Chapter 5

Threats to Maryland's Wildlife Species and Their Habitats

MARYLAND
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MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

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Introduction

Many challenges confront fish and wildlife populations. Threats to these populations can be local, statewide, regional, national, or global in scale. This chapter and the next provide information about key threats (**Element 3**) identified by MD DNR and its partners. The subsequent chapter then describes conservation actions (**Element 4**) to address these threats in Maryland and the other states of the Northeast region. State Wildlife Action Plans (SWAPs) are required to identify "problems which may adversely affect species of conservation need or their habitats" (Association of Fish and Wildlife Agencies [AFWA] 2012). These "problems" include threats that stress wildlife species and habitats, as well as management challenges such as deficiencies in data or resources for particular species or habitats. Human activities and natural processes that affect wildlife species and habitats in negative or detrimental ways are termed "threats or stressors", while the effects of these threats on particular wildlife species or habitats are known as "stress responses". Threats may be direct, affecting a species or habitat directly, or indirect, affecting a species or habitat through one or more intermediary actors or processes. Although these terms are often used interchangeably, the word "threat" is used in this document to refer to all aspects of the process by which human actions or natural events may jeopardize wildlife species and their habitats, including all of the terms described above (Terwilliger & NEFWDTC 2013). Scientific names for Species of Greatest Conservation Need (SGCN) are included in Appendices 1a and 1b. Scientific names for other species are included in the text of the chapter.

Regional Threats

There is no comprehensive assessment of threats across the Northeast region. However, numerous threats to fish, wildlife, and their habitats were identified by the Northeast states as part of their individual 2005 Wildlife Action Plans. The 13 Northeast states and the District of Columbia identified 37 common, recurring threats to SGCN or their habitats (AFWA unpublished data, 2011). The threats most frequently mentioned by Northeast states included invasive species (mentioned by all Northeast states) and industrial effluents, commercial and industrial areas, housing and urban development, and agricultural and forestry effluents (mentioned by at least 83% of Northeast states). Other important challenges mentioned by 50% or more of the Northeast states included dams and water management, habitat shifting and alteration, recreational activities, roads and railroads, storms and flooding, temperature extremes, logging and wood harvesting, problematic native species, harvest or collection of animals, lack of information or data gaps, and droughts. In addition to the specific threats mentioned in the 2005 Wildlife Action Plans, recent work by the Northeast states has emphasized the extreme importance of additional threats such as climate change, exurban developments, new invasive species, and wildlife diseases (Terwilliger & NEFWDTC 2013).

A Brief History of the Loss of Species and Wildlife Diversity

Landscapes are dynamic, shifting constantly due to storms, floods, fires, and other natural processes that can cause habitat change. In addition, habitat changes as a result of human activity have occurred for thousands of years. Native Americans in Maryland burned areas for hunting and cleared land for agriculture and settlements. It is likely that their strategy was to maintain openings in areas naturally predisposed to fire (Pyne 1982) or otherwise able to be maintained. Although landscape changes have always been part of natural ecological processes, the colonization of Maryland in 1634 and subsequent new settlements by European immigrants modified the ecological balance drastically due to the rapid increase and scale of human-related activities, creating difficulties for species and systems trying to acclimate to such rapid changes and altering traditional Native American presence and influence on the landscape. As a result of European settlement, Maryland's native forests, grasslands, and wetlands were affected at a larger scale and in new ways, and these changes in turn affected wildlife populations. Forests were cleared to make way for crops and livestock and to provide wood for construction and fuel; this happened over increasing acreage of Maryland as new settlements expanded inland from the coast. Competition from non-native European species began when colonists brought plants and animals from their homelands, both purposefully and accidentally. Livestock grazed on native grasslands and marshes, and the gradual conversion of native habitats to accommodate the settlers came at the expense of wildlife populations as well as Native American cultures.

