
Flooding at Hains Point

Chapter 5
Climate Change Vulnerability Assessments

5.1 Introduction

State Wildlife Action Plan coordinators have been challenged with incorporating climate change impacts and species responses when updating the plans in 2015. DOEE utilized the Northeast Climate Center's draft guidelines *Integrating Climate Change into Northeast and Midwest State Wildlife Action Plans* (Staudinger et al. 2015, in review) along with several other global and regional sources to help guide and compose the climate change vulnerability assessments in this chapter.

The conservation of species threatened by climate change is, unfortunately, outside the scope of the District's conservation and climate-smart actions alone. Wildlife species face threats that are outside of the District's small sphere of influence; these threats are regional, national, international, or even global in character. However, anticipating threats and the corresponding management needs will help the District proactively face the challenges climate change presents.

5.2 Climate Change Predictions

There is overwhelming evidence and scientific consensus that the climate is warming at a rate faster than it has at any point the last millennium (Kennedy et al, 2010, Masson-Delmotte et al, 2013). According to an ongoing temperature analysis conducted by scientists at NASA's Goddard Institute for Space Studies (GISS), the average global temperature on Earth has increased by about 0.8 degrees Celsius (1.4 degrees Fahrenheit) since 1880. Two-thirds of the warming has occurred since 1975, at a rate of roughly 0.15–0.20 degrees Celsius per decade. The vast majority of the temperature change is because of human emissions of carbon dioxide and other greenhouse gases.

The global temperature record represents an average over the surface of the planet. The temperatures we experience locally can fluctuate significantly because of predictable cyclical events like time of day, season, and hard-to-predict wind and precipitation patterns. But the global temperature primarily depends on the quantity of energy the Earth receives from the Sun and how much it radiates back into space; this amount changes very little. The amount of energy the earth is able to radiate back into space depends primarily on the chemical composition of the atmosphere, particularly the amount of heat-trapping greenhouse gases.

Greenhouse gases accumulate slowly and take much longer to leave the atmosphere. Increases in fossil fuel use during the post-World War II era (5% per year), boosted these greenhouse gases in the Earth's atmosphere. According to the 2014 National Climate Assessment, the strong warming trend of the past 50 years "can only be explained by human influences," especially the greenhouse gas emissions from burning of fossil fuels and deforestation (U.S. Global Change Research Program 2014).

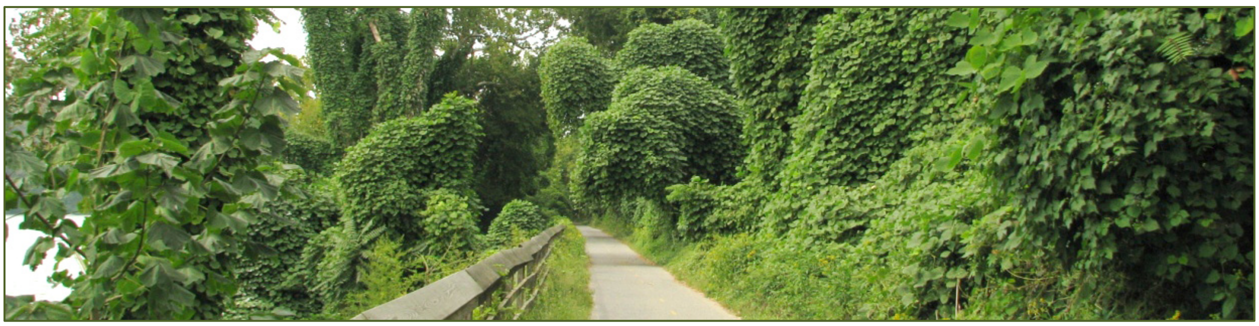
Under a "business as usual" scenario of emissions growth throughout the 21st century, global temperature is projected to rise by 3–5 degrees Celsius; under a scenario where emissions are aggressively reduced, temperature rise could likely be held in the 2–3 degree Celsius range (Collins et al, 2013). Even if emissions were stabilized, warming and sea level rise would continue for centuries owing to time lags in climate system feedbacks and also because once greenhouse gases are emitted, they remain in the atmosphere for decades to centuries (Solomon et al. 2009).

5.3 Global Predictions

Numerical models (General Circulation Models or GCMs), representing physical processes in the atmosphere, ocean, cryosphere and land surface, are the most advanced tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations. Only GCMs, often in conjunction with nested regional models, have the potential to provide geographically and physically consistent estimates of regional climate change which are required in impact and vulnerability analysis. Downscaling coarse climate projections to finer spatial resolution is increasingly being used to better align the scale of projections with the scale of land management processes and decisions. These climate projections, or climate scenarios, are valuable for considering the direction and magnitude of potential changes and prioritizing locations for adaptation actions. Downscaling climate projections to a spatial resolution relevant to manageable units allows decision-makers to better visualize what these different futures imply locally and regionally.

