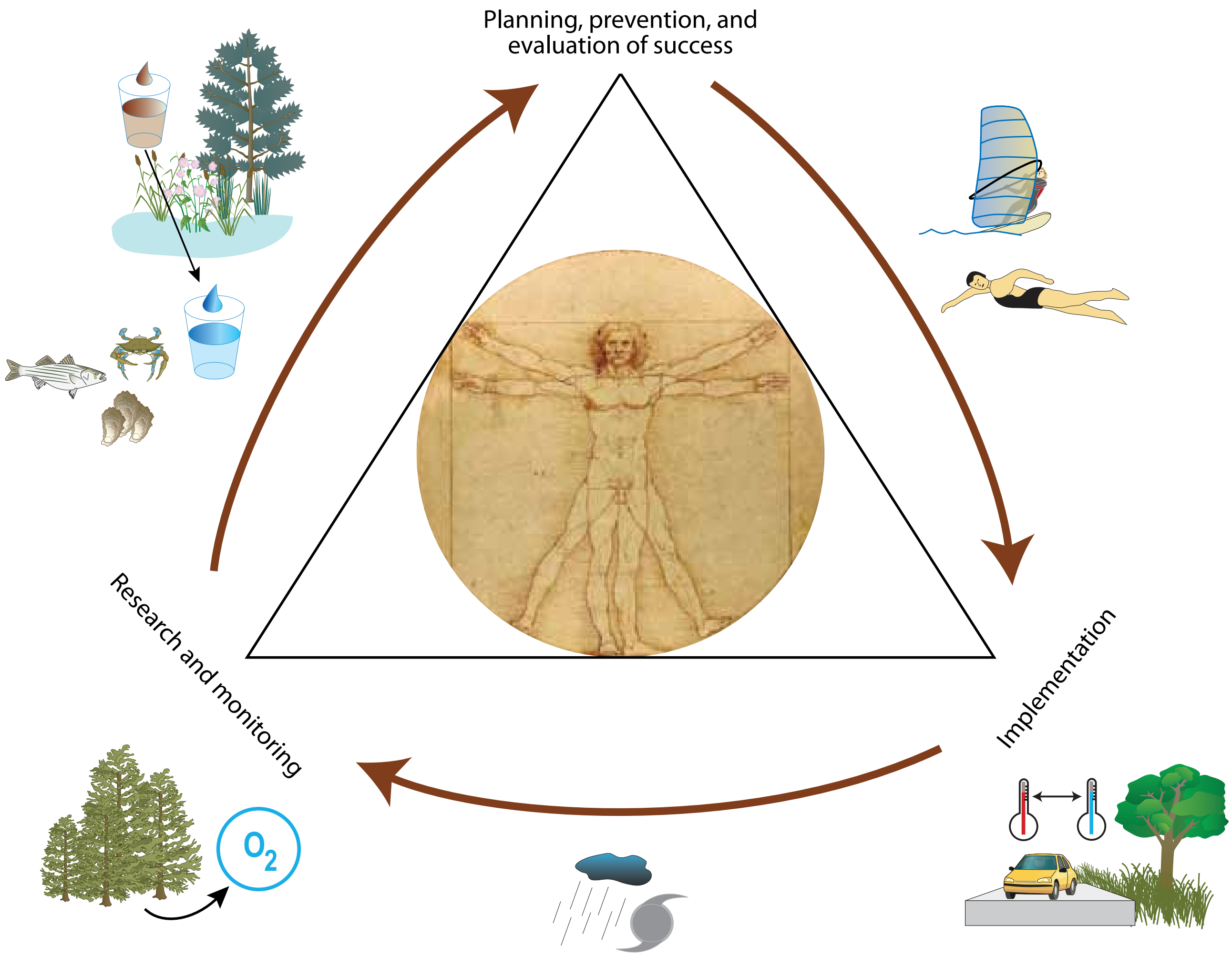


Figure 1.2: Characteristics of the body's baseline sensitivity to health problems. Exposure to external health influences related both directly and indirectly to climate, can add additional stress.

Climate impacts affecting human health



Climate change impacts

Direct

Thermal extremes (heat waves): *Heat and air quality stress will become exacerbated, particularly in urban areas.*

Weather extremes (floods, storms) and sea level rise: *Deaths, injuries, and damage to public health infrastructure will result and potentially displace vulnerable populations.*

Indirect

Air quality: *Air quality in urban areas and those where ozone and particulate matter levels are already high will likely worsen, resulting in increased asthmatic allergic response.*

Outdoor recreation: *Geographic range and incidence of vector-borne diseases will change. Beaches will close more frequently due to pathogens (e.g., from combined sewer overflows and stormwater).*

Water quality: *Altered local ecology of water and food-borne infective agents will result from diminished water quality.*

Figure 1.3: Climate change is likely to impact many of the current environmental influences on human health, by directly raising temperatures or increasing the frequency of extreme events. Indirectly, climate change will likely exacerbate existing stressors such as reduced air and water quality, and vector-prone and infectious diseases.

Non-climate stressors interact with climate change and contribute to the overall severity of climate impacts on people in Maryland. In particular, social and economic factors can significantly affect people's exposure and vulnerability to climate change, as well as their ability to quickly and fully recover (i.e., their "adaptive capacity"). Such factors include, among others, economic status, race, ethnicity, age, sex, and overall health. Although Maryland's health care system consists of many services and programs for treating and preventing illnesses that are likely to increase, many health problems triggered by environmental factors like climate change can only be solved through the collaborative effort of multiple agencies and authorities. They cannot be solved by the public health community alone. The following is a description of potentially emerging or intensifying health risks.

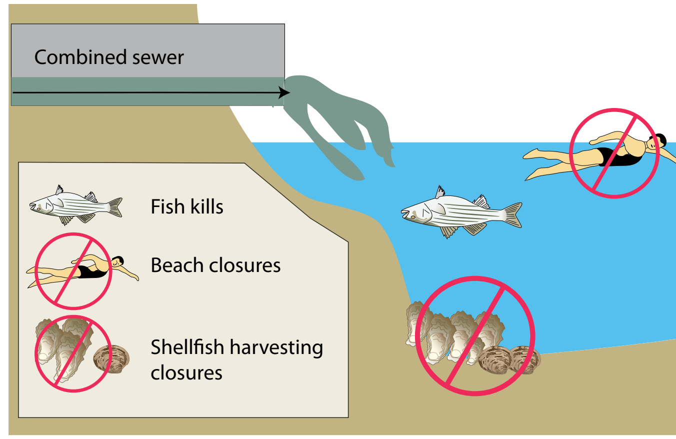
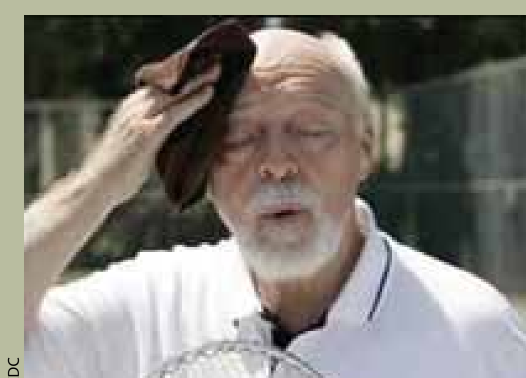


Figure 1.4: Higher than average rain events correlate with waterborne diseases, due particularly to large amounts of stormwater overflowing combined sewers or leading to septic failures. These events, projected to increase in frequency, impact fishers and recreation.

Elderly populations are more susceptible to extreme events

Climate changes can result in periods of extreme temperatures, to which the elderly population is very susceptible. Because heating and cooling are costly, many people already ration their use, and any added charges would represent an additional burden on vulnerable populations. A study in Baltimore found that ambient body temperature among seniors (65+) was increased by 0.15°F for each 1°F increase in ambient temperature.[2] Individuals took the actions listed below to adapt to temperature increases, though the most effective (e.g., air conditioning), are not available to all. Some individuals, due to lack of mobility or already-compromised health, are highly vulnerable to heat stress.



Heat adaptation measures used by study participants

Adaptation	% of individuals
Wearing less clothing	93
Drinking more fluids	90
Turning on air conditioning	88
Going outdoors	88
Turning on a fan	62
Avoiding the outdoors	60
Opening windows	57
Going to a public place with air conditioning	57
Taking cold baths or showers	45
Swimming	19

Extreme events will affect health and safety

Increases in the frequency of extreme rain and storm events and flooding due to sea level rise and coastal storms, can both directly and indirectly affect human health. These events can directly impact infrastructure such as water treatment and supply, transportation and electricity systems. Impacts on drinking water supply and treatment can result from a submergence of wells, allowing the introduction of pollutants such as salt, pathogens, petroleum and other chemical products. Septic systems can overflow, causing raw sewage to leak out and contaminate drinking water. Overflowed septic systems and combined sewer overflows (from pipes meant to handle both stormwater and sewage) can also lead to contaminated waterways, affecting swimming and water sports and the safety of shellfish gathered from the area (Figure 1.4). Impacts to transportation include vehicle accidents due to pooling water or reduced visibility and closed roadways, slowing or preventing the response of emergency vehicles such as ambulances. Electricity systems can be put out of service by powerful storm and rain events, potentially leading to power outages at pumping stations and a resultant outflow of raw sewage.

Vector-borne and water-borne diseases will likely shift with climate

Although there is some degree of uncertainty as to the direction and degree of change, many pathogens and the geographic range of many vectors (e.g., mosquitoes) that carry them respond strongly to temperature and rain and their presence is likely to increase or decrease accordingly. Further, increases in septic and combined sewer overflows may cause increases in water-borne diseases. Much of the risk to humans lies in a lack of preparedness for such events; Maryland may experience unexpected increases or decreases of certain vector-borne and infectious diseases, and potentially an influx of pathogens that have never before been a problem in the State. A few examples of potentially climate-sensitive diseases are: malaria, dengue, Lyme disease, arboviral encephalitis (mosquito-borne), hantavirus, cryptosporidiosis and cholera.[3] Increases in West Nile virus, though difficult to tie directly to climate change, are currently occurring on the eastern seaboard.[4] Other evidence has already shown potential climate-related shifts in the distributions of tick, mosquito and bird vectors.[5,6,7] Although an increase in diseases has not been expressly predicted to occur, the variability and changes in disease occurrence could leave unprepared health systems vulnerable to larger-scale infections.

Urban areas will experience heat waves most severely, due to heat absorption by dark pavement and buildings, low vegetation cover, reduced airflow, and heat emitted by buildings and vehicles. This local "heat island effect" can increase temperatures by 2-10°F in comparison to surrounding suburban and rural areas, and can also be exacerbated by surrounding urban areas.[10] This is the case in Baltimore, as the city receives contributions of polluted and higher temperature air traveling from Washington DC.[11] However, heat-related mortality does not necessarily always follow the typical urban vs. rural patterns, thus making a statewide approach difficult.[12]

CASE STUDY: Mosquito-borne disease, urbanization, and climate change

The emergence and expansion of West Nile virus in the late 1990s and early 2000s gave Americans a reason to believe they were not exempt from mosquito-borne disease. Researchers Shannon LaDeau of the Cary Institute of Ecosystem Studies and John Wallace of Millersville University have begun to investigate the complexities surrounding environmental and vector relationships that enabled this very disease to persist.[20]


CDC

LaDeau and Wallace's research suggests that urban areas may be prime breeding ground for species that can carry diseases like West Nile (vector species). Standing water, habitat for mosquito larvae, abounds in urban areas (impervious surfaces, tires, buckets, and other abandoned vessels can support large populations of mosquito larvae). Humans and birds that mosquitos feed on are found in high concentration in these areas. Climate change interacts with mosquito-borne diseases by first changing the climate drivers which influence reproduction and viability. Some mosquitoes may benefit from winter and spring increases in rain, or be harmed by summer periods of drought. Recent cases of Dengue fever in Florida have also raised concerns from the Centers for Disease Control and Prevention (CDC). The 28 cases between September 2009 and mid-April 2010 were the first seen to have come from US mosquitos since 1934.[21] Researchers will need to explore these climate issues potentially affecting vector-borne disease abundance.

Heat and air quality-related illness will likely increase in certain areas

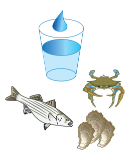
Maryland's temperature is currently rising and expected to increase by 2°F from the 1998 baseline by 2025, regardless of whether emissions are on the higher or lower scale of projections. By the end of the century, projected increases in summer temperature increases range from 4.8°F and a doubling of the number of 90°F days to nearly 9°F and a tripling of 90°F days in a low and high-emissions scenario, respectively.[8] These increases do not bode well for those individuals susceptible to heat-related illness and mortality, without air conditioning, exposed to heat during work or other activities, or with preexisting conditions. Heat-related illnesses and deaths are likely to increase, and will be most pronounced in individuals over the age of 65.[9] Increased stress on electricity supply systems due to heavy use of air conditioning can also cause brownouts, reducing access to cooling when it is needed the most.

Although associated with more uncertainty than temperature increases, air pollutants such as ozone and small particulate matter (PM2.5), are likely to worsen as climate changes, due to interactions with rising temperatures and carbon dioxide levels.[13,14] These pollutants can severely affect human respiratory health and heart function, particularly among susceptible populations, such as asthmatics.[15,16,17] Overall, PM2.5 levels have been decreasing since greater clean air requirements for power plants were put in place. However, as levels spike during periods of high temperature, summer levels are expected to increase along with temperatures and heat waves.[18] In addition, respiratory allergies may be exacerbated by the combined factors of decreased air quality and a potentially more severe and enduring pollen season.[19]

Food safety and availability may be impacted

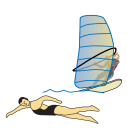
Climate change impacts on food supplies are difficult to predict. Areas that may be affected include food cost, safety, and availability during extreme events or storms. Decreases in agricultural productivity or increases in fuel costs could result in rising food costs, making it difficult for individuals to obtain adequate nutrition. At the same time, certain crops may experience increased productivity under future elevated carbon dioxide conditions in the short term, adding more uncertainty to overall impact. Increases in the risks of food-borne illness are also possible, as infections are more likely during warm summer months. This is likely due to a combination of increased outdoor eating and risk of bacterial growth, though climate is a much smaller influence than centralized food processing and distributing industries.[2]

Building resilience: examples of adaptation options

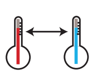


Water quality:
Protect wetlands; upgrade stormwater and water treatment infrastructure; update early warning and response systems; reduce impervious surfaces.

Air quality:
Increase urban canopy and reduce impervious surfaces (temperature reduction); improve pollution control.



Outdoor recreation:
Forecast and report conditions for recreation and fish consumption; limit access to beaches that consistently exceed health standards; reduce impervious surfaces; improve infrastructure.

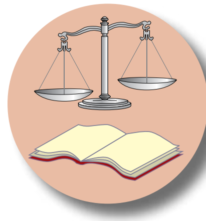


Thermal extremes (heat waves):
Reduce impervious surfaces; boost urban canopy; ensure that building codes are appropriate for future conditions.

Weather extremes (floods, storms) and sea level rise:
Revise emergency response plans; improve infrastructure; revise zonation.

Figure 1.5: Adaptation options to improve Maryland's environmental influences on human health. Although not necessarily enacted by the health community, these strategies boost the resilience of human health by reducing the additional stressors climate change may add.

STRATEGY FOR RESILIENCE



Many of the potential health issues related to climate are indirect impacts, stemming from the unsuitability or incapability of our current infrastructure to handle future climate. That said, human health issues associated with climate change are influenced by a wide range of environmental conditions and cannot be addressed by the health community alone. Many of these issues require a joint effort with the "non-health" community. A multi-agency effort to integrate health and climate concerns into decision making must address several key questions: (1) What are the threats to health and what groups are vulnerable? (2) What is it that climate change will fundamentally change about health that will require new programs or actions? (3) What existing programs, protocols, and training need to change or receive increased investment to augment their capacity? (4) What areas that cannot be adequately protected should receive stricter development regulations or higher investments in remediating existing stressors?

The following strategies highlight the need for integration of human health and vulnerability concerns into a broader range of decisions, and suggest programs that need greater capacity. Many actions should be taken regardless of climate change, offering many co-benefits such as: reducing long-term damage and costs by investing in infrastructure now, benefiting ecosystem health and supporting natural resource-based industries such as fishing or forestry, to name a few.[22] Climate change adds a greater sense of urgency to this integration, given that many of the potential health issues related to climate are indirect impacts, stemming from the unsuitability or inability of our current infrastructure to handle future climate. In order to support this integration, there is a great need for streamlined information to support targeted programs. Maryland's ability to maintain a resilient, healthy population will be increased if the quality and capacity of existing programs and infrastructure are enhanced.

Conduct vulnerability assessments to gain a better understanding of risks and inform preventive responses

Climate change adaptation strategies should be integral components of state and local planning and regulation and decision-support (i.e., local comprehensive plans, state highway plans, Maryland Codes Administration, low impact design (LID) principles). It is not sufficient to just conduct impact assessments; consultation with and guidance from state and local public health officials during decision-making is encouraged. The crosscutting nature

Harmful algal blooms and climate change

While blooms are natural phenomena that have occurred throughout history, there is some indication that climate change, in combination with existing human-derived impacts, may increase the frequency of these events.[23] Certain types of algal blooms, termed Harmful Algal Blooms (HABs), such as *Microcystis aeruginosa*, a cyanobacterium, can be toxic to humans if absorbed through skin contact, accidentally swallowed (via water containing the algae), ingested from contaminated seafood, and in some cases, through small airborne droplets. DNR, MDE, and DHMH cooperate with local health departments to track changes; this collaboration will be particularly important as conditions change.

P. Alejandro Diaz

Harmful algal blooms may increase as a result of the combined effects of pollution and climate change.

of climate change calls into question many protocols that were established in a period of more stable climate. In addition to integrating changes into the health community, there are many opportunities to incorporate health and climate information into decision making processes for transportation and growth planning, design standards for buildings, schools, sewers, and water supply infrastructure. Overall, many of the greatest safeguards against impacts to human health will depend upon communication between the explicitly health and non-health communities.

Priority recommendations:

- **Assess potential health threats and the sufficiency of Maryland's response capacity.** Maryland faces many human health concerns that may be exacerbated by climate change: heat stress, vector-borne and infectious disease, asthma and respiratory illness, food safety and availability, and water-borne disease (e.g., those associated with increased prevalence of harmful algal blooms). The degree to which existing programs for both preventive measures and emergency response are prepared for climate change should be evaluated.

- **Evaluate impacts to food safety and availability.** Potential interruptions to food availability due to extreme events and food contamination due to increased heat should be assessed and monitored.

- **Assess the vulnerability of Maryland's populations and communities to changing health threats.** An individual's location, age, pre-existing condition, genetic makeup, or socioeconomic group may make them more sensitive, exposed, or unable to adapt to climate change impacts. Although the majority of Maryland citizens may not be affected by some of these issues, these adverse climate impacts may disproportionately and severely affect certain groups.

- **Identify potential barriers to effective emergency response.** The State should work with federal partners such as the Federal Emergency Management Agency (FEMA) and local jurisdictions to determine whether there are any institutional or legal barriers preventing effective responses during emergency events, so that these barriers might be removed.

Integrate impact reduction strategies into state and local planning practices

The potential increase in frequency and severity of flooding, extreme heat, and duration of drought warrant a revision of current emergency response planning and preventive strategies. Although actual response protocols may not change, resources may have to be modified in anticipation of changing conditions. For example, the frequency of severe drought or water contamination may lead to a need for establishment of emergency water supply resources.

Priority Recommendations:

- **Improve response capacity through the development of new or expanded programs.** For example, the State should work with federal and regional partners to increase the capacity to combat existing and emerging vector-borne and infectious diseases. Federal support for surveillance and management programs such as vector-borne disease surveillance, conducted by the Maryland Department of Health and Mental Hygiene (DHMH) (in collaboration with Maryland Deparment of Agriculture (MDA) and Maryland Department of Natural Resources (DNR)) is vital for allocation of resources for risk prevention and emergency response planning. Current threats to federal funding support for vector-borne disease surveillance and control efforts represent a considerable challenge to the sustainability of such programs.

- **Address climate-related health risks in hazard mitigation and emergency response plans.** Maryland Emergency Management Agency (MEMA) and DHMH should work together, along with local jurisdictions, to evaluate the effectiveness of current alert and preparedness systems for heat emergency, storms, and poor air quality. If these systems are not resulting in changes in behavior, new alternatives to reach all populations should be explored. Additionally, the State should work with local jurisdictions to incorporate climate-related health risks into local hazard mitigation and emergency response planning.

- **Support community engagement in planning and emergency response decisions.** It was demonstrated in the aftermath of Hurricane Katrina and other environmental disasters that the engagement of stakeholders in vulnerable communities is critical for effective emergency response. The State should work at the local level with groups potentially vulnerable to extreme events such as storms, flooding, or extreme heat to establish plans and increase their response capacity.

- **Pursue opportunities to enhance and protect Maryland's "green infrastructure".** Trees, forests, wetlands, and waterways provide natural protection against the forces of climate change by improving air quality, providing shade, reducing heat, and filtering stormwater runoff. Maryland's Green Infrastructure program identifies ecologically significant lands and provides scorecard protocols for the evaluation of individual conservation projects. DNR should update its Green Infrastructure Assessment and land conservation targeting protocols to incorporate health-related climate change adaptation priorities.

Streamline and revise data collection and information dissemination channels

The development of effective climate adaptation strategies and implementation of efficacious public health interventions will depend on the ability of researchers, decision makers, and public health officials to gain access to data and metrics reflecting the current and potential vulnerability of local and regional communities and populations. Health information that can be aligned with Maryland's rich resources of spatially explicit data (e.g., land use, air and water quality) from the Maryland Department

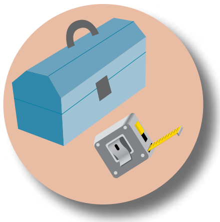
Anticipating the risks posed by climate change can reduce climate-related illnesses, visits to the doctor, and health care costs.

of Planning (MDP), DNR and others will be useful for protecting vulnerable populations and communities and prevent environmental injustices from occurring. Managers and researchers must have access to data and metrics for local and regional communities and populations in order to assess vulnerability and implement preventive measures.

Priority Recommendations:

- **Improve the resolution and availability of health and population data.** Researchers, the health community, and federal partners should work together with DHMH to evaluate the current status of information systems and privacy concerns. These agencies should assess information needs and identify feasible ways to make data more available.

- **Analyze health and population data along with other spatially explicit information** (e.g., land use, air quality, water quality). Improving the resolution and availability of health and population data and analyzing this data along with other spatially explicit information will enable the health community, as well as researchers, to better assess vulnerability and target prevention programs.



TOOLS, RESEARCH, AND EDUCATION TO INFORM SOUND DECISIONS

Maryland's many health institutions are supported by data and information conduits that alert officials to human health trends. These institutions should incorporate climate change into long-term planning and research efforts, so that the health community may be supplied with the tools to be proactive and prevent injury or illness. Investments in education are then essential to teach public health officials, planners, and other decision makers how to use the tools to formulate and implement specific actions. Targeted education efforts are particularly needed for planners, and for specific groups or communities more likely to be vulnerable to impacts. A larger public awareness campaign is needed to address many issues related to preventive measures and individual choices. New social media tactics are likely to be necessary to stimulate behavioral change.

Tools and research

- **Evaluate the current status of information systems and privacy concerns.**
- **Monitor, model and create risk maps** for areas potentially most affected by increased pathogens, contaminated water, extreme heat, flooding, harmful algal blooms, food safety and availability concerns, and air quality.
- **Develop a statewide hazard, exposure, and sensitivity-based vulnerability assessment** of these risks to human health and their causes.
- **Spatially assess existing barriers** to implementation of preventive response strategies (e.g., lack of nearby low-cost health centers, percent of insured population, lack of air conditioning, location in a floodplain).
- **Investigate ways that the "non-health" community can work to reduce human health impacts.** Among others, opportunities to explore include planning and decision-making process related to growth, development, transportation infrastructure, and water resource management.
- **Research the relationship between temperature increases, impervious surfaces, and air quality** to increase the understanding of how particulate matter is influenced by temperature increases and changes in precipitation.
- **Investigate various marketing and campaign strategies** that affect human behavior that benefit individual or community health (e.g., cooling adaptations, removing standing water to reduce mosquito presence).
- **Investigate the potential human health, economic, social, regulatory, and ecological outcomes** of various adaptation strategies, and potential social inequities that climate change may cause.
- **Investigate methods to prevent or reduce vector-borne diseases,** the effects of harmful algal blooms and water-borne diseases. In addition to proactive monitoring, some increased reporting to the public may be necessary.

Jane Hawkey

September 6, 2008: The flooded fire deparment of Madison, Dorchester County from tropical storm Hanna. Placement of new infrastructure should anticipate climate change impacts, both structurally and to access/transportation points.

Education

- **Support community engagement in hazard planning** and emergency response decision-making.
- **Undertake a larger public awareness campaign** to address preventive measures and individual choices.
- **Target education and outreach efforts** toward populations and communities most at-risk.
- **Increase climate change literacy** by incorporating climate-related health information into medical curricula and emergency response education.
- **Increase awareness of, and protocols for, new or previously rare conditions.**

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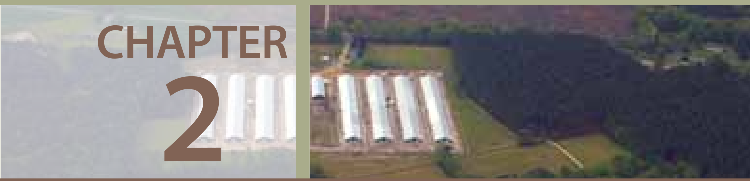


CHAPTER 2

AGRICULTURE

Lead author: Frank Coale
Contributing authors: Arvydas Grybauskas, Robert Kratochvil, Stephen McHenry, Connie Musgrove, Douglas Parker, Daphne Pee, Jennifer Timmons, John Rhoderick, and Lewis Ziska

KEY POINTS

- **Warmer temperatures and more variable precipitation will likely lead to changes in crop and animal production and pest management.** Maryland farmers will likely have to plant different crop species and more drought-tolerant varieties of the ones they currently plant. Farmers will likely face increased costs associated with the summer cooling of poultry and livestock and the need for a rapid response to variable precipitation and pest infestation.

- **More intense water management and increased technical and financial support for agricultural transitions will help boost resilience.** Changing climate is very likely to cause changes for farmers. They may need to shift the timing of planting or fertilization, or increase irrigation and the cooling of animal production facilities. As farmers adjust, state and local governments will need to provide new education and training and to help alleviate the costs and risks associated with these changes.

- **Farmers need new information tools to support decisions regarding environmental and economic conditions.** Increased investment in improved monitoring and forecasting tools would increase a farmer's ability to prevent, rather than react to, adverse impacts.

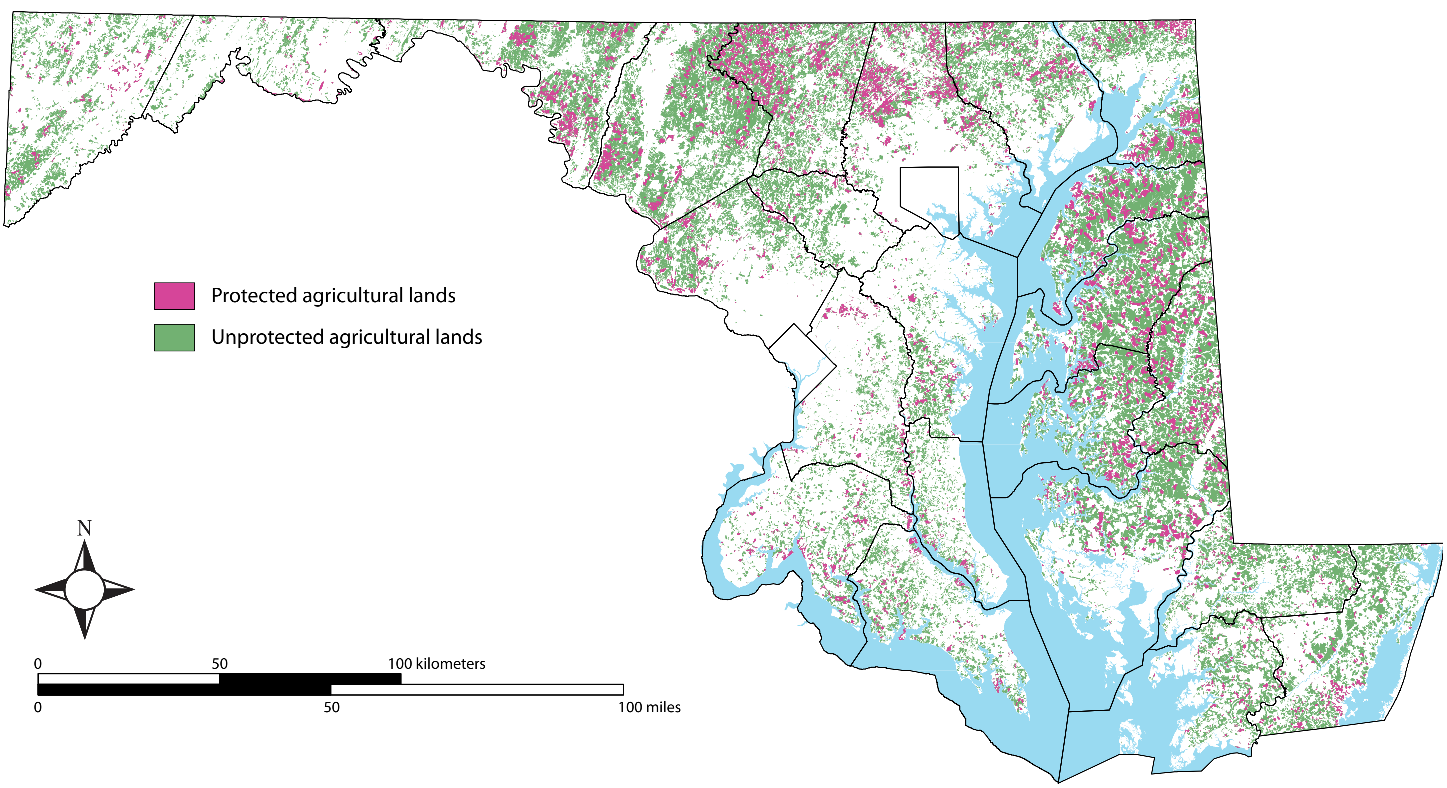


Figure 2.1: Current Maryland protected and unprotected agricultural lands. Targets for protection should be amended to take into account climate change considerations, placing priority on those farms that are likely to be more resilient in a climate change scenario. Preserved land includes land that is permanently protected from development with a perpetual conservation or open space easement or fee ownership, held by a federal, state, or local government or non-profit organization for natural resource, forestry, agriculture, wildlife, recreation, historic, cultural, or open space use, or to sustain water quality and living resources.