European settlers heavily utilized many wildlife species for food and clothing. Wild turkey (*Meleagris gallopavo)*, passenger pigeon *(Ectopistes migratorius)*, and white-tailed deer *(Odocoileus virginianus)* were hunted extensively for food, while other species, such as the now extirpated mountain lion *(Puma concolor couguar)* and timber wolf *(Canis lupus)*, were killed to reduce livestock losses or to reduce crop damage. American beaver *(Castor canadensis*) and other furbearing mammals were trapped for their valuable fur. Small game and songbirds were regular sources of food for the expanding human population in Maryland. Market hunting of waterfowl and other wildlife in the 1800s was a common event that supplied the growing cities of the Northeast with fresh meat. Fish, shellfish, and other aquatic species were harvested in increasingly large quantities.

With the industrial revolution came a slew of additional threats to Maryland's natural lands. New sources of pollution degraded Maryland's streams and waterways while booming industries logged remaining forests to produce lumber and charcoal and extracted coal to power factories and railroads. Farming communities ditched wetlands to enhance agricultural production. Various commercial interests dug canals for commerce and transportation; dammed rivers for water supplies, flood control, and power plants; and dredged channels through the estuaries to enhance shipping ports. Transportation authorities cut highways through mountains, and road networks increasingly fragmented habitats.

The combination of loss and degradation of habitat, increased subsistence and market hunting, and vermin control resulted in highly diminished wildlife populations throughout the state by the early 1900s. Some species disappeared from Maryland, and a few of these even became extinct range-wide. Elk, bison, wolves, and cougars have disappeared from the state, while the passenger pigeon and Carolina parakeet are now extinct everywhere. Some species benefited from the changes to the Maryland landscape, though these were outnumbered by the number of species that declined.

Many of these same alterations to our environment have continued through modern times, exacerbated by Maryland's ever-growing human population. As our human population burgeons and land use pressures intensify, it is increasingly important that we protect our vanishing native species and their habitats. There is clear consensus that the loss and degradation of habitats across the state from unplanned growth and unsustainable consumption remain the primary overarching threat to Species of Greatest Conservation Need, as is true nationwide (Trauger et al. 2003).

Examples of Current Threats

A number of problems threaten Maryland's fish and wildlife resources and their habitats. Many of these threats are statewide, regional, or even global in scope, while other threats affect singular species or key habitats. The 2014 Global Biodiversity Outlook cites threats to global biodiversity as invasive species introduction and domination, climate change and ocean acidification, habitat loss and fragmentation, and human disturbance (Secretariat of the Convention on Biological Diversity 2014). The Center for Biological Diversity (2011) lists the following as among the greatest threats affecting imperiled or federally-listed species in Maryland: habitat degradation and loss, climate change and anthropogenic greenhouse pollution, non-native species, and disease. Freshwater habitats are threatened by non-native species, water extraction and alteration of flow by dams and reservoirs, pollution, disease and habitat degradation (Collen et al. 2014). Coastal and marine habitats are threatened nationally by habitat loss, climate change, overexploitation, eutrophication, invasive species, pollution, disease, and aquaculture (Crain et al. 2009). Terrestrial habitats are globally threatened by habitat loss caused by unsustainable agriculture, incompatible silviculture, and rapid development (Secretariat of the Convention on Biological Diversity 2014).

Unfortunately, natural communities are rarely affected by one isolated threat. Instead, development, pollution, and invasive species often drive and intensify each other's effects. Climate change also exacerbates the negative effects of other threats. One example of an intensifying multi-threat scenario is the predicament of Maryland's Coastal Bays. The Bays are threatened by non-point source pollution, nutrient enrichment, hypoxia, contaminants, exotic species, and human population growth. Seagrasses are an important indicator of water quality health, and are essential in small water bodies such as the Coastal Bays as nursery habitats for aquatic species. Seagrass distribution, however, is currently concentrated on the ocean side of the Bays, with Sinepuxent and Chincoteague Bays having the highest abundances of seagrass. In the past four years there has been a decline in sea grass coverage by over 5,000 acres, attributed partly to plant disease (Maryland Coastal Bays Program 2014). Oysters *(Crassostrea virginica)* remain in small remnant populations only, while bay scallops have recently returned to the Bays, but in low numbers. Hard clams are below historical levels, although their population appears stable over the last decade. Forage fish populations, however, are in steady decline due to loss of habitat and food sources (Maryland Coastal Bays Program 2014). Maryland's coastal areas are also at risk of experiencing a foot of sea-level rise by 2050 and as much as 3 feet by 2100, contributing to higher storm wave heights, greater flooding in low-lying coastal areas, exacerbated shoreline erosion, and damage to property and infrastructure (Boesch et al. 2013). Tackling issues such as the decline of the Coastal Bays, due in large part to sea-level rise, is made significantly more difficult when multiple threats affect habitats and species. This chapter explores these and other human and non-human forces threatening Maryland's SGCN and their key wildlife habitats.