However, these projections are based off of many scenarios of future emissions and different models of the climate. Rather than impossibly attempting to identify the "most accurate" climate scenario, it is often beneficial to explore the maximum possible range of projected variability through the use of multiple climate scenarios. This allows us to identify where these scenarios are in agreement and the range of possible future conditions. Regional assessments of the "trends" of these models are the starting point for most land managers.

5.4 Regional Predictions



Regional assessments of projected climatic trends and impacts are rapidly proliferating throughout the United States. Leading sources include National Oceanic and Atmospheric Administration (NOAA) funded Regional Impact and Science Assessment groups and some states, such as Virginia, have funded climate impact assessments through universities. The Department of the Interior and some landscape conservation cooperatives have initiated numerous regional assessments that are compiling information on regional climate projections and impacts. Nearly all of these impact assessment programs are sources of climate projection information for individual regions.

Because of the small size and limited resources of the District of Columbia, DOEE is utilizing the vast amount of publically available data, projections and predictions, report, studies, and guidelines currently available for the District, Maryland, and Virginia. The following is a list of the primary bodies of work DOEE used to compile the climate change predictions and threats cited in this chapter:

- Virginia's Climate Modeling and Species Vulnerability Assessment: How Climate Data Can Inform Management and Conservation. (Kane, et al 2013).

- Summary of Potential Climate Change Impacts, Vulnerabilities, and Adaptation Strategies in the Metropolitan Washington Region: A synopsis of lessons learned from the Metropolitan Washington Council of Governments' climate adaptation planning initiatives from 2010–2012. (Metropolitan Washington Council of Governments. 2013).

- Building a Climate Resilient National Capital Region Federal and community agencies working together on climate preparedness and resilience. Summary of Climate Change Vulnerability and Adaptation Workshop Results Built Systems:

September–December 2013 Workforce, Community and Natural Systems: February–April 2014.

- Integrating Climate Change into Northeast and Midwest State Wildlife Action Plans. USGS Cooperative Report. (Staudinger, Morelli, and Bryan. 2015. In review).
- Climate Projections & Scenario Development: Climate Change Adaptation Plan for the District of Columbia. Department of Energy and Environment (2015 expected). Prepared by AREA Research, Kleinfelder, & Perkins+Will. Under review.
- The Vulnerabilities of Fish and Wildlife Habitats in the Northeast to Climate Change. A report to the Northeastern Association of Fish and Wildlife Agencies and the North Atlantic Landscape Conservation Cooperative. (Manomet Center for Conservation Sciences and National Wildlife Federation. 2013).

5.5 Climate Change Threats to the District of Columbia Region

Projections consistently show continued warming over the next century across all 22 states included in the Northeast Climate Science Center region (Hayhoe et al. 2007, 2008; Rawlins et al. 2012; Kunkel et al. 2013). This region includes the District of Columbia.

In general, the following trends have a high level of model agreement (i.e., there is a measure of confidence in their occurrence) across many emission scenarios for the region area as time progresses:

- Warming is occurring in every season.
- Heatwaves are becoming more frequent, more intense, and lasting longer.
- Precipitation amounts are increasing, particularly in winter and with respect to high-intensity events in summer.
- Snow is shifting to rain, leading to reduced snow packs and extent of snow cover.
- Atmospheric moisture is increasing.
- Wind speeds are declining, though wind gusts may intensify.

- Soil moisture and evapotranspiration trends are neither robustly observed nor consistent amongst modeling studies.
- Streamflow patterns may be intensifying with heavier rainfall events.
- Streams are warming.
- Severe weather may become more severe.
- Floods are intensifying and occurring more often with heavier rainfall events, yet droughts are also on the rise as dry streaks between events get longer.
- Growing seasons are getting longer, with more growing degree days expected.
- Sea level is rising at an accelerating rate.
- Tropical cyclones and hurricanes are intensifying and storm tracks are shifting northward along the coast.
- Oceans are warming and becoming more acidic.

Given all of these regional threats, the District of Columbia is obviously vulnerable to a range of issues including extreme temperatures, heavy precipitation, and sea level rise. These changes are likely to cause widespread ecosystem disruption (Kopp et al. 2014).

5.5.1 Temperature

There is potential for the District to experience an increase in frequency, magnitude, and duration of heat waves (Meehl and Tebaldi 2004). Winter minimum temperatures are projected to rapidly rise, reducing the frequency of extremely cold days. Such, increases in temperature will negatively affect wildlife habitats and SGCN.