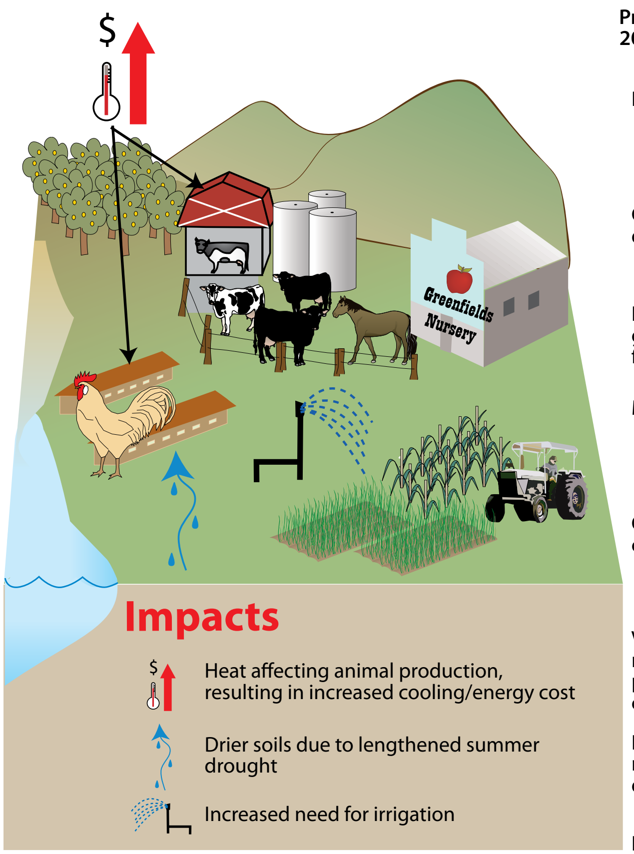
INTRODUCTION

Agriculture is the largest commercial industry in Maryland, employing about 350,000 people, primarily in the north-central and Eastern Shore regions.[1] Farms occupy about two million acres, or about one-third of the State's land, though individually the farms are, on average, much smaller than those in other states. A lot of these smaller farms are only partially owned or leased by the farmer (Figure 2.1).[2] Maryland's agriculture is diverse, including nursery plants, dairy products, beef cattle, vegetables, wheat, horses, and fruit. Poultry, fed in large part by locally produced corn and soybeans, represents the largest market value (Figures 2.2-2.3).[2]

Projected increases in temperature, precipitation variability, and frequency of extreme events associated with climate change are likely to affect the conditions upon which farming has been established. Many of the stressors farms already face are likely to intensify or become less predictable: drought frequency, winter flooding, pests and disease, and ozone levels. These changes occur in the current context of the high economic uncertainty and small profit margins, and are likely to result in increased costs to both farmers and consumers. Farmers will need technical and financial assistance from the State to help develop a strategy to adapt to a changing and more uncertain future.

Jane Thomas

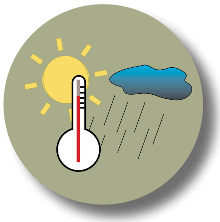
Flooded farm fields after heavy rains in July of 2006.



Product (ranked by 2007 market value, USDA Census)	Climate impact	Adaptation strategy
Poultry	Increased cooling costs; decreased production; changing disease presence	Improve energy efficiency of housing; bioenergy use; improve ability to monitor disease and quarantine
Grains, oilseeds, dry beans, peas	Water stress: increased irrigation use; winter flooding; changes in crop yield quantity and quality	Diversify cultivar and crop types; improve water management systems; improve pest forecasting
Nursery, greenhouse, floriculture, sod	Increased cooling costs; water stress	Establish emergency response systems; improve energy efficency of housing
Millk and dairy	Decreased milk productivity; changing disease presence; low-quality pasture during drought	Increase shade and cooling; improve ability to monitor disease and quarantine; manage pastures for drought
Cattle and calves	Changing disease presence; heat stress; low-quality pasture during drought	Increase shade and cooling; improve ability to monitor disease and quarantine; manage pastures for drought; farm heat-toleant breeds
Vegetables, melons, potatoes, other crops, hay	Water stress: increased irrigation use; winter flooding; changes in crop yield quantity and quality	Diversify cultivar and crop types; improve water management systems; improve pest forecasting
Horses, ponies, mules, burros, donkeys	Heat stress; low-quality pasture during drought	Increase shade and cooling; manage pastures for drought education about heat stress
Fruit trees, nuts, berries	Water stress: increased irrigation use; increased pest damage	Diversify cultivar and crop types; improve water management systems; improve pest forecasting

Figure 2.2: Major Maryland agricultural products, climate impacts, and adaptation strategy options.

CLIMATE VULNERABILITY



As the climate changes, farmers, the farm credit industry, and regulators of agricultural management practices will likely face a large and growing degree of uncertainty. Increases in temperature, and precipitation variability will shift the environmental conditions upon which Maryland farming has been fundamentally based. This will likely affect the farming community's ability to plan ahead, increase the required intensity of farm management, escalate equipment costs, and impact associated industries. Further, consumers of agricultural products will also be affected as the availability of food may be impacted by an increased frequency of severe storms and short-term droughts. Although the stresses associated with climate change are conditions that farms have been subject to before, these stresses are likely to become more intense. Increased temperatures may be considered beneficial in terms of extending the growing season, but high summer temperatures also can severely affect crop yield and animal production.[3] Potential increases in ozone, a chemical toxic to plants, are also likely. Adaptations by farmers to shifts in environmental conditions will require significant technical and financial support from federal, state, and local agencies in order to minimize impacts.

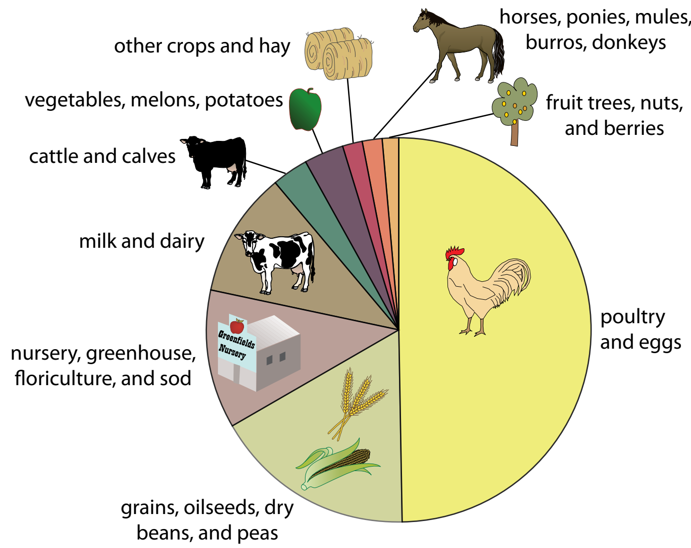


Figure 2.3: By market value, poultry is Maryland's highest value agricultural product, though much capital and land use is devoted to lower market value operations such as horse farming (USDA 2007).[2]

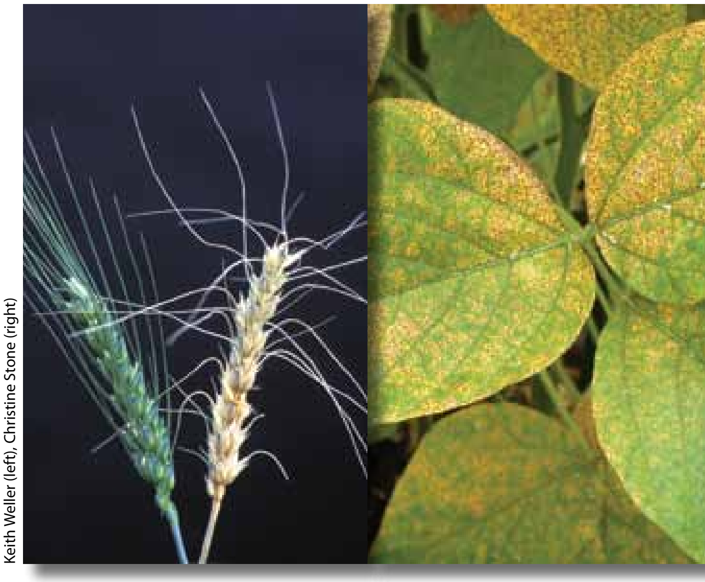
Precipitation extremes will likely affect drainage and water retention

Efficient water management may pose one of the largest operational challenges for farmers. Both drought and flooding conditions have negative effects on agriculture, resulting in production losses and requiring increased irrigation. Drought conditions reduce crop yields and dry pasture grasses on which grazing animals feed. In certain areas, winter precipitation increases may flood fields and delay spring planting, which hampers farmers' ability to produce and competitively market early-season, high-value crops such as melons, sweet corn, and tomatoes. In areas such as the lower Eastern Shore, where water drainage ditches are used to manage standing water from current average storms, the insufficiency of this drainage infrastructure to manage future high water flows will make it more difficult for the individual farmer to manage soil moisture. Poultry houses in these areas also will require siting or design alterations to avoid future flood impacts. An example of the predicted increased frequency of severe precipitation events and their consequences for farmers is the occurrence of three "thousand-year" rainfalls in Minnesota over the past seven years.[4]

Crop and animal production will shift

Current crop and animal management may not be suitable for rising temperatures, new pests, and increased precipitation variability. Climate change may be advantageous to some crops, however, by way of an extended growing season and increased carbon dioxide levels. Soybeans, for example, thrive upon increased carbon dioxide. Although increased carbon dioxide levels may benefit such crops, temperature increases, increased frequency of drought, and increased ozone may negate this effect (Figure 2.4).[5,6,7] For all plants, when their optimal temperatures are exceeded, their life cycles are shortened, which can significantly reduce their viability and yield.[8,9] These effects will likely cause shifts in the types of animals and crops raised and produced in Maryland. Many seed varieties were developed during past periods of greater climate stability. These seed supplies have very narrow genetic diversity. As a result, there is much inherent risk if a widely grown strain turns out to be inappropriate for the year, due to unforeseen stressors caused by drought or flooding. Moreover, more frequent periods of drought in summer months may not only force farmers to plant drought-tolerant varieties, but to irrigate their crops, increasing production costs. In some coastal areas, this increased water withdrawal, combined with sea level rise, can lead to saltwater intrusion into aquifers. Increased water withdrawals may also compete with other uses, in particular public water systems and/or individual homes. In low-lying areas subject to periodic tidal inundation soil quality may decrease, inhibiting plant growth.

The poultry industry is Maryland's largest agricultural component, and consumes the majority of the State's corn and soybean production.[10] In a climate change scenario, the overall heating requirements for chicken houses and other livestock barns may be reduced. However, cooling will also need to increase significantly in the summer, and although energy pricing is difficult to predict, this may outweigh heating reductions in winter, thereby increasing total costs. Increasing the operating costs of poultry production could significantly affect profits. Dairy and beef cattle farms, nursery operations, and greenhouses are also affected by increased energy costs. The dairy industry in Maryland has already declined due to market conditions and this trend is likely to continue. Increased temperatures will put a strain on feed production, which results in lower milk production. Beef cattle producers may shift to more heat-tolerant breeds. Further, horse feed may be affected, and may need to be imported from farther distances, increasing operating costs.



Keith Weller (left), Christine Stone (right)

Wheat head blight, or scab and soybean rust are potential new or increasing pests due to increased temperature.

Pests, disease, and weeds will likely shift with climate

The types of pests, diseases, and weeds seen on farms and affecting animal production will likely change and become less predictable, leaving farms more vulnerable to invasions. In addition, the frequency of pesticide application in southern regions of the United States in contrast with cooler northern regions suggests that pesticide application may increase as temperatures warm.[11.12] One disease expected to expand its range is soybean rust, a fungal pest that has caused 40 to 60 percent crop losses in the southern United States.[13,14] Although soybean rust has not yet been an issue on Maryland farms, there is an increasing probability that an infection resulting in crop loss will occur in the State as temperatures rise. Weed species are also more likely to respond to increasing carbon dioxide than most crops.[15] Research suggests that glyphosate, the most widely used herbicide in the United States, is likely to become less effective as carbon dioxide levels rise.[16] Additionally, warmer, wetter winters create a climate more suitable for animal or plant disease, such as the fungus that causes wheat scab. Bees, primary pollinators for many crops, are currently affected in many areas by bee colony disease and colony collapse disorder. Although the relationship between this disease and climate is unclear, it may also compound the problems presented for some crops by climate change, affecting the viability of crops that are dependent on bees for pollination.[17,18]

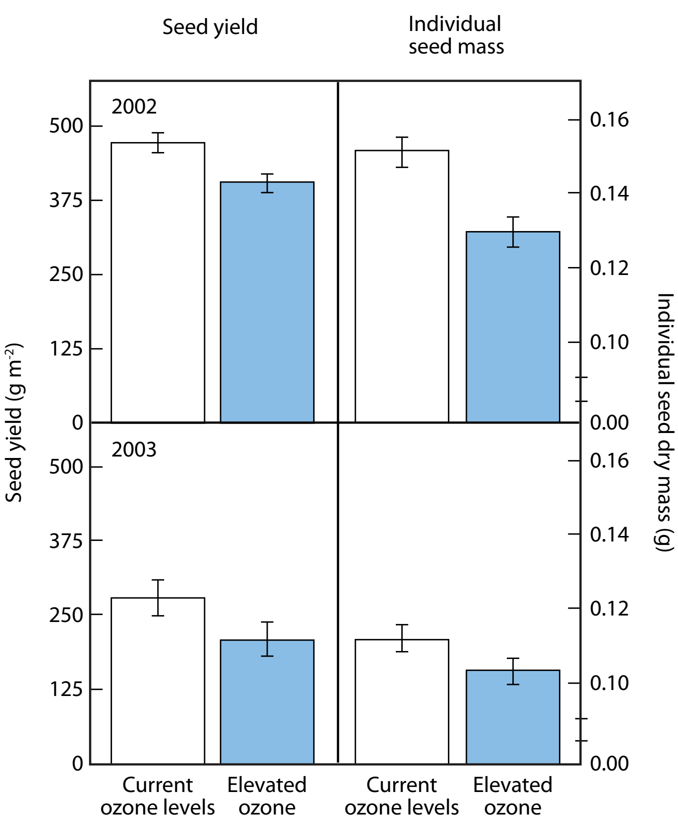


Figure 2.4: Research by Morgan et al. (2006) demonstrates that elevated ozone levels can reduce soybean yield (measured by seed weight).[19] Ozone levels are likely to increase as climate changes.

Vulnerability to pest and disease invasions is highly affected by how quickly and unpredictably invasions occur. The speed at which changes in pest pressures occur and a farmer's ability to rapidly adjust farm operations will be essential. Large-operation farmers may not be able to respond to changes quickly enough, and smaller farmers may be less capable of paying the costs associated with field or animal treatment. Additionally, the current economic situation has caused a retrenchment in Maryland's most reliable information conduits such as University of Maryland Extension. These systems are unlikely to be sufficiently able to track, monitor, and prepare farmers for rapidly occurring invasions.

Current applied research, education, and outreach are not sufficient

Maryland's applied agricultural research, education, and outreach occur through a few key channels. Programs such as those offered by the University of Maryland Extension and the Soil Conservation Service provide unbiased services, information, and training on issues such as nutrient management, farm management, integrated pest management, marketing, and other production issues. Organizations such as 4-H, Future Farmers of America, and LEAD Maryland offer programs to prepare future leaders in the farm community. High school, undergraduate, and graduate education support development of future agricultural scientists, educators, and agribusiness professionals, and promote implementation of novel and advanced management technologies. Funding for these programs has recently been constrained. In some cases, these gaps in information channels have been filled by private industry, most notably seed and chemical companies that have a primary mission of selling their products and services. Further, current ability to monitor and forecast information about changing pests, climate, and economics is relatively limited. The reduction of these information channels reduces a farmer's capacity to adapt to changes that may come.

Cost and intensity of farm management will likely increase

Although farmers are accustomed to adapting to both dry and wet years, the variability and extremes associated with climate change are more difficult to predict. The capital costs associated with adaptation may be too large for small-scale farmers, who already operate on very narrow margins. Additional risk may be added to the existing risks associated with local, national, and global markets. Farmers along Maryland's many miles of shoreline also face the long-term possibility of losing arable land to sea level rise. As a result, farmers will likely need to change the way they manage and what they grow.

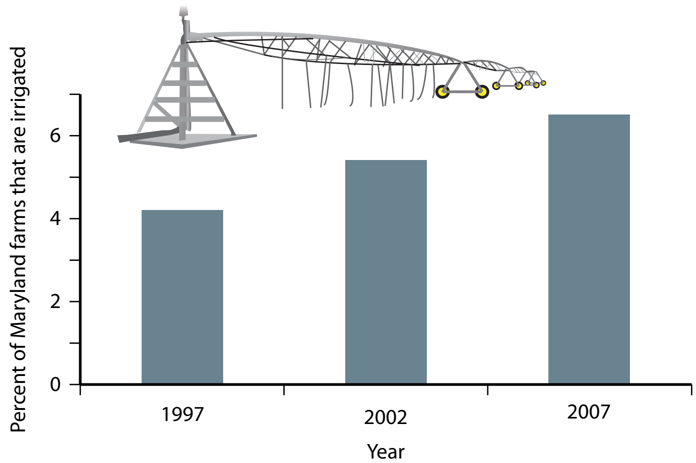


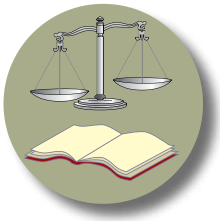
Figure 2.5: Percent of total Maryland farmland that is irrigated (USDA).[10]

Increased temperature and precipitation variability may translate to increased production costs. For example, increased use of animal cooling and irrigation, new irrigation equipment, and more frequent pest treatment all add to the total cost of farm operation. Although measurements have not been made frequently enough to discern a definitive trend, irrigated agriculture has steadily increased from 1997 to 2002 (Figure 2.5).[2] If water resources become more scarce in certain areas, restrictions or permit fees may also be placed on water use for irrigation. Climate change may lead farmers to try to apply fertilizer, pesticide, and other chemical treatments more quickly, leading to a scaling up of equipment or increased equipment costs. For example, the use of commercial fertilizer rather than spreading manure may increase, as it is more quickly applied in a narrow window of weather conditions. This shift would increase the urgency to enhance options for the management of unused manure, so that changes do not result in nutrient concerns for ecosystems. Similarly, the cost of bringing produce to local markets becomes more challenging, as it will likely become more difficult to predict pre-planned dates of harvests to meet seasonal market demands. All of these impacts contribute to the economic uncertainty surrounding the future of agriculture.

Jane Thomas

Agricultural irrigation on a farm on the Eastern Shore. Irrigation usage and costs will likely change with precipitation variability.

STRATEGY FOR RESILIENCE



Many of Maryland's agricultural operations already produce on very thin economic margins. Climate change is likely to add to current levels of stress. The following strategies are therefore geared toward building resilience by reducing stress and uncertainty. Their benefits are not exclusive to a climate change scenario; many will improve the viability of Maryland agriculture regardless of change. Climate change adds a greater sense of urgency to their adoption, due to both the speed and severity at which impacts might occur.

It is the broad goal of these strategies to help reduce stress on agricultural operations and to build the resilience of Maryland farms, despite changes they may face in the future, and to improve the quality of the Chesapeake Bay and its watershed. As climate change may affect the intensity of how farmers manage, shift agricultural best management practices (BMPs), and affect the implementation of relevant regulations, farmers need to be prepared and supported for adjustments that may be required. This may be the case for pollution regulations associated with reducing nutrient discharges to achieve Maryland's Watershed Implementation Plans (WIP) to achieve the Chesapeake Bay Total Maximum Daily Load (TMDL) by 2020, as in the State's goal, or by 2025 as per federal mandate.

Increase crop diversity, protect against pests and disease, and intensify water management

As precipitation variability increases, diversifying crop species and varieties is a strategy already being employed by some farmers (e.g., planting varieties that mature at different times or have different genetic resistance to pests). Rather than planting a single crop variety, a portfolio of different varieties may be a lower risk strategy in a highly variable climate. As precipitation patterns become less predictable, having a higher diversity of crops will increase the likelihood that a few varieties will do very well, whereas the planting of a single variety may result in increased vulnerability to adverse weather conditions. An investigation into the production and economics of various diversification schemes needs to be conducted. Funding for education and outreach programs is also needed to communicate these strategies to farmers and to help build more resilient business models. Improved water management is also needed to enhance a farmer's capacity to better handle periods of drought and heavy rains.

Scott Bauer

Grain production is usually limited to a few cultivars. Diversifying crop varieties is one strategy for boosting resilience.

Priority Recommendations:

- **Promote diversification of crop species and varieties.** MDA should continue and expand existing efforts to work with farmers at the local level to increase crop diversity. The agency should identify and offer support to farms that may benefit economically by increasing diversity through different crop rotations, different cropping schemes such as inter-cropping, novel pest management strategies, or production practices.

- **Intensify water management and conservation through research, funding and incentives.** MDA's Drainage Management Task Force should review current resources and strategies geared towards water management and identify necessary resources, education, and financial support to support "climate-ready" water management. This group should also work with local jurisdictions to improve public drainage design in agricultural areas, so that both farms and roadways can balance proper drainage and retention.

- **Protect against incoming pests, weeds, and disease.** MDA should engage the US Department of Agriculture (USDA) and surrounding states to improve and expand regional programs that forecast, detect, prevent, and eradicate pest species. Furthermore, MDA should work with the climate and agriculture science communities to develop efficient early-warning systems for likely invasions of insects, weeds and diseases.

- **Support innovative solutions that foster adaptation and also reduce energy costs and carbon footprints.** New incentives for agricultural biofuel development, methane recapture, and carbon and nutrient trading markets offer opportunities for farmers to both reduce their dependency on external, fluctuating energy costs and to benefit the environment. Maryland Energy Administration (MEA) and MDA should work together with University of Maryland Extension to support these efforts and expand technological innovation in the field.

Strengthen applied research, risk communication, and technical support

Preparing for climate change will require an interdisciplinary effort of the large agricultural community, including not only farmers, but MDA, University of Maryland Extension, DNR, MDE, farm credit and insurance industries, as well as agricultural land trusts. Communicating research, monitoring, and new technical information will be a vital component. While there should be an increased emphasis on existing programs, greater investments should be made in outreach, education, and research services (e.g., University of Maryland Extension, Soil Conservation Districts, Natural Resource Conservation Service, non-profit, and commodity organizations) that offer programs to help farmers assess the costs and benefits of various response options.

Priority Recommendations:

- **Enhance dissemination channels to improve the relay of climate information** among research institutions, Extension education, and outreach organizations. The outcome should be a strengthened ability to relay forecasted information about pests, climate impacts, and the agricultural economy to farmers.

- **Identify opportunities to support the transition of farm and agricultural practices.** Agricultural operations likely to undergo major transitions may be the most economically vulnerable. MDA should work with partners including farm credit and insurance operations to do a vulnerability assessment and establish priorities for increased education, funding, and risk management efforts to support the transitions for these vulnerable farmers.

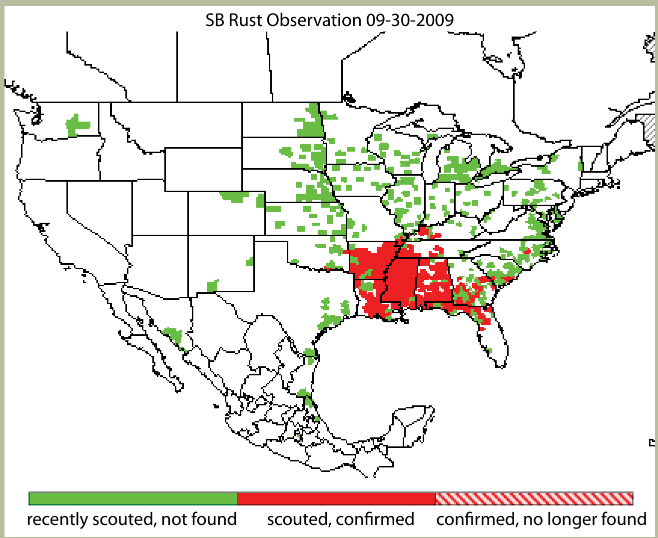
- **Enhance emergency response and risk management.** For example, if summer energy surges lead to brownouts, and farmers are unable to cool poultry houses, severe animal losses can occur. Farmers need options to avoid these losses in acute crises. The State should design an emergency response strategy that addresses climate change impacts such as severe heat and other extreme events.

Monitoring and forecasting soybean rust

The Integrated Pest Management (IPM) Pest Information Platform for Extension and Education (PIPE) is one example of a system that could be used to track and forecast pests so that farmers may be prepared for invasions. The platform includes a daily update of the grographical progress of soybean rust, excerpted below:

"On September 30th, soybean rust was reported for the first time in 2009 in North Carolina in a soybean sentinel plot in Johnston County, and in three more counties in Mississippi and Tennessee. On September 29th, soybean rust was reported for the first time in 2009 in Virginia (Suffolk County), and in eight counties in Arkansas, two counties in Georgia...In 2009, soybean rust has been found in 14 states and 293 counties in the United States, and in two states and five municipalities in Mexico."

For more information: http://sbr.ipmpipe.org



A map retrieved from IPM PIPE depicts observed significant presence of soybean rust in the southern United States on September 30, 2009 (reported by county).

Enhance existing best management practices and prioritize land preservation targets

In addition to shifts in agricultural production, changes in seasonality and precipitation are likely to affect BMPs which are geared towards protecting water quality in the Chesapeake Bay and its watershed. Practices such as manure injection (injecting directly into the soil), split fertilization (spreading fertilizer at staggered times throughout the growing season), and precision agriculture (using global positioning system (GPS) to map in-field variability and treat accordingly) can be employed to improve the timing and application of fertilizers and pesticides.

Priority Recommendations:

- **Evaluate the effectiveness of best management practices under future climate change scenarios.** Current cropping systems may be less effective if not accompanied by improved water management or soil-enhancing practices. Alternately, it may become necessary to switch to winter cover crops that are more tolerant of heavy precipitation, as winter wheat is prone to flooding impacts. The State should evaluate options for improvement, and work with agencies such as the MDA and the Natural Resource Conservation Service that provide cost-sharing programs to enhance the use of these BMPs. Supporting research will be needed to assess potential changes in BMPs.

- **Assess and revise targets for agricultural land preservation.** Maryland's many agricultural land conservation organizations such as the Maryland Agricultural Land Preservation Foundation, and the Maryland Environmental Trust should work together, along with county planners and private landowners, to assess and target agricultural areas for preservation. Assessments should include an analysis of future water resource and drainage issues and the need for agricultural diversity given future climatic conditions. Targeting should be aimed at preserving the most productive farms that are likely to adapt successfully to future climate change. Local markets for farm products should be included in this assessment.

John Rhoderick

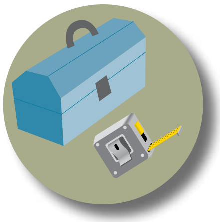
A well-managed drainage system with vegetated channel banks protects soil moisture and water quality.

CASE STUDY: Sustainable water management

The Maryland Agricultural Water Quality Cost-Share program provides grants to farmers to install conservation measures or best management practices (BMPs) to reduce impacts to manage water and erosion to safeguard water quality. Some of these strategies have additional benefits for reducing climate change impacts. Among the BMP options are structures for water control systems, which can be used to control water elevation and drainage. Sensors can also be placed within the field to relay to the farmer whether irrigation is needed. These strategies can be used to improve water retention on-site and to reduce impacts to surrounding waterways.

John Rhoderick

A water control structure built across a drainage ditch prevents gully erosion, reduces nutrient loadings, and controls water levels.



TOOLS, RESEARCH, AND EDUCATION TO INFORM SOUND DECISIONS

Farmers are highly dependent on the predictability of precipitation, temperature, and pest invasions. Advanced monitoring and modeling of these factors would vastly improve a farmer's adaptive capacity. Monitoring and modeling systems allow a farmer to have more time to prepare for, rather than react to, impending threats. Therefore, program refocusing and increased investments will be needed to support technical research and education support to sustain a competitive and resilient agricultural industry. Tools to assist Maryland farmers such as new technologies, economic strategies, and monitoring of global markets, climate, and pests will become increasingly important.

Tools and research

- **Increase funding and development of long-term monitoring and forecasting decision-support tools.** Web-based programs such as the Integrated Pest Management (IPM), Pest Information Platform for Education and Extension (PIPE) and the soybean rust monitoring initiative should be established for other pests and disease likely to increase in Maryland.

- **Undertake a mapping effort to evaluate spatial and seasonal patterns of risk.** MDA should work with DNR to identify agricultural areas that are most likely to be affected by climate change so that the more resilient areas are prioritized for protection in the short term, or for those less resilient farms, incentivized to transition in the long term.

- **Study and develop economically viable diversification practices** as well as crop varieties and animal breeds that are more tolerant of high temperatures, saline soils, drought, insect pests, and disease.

- **Identify the effects of increases in winter precipitation, more frequent summer drought and greater summer demand for irrigation on water availability.** MDA's Drainage Management Task force should take on a similar effort in the Coastal Plain region to a current effort by Interstate Commission on the Potomac River Basin, The Nature Conservancy, and Army Corps of Engineers which are currently working together to study some of these relationships for the entire Potomac River Basin.