Threat Classification System and Refinement for Maryland's Threats

References to threats in Maryland's SWAP (Plan) follow the internationally applicable hierarchical International Union for Conservation of Nature (IUCN) classification system, which was selected by the Northeast States in the Northeast Lexicon (Crisfield & NEFWDTC 2013) and recommended by the National Best Practices for State Wildlife Action Plans (AFWA 2012). Threats come from many different sources, and impacts can be observed at different spatial, temporal, and biological scales. As a result, the risk of the impacts is wide-ranging, as are actions taken in response. The Northeast Lexicon provides a hierarchical system for classifying and naming threats, based on the IUCN classification system (Salafsky et al. 2008) and threat characteristics that are important in determining threat risk and appropriate responses (Crisfield & NEWDTC 2013). Selecting a standard lexicon of threats provides consistency to identify threats to SGCN and habitats in the state, regionally, and nationwide. All of Maryland's conservation actions (Chapter 7) are organized by the IUCN threat category they address.

The three-tiered IUCN threat classification system is hierarchical and is used in the NatureServe conservation status rank calculator (see **Element 1**). Within this structure, regionally agreed upon or state-specific threats may be added when necessary. For example, "administrative barriers to conservation actions" was added as a category to the threat classification list for the Northeastern states (Crisfield & NEWDTC 2013). For the 2015 SWAP, additional threats were added only in categories 12-15. The complete IUCN Classification System can be found in Appendix 5a, including the system's three tiers, definitions, details, and further explanation regarding categorization (expositions) for the threats listed. Table 5.1 is a summarized version of Appendix 5a that illustrates the IUCN classification system framework that was used to develop the state-specific threat assessment for the SWAP.

Table 5.1 IUCN Threat Classification System.

Threat Category #	Broadest Categorization Tier	Details/Definition	Examples
1	Residential and Commercial Development	Threats from human settlements or other non-agricultural land uses with a substantial footprint.	Land conversion from natural habitats to development of housing, commercial, industrial, institutional, tourism, and recreational types.
2	Agriculture and Aquaculture	Threats from farming and ranching as a result of agricultural expansion and intensification, including silviculture, mariculture, and aquaculture.	Land conversion from natural habitats to annual and perennial crop farms (non-timber), wood and pulp plantations, livestock farming, and aquaculture.
3	Energy Production and Mining	Threats from exploring for, developing, producing, and distributing energy or geological resources.	Land conversion from natural habitats/inappropriate placement of oil and gas drilling/pipelines, mines, and renewable energy facilities such as wind and solar power.