Pyke et al. (2008), as a part of the Chesapeake Bay Program Science and Technical Advisory Committee, projects that temperatures in the Chesapeake Bay region may increase by as much as 11 degrees Fahrenheit by 2100. In the past in the District (1981–2000), there has been an average of 11 days per year exceeding 95 degrees Fahrenheit. Researchers at AREA research projected that the District will have an average of 18–20 days exceeding 95 degrees Fahrenheit per year by 2020, 30–45 days exceeding 95 degrees Fahrenheit per year by 2050, and as many as 40–70 days exceeding 95 degrees Fahrenheit per year by 2080. Ultimately, these changes in air temperature along with more concentrated precipitation regimes could result in drier, more drought-prone summers.

Most models predict the greatest warming to occur during summer, with maximum potential increases for the region ranging from 6 to 10 degrees Fahrenheit by the 2080s, and an increase in extremely warm days, clustered in the summer months, under conditions of modest winds. The timing of this warming is significant not only because it would increase evapotranspiration and decrease soil moisture, but also because it would result in warmer water temperatures in the bay and surrounding waters during the time that hypoxia is most prominent.


Snowy owl in downtown Washington, DC

Increased temperatures may lead to heat stress for species, decreased water quality and dissolved oxygen content as well as changes to food availability (Boicourt and Johnson, 2010; Kane, 2013). Temperature increases may also be problematic for species at the edge of their ranges. For example, if species are at the more southern end of their range and unable to migrate, they may not survive significant increases in temperature that are greater than they can withstand (Pyke et al. 2008). Warmer temperatures may also result in warmer waters, which could favor parasites and other pests in aquatic environments (Pyke et al. 2008; Najjar et al. 2010; Kane 2013).

Warming temperatures will also lead to changes in plant phenology, as has already been observed (Primack et al. 2004, Miller-Rushing and Primack 2008). These changes may have significant impacts on ecosystems by changing existing natural land cover types and by allowing for the spread of pests into previously unaffected regions.

5.5.2 Precipitation and Severe Storms

Precipitation trends are hard to constantly model because of the complexity of pattern and the District is in a transition zone between a predicted drier south and wetter northeast. From 1950 to 2008, the region has experienced a slight increase in average annual precipitation (Davis and Campbell 2013). In general, the region is projected to have less precipitation in the summer but more in the autumn by 2080. Regional models suggest precipitation will be concentrated in fewer events, and there will be an increase in intensity of coastal storms. These two threats will likely lead to an increase in flooding (see Figure 24). When predictions were done specifically for the District, these patterns for the smaller area of the District mimicked the patterns of the region as a whole.

Flooding will become increasingly problematic if precipitation continues to fall in heavier events, sea level rises, and storms intensify. Flooding is also heavily influenced by the amount and type of development, shore protection measures, site and building design, storm water drainage infrastructure, and other flood mitigation measures.

The Potomac and Anacostia rivers' overbank flooding originates from precipitation in the river basins; storm surge is caused by coastal storm dynamics. Both have major implications for the wildlife habitat in the District. This threat will be compounded by the impact of high levels of impervious surface. These predictions imply that a greater amount of surface water, often laden with pollutants, will arrive into the Potomac and Anacostia Rivers at a faster rate. These storm surges and flooding events will likely lead to a degradation of water quality and changes in hydrology, habitat structure, and aquatic biodiversity.