- **Increase the investigation and investment in pilot projects** that both reduce carbon and generate energy on the farm through waste or other means.

- **Research new innovative and cost-effective strategies for improved water management systems and design.** In-field sensors that measure water levels and water control structures are examples of current options.

- **Support research on how Maryland farmers can take advantage of opportunities to employ carbon sequestration strategies** or reduce dependency on external energy sources by using farming BMPs, methane recapture, anaerobic digestion, and other methods.

Caroline Wicks

Planting cover crops is one potential best management practice (BMP) for farmers.

Education

- **Explore innovative ways to improve the communication** of adaptation planning principles, focusing on understanding current information conduits (public and private) and improved distribution of information.

- **Engage agricultural-based leadership and fellowship programs**, including 4-H, Future Farmers of America, and LEAD Maryland to support climate change research and education.

- **Incorporate climate science and impact information into academic curricula.**

- **Participate in the Maryland-Delaware Climate Change Education, Assessment and Research (MADE-CLEAR) initiative** to promote increased awareness of the causes and consequences of climate change in communities where agriculture is important.

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CHAPTER 3

FORESTS AND TERRESTRIAL ECOSYSTEMS

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Contributing authors: Sally Claggett, Bert Drake, Joel Dunn, Matthew Fitzpatrick, Anne Hairston-Strang, David Inouye, Dana Limpert, William Miles, Douglas Samson, and Eric Sprague

KEY POINTS

- **Climate change will alter distributions of species and habitats and exacerbate some existing stressors at an uncertain rate and degree.** Native species populations may decline, increase, or migrate from the State while new species may migrate in due to habitat shifts. Existing stressors on species and habitats may be exacerbated by climate change.

- **Potential socioeconomic consequences include losses and shifts in ecosystem services.** Forests and terrestrial ecosystems contribute an estimated $2.2 billion to Maryland's economy and $24 billion in ecological services. The condition of these ecosystems and the services they provide is likely to be altered by climate change.

- **Managing for resilience is an important component of ensuring long-term ecosystem viability.** Strategically focused land conservation, restoration and management in "climate-sensitive" areas can increase ecosystem resilience and support biodiversity and the social and economic benefits of natural resources.

- **Ecosystem assessments and targets for land protection and restoration should incorporate climate change.** Maryland should cooperate regionally, along with other states and federal agencies, to conduct climate change vulnerability assessments and collectively establish protection and restoration priorities aimed at maintaining a diverse portfolio of protected lands at a regional scale.

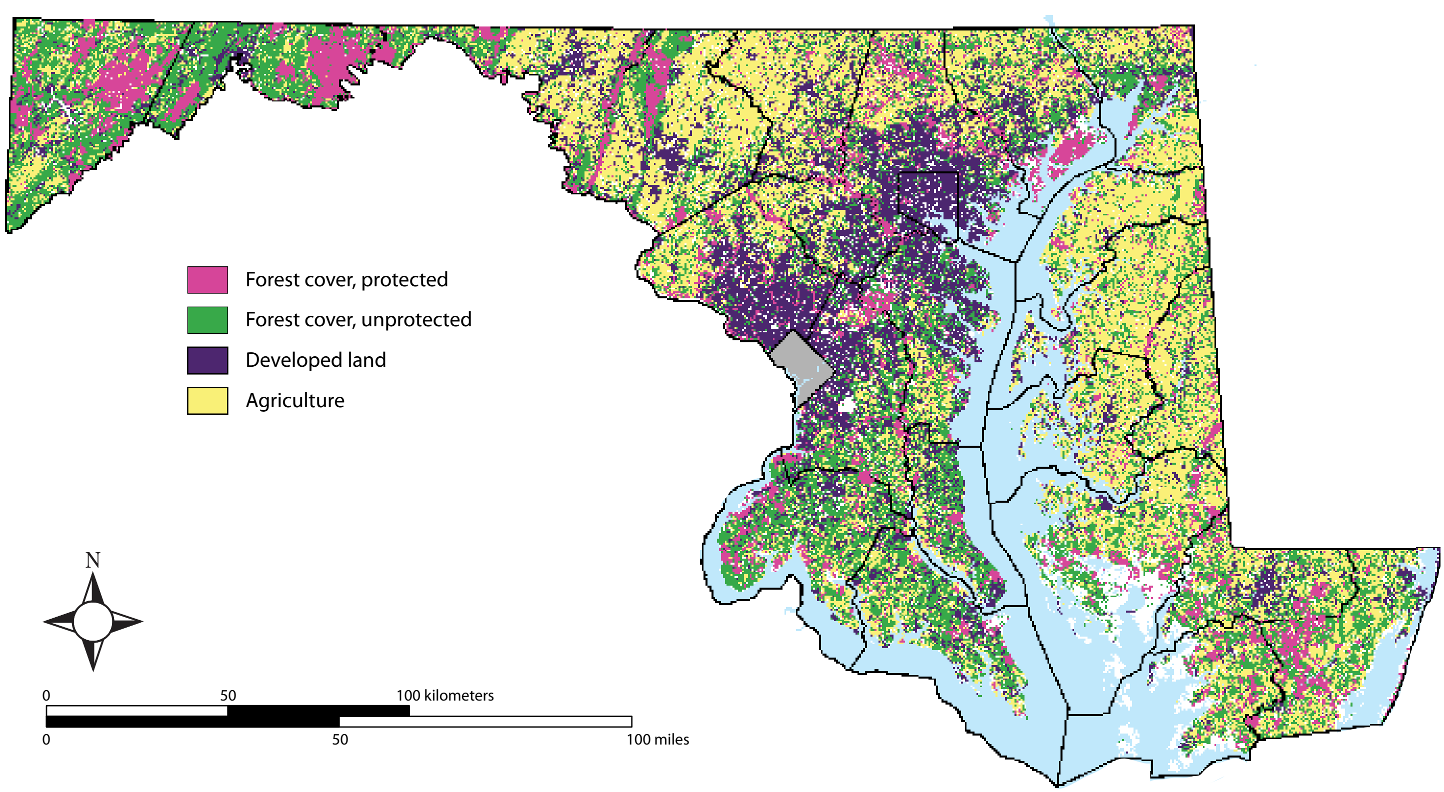


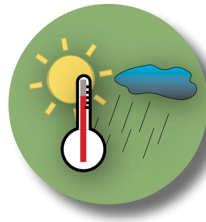
Figure 3.1: Forests cover a large part of western Maryland, including many protected acres. Land use impacts to these ecosystems are most pronounced in central and eastern Maryland, due to development and agriculture, respectively (MD DNR, MDP). Preserved land includes land that is permanently protected from development with a perpetual conservation or open space easement or fee ownership, held by a federal, state, or local government or non-profit organization for natural resource, forestry, agriculture, wildlife, recreation, historic, cultural, or open space use, or to sustain water quality and living resources.

INTRODUCTION

The diversity of Maryland's forests and terrestrial ecosystems reflects the wide variety of environmental conditions found across the State's five major physiographic provinces. From the mountains to the sea, one can hike through western Maryland's thick groves of hemlock lining deep gorges, across grassy serpentine barrens supporting the unique purple-flowered fringed gentian, by vernal pools inhabited by salamanders, and through the pine forests and hardwood swamps of the Eastern Shore. The State's forests are mostly privately owned and only 27 percent are permanently protected from development (Figure 3.1). These habitats and their plant and animal communities are shaped mainly by geology, climate, and interactions with other species. They also are subject to many existing stressors such as development, pests, and pollution, limiting their capacity to adapt.

Changes to temperature and precipitation have the potential to alter ecosystems greatly. In the face of certain change, it is our vision that through following the strategies, Maryland will enhance the long-term resilience of its forests and terrestrial ecosystems, enabling them to adapt in a manner that maintains and enhances biodiversity, and continues to provide ecological services important for supporting our quality of life, health and economic vitality.

CLIMATE VULNERABILITY



Maryland's landscape encompasses a diversity of plant and animal species and habitats. Many of these habitats and species are exposed to existing stressors such as human development, invasive species, deer browsing, storms, fire, among others (Figure 3.2). These stressors not only limit an ecosystem's capacity to adapt, but in many cases, are likely to be exacerbated by climate change. A combination of species vulnerability and adaptive capacity, and whether or not the State takes action to prevent avoidable losses of species, will determine the future composition and health of Maryland's forests and terrestrial ecosystems, and therefore, the services they provide to human society.

Shifting conditions affect species and habitat distributions and viability

Shifts in habitat due to changes in precipitation or temperature will alter the distributions of many species, potentially at a pace that may be difficult for them to achieve successful redistribution. The ability of species to keep pace with climate depends on many factors, including the speed at which: they can physically move (animals), their seeds disperse (plants); and the degree to which this movement is obstructed. In some cases, large local die-offs may occur, causing a major disruption to ecosystem function and potentially affecting the overall viability of the species. Populations of species at the northern extent of their range may become more abundant or colonize new habitat, whereas those species at the southern extent of

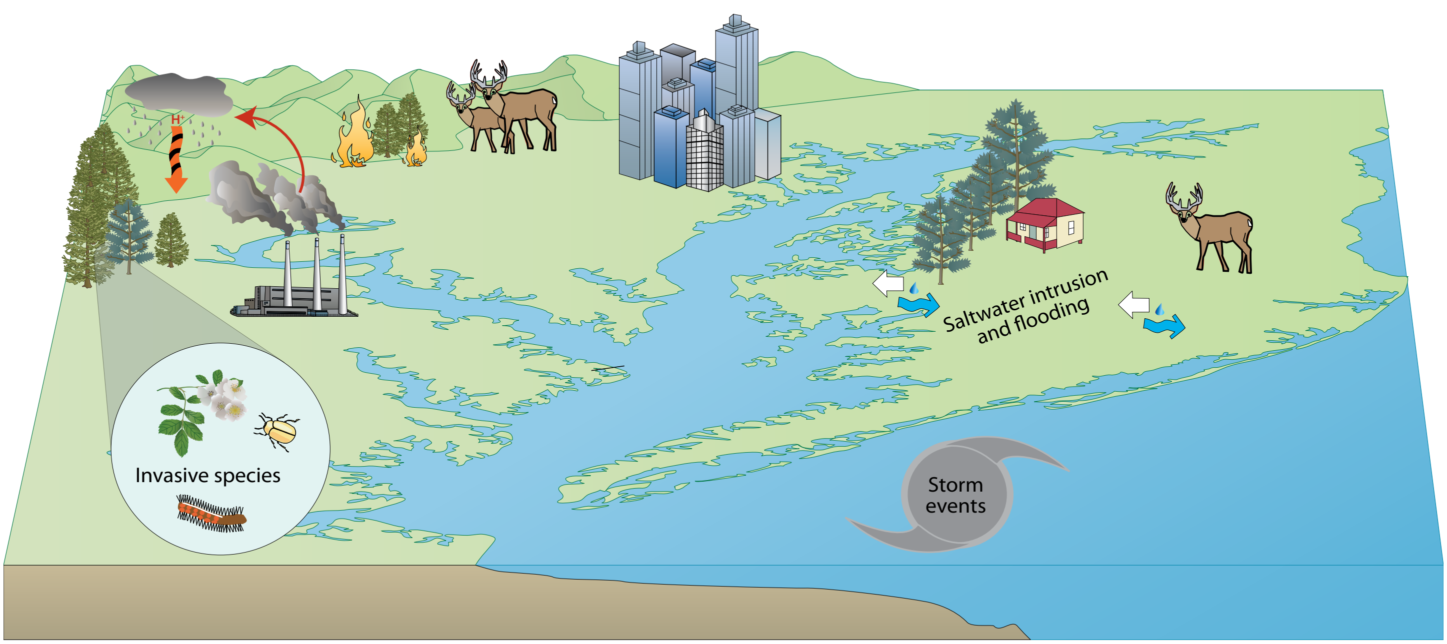


Figure 3.2: Maryland's forests and terrestrial ecosystems are affected by many existing stressors that limit their capacity to adapt to climate change. In many cases, climate change may make existing problems worse (e.g., fragmentation effects); in others, effects may be neutral.

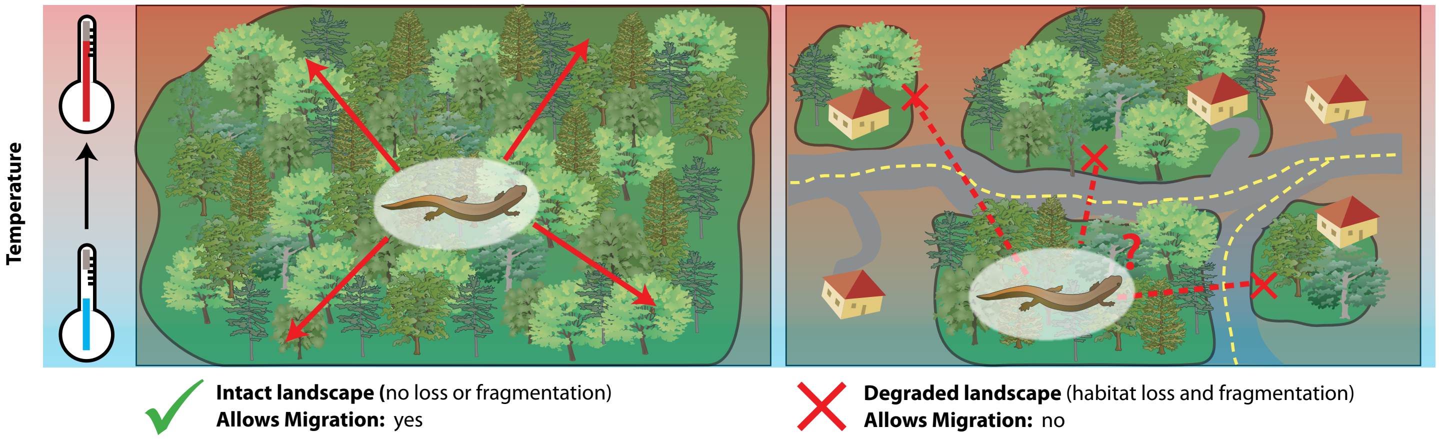


Figure 3.3: Fragmentation and habitat degradation interact with climate change by limiting species' ability to retreat or find refuge from rising temperatures or extreme events.

their ranges may migrate away from intolerable conditions or die off locally.[1,2] For example, Maryland is projected to suffer losses of its high elevation northern hardwood forests of sugar maple, beech, and birch trees, and experience expansion of oak, hickory, and loblolly pine trees.[3,4]

Alternatively, some formerly low-elevation species may be able to relocate to higher elevations in western Maryland. These shifts, combined with existing stressors could be a final straw for some species.[5,6,7] For example, the Baltimore checkerspot, Maryland's state butterfly, is a species for which the combination of climate change and other human alterations may be critical for local populations. Already shifting north toward cooler temperatures, the checkerspot is faced with disconnected and rare habitat. Similar to a loss in synchrony with habitat, climate change has also been shown to affect interactions between species.[8,9,10]

D. Gordon E Robertson

The Baltimore checkerspot will likely move from Maryland as climate changes.

Responses to new environmental cues such as earlier high temperatures can cause mismatches in phenology (the timing of seasonal events) critical for reproduction and, therefore, survival.[11,12,13] Vernal pools, key breeding habitat for wood frogs and marbled salamanders, are susceptible for two reasons: they are (1) relatively isolated and ephemeral and (2) tied to precipitation cycles. Increased spring and summer evaporation can cause vernal pools to dry out earlier (if pools disappear before tadpoles finish growing into frogs, populations plummet).[14]

As atmospheric carbon dioxide increases, plant community composition is likely to change. All plants use carbon dioxide for photosynthesis, but respond differently to changes in levels. Vines (destructive to tree growth), for example, translate carbon dioxide to growth more directly than other plants.[15] Higher carbon dioxide has also been linked to a faster spread of invasive plants and resistance to common herbicides used to control them.[16,17,18] Understory species may benefit from CO_2 increases indirectly, via an increase in plant water use efficiency.[19,20,21] However, they are also projected to be the slowest plant type to migrate, leaving them at a disadvantage.

Climate change adds to existing stressors

Development, habitat fragmentation, altered hydrologic and fire regimes, deer overabundance, invasive species, pathogens, and pollution all currently affect Maryland's ecosystems. The Maryland Department of Natural Resources (DNR) has already listed over 600 species of plants and animals as endangered, threatened, in need of conservation, or in danger of being extirpated, from habitat loss or degradation alone. Climate change compounds these existing stressors, exacerbating some and leaving others unchanged. For stressors expected to worsen, climate change adds a greater sense of urgency to their management and reduction.

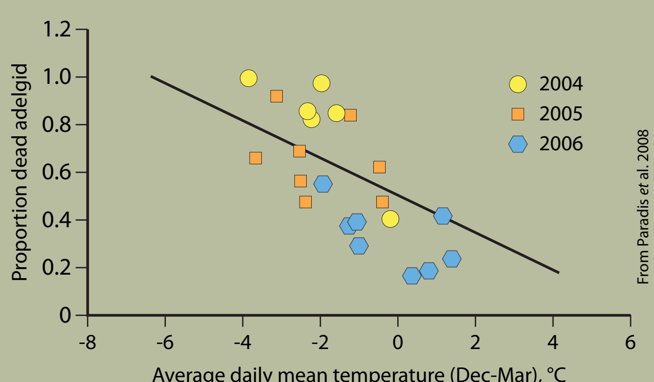
Human development pressure remains the dominant stressor to ecosystems, and has led to habitat fragmentation and a loss of approximately 100 acres of forested land a day in the Chesapeake Bay region since the mid-1980s.[22] Climate change interacts with fragmentation in a critical way. As shifting temperature and altered hydrology force less tolerant species to migrate from current habitat, fragmentation hinders this movement, leading to species stress or local extinction (Figure 3.3). As mentioned in the *Phase I* Adaptation Strategy, sea level rise will contribute to forest loss and fragmentation.

Pests and invasive species have a significant impact on forests and terrestrial ecosystems. The current presence and success of species such as the hemlock woolly adelgid and gypsy moth are predominantly a result of their opportunism in areas of human disturbance or transport through a globalized trade system. Climate change will likely affect the assemblage of pests seen in Maryland, including insects, fungal pathogens, and diseases.[13] If the spring season becomes drier, for example, gypsy moth infestations may increase. The moths defoliate trees and add fresh waste to the forest floor, sending a pulse of excess nutrients downstream to local rivers and the Chesapeake Bay.[23] Furthermore, the loss of riparian trees, such as hemlock, is equivalent to the removal of a filter between land and watershed, resulting in reduced water quality and increased stream temperatures.

Pest responses to climate change?

Influence: temperature

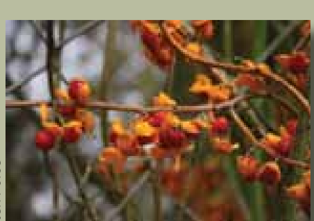
Some invasives will respond positively as climate changes. The hemlock woolly adelgid, for example, has been found to fare much better during milder winters (below).[24]



From Paradis et al. 2008

Influence: carbon dioxide increases

Invasives such as oriental bittersweet (left) and kudzu (right) are highly responsive to elevated carbon dioxide levels.



Sten Porse

Thomas R. Machnitzki

Climate change is expected to change not only the distributions and abundance of existing invaders, but also create new opportunities for invasions by organisms (including disease) that do not yet threaten Maryland's natural resources.[25] Current deer populations are higher in developed areas and already impact terrestrial plants, affecting species distribution, habitat quantity and quality, and stand development.[26,27] Deer are preferential eaters, affecting some plant species more than others.[28,29] There is little direct evidence to support deer population increases as a result of climate change, but the combined effects of grazing and stress due to changing climate may put disproportionate stress on some understory and tree species. Adequately managing these threats will require greater management flexibility, monitoring, and modeling.

Although wildfires are not a serious problem in Maryland compared to many other states, fires do occur predominantly in the spring and fall, due to an absence of moist vegetation and shade, and an accumulation of fallen leaves.[30] These wildfires are usually suppressed by rainfall. However, in drier years, many acres of forested land can be affected. Climate change may shift the timing of these wildfires, and potentially increase the favorable conditions for fire due to a higher frequency of drought.

HUMAN DIMENSIONS

Human populations are critically tied to forests, which contribute many important social, health, and economic benefits to Maryland's citizens.[1] Climate change presents many potential negative impacts to these ecosystem services, particularly in combination with the many existing stressors associated with human development. New ecosystem and carbon dioxide mitigation markets are also likely to emerge and management strategies are likely to change as a result of climate.

Changes will impact ecosystem services

The strategic conservation, restoration, and management of Maryland's forests and terrestrial ecosystems are important practices to ensure a resilient and adaptive response to climate change for both humans and ecosystems. Forests and terrestrial ecosystems regulate the timing and flow of surface and groundwater discharges to streams, rivers, drinking water reservoirs and bays; improve and protect water and air quality; store and sequester carbon dioxide; control stormwater runoff and prevent flooding; reduce urban heat and provide energy savings; protect aquatic resources such as fisheries; provide recreational opportunities; and offer cultural, health, and historic connections between humans and the environment. As climate changes, the services provided by forests and terrestrial ecosystems become even more important. For example, extreme precipitation events create excessive flooding along stream and river banks that could lead to increased bank erosion and sediment deposition, degraded water quality, and increased damage to natural and built communities on riparian floodplains. Furthermore, sea level rise, discussed further in Maryland's *Phase I* Adaptation Strategy, poses a risk to many riparian woodlands, including the economically valuable Bald Cypress Swamps in Battle Creek and Pocomoke River areas.

New markets are emerging and management strategies are likely to shift

New markets will potentially emerge for both forest products and ecological services. Maryland forest harvests are relatively small in comparison to other states. While biomass-only harvests are unlikely to be economically feasible, increased use of thinned timber for fuel wood could provide some economic opportunities. In terms of protecting and restoring forests and terrestrial ecosystems for carbon sequestration or other ecosystem markets, these opportunities are evolving. There is a strong need to understand the State's role in engaging and managing these markets. In addition to shifting market opportunities, production forest managers will likely need to adjust their forest management strategy. Principal forestry concerns such as optimum rotation length or types of species planted are tied to climate and environmental variability, and will require proactive management in order to maximize harvest profits and avoid losses.

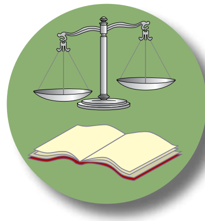
Forests protect drinking water

There is a direct connection between forests and clean drinking water. Over four million people in Maryland and Washington DC rely on water that originates from forests. The North Branch of the Potomac River and the Cacapon-Town watersheds exemplify this forest-to-faucet connection. These are two of the most important watersheds for drinking water provision in the eastern United States.

Wikimedia Commons

Stressors exacerbated by climate such as enhanced activity of pests and disease and increased incidence of drought combine with many other existing stressors to threaten water quality. To protect the long-term provision of clean drinking water, Maryland will need to implement strategies (e.g., conservation and restoration) that promote healthy and resilient forests.

STRATEGY FOR RESILIENCE



Managing for resilient forests and terrestrial ecosystems as climate changes involves a multi-layered, regional strategy to increase the understanding of vulnerable species, habitats and ecosystem services, and to establish protection, restoration, and stewardship priorities. Many of the strategies for resilience described in this chapter are not exclusive to climate change and are essential to bolster an ecosystem's ability to adapt to a variety of disturbances and maintain its functions. However, given projected temperature increases, greater variability in precipitation, and the uncertain impacts of these on forests and terrestrial ecosystems, an informed and targeted effort is needed to reduce the stressors likely to be exacerbated. Maryland's many resource management programs need to be re-examined through the lens of climate change and re-focused to achieve long-term ecosystem resilience.

USGS

Vernal pools, likely to be threatened by climate, are necessary for the survival of the locally-rare Jefferson salamander.

A framework, similar to that developed by the US Environmental Protection Agency (EPA), is recommended to boost resilience by managing for: reduction of anthropogenic stressors, representation of species and habitats, replication of ecosystem and habitat type, restoration of degraded landscapes, establishment of refugia for climate-sensitive species, and as a last resort, relocation of species to suitable habitats.[31] Enhancing connectivity among intact habitats is extremely important, as the ability for species to migrate becomes increasingly essential as climate changes. Reducing anthropogenic stress such as pollution or development is also critical, as these stressors reduce a species or habitat's capacity to adapt and recover from extreme events and climate change. Other key elements include developing strategies that are adaptive and flexible enough to respond effectively to a wide range of possible future conditions.

Expand land protection and restoration and revise targeting priorities

To boost resilience in the face of variable and unpredictable responses to climate change effects, there is a need to increase activity and revise priorities for protecting and restoring lands. Priority should be given to protecting a diverse regional portfolio of connected, ecologically valuable areas. As geologic factors may have an even greater influence on species distributions than climate, a diverse portfolio of targeted conservation and restoration priorities should use geologic features as important characteristics for maintaining diversity.[33] Land protection and restoration targets should also be informed by a vulnerability assessment of Maryland's habitats and major species with the greatest conservation need, with a goal to regionally maintain representation of vulnerable species and habitats. Replication, or protecting more than one example of each habitat/geophysical type, will help prevent local, regional, or national extinctions. This information will change over time as "climate refugee" species move and cross-jurisdictional borders to seek new habitat, highlighting the need for federal and regional partners and an alignment of protection priorities.

Understanding climate change impacts on species

A critical context of information concerning population, life history, range, and current stressors is needed to then determine whether a species is additionally vulnerable to climate change. Parameters for assessing these vulnerabilities are categorized below.*

Exposure

- *Exposure to sea level rise*
- *Distribution relative to barriers*
- *Predicted impact of land use changes*

Sensitivity

- *Dispersal ability*
- *Sensitivity to temperature and precipitation changes*
- *Specificity (in both habitat and interspecies interactions*

Documented or modeled population response

- *Change in distribution, abundance, or range size*
- *Overlap of modeled future range with current range*
- *Occurrence of protected areas in modeled future distribution*

* Adapted from NatureServe, 2010

Maryland has multiple laws and programs geared towards protecting and restoring land, including state, local, and non-profit programs such as Program Open Space, Rural Legacy, Maryland Agricultural Land Preservation Foundation, Critical Area Law, Forest Conservation Act, Sustainable Forestry Act of 2009, Maryland Environmental Trust and the many funds and programs that are funneled through the Chesapeake and Coastal Bays restoration efforts. Additionally, many federal programs support these efforts, including Land and Water Conservation Fund, the Forest Legacy Program and the Coastal and Estuarine Land Conservation Fund. These programs are all vehicles which could be used to advance on-the-ground implementation of climate change adaptation strategies.

Priority Recommendations:

- **Integrate climate data and models into existing resource assessments and spatial planning frameworks.** The State should review new and existing climate data and downscaled model products to assess the impact of climate change on future distributions of plant and animal communities and the quality of ecosystem services they provide. Regional and state-specific climate data and model outputs should be integrated into habitat or species-specific resource assessments, and subsequently, into spatial planning frameworks (i.e., Maryland Green Infrastructure Assessment, Strategic Forests Lands Assessments). The State should work with partners, such as The Nature Conservancy, to coordinate establishment of state-scale priorities with climate change adjusted eco-regional portfolios.

- **Incorporate climate change adaptation strategies into state resource management plans.** DNR should work with federal agencies and surrounding states to develop regional species protection and landscape conservation strategies to protect both potential incoming and departing "climate refugees." Methods for incorporating climate adaptation elements or implementation incentives into restoration priorities should be identified. State plans, such as the State Wildlife Action Plan and the Maryland Forest Resource Assessment and Strategy should be fully utilized to implement programming and planning for future resource conditions. Close coordination with the other mid-Atlantic states will ensure that compatible regional approaches for species and habitat migration are implemented effectively.

- **Collaborate with federal partners to support regional and national adaptation planning.** Maryland should work collaboratively with federal partners to support ongoing federal adaptation planning efforts, including those developed through the Chesapeake Bay Program, and through new federal initiatives, such as the US Department of the Interior Treasured Landscapes Initiative and the US FWS's Landscape Conservation Cooperatives.

- **Update existing land protection targeting programs and project evaluation protocols** to reflect new climate change priorities. Maryland's GreenPrint program identifies the most ecologically significant land conservation priorities in the State (Targeted Ecological Areas) and develops scorecard protocols for the evaluation of individual conservation projects. DNR should update GreenPrint Targeted Ecological Areas and revise evaluation protocols to incorporate new climate change adaptation priorities.

- **Develop climate change adaptation guidance and technical tools** suitable for local government planning needs. DNR should work with local jurisdictions to prioritize protection and restoration areas important for climate change adaptation. These priorities should be coordinated with those being developed in other sector strategies. Multiple benefits can be achieved in many instances. For example, projects geared toward the general protection of forests and terrestrial ecosystems that surround source waters can be oriented to protect habitat, watershed health, and drinking water quality simultaneously.

Adjust management practices and reduce existing stressors

Climate change will likely shift the baseline upon which management standards, incentives, regulations, and best management practices (BMPs) were formed. Therefore, in order to improve resilience and maintain ecosystem function, management practices for resource management should be evaluated and updated over time. Current practices may add unnecessary stress or be unsuitable for projected climate change and future assemblages of species. Further, many existing stressors could be managed in a different way to reduce the total amount of stress on the ecosystem.

Priority Recommendations:

- **Strengthen State and local programs to slow the loss and fragmentation of forest and terrestrial ecosystems to new development.** Local zoning, State smart growth programs, and State and local laws governing forest protection and mitigation determine the amount of forest loss due to new development in Maryland and in turn, the amount of forest potentially available for future land protection. The State should collaborate with federal, State and local government agencies to identify new or modified programs that could slow the loss and fragmentation of forest and terrestrial ecosystems to new development in Maryland.