Threat Category #	Broadest Categorization Tier	Details/Definition	Examples
4	Transportation and Service Corridors	Threats from long narrow transport corridors and the vehicles that use them, including wildlife mortality.	Land conversion from natural habitats/inappropriate placement of roads and railroads, utility and service lines, flight paths, and shipping lanes, causing unintentional mortalities along with habitat loss and fragmentation.
5	Biological Resource Use	Threats from overharvesting biological resources for commercial, recreational, food gathering, research, or cultural purposes; including both deliberate and unintentional harvesting beyond sustainable levels.	Hunting and collecting terrestrial animals, gathering terrestrial plants, logging, and harvesting aquatic resources at levels that are not sustainable.
6	Human Intrusions and Disturbance	Threats from human activities that alter, destroy, and disturb habitats and species associated with non-consumptive uses of biological resources.	Recreational, military, and work-related activities that threaten species and habitats.
7	Natural System Modifications	Threats from actions that convert or degrade habitat in the course of "managing" natural or semi-natural systems, often to improve human welfare.	Fire and fire suppression, dams and water management, incompatible shoreline stabilization, inappropriate timing of mowing.
8	Invasive and Other Problematic Species, Genes, and Diseases	Threats from introductions that have or are predicted to have harmful effects on biodiversity following their establishment, spread and/or increase in abundance.	Non-native and native plants and/or animals (aquatic or terrestrial), pathogens/microbes, or genetic materials.
9	Pollution	Threats from introduction of exotic and/or excess materials or energy from point and nonpoint sources.	Domestic and urban waste water, industrial and military effluents, agricultural & forestry effluents, garbage and solid waste, air-borne pollutants, and excess energy such as light pollution.
10	Geological Events[1]	Threats from geological events that may eliminate vulnerable species or habitat.	Volcanoes, earthquakes, and avalanches/landslides.
11	Climate Change and Severe Weather	Threats from long-term climatic changes or other severe weather that may eliminate a vulnerable species or habitat.	Habitat shifting or alteration, droughts, temperature extremes, storms and flooding.

Threat Category #	Broadest Categorization Tier	Details/Definition	Examples
12	Resource Management Needs	Threats from lack of data and information required for successful conservation and protection for SGCN and their key wildlife habitats.	A need for data and information (including inventory, monitoring, and research), environmental regulatory programs, and working with landowners and land managers on private and public levels.
13	Recreation Needs	Threats from lack of information, training, and/or recreational resources that allow for successful conservation of SGCN and their key wildlife habitats.	A need for information on potential impacts and more recreational opportunities to enhance public appreciation of wildlife conservation.
14	Education / Outreach Needs	Threats from the lack of education and outreach regarding SGCN and their key wildlife habitats.	A need for improved knowledge, support base, and education facilities; a need for training for conservation professionals.
15	Administrative Needs	Threat from the lack of administration and coordination regarding conservation.	A need for improved maintenance and dissemination of data, enforcement of laws and ordinances to protect SGCN, implementation of existing recovery plans.

[1]Minimal potential threat for Maryland, but consistent with international classification system (IUCN)

Threats to Maryland's Species of Greatest Conservation Need and their Habitats

In this chapter, threats identified for Maryland's SGCN and key wildlife habitats are described in sufficient detail to support the development of effective, focused conservation actions. Maryland's SWAP uses the extensive IUCN Threat Classification System, which considers threats regardless of their origin (local, state, regional, national, and international) if they are relevant to SGCN and their key wildlife habitats. Chapter 7 includes cross-referenced matrices of detailed threats and conservation actions for key wildlife habitats, taxa groups, and species. In response to these threats and prescribed actions, priority research, survey needs, and resulting products are described in Chapter 7. For instance, when a threat is foreseen but there is not enough information to sufficiently describe the threat or develop effective conservation actions, further research and survey efforts are listed as suggested conservation actions.

Land Conversion in the Northeast Region

Since its colonization by European settlers four hundred years ago, the Northeast region continues to be the most densely populated region in the country. That dense population is projected to increase by nearly 6 million (10%) between 2000 and 2030. This projection necessitates careful planning of further development in the region, which has lost significant amounts of biodiversity and habitat space to development activities in the past. The Northeast region was once 91% forest, supporting thousands of species, but today almost one-third of that, 39 million acres, has been developed. Forest land lost surpasses forest land protected for conservation purposes six to one, and conservation is not spread evenly across forest types. For example, 23% of northern hardwoods are protected, with 8% primarily for conservation purposes. Only 17% of oak-pine forests are protected, with 5% primarily for conservation purposes (Terwilliger & NEFWDTC 2013).

Wetlands once covered 7% of the region, and swamps, peatlands, and marshes are some of the most diverse wildlife habitat in the Northeast region. At least 2.8 million acres of wetlands, one-quarter of the original extent, have been converted to development or drained for agriculture. Through conservation efforts, the region's states have protected 25% of the remaining acres, including one-third of the largest tidal marshes. The greatest discrepancy of any wetland type occurs in river-related wetlands, such as floodplain forests, where almost a third of their historic extent has been lost and only 6% of the remaining acreage is protected. While the majority of individual wetlands have expanded slightly over the last 20 years, 67% of them have paved roads so close to them, and in such high densities, that species losses are likely. Moreover, 66% have development or agriculture directly in their 100 meter buffer zones, which can result in notable impacts on biodiversity (Terwilliger & NEFWDTC 2013).