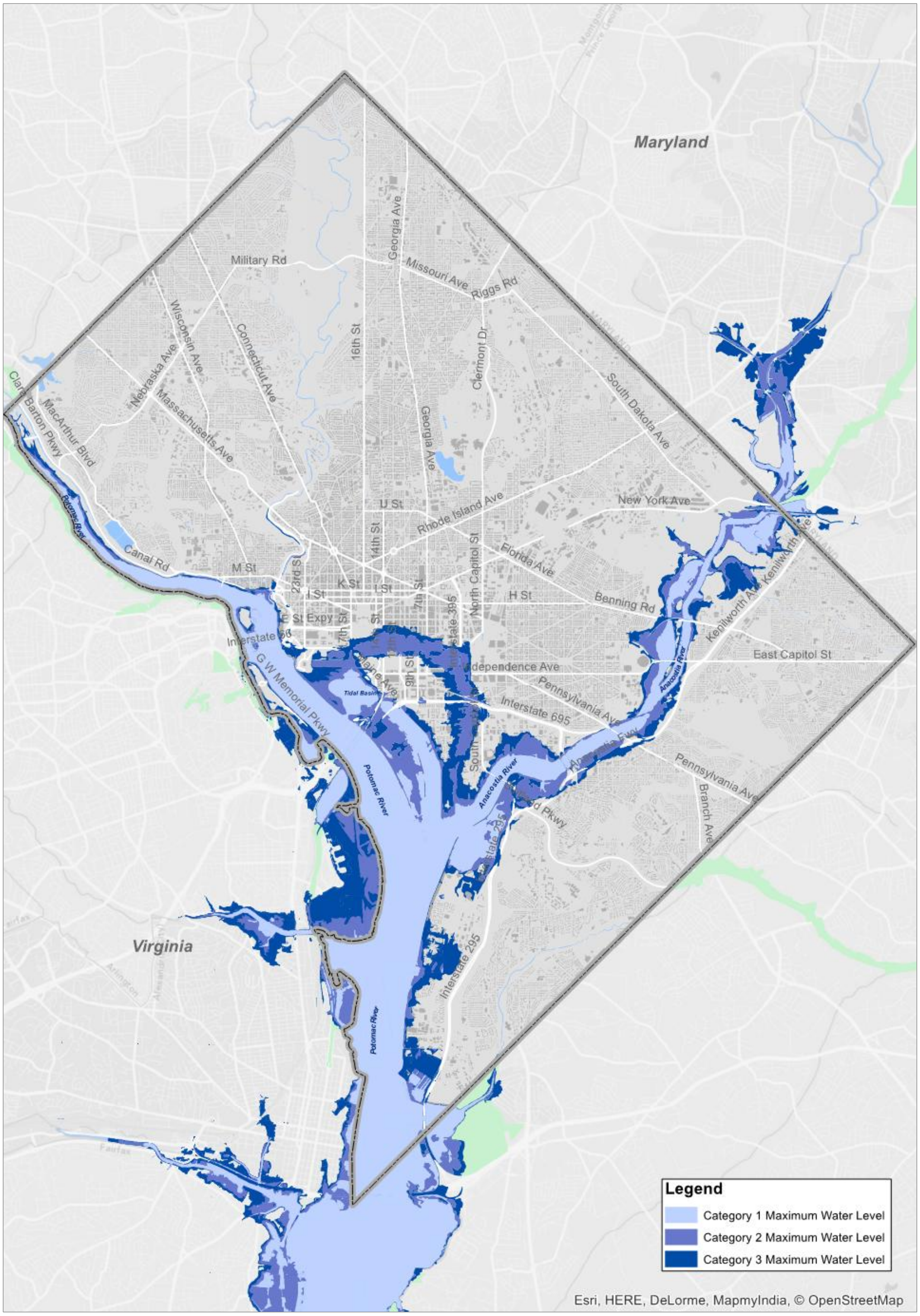


Figure 24 Sea, Lake, and Overland Surges from Hurricanes (SLOSH) hurricane storm surge inundation predictions for Washington, DC for present-day Category 1, 2, and 3 storms (North Atlantic Coast Comprehensive Study data).

5.5.3 Sea Level Rise

The Potomac and Anacostia rivers are tidal water bodies that run through the core of the metropolitan Washington region. Sea level rise over the last century on the Potomac River in Washington, DC is approximately one foot, over a third of which is due to subsidence.

The Chesapeake Bay has also already experienced 1 foot of sea level rise over the last century and is expected to experience up to 5 feet of sea level rise by 2100 (U.S. Army Corps of Engineers 2015). This includes local geological land subsidence. Future sea level rise in the District will depend on increases in future emissions and the rate at which ice melts globally. However, the Virginia Institute of Marine Science (VIMS) (2013) used climate scenarios from the Intergovernmental Panel on Climate Change to determine a range of sea level rise projections for Virginia. Based on that analysis, VIMS recommends planning for 1.5 feet of sea level rise over the next 20 to 50 years. Specific projections for the District indicate a relative sea level rise that ranges from 0.6 to 1.9 feet by 2050 and 0.9 to 3.8 feet by 2080 (DOEE 2015a). That research also supports the prediction that tropical storm events are expected to become more intense. Sea level rise and more intense storm events are expected to increase shoreline erosion, facilitate salt water intrusion, destroy habitats and ecological systems, and increase storm water overflows and sewage contamination.

As sea levels rise, marshes can be inundated and converted to shallow open water habitats or nontidal and brackish wetlands may convert to higher salinity marshes. As a result, vegetative composition will change, affecting the wildlife species that depend on these habitats. Additionally, as storms become more intense, more frequent inundation may also pose problems for vegetation and fish and wildlife species with low salinity tolerances.

DOEE used the Sea Level Affecting Marshes Model (SLAMM) to simulate impacts from sea level rise in the District region (Clough et al. 2012). DOEE was specifically interested in identifying major transitions and areas of concern for the Potomac and Anacostia Rivers. As expected, some of the primary habitats these will impact are the tidal and nontidal wetlands and forests adjacent to the rivers and some additional impact in the reaches of Rock Creek. Specifically, SLAMM predicted (2.3 feet by 2100) increases in tidal marsh and regularly flooded areas in the National Arboretum, Kenilworth Park and Aquatic Gardens Park, Anacostia Park, and lower Rock Creek. This does not include stochastic storm surge impacts, which could have devastating effects on the river ecosystems around the District. Output from a similar model used in the North Atlantic Coast Comprehensive Study (U.S. Army Corps of Engineers, 2015) is shown in Figure 25.