- **Review and revise forestry best management practices.** The Maryland Forest Service and the Wildlife and Heritage Service should review and, as necessary, revise existing forest, timber harvesting and land management protocols and BMPs to ensure that they promote and provide for resilience in ecosystem structure and services. As an example, increasing the rate of forest improvement thinings in western Maryland hardwoods may improve overall vigor, reducing their susceptibility to multiple climate influenced stressors. A comprehensive review of current management practices and guidelines that are counterproductive or "maladaptive" (e.g., continuing to reforest with green ash which is highly susceptible to emerald ash borer infestations) to climate change adaptation should be a component of this process.

- **Continue to support incorporation of the policies and strategies of *Maryland's Sustainable Forestry Act of 2009*** into state and local planning decisions. The Act provides the legal basis for enhancing the retention, protection, and sustainable management of Maryland's forested lands on public and private lands. Among the many benefits that forests provide, the Act recognizes that "forests and trees are key indicators of climate change" and that "trees and forests in urban areas provide multiple benefits, including mitigation of air pollutants and reduction of the urban heat island effect." In allocating the State's share of Program Open Space funds, the Act specifies that DNR shall consider conservation priorities with respect to protecting and restoring forests from certain threats; many of which can be attributed to the impacts of climate change, including catastrophic wildfires, hurricanes, windstorms, snow or ice storms, flooding, drought, invasive species, insect or disease outbreak and development.

Jarek Tuszynski

Current high-elevation forest species such as these red spruce, or the Eastern hemlock, will likely disappear from Maryland as climate changes.

- **Evaluate sustainable forestry certification programs** for opportunities to enhance climate resilience and adaptive capacity. The Forest Service should re-evaluate the certification criteria and work with certifying bodies, such as the Sustainable Forestry Initiative and the Forest Stewardship Councils to promote integration of climate adaptation and resilience measures into existing performance measures.

- **Improve capacity to manage and respond to stressors exacerbated by climate change.** Funding should be developed to rapidly respond to time-sensitive problems with pests, diseases, weeds, and storm damage (e.g., Forest Health Emergency Contingency Program authorized by the 2009 Sustainable Forestry Act). The capacity to respond to wildfire should be enhanced, with DNR Forest Service working with Maryland's volunteer and career fire departments and emergency response agencies to assess changing needs and preparedness. MDA and DNR should increase prevention measures and education about invasive species through organizations such as the Maryland Invasive Species Council.


Bill Miles

Planting more climate-appropriate species may be part of future restoration.

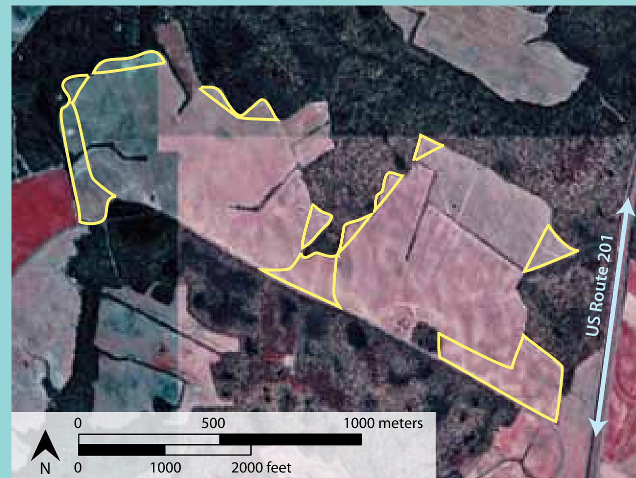
Foster stewardship on private lands

Strategies need to be integrated and implemented at a scale appropriate to the scale of future changes and disturbances. To achieve long-term resilience, strategies, including monitoring and assessment efforts, as well as management actions, should be coordinated across jurisdictional boundaries and federal, state and local governments. In addition, since 76% of Maryland forests are privately owned, with 84% of the landowners owning less than 10 acres, stewardship on private lands is critically important.

Priority Recommendations:

- **Integrate adaptation planning priorities into existing programs** that currently offer forest management services, funding, and restoration assistance to private landowners, such as the Landowner Incentive Program, Conservation Reserve Enhancement Program, and the Woodland Incentives Fund. Landowner outreach efforts should be targeted to areas suitable for developing critical habitat migration or transition zones or essential ecosystem services.

CASE STUDY: Enhancing corridors at Chino Farms

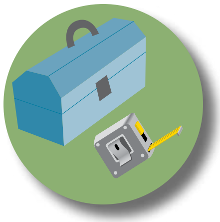


MD DNR

Chino Farms, near Chestertown, Maryland, demonstrates the practice of restoring Green Infrastructure gaps and achieving greater resilience in the face of change by improving ecosystem connectivity and quality. The owner of this 5,600-acre (2266 hectares) farm was interested in ecological restoration, but did not want to restore the entire parcel, preferring to keep a major portion of the land under agricultural management. Some of the property was converted to a prairie grassland ecosystem, while other portions were reforested, resulting in a total of 51.4 acres (20.8 hectares) of replanting. The figure at right illustrates the reforestation areas outlined in yellow that created a corridor between two large forested hubs and also increased interior forest by reforesting concave areas along the forest-field edge.

- **Develop new tools to guide adaptation stewardship activities on private lands.** DNR should assemble a team of experts to develop a model adaptation stewardship guide for private lands. The model plan will reflect a composite of actual conditions and natural features from one or more sites that best illustrate best management practices that could be implemented on-the-ground to adapt to changing conditions.

- **Develop new conservation easement mechanisms** to promote adaptation stewardship activities on private lands. State programs that administer conservation easements (Rural Legacy, Maryland Agricultural Land Preservation Foundation, Maryland Environmental Trust) should consider revisions to easement payments and agreements to promote implementation of adaptation strategies. For instance, easement valuation systems could be restructured to compensate landowners for protecting habitat migration or transition zones or easement restrictions could be adjusted to allow landowners to sell climate-related ecosystem service credits generated through revised management practices.



TOOLS, RESEARCH, AND EDUCATION TO INFORM SOUND DECISIONS

Natural resource managers need the right tools to anticipate and plan for climate change. While a great deal of the scientific and technical information is on hand, there is still a need to tailor existing tools, technical resources and educational programs to address new resource management challenges presented by climate change. As an example, DNR will need to update GreenPrint's Targeted Ecological Areas and revise evaluation protocols to incorporate new climate change adaptation priorities. New restoration assessments will also be needed in order to integrate water quality improvements with restoration efforts that also address climate change adaptation priorities, for terrestrial, aquatic and human habitats. Much of the needed tracking and assessment to inform future action will require an investigation of baseline conditions and establishment of climate change metrics. In addition to understanding the determinants of resilient and diverse ecosystems, better models and information regarding future distributions of certain habitats and species will become increasingly useful.

Tools and research

- **Assess vulnerability in a regional context** that considers the ecosystem roles species and habitats play in the region, potential future condition and distributions, and whether or not losses are avoidable. Some targets for revised assessment would be Species of Greatest Conservation Need, key ecologically important species, and key ecosystem services (e.g., riparian floodplains necessary to protect fisheries and forested watersheds to protect drinking water, among others). In addition to species, a better baseline understanding of vulnerability to disturbances, such as fires, storms, and floods is needed.

- **Provide the mapping, modeling, monitoring, and research basis for restoration targets** to determine what restoration is needed to ensure the migration of sensitive species and evaluate the need and potential negative effects of active (facilitated) versus passive migration. These would be potentially considered on a case-by-case basis for species that are very likely to survive climate change, but are severely habitat- or dispersal-limited; or are globally rare, and have uncertain migration abilities.

- **Identify restoration targets to maintain and enhance key ecosystem services.** For example, urban tree canopy assessments, coordinated through the US Forest Service and the Maryland Forest Service's Urban and Community Forest Program, should be used to identify and implement urban tree reforestation projects that will moderate urban heat island effects and reduce surface ozone air quality impairments.

- **Refine existing and expand projections of invasive species and disease** in order to evaluate control or eradication options for species, with a particular focus on urban areas, ports, and distribution centers where invasive species are likely to be introduced.

- **Establish management thresholds** (e.g., percent forest cover in a watershed needed to protect stream flows, aquatic health and temperature regimes) for a range of climate change scenarios.

- **Foster and promote opportunities to develop new emerging ecosystem service markets** such as carbon sequestration and biomass-based fuel production. DNR's Office for a Sustainable Future has been charged by the Governor's Task Force on Green Jobs and Industry to develop a plan for promoting ecosystem service markets through governmental, private-sector and non-profit participation. Research and education concerning these opportunities is needed to keep stakeholders and managers aware of changing economic opportunities.

- **Better understand the interaction between future development patterns, climate impacts and ecosystem health.** The pressures to develop widespread renewable energy projects resulting from climate change incentives should not be used to justify negative and irreversible impacts to critical ecosystems and the services they provide.

Education

- **Develop climate change adaptation guidance** for local planners, land conservation groups, forest managers, and private landowners.

- **Provide locally focused media materials, workshops, and assistance** championing the benefits of connected natural habitats, conservation zoning, low-impact development, and the importance of new "Targeted Ecological Areas" in each county.

- **Pursue adjustments to forestry curricula** (e.g., University of Maryland's Urban Forestry Program) and offer new or expanded training opportunities (e.g., University of Maryland Cooperative Extension) to inform and engage federal, state, and private land managers.

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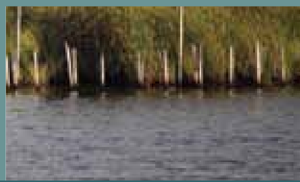
CHAPTER 4



BAY AND AQUATIC ECOSYSTEMS

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KEY POINTS

❖ **Climate change will alter species and habitat distributions and likely exacerbate existing stressors.** Rising temperatures, shifting precipitation regimes, and sea level rise will likely alter communities of aquatic plant and animal species and their habitats in Maryland.

❖ **Climate change will likely affect the services that ecosystems provide to humans such as shoreline protection, plentiful fisheries, and recreational activities.** The threats of sea level rise and other changes in hydrology are likely to impact wetlands, which provide many valuable ecosystem services and buffer coastal communities from storms and hurricanes.

❖ **Improved monitoring and assessment should be used to inform decision-making.** Resource managers will need a greater understanding of risk and better management tools to ensure the adequate protection of critical habitat and ecosystem services.

❖ **Reducing existing ecosystem stressors and revising ongoing management practices are both necessary in order to adapt.** Increasing pressures to aquatic ecosystems due in large part to urbanization and land use change should be reduced through riparian and coastal habitat protection.

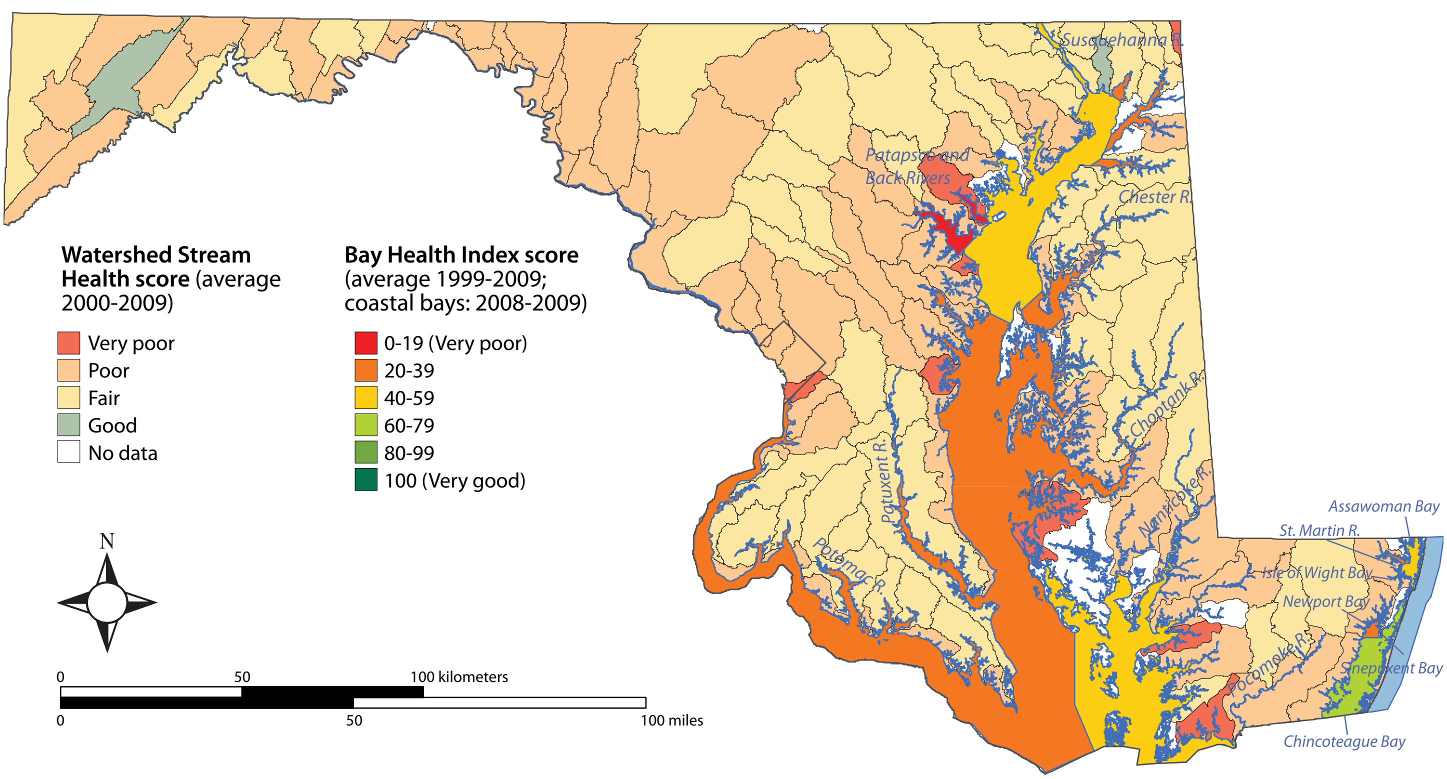
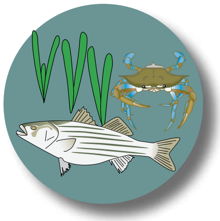
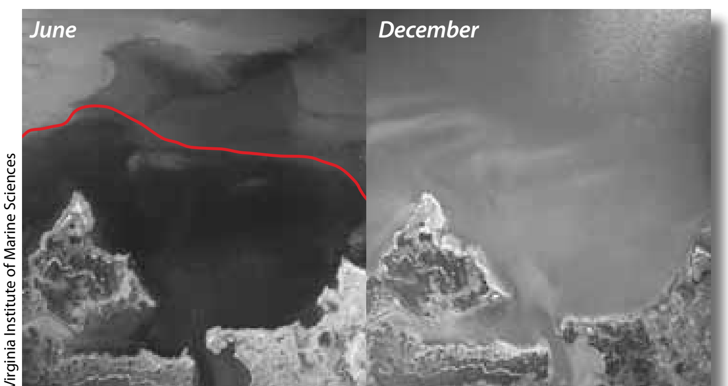


Figure 4.1: Maryland's bay and aquatic ecosystems range from the relatively healthy Chincoteague Bay to the very poor healh of the Patapsco and Back Rivers. (Data for watershed stream health from MD DNR Monitoring and Non-Tidal Assessment Division, Maryland Biological Stream Survey (MBSS). Data for Bay health index from Eco-Check.org, mean of years 1999-2009 for Chesapeake Bay, mean of years 2008-2009 for Coastal Bays.)

INTRODUCTION

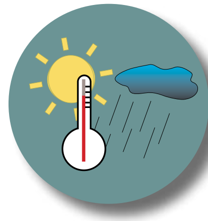


The Chesapeake Bay is the largest estuary in the United States, fed by a watershed that stretches from mountains to sea, across 64,000 square miles (166,000 square kilometers), spanning six states: Maryland, Delaware, Virginia, West Virginia, Pennsylvania, New York, and the District of Columbia. Within its watersheds and oceanfront, Maryland's extensive aquatic ecosystems range from freshwater swamps and bogs, tidal and non-tidal freshwater rivers and marshes, tidal brackish and saline rivers and marshes, and coastal bays. These ecosystems are influenced by precipitation, temperature, tropical storms, and human activity. Human development and pollution have degraded their natural resilience, leaving them more vulnerable to extreme events.[1] Climate change will likely exacerbate this problem, creating a greater threat to these ecosystems. To protect its marine, estuarine and aquatic ecosystems against future damage, the State must take action to alleviate existing stressors and to strategically conserve and restore critical bay and aquatic habitats.



A sharp dieback of eelgrass on the Little Annemessex River near Crisfield, MD in 2005, the eighth warmest year in the past century.

CLIMATE VULNERABILITY



Over the State's five major physiographic provinces, from the Appalachian Plateau to the coastal bays and Atlantic Ocean, climate change will have a varying impact ranging from temperature impacts on cold water species in the west to a loss of tidal marshes unable to keep pace with sea level rise. The vulnerability of these living resources and habitats to climate change depends upon the intensity and duration of the impact, as well as the attributes of the species and habitats that increase their ability to respond, absorb, adapt, or otherwise cope with future changes. Many of Maryland's bay and aquatic ecosystems are already under stress due to poor land use practices, pollution, and urbanization. The extent of impacts to these ecosystems is great, and influenced by watersheds that cross jurisdictional boundaries, making them difficult to protect and manage. Climate change is likely to exacerbate some of these existing stressors and cause shifts in habitat and species location.

Shifting conditions affect species and habitat distributions and survival

Shifts in habitat due to changes in river flow (as a result of precipitation change), sea level rise, acidification (as a result of carbon dioxide increases), and temperature increases will alter the distributions of many species, or in some cases, species may face local or regional extirpation due to an inability to adapt or relocate. Populations of species that are at the northern extent of their ranges in Maryland may become more abundant and relocate to new habitats in the southern part of the state, whereas those populations at their southern extent may decrease or relocate outside the state altogether. Although global climate models do not currently have the capacity to make predictions of such changes at the estuary scale, monitoring data observed

Chesapeake Bay climate change trends

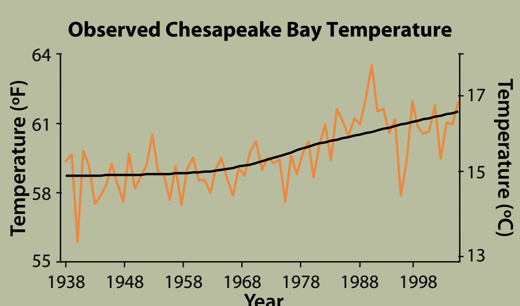


Figure 4.2: Despite annual mean fluctuations, Chesapeake Bay temperatures have risen at least 2°F since the 1930s.

Source: Temperature and sea-level rise figures: Dave Secor, Chesapeake Biological Laboratory, 2008; Image: USGS.

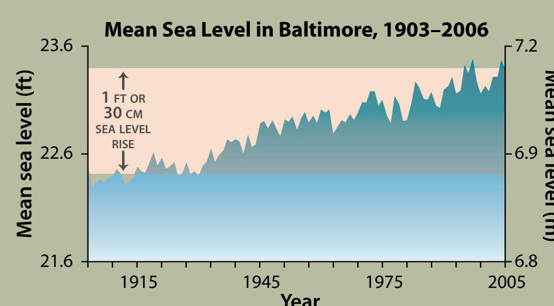


Figure 4.3: Sea level has risen significantly over the past century, increasing coastal zone flooding, impacting marshes, and altering salinity levels in the Chesapeake Bay and its tributaries.

throughout the Bay show that the Chesapeake has warmed significantly (Figure 4.2).[2] Eelgrass, which serves as critical habitat for the blue crab and many other Chesapeake Bay aquatic organisms, is negatively affected by high summer temperatures (see photos, left).[3]

Similarly, temperatures in streams and rivers are increasing and likely to worsen, causing heat stress, decreased water quality, or changes in food availability.[4] In freshwater habitats, temperature increases will exacerbate the negative effects of urbanization, particularly for coldwater stream species such as brook trout (see case study: urbanized streams). These fish may become restricted to the far reaches of western Maryland's high-elevation streams and find fewer deep, cool pools in which to seek refuge. In fresh, brackish, and saline waters, fish parasites associated with warmer waters can also be expected to increase, threatening native fish populations.[5]

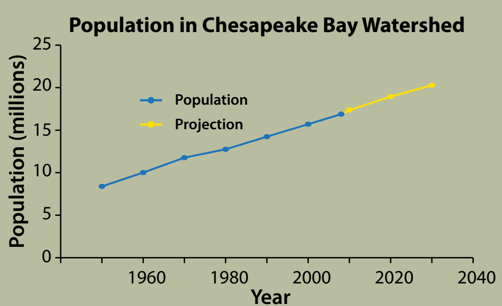
Changes in stream flow, due partially to drought, have the potential to drastically impact the aquatic plant and animal communities living in Maryland's creeks, streams, and rivers.[6] Groundwater levels, which are critically important to maintaining healthy stream discharge conditions, are also likely to be affected if drought frequency increases. This is important for many seasonal wetlands such as the sedge/tussock meadow wetlands of north central Maryland. These wetlands provide habitat for the federally endangered bog turtle. In western Maryland, extensive mountain peatland wetlands, often at the headwaters of streams, harbor dozens of rare plant and animal species, and provide habitat for thousands of common native species.

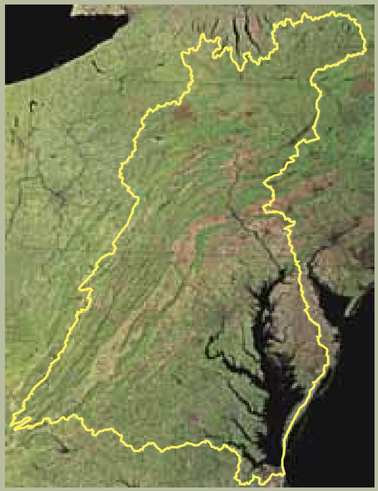
Although rivers, streams, and creeks vary greatly, native species within them have adapted to a specific range of conditions over a long period of time. Climate change will bring more abrupt alterations in comparison.[7,8] For example, earlier snowmelt can cause vegetation seed stranding and aquatic insect and fish life history cycles to be out of sync with critical river flows.[9] Finally, increased flooding due to heavy rains combined with already elevated stormwater volumes may increase soil erosion and degrade water quality.

Tidal marshes are likely to need additional protection measures due to blockages preventing their ability to migrate upland as sea level rises.

Estuarine salinity naturally fluctuates in response to a number of factors, principally seasonal flows of fresh water from rivers, but also tides, winds, and circulation. As a result of sea level rise (Figure 4.3) and changes in precipitation, future salinity levels in coastal waters are uncertain. Although many fish and other aquatic organisms are able to either avoid or adapt to minor salinity changes, they may be unable to handle a longer duration of such changes.[10,11] Tidal freshwater marshes may be particularly vulnerable to saline intrusion as plant species with narrow salinity tolerance may experience large-scale losses leading to significant ecosystem modifications.

Watershed population and development trends





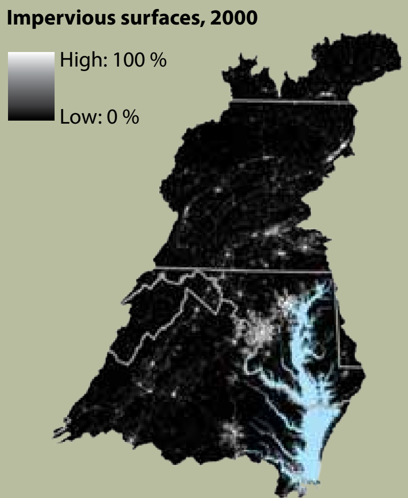


Figure 4.4-4.5: Population and development (indicated by an impervious surface map, right) have been steadily increasing over the past century, impacting the streams, lakes, and bays of Maryland.

Source: Figures, Chesapeake Bay Program; image, USGS

Climate change will compound existing stressors

Maryland's aquatic ecosystems are already under significant environmental stress, particularly in the central part of the State and along Maryland's Eastern Shore. Existing stresses including habitat destruction, increased stormwater runoff, overfishing, invasive species, and nutrient and sediment loading are already degrading streams, creeks, and rivers around the state.[12] For some major river systems (e.g., the Potomac, the Susquehanna, the Nanticoke), many of these impacts are also occurring in other states upstream of Maryland's borders. While over time the impacts from existing human activities may be worse than those due to climate change, there is concern that climate change will exacerbate existing stressors, increasing the vulnerability of bay and aquatic ecosystems already under human-induced stress.

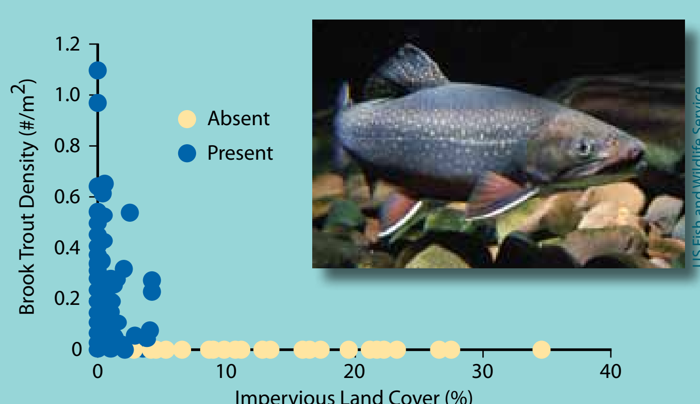
For example, the higher water temperatures and increased precipitation that may come with climate change may worsen water quality impairments caused by runoff from impervious surfaces and development. High temperatures and fast-moving, larger volumes of stormwater running off roads, and other impervious services will likely carry increased loads of sediments and pollutants into waterways, clouding the water and negatively impacting aquatic species, and covering aquatic plant beds.[13] Similarly, increased intensity of rain events on cropland may increase rates and volumes of nutrient and sediment runoff into drainage ditches and local streams. Temperature and precipitation changes may also be advantageous to invasive plant and animal species.

More than 700 existing blockages to fish passage (dams and other obstructions) in Maryland slow or prevent fish from reaching critical spawning areas or affect critical flows.[14,15] Climate change is not likely to affect these barriers directly. Indirectly, though, as climate changes they may severely affect the ability of a species to move away from unsuitable habitat. Adaptation measures to control larger stream flows, such as the construction of new dams, levees, or hardened stream banks, would further degrade habitats. Coastal wetlands similarly face blockages to migration, through pavement, bulkheads, and riprap, which can slow or stop their retreat to higher ground. If wetlands do not have adequate space to migrate inland, sea level rise may result in a drastic reduction in tidal marsh. Some bird species dependent on tidal marshes for nesting, such as the salt marsh sparrow, could become threatened as a result. Loss of tidal marshes will also negatively affect stream, river, and bay water quality, as marshes act to absorb, filter, and clean polluted runoff.

CASE STUDY: Urbanized streams as models for climate change

Bay and aquatic ecosystems facing both urbanization and climate change will likely fare the worst. Many of Maryland's urbanized streams are already under severe stress, which may intensify as the climate changes. Ongoing development has resulted in a significant increase of impervious surface cover in Maryland's urban areas. This in turn causes extreme stream flows which often contain higher-temperature, pollutant-laden stormwater. For fish and other animals sensitive to temperature and water quality changes, such as the brook trout, populations may be drastically affected (below). The significant effects of urbanization on streams may be considered forewarning of the impacts of climate change.

Land cover in the Goodwin Run watershed in Baltimore County in 1972 and 2004, respectively.



The presence of brook trout is extremely sensitive to increases in impervious surface cover (4 percent threshold).[16]

HUMAN DIMENSIONS

The Chesapeake Bay, along with Maryland's streams and Coastal Bays, provide a multitude of natural resources and benefits to Maryland's citizens. The economic value of the entire Chesapeake Bay is conservatively estimated to be approximately $1 trillion, annually.[17] Bay and aquatic ecosystems filter drinking water, replenish groundwater supplies, reduce erosion and sediment loads, buffer against storms and floods, and provide water for agriculture and habitat for animals. Over two-thirds of commercial fish and shellfish utilize tidal wetlands for nursery or spawning habitat.[18] Tourism of Maryland's bay and aquatic resources also generates $11.72 billion in annual visitor spending; 62 percent of which takes place in coastal counties.[19]

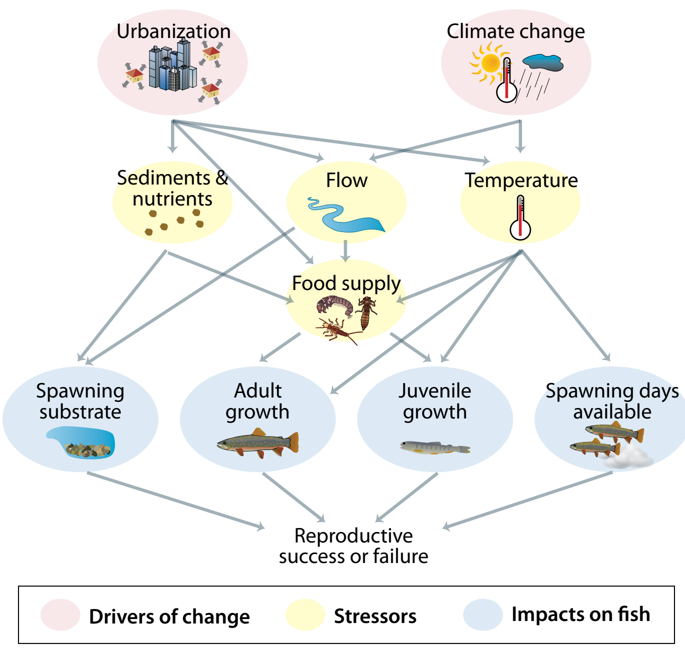


Figure 4.6: Human development and climate change compound to affect different stages of fish life cycles. Adapted from Nelson et al., 2008.[20]

The combined effects of hydrology changes caused by both heavily urbanized areas and changes in temperature and precipitation will likely affect the quantity and quality of fresh water and the health of marshes. If precipitation becomes more variable, freshwater supplies may be further impacted due to increasing withdrawal of groundwater from critical reserves. The maintenance of sustainable groundwater resources is critical to humans, as well as aquatic organisms. The effects of sea level rise and local land subsidence on coastal wetlands are likely to affect the services these ecosystems provide. An increased frequency of coastal storms and precipitation extremes could also cause the overflow of untreated wastewater, contaminating drinking water supplies and increasing the frequency of beach and shellfish harvesting closures.