Riparian areas, defined as the narrow 300-foot zone flanking all streams and rivers, are important for stream function and habitat. Conversion of this natural habitat in the Northeast region exceeds its conservation two to one, with 27% of riparian areas converted and 14% protected. Historically, 41% of the region's streams were linked in huge interconnected networks, each over 5,000 miles long. Today none of those large networks remain, and even those over 1,000 miles long have been reduced by half. A corresponding increase in short networks, less than 25 miles long, now account for 23% of all stream miles—up from 3% historically. This highly fragmented pattern reflects the density of barriers, which currently averages seven dams and 106 road-stream crossings per 100 miles of stream. Water flow defines a stream; 61% of the region's streams have flow regimes that are altered enough to result in biotic impacts. One-third of all headwater streams, which are subject to drying up, have diminished minimum flows, resulting in a reduction of habitat. As much as 70% of the large rivers in the Northeast region have reduced maximum flows. A high flowrate in a large river is important in order to decrease the amount of nutrient laden water delivered to the river's floodplains (Terwilliger & NEFWDTC 2013).

Land Conversion and Habitat Fragmentation in Maryland

Habitat loss is the single greatest threat to biodiversity in the United States (Stein et al. 2000). Across the state of Maryland, human encroachment on, and development of, important natural lands remain the primary and ever-increasing threats to SGCN. Examples of different types of land development include residential, commercial, and other types of buildings, with their associated roads and parking areas; energy production and mining operations; and transportation and service corridors. All of these land development categories include the threat of habitat fragmentation, or the division of continuous habitats into smaller, isolated patches, in Maryland and throughout the Northeast region. To support the survival of both terrestrial and aquatic SGCN, actions are needed to decrease the impact of these activities and to address the overall need for better planning, research, and surveys. An awareness of the many, varied threats presented by major forms of human development and land conversion is crucial for understanding our evolving responsibilities in conservation.

At the time of European colonization, Maryland was estimated to be 95% forest and 5% tidal wetland (Besley 1916; Powell & Kingsley 1980). By 1993, the state's forests and wetlands had both been reduced by half (Weber 2003). Human development drives land cover changes in Maryland; from 1973 to 2010, urban land use statewide more than doubled (Figure 5.1 and Table 5.2).

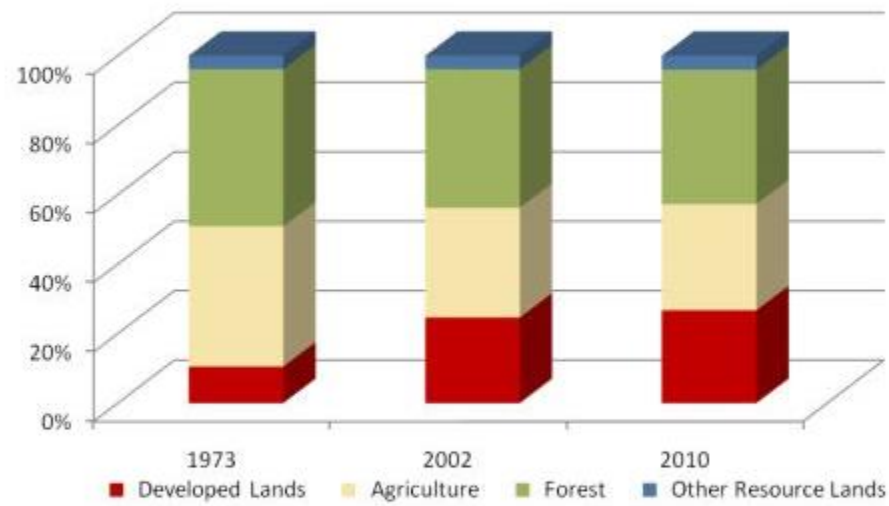


Figure 5.1 Land use change, 1973-2010. Source: MD Department of Planning

Table 5.2 Land use changes in Maryland, 1973-2010 by total acres. Source: MD Department of Planning. Land Use Category definitions can be found at **http://www.mdp.state.md.us/PDF/OurWork/LandUse/metadata.pdf**