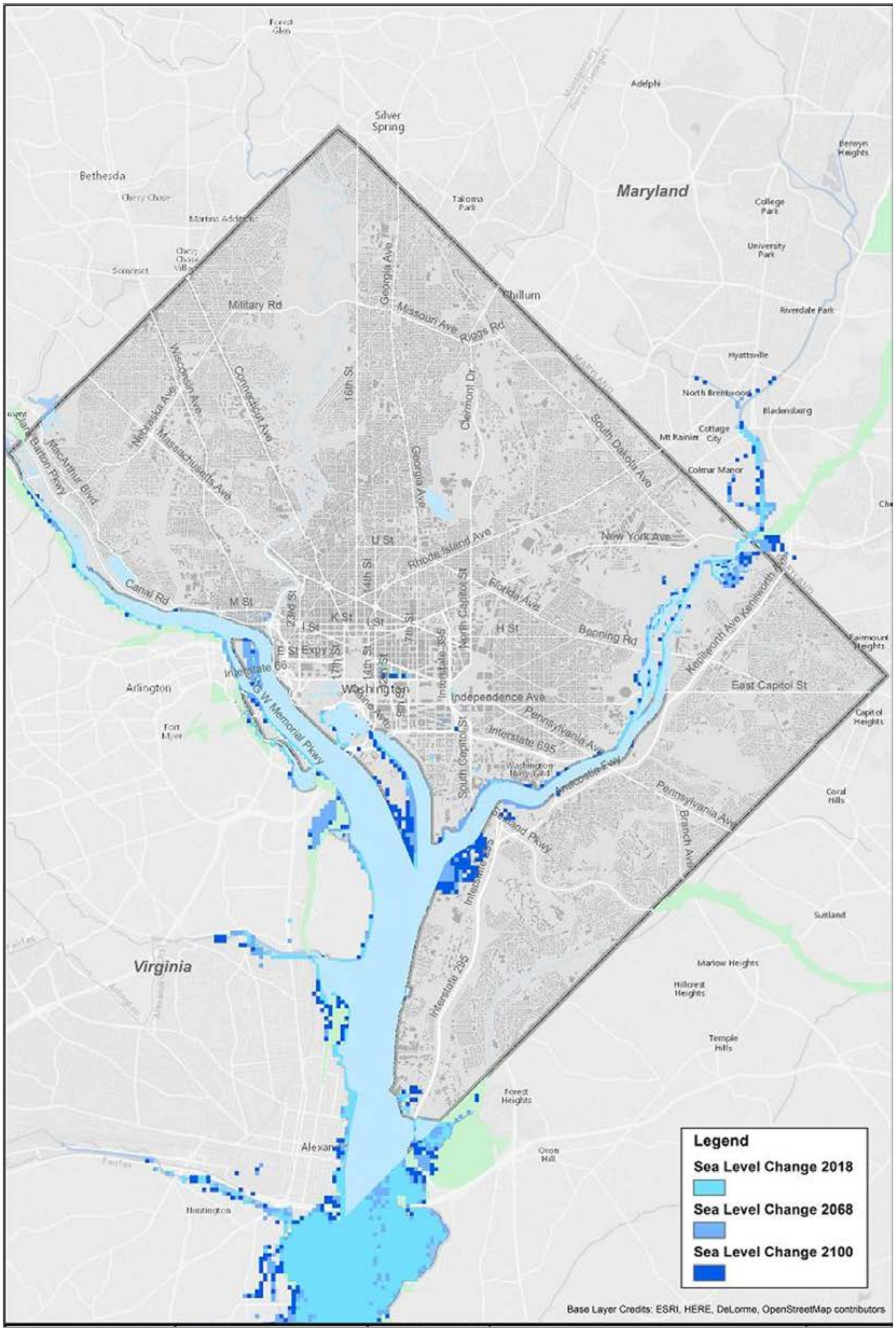


Figure 25 Relative sea level rise inundation predictions in Washington, DC from the North Atlantic Coast Comprehensive Study (U.S. Army Corps of Engineers). High sea level rise scenario for years 2018, 2068, and 2100.

5.6 Species and Habitats at Greatest Risk and Most Vulnerable to Climate Change

This section outlines the major implications of climate change on the District's SGCN and critical habitats. DOEE recognizes that habitat and species are vulnerable to climate change, but any analysis of threats must take into account the geographical context. The District has very small amounts of wildlife habitats and small wildlife populations in comparison to the entire northeast region. Regardless, it is beneficial to identify expected changes and threats to the habitats and wildlife that do exist in the District. While it may not be feasible to significantly mitigate climate change impacts due to the District's size and urban character, understanding the threats and prioritizing any potential mitigation is still important.