STRATEGY FOR RESILIENCE

Protecting Maryland's bay and aquatic ecosystems in the face of climate change requires a multi-layer, regional approach involving both Maryland and surrounding states. These ecosystems are challenging to protect as they transcend jurisdictional boundaries, cover both private and public lands, and are heavily influenced by growth and land use. An approach to this complex management challenge includes protecting a larger portfolio of intact habitats, employing best management practices (BMPs), stringent regulation of land use, enforcing pollution standards, and establishing new priorities for bay and aquatic restoration in light of climate change.

Ben Longstaff

Riparian buffers, such as those found on farm field edges, reduce sediment and nutrient loads to waterways.

Advance protection of at-risk species and habitats

Maintaining or replicating a diverse portfolio of protected habitats and geological features will be important to safeguard against local, regional, or even national extinctions.[21,22] Protection and conservation of high-quality, intact habitats should be emphasized to minimize the need for more intensive strategies such as restoration. Targets for protected areas and resilience measures should be particularly informed by an assessment of at-risk species, habitats, and ecosystem services likely to become even more critical in the future. In addition, resource managers will need to consider "climate refugees," or species migrating from other states, that may also be in conservation need. Priority should also be given to ensuring the (redudant) protection of a diverse portfolio of areas and habitats.

Priority Recommendations:

- **Revise state-level protection targeting programs** to reflect climate change adaptation priorities. Land protection programs such as Maryland Environmental Trust, Program Open Space, Rural Legacy, Maryland Agricultural Land Preservation Foundation should use downscaled projections of climate conditions as well as potential "at-risk" species and habitats to inform and revise protection goals. Areas to target may include (1) riparian, forested buffers; (2) saltwater marshes in danger from erosion, and the many other wetland types across Maryland sensitive to hydrologic changes; (3) tracts of upland habitat where wetlands migration is likely to occur as sea level rises; and (4) areas used to supply drinking water resources.

Jane Thomas

A wetland stabilization and restoration effort in Blackwater National Wildlife Refuge on the Eastern Shore. Sea level rise will adversely affect these wetland habitats.

- **Develop new protection and conservation mechanisms** to promote adaptation stewardship activities on private lands. DNR should explore development of a Climate Change Adaptation Easement, which could either work in concert with existing easement programs or independently. Such an easement could be used to incentivize a landowner to implement specific adaptation stewardship activities (e.g., living shoreline, increased storm buffer, wetland migration transition zone) on private lands.

- **Amend legal mechanisms to designate and protect temperature-sensitive streams.** The Code of Maryland Regulations (COMAR) establishes legal protections for Use Class III (Reproducing Trout Waters) and Use Class IV (Stocked Trout Waters) streams. DNR should analyze the future effects of climate change on Use Class III and IV waters and consider regulatory amendments to strengthen provisions to build in climate safeguards.

- **Implement an adaptive management approach.** Climate change is predicted to affect many habitats and ecosystem attributes that influence fish and shellfish population dynamics including stock productivity and recruitment, however, many specific effects remain speculative and variable depending on the species. DNR's Fisheries Service should continue collecting data on fish distribution, abundance, and recruitment and adjust fishery management strategies and actions to maintain appropriate levels of abundance, age structure, and recruitment as environmental conditions change due to climate change.

Restore critical bay and aquatic habitats to enhance resilience

The State should evaluate opportunities to increase healthy wetlands, restore stream connectivity, and protect rapidly disappearing islands. In the near-term, the State should collaborate with federal, state, and regional partners to identify and pursue low-cost, high-value strategies for restoring vulnerable ecosystems. Wetlands and islands offer key habitat for many species, including nesting habitat for birds and spawning and nursery habitat for fish and shellfish.[23,24] Stream restoration projects should be targeted towards streams and rivers that are not currently impacted by urbanization, or where impacts may be feasibly reduced.

Priority Recommendations:

- **Proactively pursue, design, and construct habitat restoration projects to enhance the resilience** of bay and aquatic ecosystems to the impacts of climate change. DNR and regional partners should assess and incorporate factors associated with climate change, including maintenance and monitoring needs, into restoration project planning, design, and guidance.

- **Conduct an audit of state-owned lands** to identify habitat restoration potential for enhancing ecosystem resilience and increasing on-site carbon sequestration. After the federal government, DNR is one of the largest land managers in the State. Similar to the agency's efforts to restore natural filters on state-owned lands, DNR should identify opportunities for habitat restoration to enhance bay and aquatic resilience on the lands it manages.

- **Increase on-the-ground implementation of existing stream restoration practices.** The effects of climate change on streams are likely to emulate the current and past effects of urbanization (e.g., increased water temperatures, higher storm-related flows, lower base flows). Therefore, there is an even greater need to continue to employ many of the same techniques used to protect streams from the effects of urbanization (e.g., intact vegetated riparian buffers, storm water management, sediment controls).

Reduce existing stressors

It is critical to reduce existing pressure on vulnerable habitats and species in order to increase the resilience of Maryland's bay and aquatic ecosystems. As excessive nutrients, sediments, and chemicals from fertilizers, the atmosphere, and other sources already degrade the condition of the majority of Maryland's bay and aquatic ecosystems, a prudent strategy is to reduce these stressors, in order to improve the resilience of native species and aquatic communities.

Priority Recommendations:

- **Remove barriers to habitat connectivity.** DNR should work with citizens and counties to remove barriers to stream connectivity, garnering public support particularly for those low-functioning or decommissioned dams and other obstructions (see Octoraro and Raven Rock Creek case study).

- **Reduce impervious surface cover.** Under the leadership of Maryland Department of Environment, the State should continue efforts to reduce impervious surfaces and stormwater runoff from new development in accordance with the Stormwater Management Act of 2007. Efforts to replace impervious surface in existing development areas with pervious pavement or other porous materials should be enhanced and impervious surface retrofit goals should be strengthened in municipal storm sewer system requirements.

Melissa Andreychek

Pervious surface cover, like this parking lot, allows groundwater infiltration and reduces runoff during storm events.

- **Prepare for new or expanding ranges of invasive species.** The State should control existing non-native invasions and prepare for new invasive species and disease with a focus on prediction and prevention. Priority should be given to: (1) tightening ballast water regulations; (2) tightening cleaning and transportation practices for boats and recreational fishing gear; (3) banning the sale of invasive plants and animals; and (4) increasing monitoring and control of invasive marsh and coastal plants.

CASE STUDY: Octoraro and Raven Rock Creek dam removals

One way to build resilience in the face of a changing climate is to boost habitat connectivity by removing blockages to fish and other species that need to make their way upstream (or away from stressful conditions). Although Maryland still has many existing dams, two dam removal projects demonstrate how a single removal can result in positive impacts. Octoraro Dam, located on Octoraro Creek in Cecil County (a tributary to the Susquehanna), was removed in 2005. Monitoring in 2008 showed that herring and hickory shad were successfully passing the former dam and spawning in upstream habitats. Biologists in Pennsylvania also noted herring for the first time at the next upstream blockage, approximately 14 miles upstream from the former dam.

MDDNR

The Octoraro River before dam removal.

MDDNR

The Octoraro River after dam removal, allowing fish to pass upstream and reproduce.

Raven Rock Dam on Raven Rock Creek in Washington County (tributary to Antietam Creek/Potomac River) was removed in 2007. Biologists with MD DNR Fisheries service observed immediate upstream passage by brook trout following the removal and restoration of the creek. In addition to restoring passage, the project resulted in reduced stream temperatures and moderated stream flow.

Foster a collective response to climate change

A complex array of agencies and organizations is involved in the management of bay and aquatic ecosystems in the State of Maryland. While some are focused on species-specific management, others work more broadly on restoring and protecting the Chesapeake and Coastal Bays at-large. Guiding the efforts of this mix of organizations are hundreds of management plans and strategic guidance documents. Each of these programmatic documents represents an opportunity to address climate change adaptation needs and establish adaptation priorities.

For example, at the regional level many large-scale strategies, such as those put forth by the Strategy for Protecting and Restoring the Chesapeake Bay,[25] the State of the Science Report by the Chesapeake Bay Program Scientific and Technical Advisory Committee,[26] and other reports produced by non-governmental organizations, address ambitious goals to clean up the Bay and adapt to climate change. Incorporating climate change issues into new and existing management plans is key to developing a collective and integrated response to climate change.

Jane Thomas

Poplar Island, an island restoration project that beneficially utilizes dredge spoil from Baltimore Harbor, offers one example of potential restoration projects to counter the effects of sea level rise.

Priority Recommendations:

- **Adjust bay and watershed restoration priorities in light of a changing climate.** The next generation of restoration priorities must take into account the impacts of climate change expected by the middle of the century and beyond. The Federal Strategy for Restoring and Protecting the Chesapeake Bay, released in September 2010, recommends that the effects of climate change on pollution loads in the Chesapeake Bay watershed be evaluated by 2017. The US Geological Survey (USGS), Pennsylvania State University, and Chesapeake Bay Program are working collectively to conduct this analysis. Maryland's state agencies should strongly support this effort and incorporate study results into the establishment of future restoration priorities, including the development of Phase II Watershed Implementation Plans and further revisions to the Total Maximum Daily Load (TMDL) goals for impaired waters.

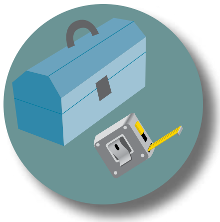
- **Integrate both adaptation and mitigation reduction strategies** into natural resource management plans and programs. In October, 2010, DNR adopted a formal policy requiring the agency to incorporate climate change considerations into any new or updated resource management assessments and strategic planning documents (e.g., Wildlife Action Plan, Coastal Zone Management Program, Coastal and Estuarine Land Conservation Plan, Fisheries Management Plans, Tributary Strategies and Watershed Implementation Plans). DNR's sister agencies, as well as its non-governmental partners, should make a similar commitment to ensure that collectively as a State, natural resources are managed with an understanding of the effects of climate change.

- **Revise fishery and wildlife management to build in climate resilient safeguards.** DNR should evaluate and potentially revise the management of its fisheries and wildlife, building in greater safeguards to population levels. For example, fishing regulations, such as catch number and length, and fishing season dates may need to change in order to support a more sustainable fishery in the face of climate change. DNR should work with federal and regional partners to evaluate current management strategies to identify methods for reducing stress or stabilizing population dynamics likely to be affected by climate change.

Tim Carruthers

Fishing regulations for commercial and recreational fishers might need to change to protect valuable fishery populations.

- **Increase collaboration among federal, state, local and regional climate change adaptation partners.** The State must work collaboratively with federal, regional, and local partners to define its role, share its resources and expertise, and relay State priorities with respect to climate change adaptation.



TOOLS, RESEARCH, AND EDUCATION TO INFORM SOUND DECISIONS

Maryland decision-makers need better tools to protect critical ecosystems in the future. Financial, educational, scientific and political support will also be necessary in order to assess conditions and to research new ways to build up the resilience of bay and aquatic ecosystems to the impending impacts of climate change. Using a combination of data collection and mapping, Maryland can stay ahead of the curve in terms of protecting vulnerable ecosystems and understanding the cumulative effects of climate change and human development. The State should work not only to track and understand these effects, but also to understand the effectiveness of efforts to reduce impacts.

Tools and research

- **Conduct vulnerability assessments** to gain a better understanding of the long-term impacts of climate change and inform resource management. DNR should assess the vulnerability of Species of Greatest Conservation Need, Threatened and Endangered species, and otherwise major key species, including bay and aquatic fisheries, and habitats critical for ecosystem function.[27] Once complete, DNR should integrate species or habitat-specific vulnerability assessments into existing spatial planning frameworks (i.e., Blue and Green Infrastructure).

- **Establish a comprehensive long-term Chesapeake and Coastal Bays and watershed monitoring and assessment program** for reporting bay and aquatic species, habitats, and ecosystem responses to climate change. The overall monitoring effort should be integrated with existing assessment programs (i.e., National Oceanic and Atmospheric Administration (NOAA) Integrated Ecosystem Assessment, the National Park Service, the National Fish and Wildlife Federation, the National Estuarine Research Reserve, and DNR's Chesapeake and Coastal Bays water quality and habitat monitoring programs) and closely coordinated with ongoing efforts of federal, state, and regional partners. Changes in pH and the impacts of acidification on organism skeletons and shells should be closely monitored, with particular attention to oysters, clams, and mussels.

- **Develop ecosystem-based indicators and metrics.** DNR's Fisheries Service should continue to work with the Chesapeake Bay Program's ecosystem-based fishery management project to develop quantitative ecosystem metrics which will include climate effects on fish habitat. The Fisheries Service should utilize the indicators, once determined, to provide a more holistic approach to managing fisheries.

- **Learn more about the potential for positive impacts of climate change** on existing fish and wildlife resources within our state and region, and how Maryland could capitalize on new opportunities.

- **Work with regional partners to model and monitor effects of sea level rise** including changes in salinity and flow regime. The Chesapeake Bay Program, research partners, and states in the Chesapeake Bay watershed should work collectively to monitor changes, and to analyze stream flow and hydrologic data to better understand interactions between groundwater and sea-level rise. Wetland soil accretion in response to sea-level rise, using USGS wetland accretion and elevation data, should be monitored further.

- **Research potential "maladaptation" strategies** and determine how to avoid unintended impacts.

Education

- **Advocate a "no-regrets" philosophy.** The strategies outlined in this strategy are not exclusive to climate change and would benefit ecosystems even in a more stable climate. However, given projected temperature increases and precipitation and climatic variability, it is even more urgent to take these steps now, despite uncertainty about the extent of climate change.

- **Incorporate climate change elements into the existing education curricula.** NOAA's National Estuarine Research Reserve Coastal Training Programs, its Climate Literacy Program, and EPA's Climate-Ready Estuaries Program are great resources. Specific content concerning the effects of climate change on Maryland's ecosystems should be included in the content being developed during the planning of the National Science Foundation-supported Maryland and Delaware Climate Change Education, Assessment and Research (MADE-CLEAR) initiative.

- **Conduct a needs assessment of local decision-makers** to evaluate climate change adaptation training and information needs. Results of the assessment should be used to guide the design and implementation of a climate adaptation training program. This program should include workshops and other forums to transfer skills to coastal decision makers so they can better confront and adapt to climate change.

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CHAPTER 5

WATER RESOURCES

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Contributing authors: Allen Davis, Jason Dubow, Jeff Halka, William Hewes, Ronald Klauda, Lyn Poorman, Jeff Raffensperger, Sean Smith, and Claire Welty

KEY POINTS

- **Water quantity, quality, and infrastructure will be affected by climate change.** Precipitation is expected to become more variable, which may impact water quality and stress water supply infrastructure. Although average precipitation is anticipated to increase slightly, this is most likely to occur in winter and not during summer months of maximum demand.

- **Climate change will increase summer demand for water.** More frequent and possibly more extreme summer drought, combined with increased population, will raise water demand and exacerbate problems associated with stressed resources.

- **Building resilient water resources will require increased flexibility and regional, adaptive management.** Climate change will intensify variability in conditions affecting water management. A greater sense of urgency is placed on the need for conservation, integrated planning efforts, and infrastructure replacement.

- **Relationships among water availability, use, and climate change require further investigation.** Increased research efforts are needed to understand water availability in the context of future population and climate.

- **Planning for the increased probability of extreme weather events and flood hazards should be an element of an adaptive strategy for climate change.** The combined effects of increased variability in weather patterns and increased urban development will continue to increase the potential for flooding in many communities. Multiple strategies are needed to reduce associated hazards to life and property.

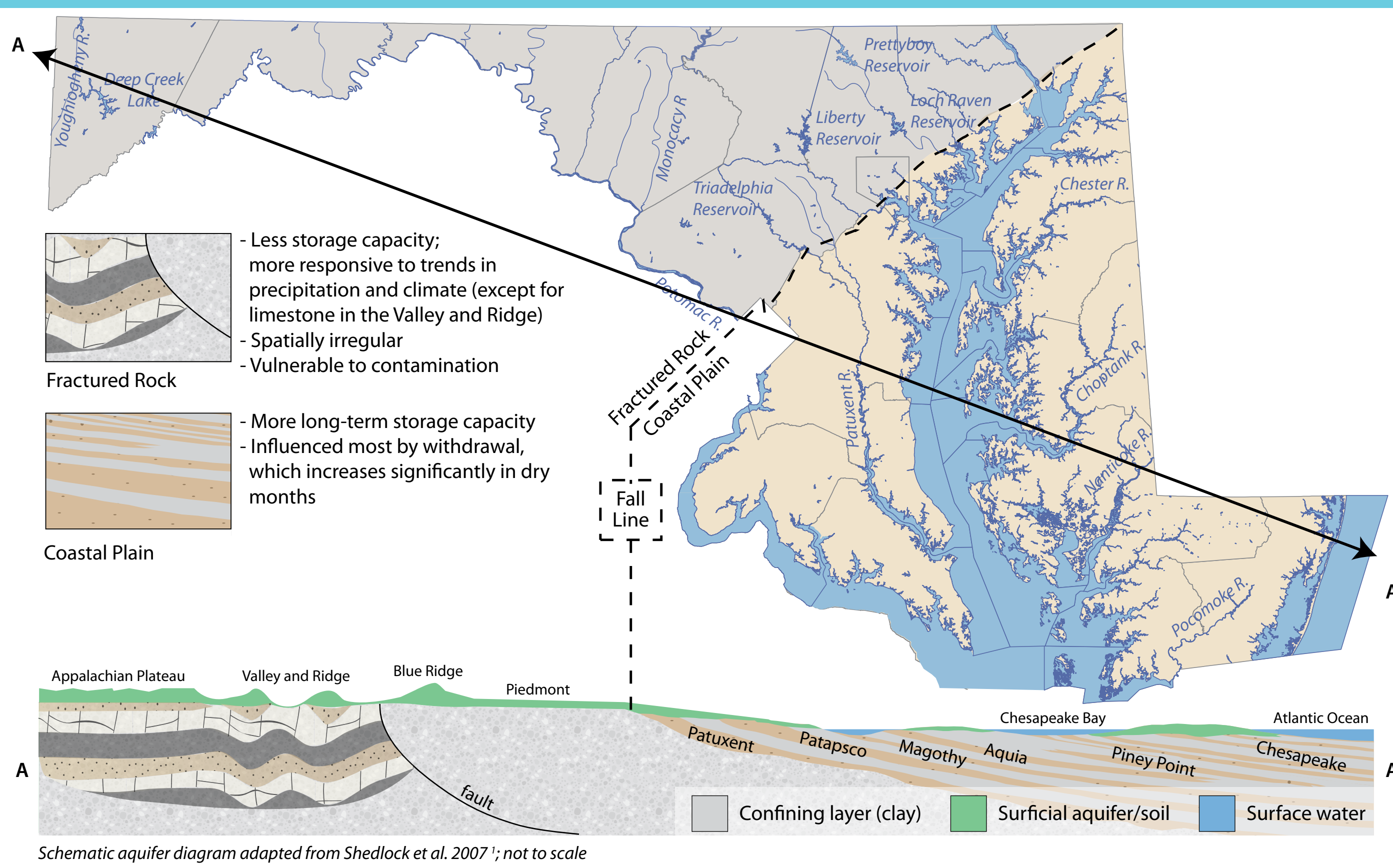


Figure 5.1: Maryland's Fractured Rock and Coastal Plain groundwater aquifers, major sources of freshwater for the State, respond differently to climate.[1]

INTRODUCTION

Maryland citizens use water withdrawn from rivers, streams, reservoirs and groundwater aquifers. In the Baltimore and Washington DC metropolitan regions, surface water sources managed by public water systems provide water to more than three million people. Most individuals outside of these major supply areas use groundwater from the Fractured Rock aquifers in western Maryland, or the Coastal Plain aquifers in southern Maryland and the Eastern Shore, withdrawn from either municipal or individual wells (Figure 5.1).

The quantity and quality of these resources will be variably affected by projected climate change, due largely to regional differences in geology and trends in population and water use.[2] Further, agricultural and non-agricultural irrigation demand is expected to continue to increase. Across the State, a strategy for Maryland's future must address the compounding influences of land use and climate change. Aging water infrastructure, impervious surfaces, and urbanization contribute to water quantity and quality problems that may be exacerbated as climate changes. With sufficient investment in management and infrastructure, impacts to Maryland's water resources may be minimized.

CLIMATE VULNERABILITY

As reported in the 2008 report of the Scientific and Technical Working Group of the Maryland Commission on Climate Change, there is less certainty concerning the projected effects of climate change on precipitation than there is concerning temperature.[2] Within the scope of this uncertainty, Maryland is projected to experience modest increases in total annual precipitation, mostly during winter months. Frequency of both wet and dry periods and intensity of extreme precipitation are likely to increase. As summer temperatures rise, drought is projected to occur more often even if average summer precipitation does not change significantly.[2] These changes have the potential to significantly impact water supply, quality, and management priorities. Stresses will be particularly acute in areas that do not have the capacity and flexibility of the major public systems in the Baltimore and Washington metropolitan service areas. Furthermore, much of Maryland's water supply and treatment infrastructure is already aging or under stress. During the summer months, water supply may become more stressed, as demand peaks during this time, particularly due to increased use of both agricultural and non-agricultural irrigation. A likely increase in the frequency and intensity of flooding and stormwater will significantly impact Maryland's urban and rural areas, damaging roads, pipes, buildings, water treatment facilities, crops, and ecosystems.

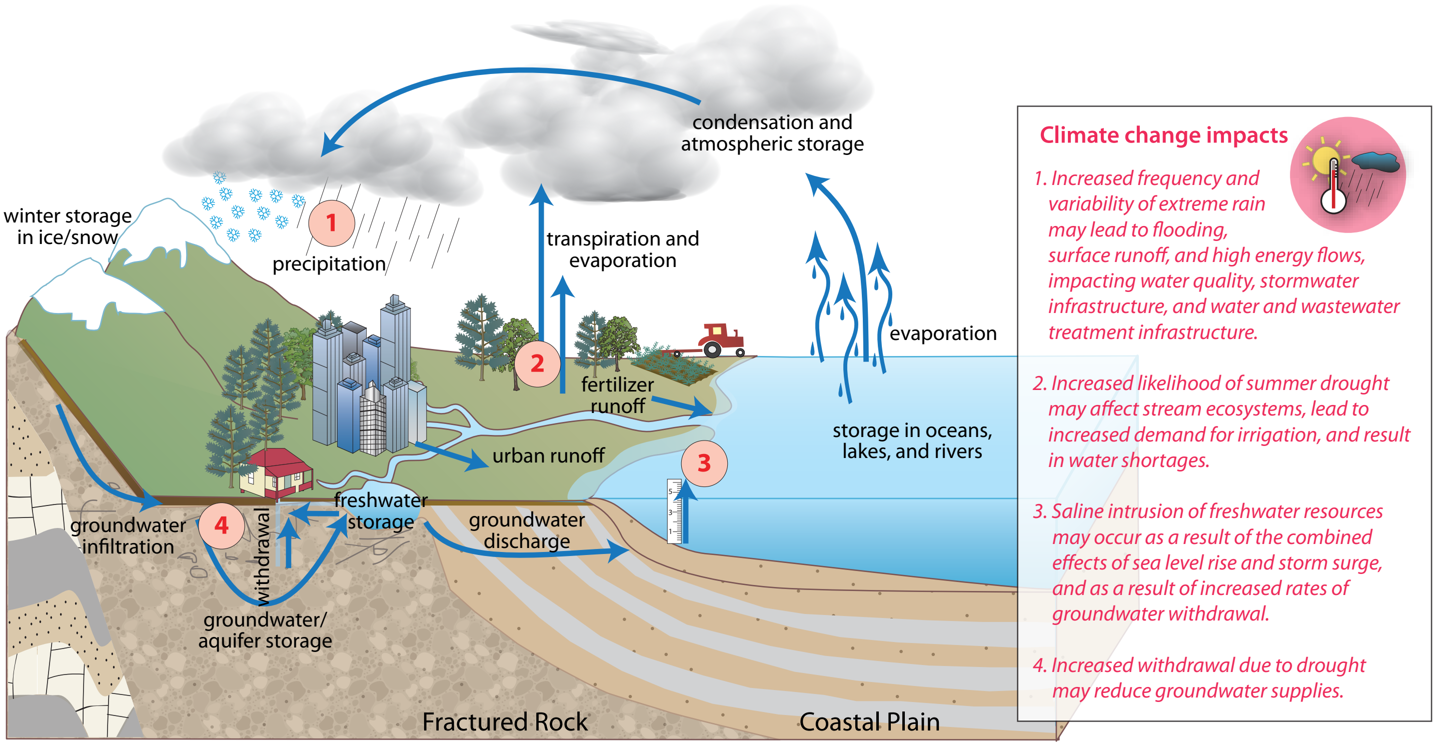


Figure 5.2: Climate change will likely affect the drivers of the water cycle and exacerbate some water quality impacts. Issues caused by urbanization in streams will be exacerbated.

Increased winter precipitation and more frequent summer drought will affect water quantity

Although Maryland has relatively abundant water resources, shortages can occur when supply is unable to keep pace with population and climatic pressures.[2] Projected rising temperatures will increase rates of evaporation. As rainfall patterns become more variable and less reliable, drought will periodically stress water supplies and make them less predictable in many areas (Figure 5.2). The ability of the water supply to meet future demand will vary locally and is shaped by water resource availability, development and growth patterns and the degree of interconnection and collaborative management among jurisdictions. Maryland's population is projected to grow 20 percent by 2030, increasing water demand by 16 percent across the State.[3]

Water demand will vary by region, increasing by 40 percent in southern Maryland and 30 percent on the Eastern Shore.[4,5] In dry summers peak demands for irrigation will increase. For example, water use for irrigation on the Eastern Shore increased from 36 percent of total demand to 50-60 percent in the moderate drought year of 2007.[3] In some low-elevation coastal areas, the combined effects of increased groundwater withdrawal and sea level rise can lead to saltwater intrusion into Coastal Plain water resources, rendering them unfit for consumption.[6] The State can expect heightened emergency restrictions enacted regionally or at the county level if water supplies are not managed to address projected demand and climate impacts.

"Two Carroll Schools Find Ways To Work Around Water Woes"

August 29, 2002

"The drought that has drained residential wells, turned farm fields to dust and depleted streams and reservoirs has extended its reach...Two Carroll County elementary schools replaced drinking fountains with water coolers yesterday and served lunch on disposable trays to eliminate dish washing, after one school ran out of water twice this week and the other's well began kicking up mud and gravel."[7]

-Jennifer McMenamin, The Baltimore Sun


Jim Schuyler, featured in The Baltimore Sun

Prettyboy reservoir, Baltimore County in October 2002.


Caroline Wicks

Irrigation use can spike significantly in a drought year: in 2007, irrigation on the Eastern Shore consumed between 50 and 60 percent of total water withdrawn in the region. In an average year, Eastern Shore irrigation comprises 36 percent of water withdrawal.[3]

Of the metropolitan water supply systems in Maryland, the Baltimore system draws mainly from three reservoirs and, during severe droughts, from the Susquehanna River. This water is treated and distributed to service areas in Baltimore City and most of Baltimore County and supplements supplies in parts of Howard and Anne Arundel Counties, providing water to 1.8 million individuals and many industries and institutions. Some untreated water supplements supplies in Harford and Carroll Counties. The Baltimore service area will likely have sufficient water resources in most future years, due to reservoir supplies that are likely to benefit from projected winter-spring precipitation increases. Maryland is working with local governments and other stakeholders, including the Susquehanna River Basin Commission, to secure reliable water sources to supplement Baltimore's reservoir system.

In rapidly developing areas dependent on the Fractured Rock aquifers, particularly in the Piedmont region, the effects of drought periods may become particularly pronounced. The majority of water stored in the Fractured Rock aquifers is stored in shallow fissures above the underlying bedrock, and availability of groundwater therefore may be affected by seasonal or longer-term drought. The primary exception to this pattern occurs in the limestone valley areas within the Fractured Rock region that includes Hagerstown and Frederick. These areas have more storage, but because the limestone is soluble they are also more susceptible to contamination from the surface.[8] The Coastal Plain aquifers, supplying the Eastern Shore and lower western shore of the Chesapeake, are likely to be affected by climate change, but indirectly. Much of the water in the Coastal Plain currently being withdrawn is from deep, confined aquifers, and represents many years' worth of storage rather than the more immediate connection between rain and surface water that exists elsewhere. Therefore, these aquifers will be less directly affected by year-to-year variations in precipitation and will be affected to a greater extent by long-term trends toward increased irrigation withdrawal by farmers and other landowners.[9]

quality in small urban streams as well as large rivers like the Potomac.[3,11,12] These streams and rivers may be the source of water for some public drinking water systems in Maryland. With projected increases in extreme rain events and frequencies of intense storms these issues are likely to be exacerbated by climate change.

Climate change also poses challenges to the integrity and safety of infrastructure and drinking water and wastewater treatment systems that are already under stress and will also likely exacerbate the urban flooding events that already are periodically observed in Baltimore City and County, as well as many other jurisdictions. In low-lying areas, such as parts of the Eastern Shore and southern Maryland, flooding caused by storm runoff, coastal storm surge, or sea level rise can also contaminate drinking water sources by overflowing sewers and septic systems, submerging wells and allowing pollutants such as salt, pathogens, petroleum and other chemical products to enter the water supply.


Kate Boicourt

Land use and increased climate variability are likely to amplify pulses of polluting contaminants

Recent analysis by Kaushal et al. has shown the potential for larger pulses of contaminants to enter streams, rivers and the Chesapeake Bay due to land use change and increased climate variability. "In 2002, the mid-Atlantic region experienced record drought levels. In September 2003, Tropical Storm Isabel produced large amounts of rainfall in the Chesapeake Bay region and freshwater flow into the Chesapeake Bay was 400 percent above the long-term monthly average. Record drought conditions followed by a very wet year coincided with pulsed watershed nitrogen exports and one of the most severe zones of hypoxia, or 'dead zones,' reported in the Chesapeake Bay."[17] As precipitation extremes increase, pulses of pollutants such as these are likely to change in "amplitude, frequency and duration," having many implications for the way these pollutants are managed, through regulations such as Total Maximum Daily Loads (TMDLs).