DOEE identified several habitats and several species on which to focus climate vulnerability assessments. These are species and habitats that may be disproportionately impacted by the threats of climate change. As more climate projection data becomes available DOEE may further expand these vulnerability analyses and consider additional species.

5.6.1 Habitats

To assess changes to habitats, DOEE reviewed and summarized the major ecosystems and land cover types identified by the Manomet Center for Conservation Science's report entitled "The Vulnerabilities of Fish and Wildlife Habitats in the Northeast to Climate Change" (MCCS and National Wildlife Foundation (NWF) 2013) and investigated the fates of specific tree species in the U.S. Forest Service's Tree Atlas program (Landscape Change Research Group 2014) to assess specific forest changes in the District.

Upland Forests

Based on the work of Hector Galbraith and others (MCCS and NWF 2013), there are two general types of forest land cover that are vulnerable within the District: Northern Hardwood forests and Central Mixed Oak-Pine forest, ranging from highly vulnerable to vulnerable, respectively. These two categories are analogous to the Macrogroups presented in Chapter 3. Northern Hardwood Forest habitats are distinct by region and occur in many different forms across the northeast region and overall floristic composition varies with location and specific site conditions. For example, the Macrogroup contains Habitat Systems common to both the oak-hickory forests of the south and the boreal forests of the north. Central Mixed Oak-Pine forests are also comprised of many different varieties, depending on soil, climate, slope, and land use history. In comparison with Northern Hardwood forests, Central Mixed Oak-Pine forests are typical of warmer climatic conditions and a longer growing season. They generally occur further south, on sunnier, warmer south- or west-facing slopes, and at lower elevations than Northern Hardwoods (Collins and Anderson 1994, Fike 1999, Thompson and Sorenson 2000, Edinger et al. 2002, Harrison 2004, Sperduto and Nichols 2004, Virginia Natural Heritage Program 2011).

DOEE utilized the Tree Atlas program (Iverson et al, 2008) to help identify potential changes to specific forest species. The primary areas with these forest types in the District occur in Rock Creek Park, Fort Dupont Park, the National Arboretum, Glover Archibold Park, and areas along the Potomac River. Tree Atlas projected a decrease in flowering dogwood (*Cornus florida*), white oak (*Quercus alba*), and northern red oak (*Quercus rubra*). In general, we expect to see encroachment by heat-tolerant pine species in both forests, but Northern Hardwood forests will be the most vulnerable.

Based on regional predictions, while there may not be drastic changes in forest structure, there will likely be an increase in heat-tolerant conifer species in both forest types and a potential shift to oak-pine forest in some areas (Prasad et al. 2007).

Tidal Wetlands/Vernal Pools/Riparian Forests

The health and quality of tidal and nontidal wetlands will be affected by climate change. As the quality of a wetland degrades, so does the value of that wetland to the District's wildlife. More precipitation can lead to increased erosion and sedimentation and thus adversely affect priority habitats such as submerged aquatic vegetation and species of greatest conservation need that are dependent on them (e.g., the Queen snake).

As sea levels rise, marshes can be inundated and convert to shallow open water habitats or nontidal and brackish wetlands may convert to higher salinity marshes. These new shallow water habitats and higher salinity marshes will not support the same vegetative composition as the existing nontidal and tidal wetlands in the District, which will affect the wildlife that depend on these habitats. Additionally, as storms become more intense, more frequent inundation may also pose problems for vegetation and fish and wildlife species with low salinity tolerances.

Vernal pools or ephemeral wetlands are important temporary wetlands that support a wide variety of macroinvertebrates and provide breeding grounds for amphibians, such as the wood frog. These pools are typically precipitation-filled, and their hydrology is dependent on precipitation and evaporation. These characteristics make them sensitive to climate and climate change. Vernal pools will likely be impacted by higher temperatures and longer durations between rain events, which will directly, negatively impact the populations that depend on these pools.

Meadows

Changes in temperature and precipitation regimes could negatively affect meadows as temperatures increase and summers become drier and more drought prone. However, research is showing that many meadow plant species are already relatively drought tolerant. Shrublands and meadows may not be as affected by climate change as other habitats if they can maintain their diverse composition of vegetation species (Craine et al. 2012). It is important to note that meadows may succumb over time if there is extended, severe drought (Craine et al. 2012). To maintain diversity and help build resiliency in meadows within the District, it will be important to implement any management options available to support these habitats.