Precipitation extremes and flooding will affect infrastructure and drinking water quality

Heavy rainfall events and urban stormwater already affect water supplies directly, by damaging water infrastructure or flushing pulses of pollutants into source waters, degrading water quality and requiring increased treatment. Good stormwater management practices and regulation have achieved more traction only in more recent years, leaving behind a legacy of impacts from existing development and impervious surfaces. Many urban systems are already under great stress as a result of development in headwater source areas as well as aging, crumbling infrastructure in the distribution system. Furthermore, stormwater infrastructure in many older urban areas already is undersized by comparison with the flow volumes being generated from the upstream watershed, and flooding occurs more often than would be observed in a rural watershed. It is estimated that Maryland's drinking water infrastructure alone needs an investment of $5.4 billion over the next 20 years.[10] Due to a high level of impervious surface, development and storm events can lead to sanitary sewer overflows in those systems where sanitary and storm sewers are combined. These spills affect raw water

Temperature and precipitation extremes will affect aquatic ecosystems

With an increased frequency of extreme precipitation, problems such as stream bank erosion and increased sediment volume will increase, harming aquatic organisms and ecosystems.[13] A recent study, however, has shown that the most severe impacts to ecosystems will likely be temperature increases and spikes due to urbanization and climate change. As a result of these factors, both urbanization and climate change, stream temperatures have risen over the past hundred years, affecting almost every recreationally important fish species.[14,15,16] Climate change will likely exacerbate this existing problem. Increased ambient temperatures also translate to increased evaporation, reducing flows critical for survival and concentrating pollutants during periods of low stream flow. Groundwater supplies, likely to be affected by withdrawals during drought periods, are also critically tied to the flow of nearby streams.

STRATEGY FOR RESILIENCE

Climate change calls into question long-term planning methods that were established during a time of more stable conditions, presenting additional challenges to achieving sufficient water quantity, quality and working infrastructure. Water managers will need to identify and develop options that enhance the resilience of Maryland's water resources and maintain a flexible, adaptive management approach under conditions of uncertainty. Further, the recommendations of the 2008 Final Report of the Advisory Committee on the Management and Protection of the State's Water Resources should be followed in order to improve the management of our resources. Meeting human and ecosystem needs will require integrated, regional planning efforts across county boundaries, based on hydrogeology, access to water resources and infrastructure condition.

Decisions potentially affecting water resources such as land use change should be closely connected to water resource management needs. Current Maryland Department of Environment (MDE) policies are aimed at ensuring that water withdrawals do not have unreasonable impacts on the water resource or other users. New tools are needed to assist water managers and decision-makers to evaluate and implement policies that ensure adequate water supplies and protect the resource.

Ensure long-term safe and adequate water supply for humans and ecosystems

Securing safe and adequate water resources involves managing for a sustainable water supply for humans and safeguarding critical stream flows and water quality for ecosystems. A first step towards achieving this goal lies in improving the existing information about the State's water capacity: how much water the State has available, how water is being used, and what new opportunities exist for meeting future demand. In addition to the other recommendations of the Advisory Committee on the Management and Protection of the State's Water Resources, the State and federal government should continue to fund the current Fractured Rock and Coastal Plain water supply studies to increase this understanding. Using this information to plan in an integrative, adaptive way, based on shared water resources rather than on political boundaries, will be invaluable in preparing for a changing climate.

Part of sustainably managing water also lies in ensuring that there is adequate funding. As the Wolman report states "No entity in Maryland has been required to pay the full cost of withdrawing or using water, a precious, public, natural resource."[3] Other states in the Mid-Atlantic region, as well as many states nationwide, charge users for obtaining water withdrawal permits, but historically Maryland has not had a fee for water appropriation permits. Users should contribute towards the costs of administering the water appropriation permit program, and of undertaking other important activities related to management of the State's water resources.

CASE STUDY: Managing water wisely through regional coordination in the Washington, DC Metropolitan area

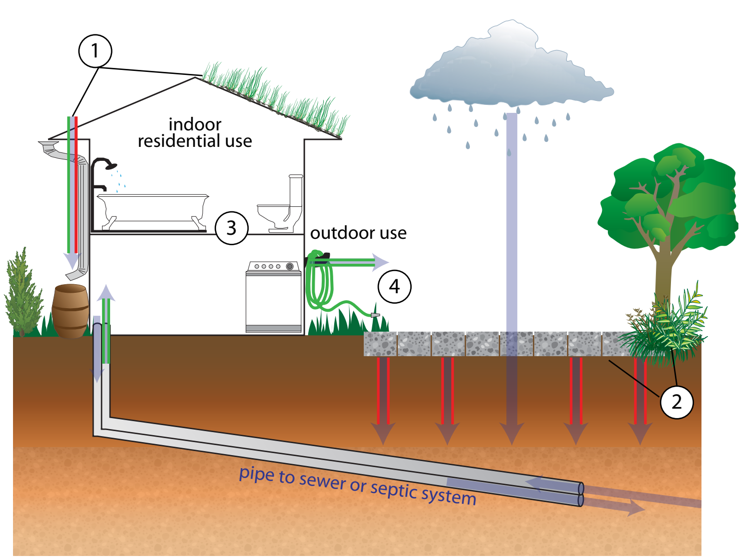
Jan Kronsell

The Potomac River at Great Falls National Park.

During the 1960s and 1970s, alarms were raised as the Washington, DC area was expected to face severe reductions in water availability, requiring intensive engineering solutions such as dams and inter-basin transfers. In an attempt to prevent the need for these largely unpopular solutions, it was proposed that an alternative way would be to combine the operation of local utilities water resources (traditionally operated individually). It was shown that this approach would be able to provide sustainable supplies for a long term without any large engineering solutions. The adoption of this policy in 1982 resulted in an avoidance of impacts from severe drought. During times of drought, the three major water utilities of the DC area follow water allocations given to them by the Interstate Commission on the Potomac River Basin (ICPRB), independent from the management of any of the utilities. In addition to this "shared resource" approach during stressed periods, the ICPRB "routinely conducts drought preparedness exercises to strengthen the lines of communication among principal staff who will be involved in managing water supplies during actual drought."[18] By successfully cooperating beyond jurisdictional boundaries and continuing to prepare managers for extremes, the management of the Washington area provides a good model for managing water for future conditions.

Water supply is not uniformly available across the State. MDE and MDP should continue working with local jurisdictions to improve long-term planning related to water supply, and encourage them to manage land use patterns and direct growth and development toward areas where water is more readily available. Careful planning can help the State meet future water supply needs as climate changes, while avoiding or reducing the need for additional exploration and development of new water resources, which can be very expensive. Water suppliers should consider increasing storage capabilities to increase resilience. Efforts to protect current and potential high-quality water resources, and reduce impervious cover are necessary to ensure a sustainable water supply. Local governments should be encouraged to adopt ordinances to protect water recharge areas for public water supply sources, which have been mapped by MDE.

Water efficiency, conservation and managing demand are among the most cost-effective strategies for securing a long-term water supply. Homeowners should be encouraged to reduce water use within the home and in the landscape (Figure 5.3). There are also opportunities to reduce water demand by modifying industrial processes, employing water-efficient agricultural technologies, and using reclaimed water for non-potable purposes. Reducing demand in all sectors can boost the resilience of Maryland's water resources regardless of climatic changes.



Increase infiltration and reduce stormwater:

1. Reduce roof runoff with vegetated "green roofs" and rain barrels.
2. Use pervious pavement and rain gardens to promote infiltration.

Conserve:

3. Replace toilets, showerheads, and washers with low flow models.
4. Landscape with drought-resistant plants, and, if necessary, water lawns only during cool parts of the day (morning or evening).

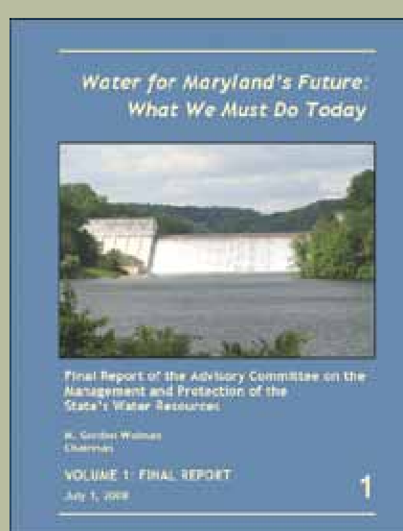
Figure 5.3: Opportunities to prevent runoff and increase groundwater recharge at home.

Priority Recommendations:

- **Adopt and fund the recommendations of the 2008 "Wolman Committee" report.** The Advisory Committee on the Management and Protection of the State's Water Resources conducted a comprehensive evaluation of water supply needs within Maryland over a six year period. The Wolman Committee's series of recommendations are highly relevant to sound planning for the security of Maryland's water supply, and prospective climate change reinforces the need to build those recommendations into state policy.

The recommendations of the Advisory Committee on the Management and Protection of the State's Water Resources

In 2008, an extensive report on the management and protection of the State of Maryland's water resources was released, cautioning that "if Maryland continues to under-invest in its water resource programs, severe droughts such as those Maryland experienced in 1999 and 2002 will likely result in threats to public health, parched aquatic systems, building moratoria, stressed communities, stagnation of irrigation-dependent farming on the Eastern Shore, and fewer new water-using commercial and industrial facilities in the State."[3] One of the major themes for solutions to this problem was the need for increased collaboration among planning agencies and integrated planning with the water resources community. These recommendations are prerequisites to improving current and long-term water management. Climate change pressures reinforce the need to act on these recommendations, and to plan for future water use scenarios in terms of climate and development.



Report Highlights:

- *Obtain basic data needed to assess and protect resources;*
- *Develop a statewide water supply plan;*
- *Protect source watersheds, recharge, and wellhead areas;*
- *Establish a permit fee to fund the cost of managing the State's water resources;*
- *Adjust public drinking water rate structures to cover the costs of operation and maintenance and encourage water conservation;*
- *Use outreach and education to increase understanding and support for a strong water management program.*

- **Manage water through the lens of future climate and population.** Water managers and planners should take a precautionary approach to manage water supplies and boost the resilience of water supply operations. Maryland should continue working to further the understanding of water availability and its relationship to projected climate changes such as the increased frequency of summer drought and winter precipitation, and other factors including population growth, land use, and critical ecological stream flow considerations. Climate projections should be coordinated regionally, and incorporated into the guidance and functioning of the Water Resources Element (WRE) of local comprehensive plans.

- **Enhance planning and coordination within the water resource community** to ensure that safe and adequate water resources are available to meet the needs of Maryland citizens. Encourage multijurisdictional coordination among state agencies such as MDE, MDP and Maryland Department of Transportation (MDOT), as well as among counties and municipalities, to evaluate ways in which water quantity needs of all jurisdictions can be met, and source waters and recharge areas could be better protected.

- **Encourage water suppliers to evaluate and improve their resilience** to climate change effects, including sources, treatment processes, storage, conservation measures, emergency response measures, and other daily operations likely to be affected by climate. Water utilities should employ rate structures that encourage water conservation and provide sufficient funds to maintain and upgrade infrastructure, as well as to evaluate and implement planning and response activities that ensure water systems remain viable through future climate changes.

- **Promote demand management and water conservation practices.** MDE should work with local jurisdictions and water suppliers (and provide funding or technical assistance where necessary) to promote water conservation, encourage the use of best management practices that reduce demand, and advance the use of water reuse technologies.

- **Assess, target and protect high-quality water recharge areas** to absorb stormwater and boost groundwater supplies. MDE should lead an effort to assess high-quality recharge areas (i.e., areas where the quality of infiltrated water will not cause aquifer contamination) and map them so that these areas might be targeted for protection, using the currently required WRE and Stormwater Management Act of 2007 as additional support. Under Article 66B, the State requires counties and municipalities to adopt a Sensitive Areas Element in local comprehensive plans, for which aquifer recharge areas and public water supply basins are optional. MDE and MDP should work with local jurisdictions to adjust standards for development near these and source water protection areas. Options for storing excess water volume from floods when infiltration capacity is difficult or impossible should be explored (e.g., reconnecting river channels to the floodplain, groundwater injection of stormwater).

Maryland Stormwater Act of 2007

In 2007, the State of Maryland passed a law requiring stormwater in new development to mimic natural recharge conditions. The Act requires that Environmental Site Design (ESD), through the use of nonstructural best management practices (BMPs) and other better site design techniques, be implemented to the maximum extent practicable. In 2009, Maryland Department of Environment (MDE) formally adopted final stormwater management regulations and in 2010, local implementation of ESD began.

Reduce the impacts of flooding and stormwater

Flooding and stormwater from extreme precipitation events and inundation of low-lying coastal areas by storm surge already impact Maryland infrastructure and water quality particularly in highly developed areas. The variability and stress that water treatment systems must handle will likely be exacerbated. Throughout the State, there must be a concerted effort to reduce the impervious surface cover that prevents groundwater recharge and increases the flow of polluted runoff into waterways. Proactive planning with low impact development (LID) principles can prevent or reduce the need for many of the more resource-intensive engineering solutions to high volumes of stormwater. In cases where existing water supply and treatment infrastructure (pipes, water and wastewater treatment systems) is particularly vulnerable, or where capacity is insufficient to handle future conditions, repair or replacement should be prioritized according to an assessment of vulnerability. Sanitary sewers, for example, are in need of greater management attention, particularly if they are currently located in or near the floodplain. For all new water supply and treatment infrastructure, target capacities should take into account the likelihood of increased precipitation variability and extremes.

Recently, the State Board of Public Works and local jurisdictions have allotted funding to separate combined sewers and improve sewer structural integrity in Dorchester and Allegany Counties, among other jurisdictions.[19] This focus on improving infrastructure should be continued and presents an opportunity to update designs for future conditions.

Andrew Miller

Researchers, working with staff from the Baltimore City Department of Public Works, evaluate an incised section of Powder Mill Run for restoration potential. Urban streams such as this one become incised when subjected to elevated storm flows.

Maryland should continue to work to increase the amount of water infiltration, first and foremost focusing on reducing the total volume of stormwater, transferring rainwater into groundwater, as is required by the Stormwater Act of 2007. The benefits of infiltration are many, including increased groundwater availability, improved water quality (via stormwater reduction), and more reliable stream base flow. In areas that are highly vulnerable to stormwater but where stormwater controls are less practicable (i.e., existing heavily developed areas), alternative strategies may be required. MDE, MDOT and State Highway Administration should provide guidance for accommodating new climatic conditions without inadvertently affecting water quality. Response plans and flood management protocols for acute storm events also need to be completed at the local level.

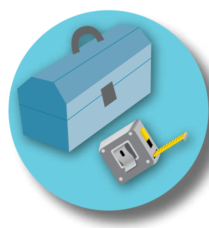
Priority Recommendations:

- **Encourage the removal of vulnerable or high-hazard water supply and treatment infrastructure** that pose a threat to public or environmental safety.

- **Prevent inundation and overflow of on-site disposal systems (OSDS).** As sea level rises and groundwater levels increase, the inundation of existing OSDS, particularly in areas prone to coastal flooding, is a major concern. Outside of the coastal zone, OSDS overflows, which already lead to raw sewage leakage in Maryland, are likely to worsen as precipitation extremes become more frequent. Technical, incentive, and replacement solutions to address the problem of aging, failing, or inundated septic systems should be developed. The establishment of a permit fee for new septic systems should be evaluated to fund permiting programs, enforcement and support development and implementation of innovative technical solutions.

- **Revise Clean Water Revolving Fund criteria** to require use of Environmental Site Design techniques (see *Maryland Stormwater Act of 2007*) as a condition on funding for stormwater or combined sewer projects.

- **Invest in an improved understanding and communication of flood probabilities and hazards.** The combined effects of increased variability in weather patterns and increased urban development will continue to increase the potential for flooding in many communities. Multiple strategies are needed to reduce associated hazards to life and property.



TOOLS, RESEARCH, AND EDUCATION TO INFORM SOUND DECISIONS

Long-term monitoring and research efforts are critical. As Maryland experiences a new suite of hydrologic and temperature conditions, the State will need to gain a better understanding of these conditions in order to develop an adaptive management framework. Coordination with the research community, combined with funding for the development of new prediction tools will improve this ability. The resolution of climate models is improving and will continue to do so, but efforts to understand the impacts of climate change at local scales must be supported.

Tools and research

- **Continue long-term monitoring programs and innovative data analyses** to quantify critical stream flows. Data collected through DNR's Maryland Biological Stream Survey should be incorporated into the Fractured Rock study. The results of related studies (e.g., the Middle Potomac Watershed Assessment being conducted by the Interstate Commission on the Potomac River Basin and the Nature Conservancy) should help the State establish thresholds and improve management. The Aquifer Information System that is currently being developed is a potential avenue to manage groundwater levels and well withdrawal data and report conditions.

- **Investigate altered flood probabilities** in light of changes in both precipitation and sea level. Existing flood-hazard maps are being updated to reflect new sources of high-resolution topographic information. There is growing consensus, however, that past methods for assessing flood probabilities based on historical records are not adequately accounting for future change.[20,21,22] In addition, new information suggests potentially much higher rates of sea level rise than were envisioned in the most recent Intergovernmental Panel on Climate Change report, which in turn would increase the probability of flood inundation by storm surge in coastal areas of Maryland.[23,24]

- **Conduct a series of pilot studies to determine the impacts of increasing aquifer recharge** in various parts of Maryland.

- **Continue to investigate the consequences of varied stormwater control measures** on water quality. The State should further support or provide incentives for innovative strategies in urban or contaminated areas where recharge is not an option.

- **Investigate opportunities to reconnect streams to floodplains**, particularly in areas susceptible to flooding.

- **Develop new tools to guide integration of climate science and adaptation strategies** into plans and programs, including local government WRE.

Innovative ways to infiltrate stormwater are needed, such as this rain garden installed at the Nanticoke Watershed Alliance.

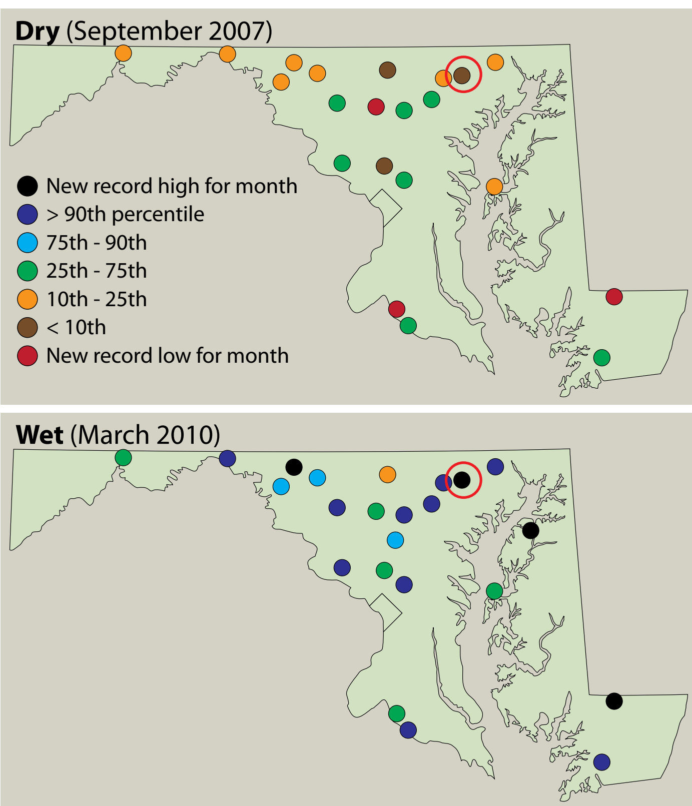
Education

- **Engage Maryland's citizens, planners** and others who influence Maryland's water supply, demand and watersheds.

- **Provide guidance tools and seminars** on issues such as stormwater design, wellhead protection, and sediment control.

- **Enhance existing education and training programs** to include climate-related information.

- **Promote added incentives for the use of low impact development (LID), rain barrels/cisterns, rain gardens and water conservation.**



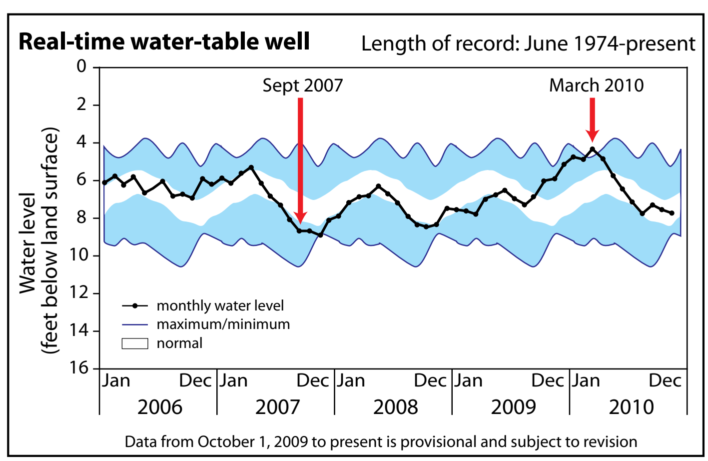


Figure 5.4: The graph on the right shows groundwater level data for a well in Harford County (circled in the maps to the left) after dry conditions in late summer 2007 and a large winter precipitation event in early 2010. These real-time data are important decision support tools as climate changes. Source: USGS.

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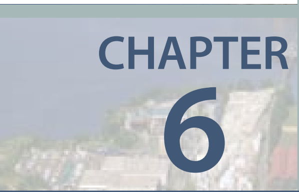
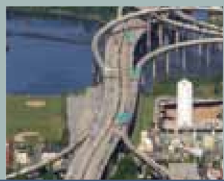


CHAPTER 6



POPULATION GROWTH AND INFRASTRUCTURE

Lead author: Gerrit Knaap
Contributing authors: Marty Baker, Peter Claggett, Zoë Johnson, Christopher Pyke, Dru Schmidt-Perkins, and Joseph Tassone

KEY POINTS

❖ **Temperature and precipitation extremes will likely harm infrastructure and affect human health.** Increases in precipitation and the intensity of storm events will likely exacerbate existing problems, particularly in urban areas. Problems associated with stormwater, flooding, heat stress and air quality will likely worsen.

❖ **Building codes, infrastructure design, emergency management, and planned development should be oriented to reduce impacts caused by increased climate variability and extremes.** Maryland's built environment needs to be reinforced to prepare for new temperature and precipitation regimes. Over time, changes to the system, including the operation, maintenance, design and management of much of the State's built infrastructure may become necessary.

❖ **For sustainable growth, planning efforts must reflect and address projections for both population growth and the effects of climate change.** Many areas in Maryland are expected to experience increased growth and development. Decisions about growth need to factor in climate impact projections.

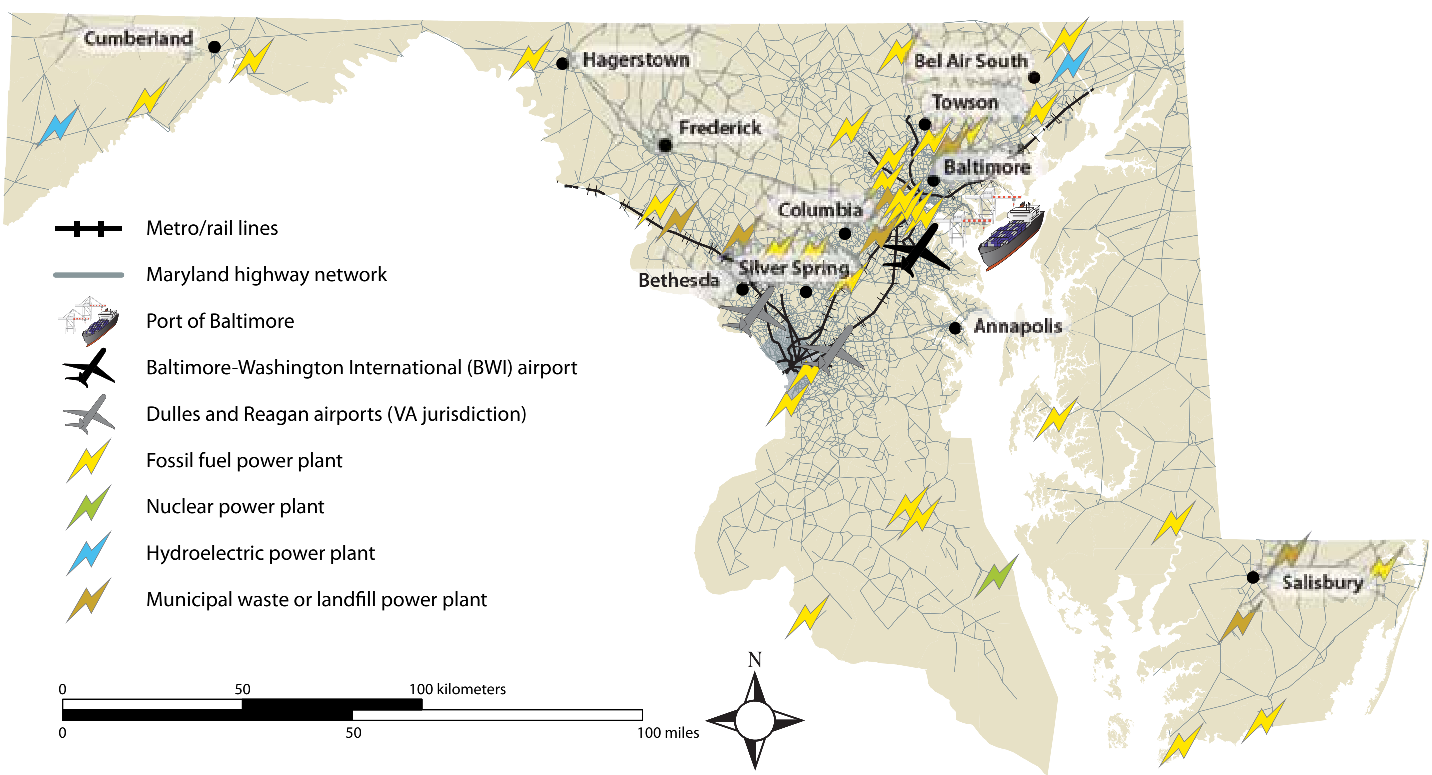


Figure 6.1: Major infrastructure will likely be subject to different climate change impacts across Maryland, ranging from inundation of lower elevation coastal areas to heat and precipitation impacts, particularly in the urbanized areas of the Baltimore-Washington corridor.

INTRODUCTION

Maryland's growing population lives and works primarily in a built environment and is reliant on transportation, water, and communication and energy networks, spanning a wide range of landscapes, from cooler Appalachian Mountains in the west, to low-lying areas of the Eastern Shore. These systems, regulated in part at the state level, but more directly influenced by local decision-making, are subject to the pressures of shifting populations and often unreliable sources of funding support needed to address maintenance, planning, and upgrade. The projected effects of climate change, including increases in precipitation variability and extremes, winter precipitation and temperature, may affect the frequency, severity and timing of many existing problems, such as stormwater, or buckling of roads and malfunctioning train systems due to heat waves.[1] Historical and current climate conditions may no longer be adequate to guide planning, design, operation and maintenance decisions.

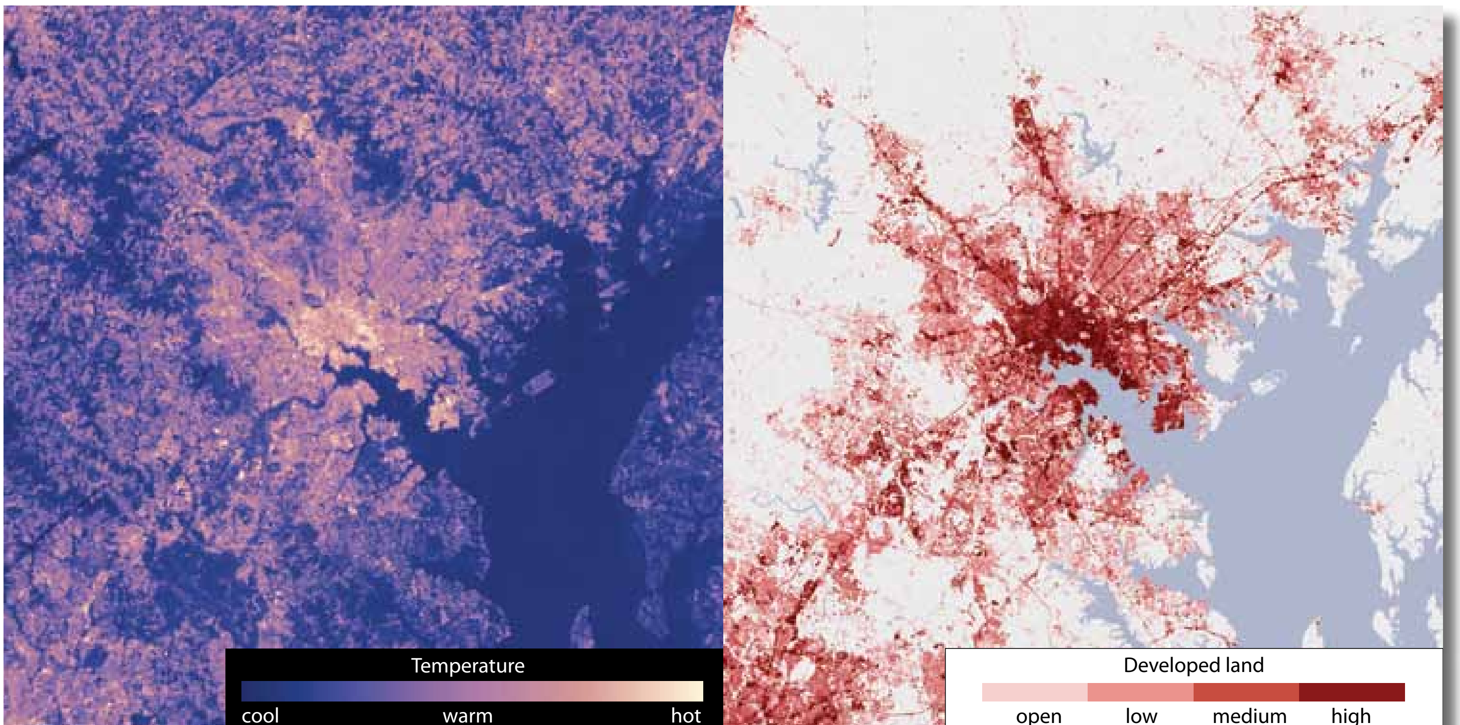
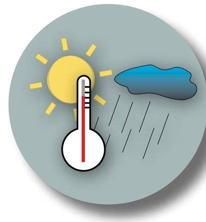


Figure 6.2: Developed areas in Baltimore exhibit the heat island effect on a hot August day in 2001. Temperature signal is uncalibrated. (NASA National Land Cover Database and Landsat 7 imagery)

CLIMATE VULNERABILITY



Sea level rise and coastal storms will cause some of the most severe climate impacts in Maryland, as described in the *Phase I* Adaptation Strategy.[2] Climate change will also likely undermine many other important climate assumptions (i.e., temperature, precipitation, storms) used in the planning, design and operation of these systems, which are highly expensive to retrofit. Infrastructure that is already stressed or exceeding capacity due to age or population pressures (for example, 29 percent of Maryland bridges are structurally deficient or obsolete) will likely worsen in many cases, adding a greater sense of urgency to employing system assessments, capacity adjustments and repairs.[3] Construction or maintenance may become more difficult or costly due to a need for increased maintenance and protection of workers during extreme events.