5.6.2 Species

For the in-depth vulnerability consideration for SGCN, DOEE considered Tier 1 SGCN. Of those Tier 1 species, DOEE identified several SGCN that could be disproportionately impacted by the threats of climate change. This was based on range, habitat need, life history, available data, and professional consensus. For example, if species are at the southern end of their range, they may not survive significant increases in temperature (Pyke et al. 2008). Also, if a species is a habitat specialist or dietary specialists, or is dependent on habitats that will likely change greatly due to climate change, they are at greater risk (Both et al. 2009; Glick et al. 2011; Bellard et al. 2012; Lurgi et al. 2012; Staudinger et al. 2013; Pacifici et al. 2015). However, if a species is in the heart of its range in DC, it is more likely to persist, especially if the probability of its occurrence is high.

Once these species were selected, we attempted to evaluate general vulnerability by identifying how each species might react, based on their exposure, sensitivity and adaptive capacity (Staudinger et. al. 2015). DOEE use a peer-reviewed literature search, species vulnerability models, such as NatureServe's Climate Change Vulnerability Index (CCVI) (Young et al. 2011, Faber-Langendoen et al. 2012), and expert opinion. The CCVI, as applied to the selected species, resulted in a variety of predictions, all of which reflected increased vulnerability. This was not surprising given the fact that we selected species that had specific life-history trait that would be impacted by climate change. Because of these generalizations, we choose to assign two categories: Vulnerable or Highly Vulnerable. The assessment of vulnerable indicates we think that abundance and/or range within the District will likely decrease by 2050. The assessment of highly vulnerable indicates we think that abundance and/or range within the District will likely significantly decrease by 2050.

Herpetofauna

Freshwater turtles are perhaps the best studied taxonomic group in terms of response to climate change. They will be affected by climate change in a variety of ways, but most impacts are from changes in water temperature and flow. The turtle we selected for vulnerability consideration was the spotted turtle (*Clemmys guttata*) because of severe weather predictions and changes in hydrology in the District. We consider the spotted turtle highly vulnerable to climate change because of the potential for increased flooding which may displace large parts of populations, elevate mortality rates, and decrease breeding success.

The queen snake (*Regina septemvittata*) was selected and ranked as highly vulnerable to climate change because of its direct, documented dependence on clean running streams and watersheds with cool water. The specificity surrounding the habitat requirements of water quality, temperature, and substrate make this designation reasonable. The habitat requirements are directly related to their primary prey, fresh water crayfish.


Spotted salamander egg mass

Amphibians are particularly susceptible to the effects of changing climates because of their restrictive physiological requirements and low movement ability. We selected two amphibians for climate change vulnerability assessment: spotted salamander (*Ambystoma maculatum*) and wood frog (*Lithobates sylvaticus*).

Based on our expert opinion and the CCVI, both amphibians were assessed as highly vulnerable because of their close association with vernal pools or ephemeral wetlands and adjacent upland forest. This designation was primarily based on potential future changes in precipitation and overall hydrologic regimes. Changes in precipitation and vegetation can both significantly impact the vernal pools and ephemeral wetlands these species utilize for breeding. Plants, especially trees, influence vernal pool water levels through transpiration and by creating shade which slows evaporation and moderates pool temperatures. Therefore, any climate-induced change in the timing and duration of leaf-on in the deciduous vegetation will likely have an effect on ground water patterns. This could change how and when the areas refill with water, which will in turn affects salamander reproductive success. Additionally, an increase in the magnitude, frequency and/or change in the timing of major storm events in the late summer or early fall may adversely affect breeding conditions, by causing the areas to fill prematurely. Lastly, higher temperatures may cause drying through evaporation before the eggs have hatched.

Birds

Massive modeling projects and demographic analyses have been done by many different organizations and agencies to attempt to quantify what the bird world will look like as the climate warms. For example, Audubon scientists have used hundreds of thousands of citizen science observations and sophisticated climate models to predict how birds in the U.S. and Canada will react to climate change (National Audubon Society 2014). For many species that have the southernmost edge of their summer range near Maryland and Virginia, the changing climate will likely push the range of these birds farther North. The American kestrel (*Falco sparverius*), scarlet tanager (*Piranga olivacea*), veery (*Catharus fuscescens*), bobolink (*Dolichonyx oryzivorus*), and the Baltimore oriole (*Icterus galbula*) are a few such birds.

Allowing for migration in this one instance, the bird we selected for vulnerability consideration was the wood thrush (*Hylocichla mustelina*). In the late 20th century, the wood thrush was commonly investigated to determine the health of Eastern forests. Nest parasitism, nest predation, and habitat fragmentation were commonly cited as the reasons for the bird populations' sharp decline. DOEE predicts that the wood thrush will be highly vulnerable to climate change, and in fact, the Audubon's climate model projects an 82% loss of its current summer range by 2080. This species favors areas with moist soil and high understory cover. Therefore, continued persistence of wood thrush in the District is likely to depend solely on forest composition and forest health (see Upland Forest). Climate change likely threatens the wood thrush primarily through increasing temperatures, which decreases soil moisture and alters forest vegetation.