By 2030, Maryland is expecting one million new citizens and 400,000 new homes; estimates slate Harford and Anne Arundel counties to receive 28,000 relocating military employees; other increases are expected around the State.[4,5,6] Growth often means higher percentages of impervious pavement and developed land, leading to increased heat and stormwater volumes in urban areas (Figure 6.2). Depending on the distribution of this growth, certain areas are likely to be disproportionately more vulnerable to these impacts (i.e., if development in 2030 is consistent with the current trends rather than the Smart Growth scenario,

Figure 6.3). Without proper infrastructure, growth control and preparation, many of the existing problems associated with heat waves and extreme precipitation will intensify as the climate changes.

Temperature increases and extremes may affect energy demand, infrastructure, and human health

In a lower emissions scenario, the number of days exceeding 90°F in the coming decades in Maryland may double by the end of the century (from 30 to 60 days in an average summer). Under a high emissions scenario, nearly all summer days would exceed this level (90 days). Winter temperatures are expected to warm, though less than in summer (a difference of between 0.8 and 2°F in low- and high-emissions scenarios, respectively).[7] Changes of this magnitude will result in less winter heating and a higher demand for summer air conditioning. The degree to which this will change overall yearly energy demand is uncertain, although seasonal peaks may shift or be more heightened in summer. Between 2007 and 2008, new efficiency standards and programs have contributed to a 2.2 percent reduction in Maryland's per capita energy consumption, though increases in population may change this trend in terms of total energy consumption.[8] Fuel prices and climate mitigation efforts may also push consumers and producers to increase efficiency. Increases in temperature and drought frequency are likely to also affect energy demand and generation by causing an increased amount of energy used for water pumping and by decreasing the efficiency of thermoelectric power generation.

These high summer temperatures have many other implications for developed areas, including impacts to human and ecosystem health. Research demonstrates that regions with low air quality levels may worsen, or possibly fail to meet standards; some are already considered in non-attainment of Clean Air Act standards and require improvement (see *Chapter 1, Human Health*).[9] Effects include a possible worsening of smog (ground-level ozone) and particulate matter levels, which impact human respiratory health and allergens.[10] These effects will likely be most pronounced in urban areas, as buildings and pavement retain heat, leading to higher temperatures (Figure 6.2). For example, Baltimore's air quality is not only affected by local air pollution but by that of Washington, DC, as well. Warm air rising over metropolitan Washington slows prevailing winds and, thus, reduces cooling and cleaning effects in Baltimore.[11] These impacts to human health may, in the long-term, lead to the eventual tightening of environmental regulations with respect to industry and transportation.

Increased temperatures are likely to have mixed effects on Maryland's transportation networks. Although decreases in frost and ice may diminish disruptions and cold-related degradation (e.g., through use of road salt), extreme heat may result in increased thermal expansion and a thereby threatened integrity of roadways, rails and bridges. Significant concern also exists regarding the ecosystem effects of rising stream temperatures adjacent to urban areas, due to both increases in ambient temperatures and the temperature of stormwater running off hot impervious surfaces.[12]

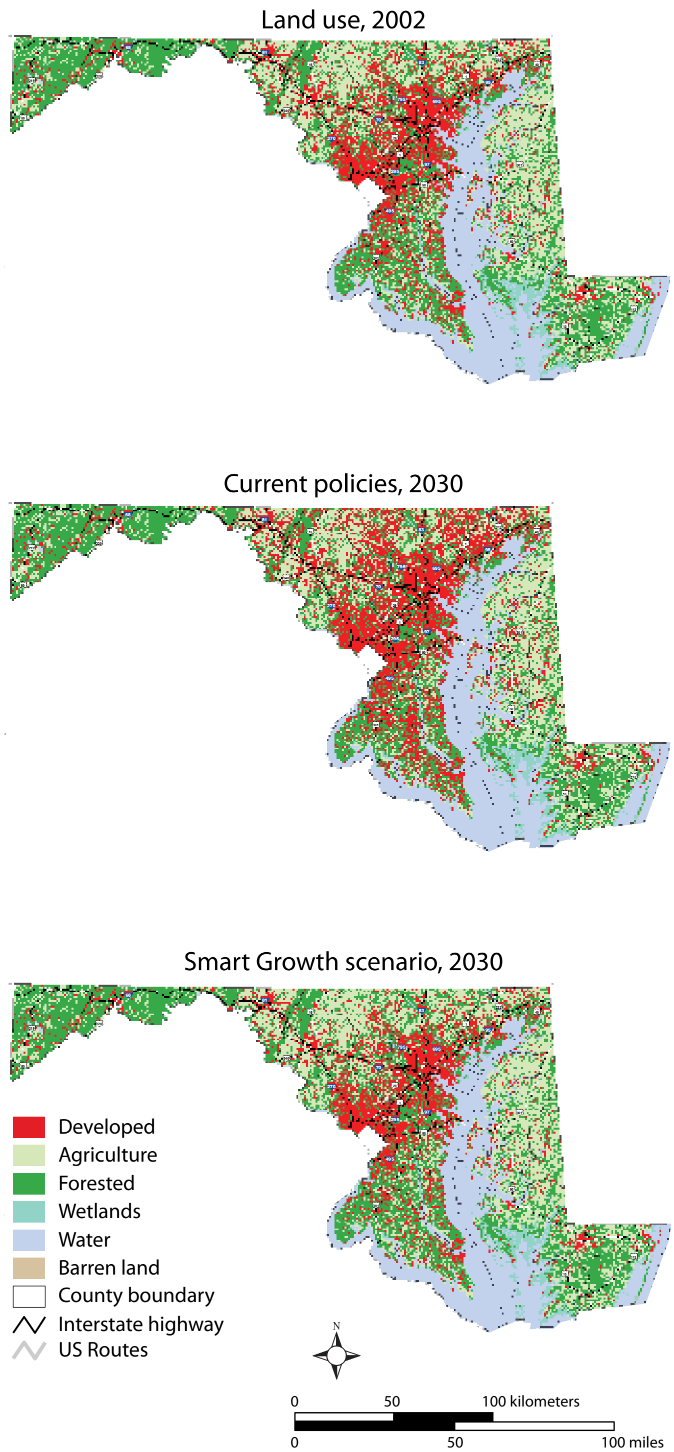


Figure 6.3: Land use (2002) and projected growth (2030) based upon current policies or implementation of Smart Growth principles. Map source: Maryland Department of Planning.

Precipitation variability and extremes will likely harm infrastructure and surrounding ecosystems

Although impacts to these systems will be variable, storm intensity and precipitation increases will likely exacerbate existing problems associated with stormwater, flooding and non-point source nutrient pollution, across the State. Buildings and infrastructure already in floodplains are particularly at risk. Furthermore, flooding in both low-lying and heavily urbanized areas may cause erosion and mudslides, potentially affecting airports, railways, roads, tunnels and energy systems. These impacts can also be expected to cause transportation disruptions, delays, accidents, communications systems failures and power outages.[13,14,15,16] Whereas areas covered in soil or vegetation allow rainwater to infiltrate into the ground, impervious surfaces, such as highway systems, may trap water and become flooded.

Changes in runoff may affect coastal transportation and shipping as well, due to the specific depth required to maintain Maryland's ports and coastal shipping channels.[17] Further, stormwater and sewer infrastructure, already stressed during heavy rain events, will likely be further stressed and exceed capacity, leaking raw sewage into adjacent rivers and the Chesapeake Bay. This problem is especially true in older urban areas that still suffer from combined sewer systems. At the site level, Environmental Site Design (ESD) and low impact development (LID) minimize stormwater runoff. At the regional level, Smart Growth minimizes overall stormwater runoff and impervious surface cover by reducing per household impact of new development.[18] Impacts of precipitation changes on Maryland's water supply and treatment infrastructure are discussed in more detail in *Chapter 5: Water Resources*.

Maryland's energy systems will also likely be affected by precipitation increases and flooding. Storms and flooding may result in damaged power lines or outages.[19] These impacts will also likely make energy supply more expensive to consumers. In terms of power generation, there is much uncertainty surrounding whether or not increased precipitation during winter months will benefit average hydroelectric power generation, as other factors such as decreased efficiency due to temperature increases or drought conditions in the summer may offset winter benefits. Despite the uncertainty associated with overall changes in precipitation, increases in variability will challenge the management of Maryland's energy systems if climate change is not taken into consideration.

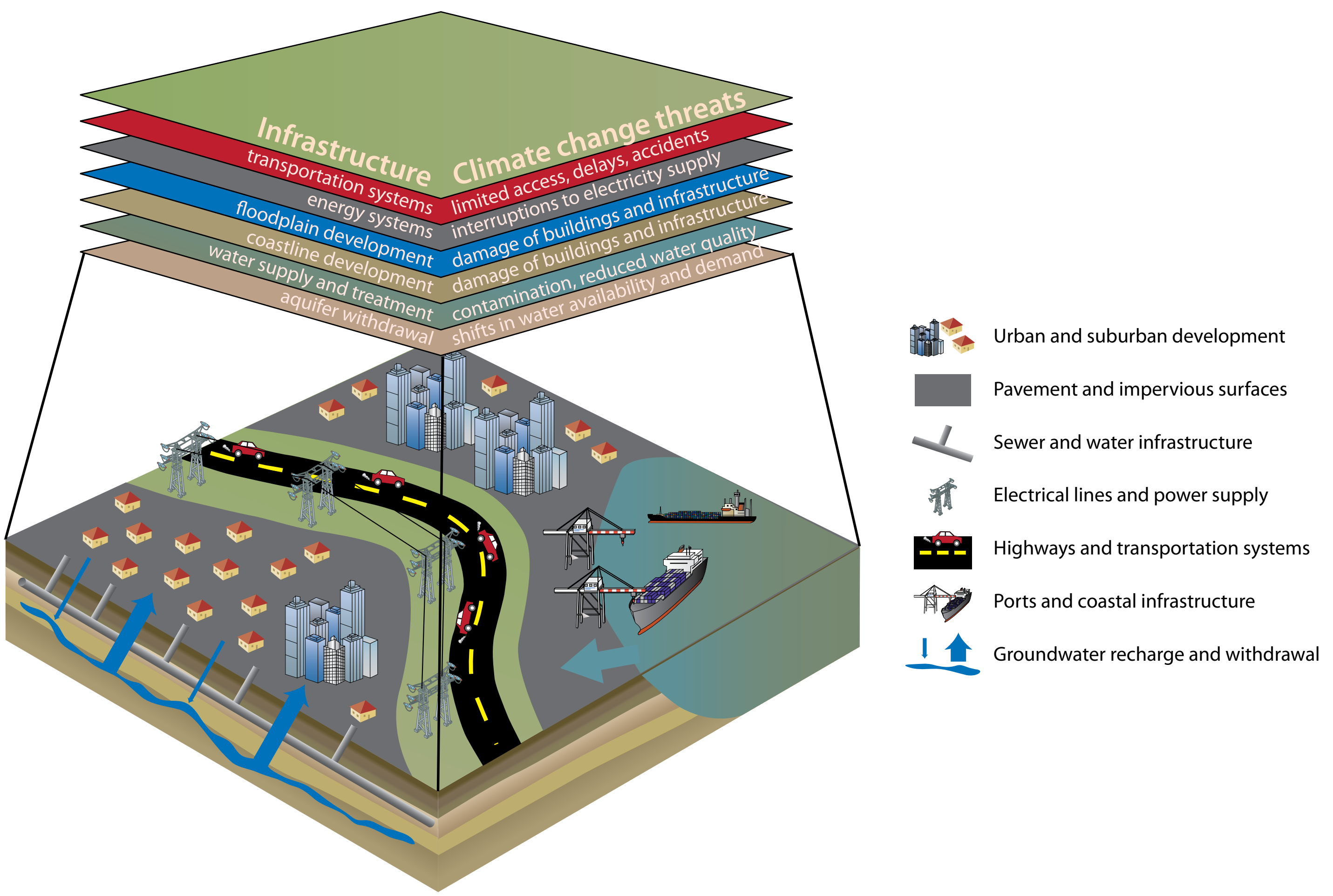


Figure 6.4: Analyzing Maryland's growth and infrastructure systems will require a spatial vulnerability approach, that takes into account the current infrastructure capability and climate change influences on those systems.

STRATEGY FOR RESILIENCE

At the state level, Maryland Department of Planning (MDP) provides technical, policy, and implementation support for local jurisdiction plans, programs, and ordinances, while the Maryland Department of Housing and Community Development (DHCD) and Maryland Codes Administration adopts state-wide building codes. Maryland Department of Transportation (MDOT) oversees the planning, construction, and operation of Maryland's highway, transit, maritime and aviation facilities, under the direction of the Transportation Secretary. The Secretary chairs the Board of the Maryland Transportation Authority, which operates Maryland's toll facilities such as the Chesapeake Bay Bridges. MDOT also funds the Maryland portion of the Washington Metropolitan Area Transit Authority. Certain regulations for building and development are also set at the State level, such as the Critical Area Law and Environmental Site Design requirements. For energy and efficiency issues, the Maryland Energy Administration (MEA) provides guidance, policy, standards and technical assistance to local jurisdictions and citizens, and works with the private energy utility companies and others to create energy conservation programs.

Leif Skoogfors

FEMA workers assess damage to a bridge in Dorchester County after severe rain and flash-flooding occurred in June 2006.

At the local level, jurisdictions shape the implementation of State policy and regulation regarding planning and zoning, energy and building, and to what extent low impact principles are followed. Future climate considerations should be embedded into all infrastructure and planning decisions, at all levels of government. Infrastructure design, planning and zoning and management plans should be targeted for the conditions likely to be experienced during their respective lifetimes of use (e.g., a 50-year building should be planned for what conditions are likely in 50 years).

The following strategies will benefit Maryland's citizens, buildings and infrastructure, regardless of climate change. However, climate change is likely to make existing stressors worse, adding a sense of urgency to the use of Smart Growth and low impact design (LID) principles, infrastructure improvements, or updates before damages become more severe. Proactive planning for new and redevelopment is critical to help avoid more costly repairs or retrofits that would be otherwise necessary in the future.

Ensure safety, clean water, clean air, and sufficient infrastructure

The State must work with federal and local partners to assess state and local capacity to ensure safety, clean water, clean air and sufficient infrastructure in the context of climate change. Although replacing or retrofitting existing infrastructure for the future will be expensive, funding for improvement is needed now, so that impacts do not dwarf expenses later.[12] Operational changes such as closures and detours, speed reductions, or limitations on the use of infrastructure will need to be considered in some cases. Infrastructure network planning will need to be continually updated, as more data becomes available, new adaptation strategies are tested and as climate continues to change.

Priority Recommendations:

- **Address funding and revenue constraints** to ensure adequate support for current and future infrastructure needs. A vital component of a climate change adaptation strategy is to ensure that there is adequate funding to support implementation over the long-term. As always, there are many competing priorities for the allocation of limited state and federal dollars for infrastructure planning, design and project construction. In the short-term, the State should seek outside funding to support the development of a climate change analysis and decision-making planning and policy guide for use by state, regional, local and private organizations as they begin to implement the recommendations contained in this report. Over the longer-term, the State will need to review and adjust its existing infrastructure funding priorities to account for critical planning and construction needs in light of climate change.

- **Conduct a comprehensive analysis of the vulnerability of Maryland's infrastructure** to prioritize network repair, replacement, or decommissioning (Figure 6.4). Such an assessment will enable planners to identify future infrastructure impacts caused by both shifting populations and climate change. MDOT agencies (i.e., State Highway Administration (SHA), Port Administration and Aviation Administration) have largely completed an assessment of infrastructure vulnerability to sea level rise. Based on the results of the analysis, MDOT is proposing to consider impacts when planning for future projects and where possible develop plans for the eventual relocation of sensitive infrastructure to higher elevations investigating flood protection alternatives. Further work to assess state-wide infrastructure vulnerability and to conduct a more in-depth anlaysis of climate impacts (i.e., precipitation change, increased temperature) will require additional funding.

A strategy for reducing Maryland's vulnerability to sea level rise and coastal storms was proposed in the *Phase I* report of Maryland's adaptation efforts. Some counties have already incorporated adaptation measures into planning documents (such as Ocean City, above).

- **Develop a "lead by example" investment policy to guide state investments** in areas particularly sensitive to effects of climate change (e.g., require consideration for locating development in areas prone to sea level rise). The State should consider expanding the policy to affect funding assistance for local projects not in accordance with policy guidelines.

- **Reduce regional air quality impacts in Maryland.** Maryland Department of Environment (MDE) is charged with carrying out mandates from the Clean Air Act, working to create State Implementation Plans designed to attain and maintain National Ambient Air Quality Standards. Maryland is continuing to develop air quality plans that reduce emissions from in-state sources and target the attainment of the US Environmental Protection Agency's (EPA) standards. MDE is a national leader in pushing for stringent national rules and the reduction in transported pollution. Transported pollution is a significant cause of Maryland's air quality problems and on bad air days as much as 70 percent of Maryland's air quality problem comes from transported pollution. Metropolitan planning organizations (MPOs) in Maryland should coordinate with MPOs across the country to ensure their models and plans are updated to adequately address anticipated effects of temperature on air quality.

Plan for precipitation-related weather extremes and increase resilience to rising temperatures

Many of Maryland's jurisdictions have recently experienced severe urban flooding, stormwater flows, and extreme winter precipitation. The powerful blizzards of February 2010 showed that the State needs to be better prepared for future weather emergencies. Design and construction codes need to be assessed and revised to reflect both changes in population and climate. While the Maryland Stormwater Act of 2007 requires new private, state and federal development to take both impervious surface and Environmental Site Design techniques into account to reduce impacts,[20] it does not address issues related to future climate. Heavily urbanized areas will need improved stormwater strategies and design to accommodate greater storm intensity. In addition, the impacts of heat on infrastructure may require the revision of design and planning considerations. As urbanized areas will be impacted most severely, cities should work to find ways to reduce heat and to accommodate communities or individuals vulnerable to high temperatures.

Figure 6.5: The filtration capacity of a natural versus impervious system. Areas with lower impervious surface cover have superior capacities for infiltration (adapted from US Environmental Protection Agency's Protecting water quality from urban runoff, 2003).

Priority Recommendations:

- **Assess the economic costs resulting from severe weather events.** The State should analyze economic and other costs to Maryland residents resulting from events such as the severe weather during the winter of 2010. The analysis should also provide estimated state and local budget projections to increase preparedness and response in anticipation of future like storms.

- **Identify State investment needs to prepare for future weather emergencies,** including snow, hurricanes, drought, floods, and other emergencies. State agencies, including MDOT and Maryland Emergency Management Administration (MEMA) should provide input to State-wide analysis to recommend strategies.

- **Accelerate use of improved stormwater management strategies and environmental site design (ESD).** Growth in urban areas is likely to increase problems associated with stormwater runoff (Figure 6.5). MDE, MDP, MDOT, DNR and all State agencies should work with federal and local partners to ensure the implementation of ESD according to Maryland law and regulations. In addition to using ESD for all new development as required currently, cost-effective, site appropriate, and adaptive solutions should be identified for existing urban areas where little or no management exists. This will require reconciling conflicts with ESD implementation caused by concentrated growth policies and public works and planning and zoning codes. Using innovative solutions like widespread ESD controls and improved stormwater management BMPs and strategies will better protect sensitive ecosystems and critical infrastructure to meet current needs and address future conditions.

- **Enhance the preparedness of transportation, utilities, and emergency service providers to respond to weather-related emergencies.** As relevant data becomes available, responsible agencies should expand analysis to include potential issues arising from heavy rain and snow events, heat extremes, and other emerging public concerns.

- **Develop operation contingency plans for critical infrastructure, including energy supply and distribution** networks. Maryland's state agencies should work with regional and local partners to assess emergency response systems, the sufficiency of emergency shelters, and evacuation capacity of communities and transportation access bottlenecks. This effort will entail preparing to take some infrastructure out of operation. As certain vulnerable, but necessary, networks may have to be turned off or averted during extreme events, having alternatives in these areas may be increasingly necessary (e.g., other means of access or extra bus links). Additionally, the State should develop a coordinated plan including Maryland's energy utilities to determine preparedness for an increased frequency of extreme events.

- **Increase urban tree canopy.** Maryland should boost its ongoing efforts to increase urban tree canopy. Trees improve Maryland's resilience to climate change by providing urban heat reduction, stormwater reduction and air filtration. Collaboration among regional, federal, state, local and resource agencies will be required to successfully meet this goal.

- **Strengthen building and infrastructure design standards.** The State should coordinate efforts with Maryland Department of General Services (DGS) and Maryland Department of Housing and Community Development (DHCD), MDOT and other agencies to assess current building codes, transit lines, Maryland Area Regional Commuter (MARC) trains, airports, communications systems and community design standards to determine suitability for both current risks and future conditions. Designs that emphasize both efficiency and adaptation benefits should be encouraged.

Jason Cohen

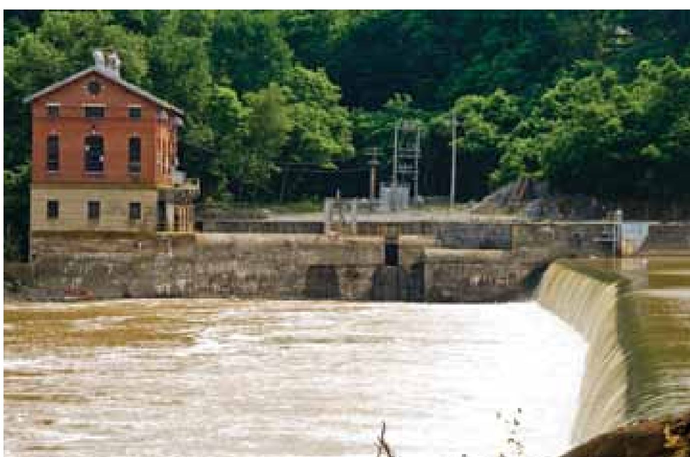
Bowleys Quarters (east of Baltimore): Hurricane Isabel storm surge in September 2003.

Institutionalize consideration of climate change

Climate change considerations should be institutionalized into future goals and metrics of preparedness at the regional, state and local government levels. This integration will be essential in order to increase Maryland's adaptive capacity. Climate change is not a single issue, but an overarching factor that shifts the conditions under which Maryland's infrastructure and planning decisions take place (Figure 6.6). The Maryland Commission on Climate Change recommended this integration in the *Phase I* adaptation strategy for sea level rise, and it applies to other climate issues as well. Development patterns, transportation and public infrastructure planning are tightly linked, and therefore should be considered together for purposes of adaptation: preventing excessive urban heat, poor air quality and water quantity and quality problems (Figure 6.4). Regional coordination of planning and regulation may help avoid disproportionate impacts in some areas.

Priority Recommendations:

- **Promote integration of climate change adaptation strategies** into state and local policies and programs. At the local level, MDP, DNR, and MEMA should continue to work with local jurisdictions to incorporate consideration of climate change into comprehensive emergency response planning efforts. The State should add a Future Climate Planning Element to Maryland Planning Act Article 66B §3.06(b) of the Annotated Code of Maryland for county comprehensive plans. The State recommended this for sea level rise in the *Phase I* Adaptation Strategy, but the influences of other climate change impacts (e.g., increased temperature and precipitation extremes) should also be incorporated into planning decisions at the local level. At the state level, MDP should work to ensure climate change considerations are adequately addressed in the State Development Plan (Plan Maryland), currently under development.



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A hydroelectric dam on the Potomac River, near Williamsport in western Maryland. An assessment of the vulnerability and capacity of Maryland's energy systems is needed.

- **Integrate climate vulnerability data into state and local spatial planning frameworks** (e.g., Green Print, Growth Print). These spatial planning frameworks are often the foundation upon which decisions regarding future growth and development are made and are an essential tool to promote integration of climate change information at the state level.

- **Consider climate change issues in combination with ongoing growth and development planning efforts.** The Sustainable Growth Commission and MDP should seek input from private sources and multiple levels of government including resource agencies to help guide the integration of land use, infrastructure planning, and climate change adaptation strategies. Priority should be

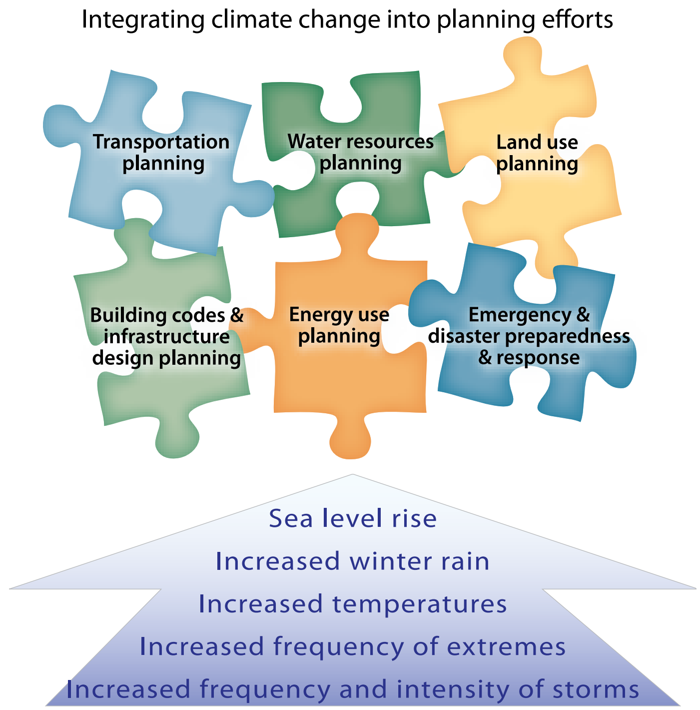


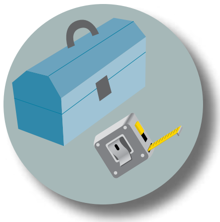
Figure 6.6: There is no single point of response to climate change. Integrating future climate projections into planning efforts across the board is critical for building Maryland's adaptive capacity.

given to examining the vulnerability of existing Priority Funding Areas to the impacts of sea level rise and coastal storm surge. The State should also support and provide data for local level efforts.

- **Explore incentives to promote sound planning practices.** Options such as incentives, taxation structure adjustments, or funding assistance should be explored as a means to encourage sound investments or conversely to discourage infrastructure placement in vulnerable or hazardous areas.

- **Investigate the impacts of climate change on future energy needs.** In July 2010, Governor Martin O'Malley signed Executive Order 01.01.2010.16 calling for the creation of a Long-Term Electricity Report by the end of 2011. The report, being prepared by DNR's Power Plant Assessment Program, will assess future electric energy use requirements and peak electric demand requirements, and identify sources and alternative resources to meet any gaps in these requirements. The impact of climate change on future energy needs should be assessed as a component of the plan.

- **Create a framework and standards for the placement and use of alternative energy.** Emerging alternative energy sources such as wind will require new review concerning site placement and impacts on surrounding people and ecosystems. The State should work proactively to develop a framework for decision-making regarding these energy sources.



TOOLS, RESEARCH, AND EDUCATION TO INFORM SOUND DECISIONS

Detailed data and mapping efforts are critical to assessing the vulnerability of a system to climate change and to develop strategies to boost resilience. Maryland needs an integrated monitoring and modeling system that tracks impacts to multiple infrastructure components, environmental changes and public impacts in the context of population, climate and environmental influences. Tracking infrastructure age, damage and capacity, in this context, will enable the development of decision-support tools to assist planners and managers with making proactive rather than reactive (and more costly) decisions. Identifying infrastructure and populations vulnerable to climate change impacts will require a large research and assessment component. This information can be used to inform state and county planning efforts, for those areas expected to experience large impacts as a result of climate change, as has been done with inundation concerns in Worcester County.[21]

In the short-term, there is a critical need to establish and disseminate state-specific climate data and information in order to develop a common understanding of future planning needs at both state and local scales. This is an important first step to ensuring climate issues are included during infrastructure planning, design, construction and budget processes.

Tools and research

- **Develop state-level data and decision-support tools.** Collaborate with federal partners (i.e., NOAA Climate Service, US Geological Survey) to downscale global, national and regional climate-data and information tailored to state-planning needs. State-specific climate data is essential for the development of finer-scale vulnerability assessments, decision support tools, and to address the cost-effectiveness and co-benefits of adaptation strategies across a range of climate change scenarios.

- **Develop a web-based climate change planning tool.** Using state-specific climate data, the University of Maryland, with input from Maryland's state agencies should develop decision-support tool that will identify climate change risks (e.g., urban heat islands) for specific geographic areas throughout the State.

- **Increase the understanding of the combined impacts of growth and climate** on future resources. An interdisciplinary group comprised of representative from MDOT, MDP, MEA, DNR, MDE, DHCD, and other affected parties should work with local jurisdictions to assess the vulnerability of the State's infrastructure to climate change.

- **Continue to develop long-term growth projections,** monitor current trends, and pair these population distribution data with climate change risk maps. Tracking change should also include monitoring of new infrastructure materials or technology as they may carry higher uncertainty and potential quality risks.

- **Establish metrics for monitoring progress towards achieving adaptation goals.** Modeled after Governor O'Malley signature *BayStat* Program, Maryland's state agencies have been tracking and reporting measurable progress towards meeting the State's 25 percent greenhouse gas reduction goal. Maryland should implement a similar program to monitor progress on implementation of adaptation strategies.

- **Assess the need for increased dredging of shipping channels and ports** due to increased sea levels and changes in sediment loads.

Joanna Woerner

Cranes unload shipping container cargo near the Port of Baltimore.

Education

- **Launch a Climate-Smart Growth and Infrastructure education campaign.** A Climate-Smart Growth and Infrastructure education campaign is recommended as an avenue to assist the integration of future climate elements into design and planning efforts. Through such an effort, the State will be able to engage local municipal engineers and the transportation, growth, energy and water resources communities, and work closely with public utilities, relevant private corporate sector entities, educational institutions and non-profit organizations to determine the needs of local jurisdictions and to convey the need for building resilience.

- **Conduct targeted outreach to local and regional entities** (including metropolitan planning organizations (MPOs)) to ensure common understanding of risks, promote consistency in cooperative forecsting, and inform land use decision-making.

- **Promote climate change literacy** through constituent education and professional training opportunities.

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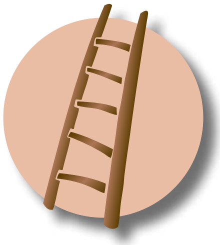
FUTURE STEPS AND DIRECTION



The Adaptation Challenge

Adaptation, together with mitigation, is necessary to address the impacts of climate change. We must substantially reduce greenhouse gas emissions in order to limit the human interference with Earth's climate system and thus avoid the most severe impacts in Maryland. At the same time, we must take steps to enhance the resilience of our natural and human-based systems to the consequences of climate change to which we are already committed or which might occur as a result further human emissions of greenhouse gases. Climate change adaptation, however, is an extremely complex process. As detailed in the sector-based analyses, there is no single means of response. As stressed in a recent report by the National Academies,[1] climate change adaptation must be a highly integrated process that occurs on a continuum, across all levels of government, involving many internal and external partners and individual actions, and often evolves at different spatial and temporal scales.

Maryland is not alone in taking up the challenge to adapt to climate change. The federal government is undertaking the development of a comprehensive adaptation strategy.[2] Maryland is, in fact, at the vanguard with but a few states that have begun the development of adaptation strategies, notable among them is California.[3] Local governments, including through the Metropolitan Washington Council of Governments,[4] are also beginning to take up the adaptation challenge.

Phase II

This report, Phase II of the Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change, is an important and necessary, but by no means final step, in developing a strategy. It expands upon the *Phase I* Adaptation Strategy to lay the foundation for reducing coastal vulnerability with strategies for building resilience to climate change for Maryland's citizens and ecosystems within six additional sectors. The recommended strategies, are numerous, often interrelated, and vary in level of specificity. The *Phase II* report is intended as a framework to direct state-action, engage policy-makers and stakeholders, and facilitate collaboration among federal, regional and local partners. Further detailed planning, stakeholder engagement, prioritization and sequencing by the appropriate state agencies will be required to refine and implement the strategies.

Next Steps

It is envisioned that the *Phase II* Strategy will provide the basis for guiding and prioritizing state-level activities with respect to both climate science and adaptation policy within short to medium-term timeframes (i.e., 1 – 5 years). In order to move forward, critical next steps are required along several fronts.

Disseminate

The *Phase II* report should be widely disseminated in multiple forms, including short summary brochures as well as the full report. Local governments and sector-based organization (e.g., farmers or water resource managers) should be particularly targeted for dissemination. The Maryland Smart, Green and Growing website and those of the relevant state agencies should provide links to the report summary.

Prioritize and Commit

This report is a product of the Maryland Commission on Climate Change. It is by no means, however, the final work product or strategy on climate change adaptation. It should be viewed as a "living document" that will be routinely reviewed and updated as new climate science and information becomes available and we gain a better understanding of how to adapt to climate change. The Commission, in conjunction with the responsible state agencies, should consider the strategies included herein and provide direction regarding which of the strategies are of higher priority for further development and implementation (See Implementation Guidance Table).

State agency leads, as well as internal and external partners that will be key to advancing the recommended adaptation strategies are identified for each priority recommendation. Over the next six months, the lead agencies will continue to assess, prioritize, and develop implementation plans for each suite of adaptation strategies. Detailed implementation plans will be developed and presented to the MCCC at its Spring 2011 meeting.

IMPLEMENTATION GUIDANCE

Implementation Priority: Low; Medium; High (needs immediate attention); To Be Determined (TBD)
Implementation Timeframe: Ongoing (component of existing program); Short (1-3 years); Medium (3-5 years); Long-Term (5+ years); To Be Determined (TBD)
Potential Implementation Cost: Low ($0-100,000); Medium ($100,000-200,000); High ($200,000+); To Be Determined (TBD)

Human Health

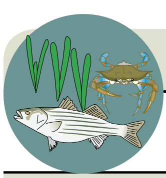
	Priority Recommendations	Lead Agency	Key Partners	Priority	Timeframe	Potential Cost
Conduct vulnerability assessments to gain a better understanding of risk and inform preventative measures.	Assess potential health threats and the sufficiency of Maryland's response capacity.	DHMH	MEMA	TBD	TBD	TBD
	Evaluate impacts to food safety and availability.	DHMH	MDA	medium	medium-term	TBD
	Assess the vulnerability of Maryland's populations and communities to changing health threats.	DHMH	MDP, MDE	medium	long-term	TBD
	Identify potential barriers to effective emergency response.	DHMH	MEMA	high	medium-term	TBD
Integrate impact reduction strategies into State and local planning practices.	Improve response capacity through the development of new or expanded programs.	DHMH	MEMA	medium	long-term	high
	Address climate-related health risks in hazard mitigation and emergency response plans.	DHMH	MEMA	medium	TBD	TBD
	Support community engagement in planning and emergency response decisions.	DHMH	MEMA	medium	long-term	TBD
	Pursue opportunities to enhance protection of Maryland's "green infrastructure".	DNR	DHMH, MDP	TBD	TBD	TBD
Streamline and revise data collection and information dissemination channels.	Improve the resolution and availability of health and population data.	DHMH	UMD, MDP, CDC, EPA	high	ongoing	high
	Analyze health and population data along with other spatially explicit information (e.g., land use, air quality, water quality).	DHMH	DNR, MDP, MDE, EPA, CDC	high	ongoing	high

Agriculture

	Priority Recommendations	Lead Agency	Key Partners	Priority	Timeframe	Potential Cost
Increase crop diversity, protect against pests and disease, and intensify water management.	Promote diversification of crop species and varieties.	MDA	UMD Extension (UME), local agricultural producers	low	ongoing	TBD
	Intensify water management and conservation through research, funding, and incentives.	MDA	UME, MDE, DNR, USDA, EPA, Bay Trust	high	ongoing	high
	Protect against incoming pests, weeds, and disease.	MDA	UME	low	ongoing	TBD
	Support innovative solutions that foster adaptation and also reduce energy costs and carbon footprints.	MDA	UME, MEA	medium	ongoing	TBD
Strengthen applied research, risk communication, and technical support	Enhance dissemination channels to improve the relay of climate information.	MDA	UME, SCDs, NRCS, NGOs, commodity orgs	low	ongoing	TBD
	Identify opportunities to support the transition of farm and agricultural practices.	MDA	UME, NRCS, Farm Credit, insurance industry	low	long-term	TBD
	Enhance emergency response and risk management.	MDA	UME, Farm Credit, insurance industry	low	ongoing	TBD
Enhance existing best management practices and land conservation targets.	Evaluate the effectiveness of BMPs under future climate change scenarios.	MDA	UMD, DNR, MDE	low	ongoing	TBD
	Assess and revise targets for agricultural land preservation.	MDA	local and regional land trusts	low	ongoing	TBD

Forests and Terrestrial Ecosystems

	Priority Recommendations	Lead Agency	Key Partners	Priority	Timeframe	Potential Cost
Expand land protection and restoration and revise targeting priorities.	Integrate climate data and models into existing resource assessments and spatial planning frameworks.	DNR	EPA, CBP, USDOI, USFWS, NGOs, NASA, NOAA	high	medium-term	medium
	Incorporate climate change adaptation strategies into State resource management plans.	DNR	MDP, EPA, CBP, USDOI, USFWS, NOAA, USFS, NGOs	high	medium-term	low
	Collaborate with federal partners to support regional and national adaptation planning.	DNR	EPA, CBP, USDOI, USFWS, NOAA, USFS, NGOs	medium	medium-term	low
	Update existing land protection targeting programs and project evaluation protocols.	DNR	EPA, CBP, USDOI, USFWS, NOAA, USFS, NGOs	high	ongoing	medium
	Develop climate change adaptation guidance and technical tools suitable for local government planning.	DNR	MDP, UME	high	ongoing	medium
Adjust management practices and reduce existing stressors.	Strengthen State and local programs to slow the loss and fragmentation of forest and terrestrial ecosystems to new development.	DNR	MDP, MDE, MDOT, USFWS, USFS, EPA, CBP, NGOs	high	ongoing	medium
	Review and revise forestry best management practices.	DNR	UME	medium	medium-term	medium
	Continue to support incorporation of the policies and strategies of Maryland's Sustainable Forestry Act of 2009 into State and local planning decisions.	DNR	State Forest Conservancy District Boards	high	ongoing	low
	Evaluate sustainable forestry certification programs for opportunities to enhance climate resilience.	DNR	Sustainable Forestry Initiative, Forestry Boards, Forest Stewardship Councils	medium	medium-term	medium
	Improve capacity to manage and respond to stressors exacerbated by climate change.	DNR	MDA, MD Invasive Species Council, Forest Health Emergency Contingency Program	medium	short-term	high
Foster stewardship on private lands.	Develop new tools to guide adaptation stewardship activities on private lands.	DNR	Forest Stewardship Councils, UMD Extension	high	short-term	medium
	Incorporate adapatation concerns into existing programs.	DNR	USFS, Forest Stewardship Councils, UMD Extension	high	short-term	medium
	Develop new conservation easement mechanisms to promote adaptation stewardship activities on private lands.	DNR	USFS, Forest Stewardship Councils, UME, MDA	high	ongoing	low



Bay and Aquatic Ecosystems

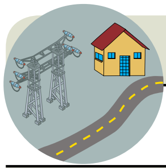
	Priority Recommendations	Lead Agency	Key Partners	Priority	Timeframe	Potential Cost
Advance protection of at-risk species and habitats.	Revise state-level protection targeting programs to reflect climate change adaptation priorities.	DNR	UMD, USACE, USGS, USFWS, NOAA, NGOs	high	ongoing	low
	Develop new protection and conservation mechanisms to promote adaptation stewardship activities on private lands.	DNR	UMD, USACE, USGS, USDOI, USFWS, NOAA, NGOs	medium	medium-term	medium
	Amend legal mechanisms to designate and protect temperature-sensitive streams.	DNR	MDE, EPA	high	ongoing	medium
	Implement an adaptive management approach.	DNR	MDE, MDOT, MDA, MDP, federal partners, NGOs	high	medium-term	low

Bay and Aquatic Ecosystems, continued

Priority Recommendations		Lead Agency	Key Partners	Priority	Timeframe	Potential Cost
Restore critical bay and aquatic habitats to enhance resilience.	Proactively pursue, design, and construct habitat restoration projects to enhance the resilience of bay and aquatic ecosystems.	DNR	USACE, USGS, USFWS, NOAA, EPA, CBP, NGOs	high	long-term	high
	Conduct an audit of state-owned lands to identify habitat restoration potential for enhancing ecosystem resilience and increasing on-site carbon sequestration.	DNR		medium	short-term	low
	Increase on-the-ground implementation of existing stream restoration practices.	DNR	USGS, EPA, CBP, USFWS	high	short-term	high
Reduce existing stressors.	Remove barriers to habitat connectivity.	DNR	MDE, USFWS, NOAA	high	ongoing	high
	Reduce impervious surface cover.	DNR, MDE	MDP	high	ongoing	high
	Prepare for new or expanding ranges of invasive species.	DNR	MDA, MD Invasive Species Council, USFWS	high	ongoing	medium
Foster a collective response to climate change.	Adjust bay and watershed restoration priorities in light of a changing climate.	DNR	MDE, UMD, NOAA, USGS, EPA, Penn State, USFWS	medium	ongoing in Coastal Plain	medium
	Integrate both adaptation and mitigation reduction strategies into natural resource management plans and programs.	DNR	USFWS, NOAA, NGOs	high	short-term	low
	Revise fishery and wildlife management to build climate resilient safeguards.	DNR	USFWS, NOAA, NGOs	high	long-term	medium
	Increase collaboration among federal, state, regional, and local climate change adaptation partners.	DNR	UMD, NOAA, USGS, EPA, NGOs	high	short-term	low

Water Resources

Priority Recommendations		Lead Agency	Key Partners	Priority	Timeframe	Potential Cost
Ensure long-term safe and adequate water supply for humans and ecosystems.	Adopt and fund the recommendations of the 2008 "Wolman Committee" report.	MDE	DNR, MDP, local governments, federal partners	high	ongoing	high
	Manage water through the lens of future climate and population.	MDE	MDP, DNR, local governments	high	ongoing	TBD
	Enhance planning and coordination within the water resource community.	MDE	MDP, local governments	high	long-term	TBD
	Encourage water suppliers to evaluate and improve their resilience.	MDE	water utilities, local governments, MEMA, EPA	high	long-term	TBD
	Promote demand management and water conservation practices.	MDE	local governments, MDA, business community	medium	ongoing	TBD
	Assess, target, and protect high quality water recharge areas.	MDE	DNR, MDP	medium	long-term	TBD
Reduce the impacts of flooding and stormwater.	Encourage the removal of vulnerable or high-hazard water supply and treatment infrastructure.	MDE	water utiles, local governments	low	long-term	TBD
	Prevent inundation and overflow of on-site disposal systems.	MDE	local governments	medium	long-term	TBD
	Revise Clean Water Revolving Fund criteria.	MDE		low	short-term	low
	Invest in an improved understanding and communication of flood probabilities and hazards.	MDE	DNR	medium	long-term	TBD



Population Growth and Infrastructure

Goal	Priority Recommendations	Lead Agency	Key Partners	Priority	Timeframe	Potential Cost
Ensure safety, clean water, clean air, and sufficient infrastructure.	Address funding and revenue constraints to ensure adequate support for current and future infrastructure needs.	MDOT, MDE	MEMA, DGS, utilities, local governments	medium	ongoing	TBD
	Conduct a comprehensive analysis of the vulnerability of Maryland's infrastructure.	MDOT, MDE	MEMA, DGS, utilities, local governments	medium	ongoing	high
	Develop a "lead by example" investment policy to guide State investments.	DNR	all State agencies	high	short-term	low
	Reduce regional air quality impacts in Maryland.	MDE	MDOT, EPA, MPOs, other states	high	medium-term	high
Plan for precipitation-related weather extremes and increase resilience to rising temperatures.	Assess the economic costs resulting from severe weather events.	MDOT	MEMA, utility providers, local governments	low	TBD	TBD
	Identify State investment needs to prepare for future weather emergencies.	MDOT, MEMA	utility providers, local governments	low	TBD	TBD
	Accelerate use of improved stormwater management strategies and environmental site design (ESD).	MDE	DGS, DNR, MDOT, UMD, local governments	high	ongoing	high
	Enhance the preparedness of transportation system and utility providers.	MDOT, MEMA	PSC, MEA, utility providers, MPOs	low	TBD	TBD
	Develop operation contingency plans for critical infrastructure.	MDOT, MEMA	utility providers	medium	ongoing	TBD
	Increase urban tree canopy.	DNR	local government	high	ongoing	high
	Strengthen building and infrastructure design standards.	DHCD	local government, MDOT, MEA, MDE, MEMA	high	ongoing	TBD
Institutionalize consideration of climate change.	Promote integration of climate change adaptation strategies into State and local policies and programs.	MDP	DNR, MEMA	high	long-term	medium
	Integrate climate vulnerability data into State and local spatial planning frameworks.	MDP	DNR	high	long-term	medium
	Consider climate change issues in combination with ongoing growth and development planning efforts.	MDP	Sustainable Growth Commission, local governments	high	short-term	low
	Explore incentives to promote sound planning practices.	MDP	MEA, UMD	high	medium-term	TBD
	Investigate the impacts of climate change on future energy needs.	DNR	MDE, MEA, MDA, DBED, MDP, MDOT	high	ongoing	medium
	Create a framework and standards for the placement and use of alternative energy.	DNR, MEA	MDE, MDA, DBED, MDP, MDOT, Critical Area Commission, UMD	high	ongoing	medium

Implementation Priority: Low; Medium; High (needs immediate attention); To Be Determined (TBD)
Implementation Timeframe: Ongoing (component of existing program); Short (1-3 years); Medium (3-5 years); Long-Term (5+ years); To Be Determined (TBD)
Potential Implementation Cost: Low ($0-100,000); Medium ($100,000-200,000); High ($200,000+); To Be Determined (TBD)

Frame

Tasks leading toward adaptation must be framed to include local, state and federal actions. The State of Maryland should strategically focus on policies, programs and actions to prepare communities and natural systems to adapt to the effects of a changing climate. Particularly important is the building of local government capacity to understand and anticipate climate change and appropriately incorporate adaptation into long-term planning and resilience of infrastructure. Maryland should identify opportunities for future cooperation and collaboration with federal partners, including the Department of the Interior's Climate Science Centers, and the National Oceanic and Atmospheric Administration Climate Service, and the the Council on Environmental Quality's Climate Change Adaptation Work Group.

Maryland should develop and implement its strategy through partnership with federal laboratories and programs based in the state, universities, stage agencies, and corporations to become a national and international center of excellence for climate change science and technology. Each of the fifty states faces its own unique set of challenges and is in the best position to assess the risk and implement solutions. The Federal Administration and Congress should recognize the primacy of states as "first responder" in protecting the health, safety and welfare of their citizens, economies, natural resources and built environments, and to leave them the autonomy to continue their leadership and be the "laboratories for innovation" in climate protection (pulled from Building a Federal-State Partnership). Fundamental to the requirements for effective adaptation is the ability to monitor, assess, and forecast climate changes. This should be provided through enhanced federal programs for integrated observation systems and climate services in partnership with the states, universities, and private sector.

As Maryland begins to update state plans, such as the State Wildlife Action Plan and the Maryland Forest Resource Assessment and Strategy to reflect climate change priorities, they should also coordinate with regional partners, including surrounding states to address needs for compatible regional approaches to species and habitat migration. Federal efforts and plans, including those developed through the Chesapeake Bay Program, and through new federal initiatives, such as the US Department of the Interior Treasured Landscapes Initiative and the US Fish and Wildlife Service's Landscape Conservation Cooperatives, should be encouraged to work closely with Maryland and its state, local and non-profit partners to reflect these adaptation strategies.

Educate

All sectors included recommendations for education. Although many concerned education of specific managers or clients, a call for broader education of the citizenry about climate change and the need to adapt was also often mentioned. The Maryland Commission on Climate Change should consider how to best advance its education agenda to fill this need. The recently funded Maryland and Delaware Climate Change Education, Assessment and Research (MADE-CLEAR) planning initiative could provide an impetus for such efforts.

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APPENDIX A: MEMBERSHIP LISTS

Maryland Commission on Climate Change

Robert M. Summers, Acting Secretary, Department of the Environment
Delegate Kumar P. Barve, MD General Assembly
Delegate Virginia P. Clagett, MD General Assembly
Alvin C. Collins, Secretary, Department of General Services
Richard Muth, Director, MD Emergency Management Agency
Christian S. Johansson, Secretary, Department of Business and Economic Development
T. Eloise Foster, Secretary, Department of Budget and Management
Senator Brian E. Frosh, MD General Assembly
Nancy S. Grasmick, Superintendent of Schools Department of Education
John R. Griffin, Secretary, Department of Natural Resources
Richard Eberhart Hall, Secretary, Department of Planning
William E. Kirwan, Chancellor, University System of Maryland
Douglas R.M. Nazarian, Chairman, Public Service Commission
Andrew Lauland, Advisor, Governor's Office on Homeland Security
Senator Paul G. Pinsky, MD General Assembly
Senator E. J. Pipkin, MD General Assembly
Beverley K. Swaim-Staley, Secretary, Department of Transportation
Earl F. Hance, Secretary, Department of Agriculture
Delegate David D. Rudolph, MD General Assembly
Raymond A. Skinner, Secretary, Department of Housing and Community Development
Elizabeth "Beth" Sammis, Acting Commissioner, Maryland Insurance Administration
Malcolm D. Woolf, Director, Maryland Energy Administration

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Adaptation and Response Chair: Secretary John R. Griffin, Maryland Department of Natural Resources

Scientific and Technical Chair: Donald F. Boesch, University of Maryland Center for Environmental Science

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*The views expressed are the author's own and do not represent official EPA policy.

APPENDIX B: MARYLAND EXECUTIVE ORDER ESTABLISHING THE MARYLAND COMISSION ON CLIMATE CHANGE

01.01.2007.07
Commission on Climate Change

WHEREAS, As reported by the United Nations Intergovernmental Panel on Climate Change (IPCC) in February 2007, there is now near universal scientific consensus that the world climate is changing, with an estimated rise in temperature between 1.98 – 11.52° F and as much as 7 to 23 inches of global sea level rise, over the next century;

WHEREAS, Human activities, including coastal development, the burning of fossil fuels and increasing greenhouse gas emissions are contributing to the causes and consequences of climate change;

WHEREAS, Maryland's people, property, natural resources, and public investments are extremely vulnerable to the ensuing impacts of climate change, including sea level rise, increased storm intensity, extreme droughts and heat waves, and increased wind and rainfall events;

WHEREAS, The effects of climate change already are being detected in Maryland, as historic tide-gauge records show that sea level has risen one-foot over the last century within State waters;

WHEREAS, Based on the current IPCC estimates and the rate of regional land subsidence, Maryland may experience an additional two to three foot sea level rise along its coast by the Year 2099;

WHEREAS, Recent State actions demonstrate Maryland's strong commitment to addressing both the drivers and consequences of climate change:

- Formulation and implementation of a State Sea Level Rise Response Strategy (2000);
- Passage of the Healthy Air Act (2006);
- Development of Maryland Transition Reports which call for State level action to address the drivers and consequences of climate change (2007);
- Passage of the Clean Cars Act (2007); and
- Participation in the Regional Greenhouse Gas Initiative (2007).

WHEREAS, It is imperative that Maryland State Government, as well as local governments, continue to lead by example in the scope and variety of services and activities that government provides and undertakes; and

WHEREAS, More must be done to reduce greenhouse gas emissions and prepare the State of Maryland for the likely physical, environmental, and socio-economic consequences of climate change.

NOW, THEREFORE, I, MARTIN O'MALLEY, GOVERNOR OF THE STATE OF MARYLAND, BY VIRTUE OF THE AUTHORITY VESTED
IN ME BY THE CONSTITUTION AND LAWS OF MARYLAND, HEREBY PROCLAIM THE FOLLOWING EXECUTIVE ORDER, EFFECTIVE IMMEDIATELY:

A. Established. A Climate Change Commission is hereby established to advise the Governor and General Assembly on matters related to climate change.

B. Tasks. The Commission shall develop a Plan of Action to address the drivers and causes of climate change, to prepare for the likely consequences and impacts of climate change to Maryland, and to establish firm benchmarks and timetables for implementing the Plan of Action.

C. Membership.

(1) The Commission shall consist of up to 21 members, including:

(a) The Secretary of Agriculture, or the Secretary's designee;
(b) The Secretary of Budget and Management, or the Secretary's designee;
(c) The Secretary of Business and Economic Development, or the Secretary's designee;
(d) The State Superintendent of Schools, or the Superintendent's designee:
(e) The Secretary of Natural Resources, or the Secretary's designee;
(f) The Secretary of the Environment,or the Secretary's designee;
(g) The Secretary of Planning, or the Secretary's designee;
(h) The Secretary of Transportation, or the Secretary's designee;
(i) The Director of the Governor's Office of Homeland Security, or the Director's designee;
(j) The Director of the Maryland Energy Administration, or the Director's designee;
(k) The Secretary of Housing and Community Development, or the Secretary's designee;
(l) The Maryland Insurance Commissioner, or the Commissioner's designee;
(m) The Director of the Maryland Emergency Management Agency, or the Director's designee;
(n) The Chairman of the Public Service Commission, or the Chairman's designee; and
(o) The Chancellor of the University System of Maryland, or the Chancellor's designee;

(2) The Speaker of the House of Delegates and the President of the Senate are invited to appoint 3 members, respectively, from the House of Delegates and Senate, to serve as members of the Commission.

D. Chair. The Chair of the Commission shall be designated by the Governor from among the members of the Commission.

E. Staff Coordination. The Department of Natural Resources and Department of the Environment shall jointly staff the Commission in coordination with other State agencies as directed by the Chair.

F. Working Groups. The Commission shall be supported by Working Groups, to be established by the Chair, as follows:

(1) Scientific and Technical Working Group.

(a) Tasks. The Working Group shall develop a Comprehensive Climate Change Impact Assessment. The Assessment should:

(i) Advise the Commission, as well as other Working Groups, on the scientific and technical aspects of climate

change;
(ii) Inventory Maryland's greenhouse gas emission sources and sinks;
(iii) Calculate Maryland's "carbon footprint" to measure the impact of human activities on the environment based on the State's greenhouse gas production;
(iv) Investigate climate change dynamics, including current and future climate models and forecasts; and
(v) Evaluate the likely consequences of climate change to Maryland's agricultural industry, forestry resources, fisheries resources, fresh water supply, aquatic and terrestrial ecosystems, and human health.
(b) Chair. The Scientific and Technical Working Group will be chaired and staffed jointly by the University System of Maryland, the Maryland Department of the Environment and the Department of Natural Resources.
(2) Greenhouse Gas and Carbon Mitigation Working Group.
(a) Tasks. The Working Group shall develop a Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy. The Strategy should:
(i) Evaluate and recommend goals that include but not be limited to the reduction of Maryland's greenhouse gas emissions to 1990 levels by 2020 and 80% of 2006 levels by 2050;
(ii) Recommend short and long-term goals and strategies that include both energy and non-energy related measures to mitigate greenhouse gases and offset carbon emissions; and
(iii) Provide a detailed implementation timetable, with benchmarks, for each recommendation and strategy.
(b) Chair. The Greenhouse Gas and Carbon Mitigation Working Group shall be chaired and staffed jointly by the Department of the Environment and the Maryland Energy Administration.
(3) Adaptation and Response Working Group.
(a) Tasks. The Working Group shall develop a Comprehensive Strategy for Reducing Maryland's Climate Change Vulnerability. The Strategy should:
(i) Recommend strategies for reducing the vulnerability of the State's coastal, natural and cultural resources and communities to the impacts of climate change, with an initial focus on sea level rise and coastal hazards (e.g., shore erosion, coastal flooding);
(ii) Establish strategies to address short and long-term adaptation measures, planning and policy integration, education and outreach, performance measurement, and as necessary, new legislation and/or modifications that will strengthen and enhance the ability of the State and its local jurisdictions to plan for and adapt to the impacts of climate change;
(iii) Work with local governments to identify their capacity to plan for and adapt to sea level rise;
(iv) Develop appropriate guidance to assist local governments with identifying specific measures (e.g., local land use regulations and ordinances) to adapt to sea level rise and increasing coastal hazards; and
(v) In consultation with the Scientific and Technical Working Group, propose a timetable for the development of adaptation strategies to reduce climate change vulnerability among affected sectors, such as agriculture, forestry, water resources, aquatic and terrestrial ecosystems, and human health.
(b) Chair. The Adaptation and Response Working Group shall be chaired and staffed jointly by the Department of Natural Resources and the Department of Planning.
(4) Additional Working Groups and/or Subcommittees to Working Groups may be created, as necessary, to accomplish the Commission mandate and Working Group Tasks.
(5) Appointments.
(a) The Chair of the Commission shall appoint Working Group and Subcommittee members who broadly represent both public and private interests in climate change, including but not limited to: Other levels of government, academic institutions, renewable and traditional energy providers, environmental organizations, labor organizations, and business interests, including the insurance industry.
(b) Working Group and Subcommittee members shall serve at the pleasure of the Commission.
(c) Working Group and Subcommittee members may not receive compensation for service.

G. Milestones.
(1) Within 60 days of the effective date of this Executive Order, the Commission shall be convened and Working Group members appointed.
(2) Within 90 days of the effective date of this Executive Order, Working Groups shall meet and establish individual work plans.
(3) Within one year of the effective date of this Executive Order, the Commission shall present to the Governor and General Assembly the Plan of Action, including the Comprehensive Climate Change Impact Assessment, the Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy, and the Comprehensive Strategy for Reducing Maryland's Climate Change Vulnerability.

H. Reporting. The Commission shall report to the Governor and General Assembly on or before November 1 of each year including November 1, 2007 on the Plan of Action, including an update on development of the Plan of Action, implementation timetables and benchmarks, and preliminary recommendations, including draft legislation , if any, for consideration by the General Assembly.

GIVEN Under My Hand and the Great Seal of the State of Maryland, in the City of Annapolis, this 20th Day of April, 2007.

____

Martin O'Malley
Governor

ATTEST:

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Dennis Schnepfe
Interim Secretary of State