Small Mammals

Mammals represent a diverse group of vertebrates in the District with respect to range of habitats occupied, dispersal ability, and body size. Mammals occupy both aquatic and terrestrial habitats; while only the bats are capable of flying, none of the mammal species have restricted dispersal ability as defined by the CCV index. However, some small mammal species, such as shrews, are physically limited by the urban character of DC, and tend to move more when it rains. Other small mammals are dependent on rain events for dispersing. Therefore, changes in rainfall and extreme rain and storm events can have a detrimental effect on small mammal populations, and thus overall diversity, potentially favoring particular species (Pauli et al. 2006). Because of these issues, we selected the northern short-tailed shrew (*Blarina brevicauda*) and the meadow vole (*Microtus pennsylvanicus*) for vulnerability assessment. The meadow vole's optimal habitat consists of moist, dense grassland with substantial amounts of plant litter. Habitat selection is largely influenced by relative ground cover of grasses and forbs; soil temperature and moisture. Unfortunately, open meadows in the district are already stressed with high rates of invasive species and flashy hydrology. Climate change will likely aggravate those conditions further. Climate change threats will likely impact the meadow vole population through loss of soil moisture from higher temperatures and vegetation changes in their primary habitat. Similarly, the northern short-tailed shrew prefers mesic soils and leaf litter with natural land cover. As periods of drought extend, soil moisture will likely decrease, resulting in a reduction of the shrews' prey base, primarily insects, earthworms, voles, snails, and other shrews. For these reasons, DOEE designated both mammals as vulnerable.

5.7 General Biological Responses, Adaptations, and Actions for SGCN and Their Habitats

5.7.1 General Actions

DOEE will prioritize areas with high ecosystem services and habitat value for restoration and/or protection such as stream buffers, wetlands, open meadows, and forest. All of these habitats are vulnerable and given the lack of natural land cover in DC, it is crucial that we protect what is there and restore what we can. Climate-smart management actions are presented here within the context of habitats management only. Each species assessed will be addressed under their respective land cover/habitat type.

5.7.2 Upland Forests

To best manage forest as the climate changes, it will be imperative to understand how climate may affect potential future composition of forests in the District and how that may affect SGCN. Managers must routinely consult recently available climate data through programs such as the U.S. Forest Service's Tree Atlas when planning management and conservation of these forests. Primary management of forested lands within the District should focus on forest health, promoting the protection of private forested land, and reestablishment of forest when appropriate. In regards to forest health, conservation and management efforts may need to focus on trees that can better withstand higher salinities, increased temperatures, and drought, among other impacts. Invasive species monitoring and prevention will also become even more important to include in forest management as climate change may favor vine growth, tree pests, diseases, and invasive species. Protection of private forested lands through incentive programs and incentives such as present use value tax status, forest mitigation bank programs, or transfer of development rights is crucial (Davis and Campbell 2012) and should be promoted. These types of actions will be some of the only options for managing for species such as the wood thrush.

5.7.3 Wetlands/Vernal Pools/Riparian Forests

Wetland habitats are the primary land cover type and habitat used by the majority of the species we selected for vulnerability consideration. The queen snake, spotted turtle, wood frog, and spotted salamander all fall under consideration when managing these types of areas.

When feasible, DOEE will restore and enhance vegetation within existing wetlands to support changing conditions (e.g., using vegetation species that can withstand a broader array of conditions like more frequent inundation and higher salinity levels).

When planting, restoring, or maintaining riparian buffers, managers will attempt to plant only native tree and shrub species that can tolerate flood conditions, and inundation tolerance will be considered when selecting plant species. Because sea level rise will likely be an issue in many of these areas, vegetation species that have a broader salinity tolerance should be considered. Furthermore, shading species (to reduce water temperatures) must be included when working in riparian areas.

Additionally, considering native species that may provide better erosion control (broader, deeper roots) than other species also could be used. Techniques and tools may be needed (e.g., fencing, biomats, etc.) to ensure success. Minimizing impervious surface will be even more important under climate change as increased storm intensity will result in increased levels of storm water runoff. Improving stormwater control methods, to ensure they account for predicted changes in precipitation and flow, will help minimize the future impacts of stormwater as the climate warm (Kane, 2013).

5.7.4 Meadows

DOEE must work to protect, preserve, and create large tracts of open meadow habitats that provide refugia for many SGCN. Focusing on removing non-native species and ensuring a diverse mix of plant species will ensure that species such as the meadow vole and northern short-tailed shrew. Although the shrew often uses a variety of habitats, grasslands are one of its preferred habitat types. Both species depend on moist, healthy soils. The more diverse, healthy, and abundant the meadows are in the District, the more likely these and other SGCN will have the resilience to persist in the District.