Land Use Category		Land area (acres)		
		1973	2010	Change[1]
Very Low Density Residential	*Urban Development*		311,037	
Low Density Residential		197,152	567,966	370,814
Medium Density Residential		188,411	305,281	116,870
High Density Residential		48,945	96,206	47,261
Commercial		74,231	98,714	24,483
Industrial		16,290	62,382	46,092
Other Developed Land[2]		129,501	222,651	93,150
Sum of above		***654,530***	***1,664,237***	***1,009,707***
Agriculture		2,521,993	1,908,887	-613,106
Forest		2,827,495	2,418,478	-409,017
Wetlands		231,416	230,300	-1,116
Barren Lands		9,763	19,522	9,759
Sum of Land Area		***6,245,197***	***6,241,424***	***-3,773***
Water		1,681,348	1,685,265	3,917
Total		**7,926,545**	**7,926,689**	**144**

[1] These numbers should be treated as approximations, rather than as absolute values. Differences in technology, data processing methods, data accuracy, and other factors should be considered when reviewing this table. Land use category "very low density residential" was added to land use statistics in 2010.
[2] Includes Transportation and Institutional category.

While the western part of the state continues to have the largest blocks of forest, habitats are now becoming fragmented as development moves into the area and converts the contiguous habitat into smaller patches like those in the eastern and southern portions of the state (Weber & Aviram 2002). An assessment of development patterns in the state from 1997 to 2000 determined that western Maryland suffered the highest losses of forests (over 8,600 acres) that were formerly large, contiguous forest blocks. Furthermore, an analysis of the risk of forest loss based on these development patterns found that the counties most likely to be further developed, and thus to lose additional forest, are Cecil, Garrett, Howard, Montgomery, St. Mary's, and Washington (Weber 2004). The areas least likely to be developed are the lower Eastern Shore and Allegany County in western Maryland (Figure 5.2).

Figure 5.2 Forest loss 2000-2012. Source: North Atlantic Landscape Conservation Cooperative, USGS

Including agricultural development, 55% of the 6.2 million acres of land in the State has been developed, and much of the undeveloped land is fragmented to the point where natural habitats cannot persist. More than 28% of this land—just over 1 million acres— has been developed since 1973 (Figure 5.3). In other words, it took three centuries to develop the first 650,000 acres of land in Maryland and 40 years to develop the next million. As population trends continue on an upward trajectory, human development will continue to increase. Close analysis of the impacts of development in Maryland will continue to be necessary. Devastation of the natural habitat on which healthy ecosystems depend has consequences possibly as severe as the extinction of some of Maryland's SGCN. Because wildlife depend on a network of resources, the extinction of one species often results in reductions in biodiversity in the entire ecosystem.

Residential and Commercial Development (IUCN 1)

The conversion of natural areas to cities, towns, and residential settlements *(IUCN 1.1)*, commercial and industrial operations *(IUCN 1.2)*, and recreational and tourism sites *(IUCN 1.3)* can have a major impact on Maryland's animals, plants, and natural habitats. Increasing development reflects the increasing human population in Maryland (see Chapter 1). Maryland is the fifth most densely populated U.S. state, with the second greatest rate of population increase among states in the northeast region since 2010 (U.S. Census Bureau 2014).

While cities and towns have certainly grown larger in area and population size, the most harmful effects of land development are caused by urban sprawl. Urban development in Maryland has occurred in three waves, first in close suburbs near Washington DC and Baltimore, then in the outer ring of suburbs bordering highways, and most recently in far-flung exurbs in portions of western Maryland, Southern Maryland, and the Eastern Shore (Figure 5.3). A similar pattern has occurred around smaller cities at a smaller scale, such as Bel Air, Frederick, Hagerstown, La Plata, and Salisbury (Maryland Department of Planning 2011).

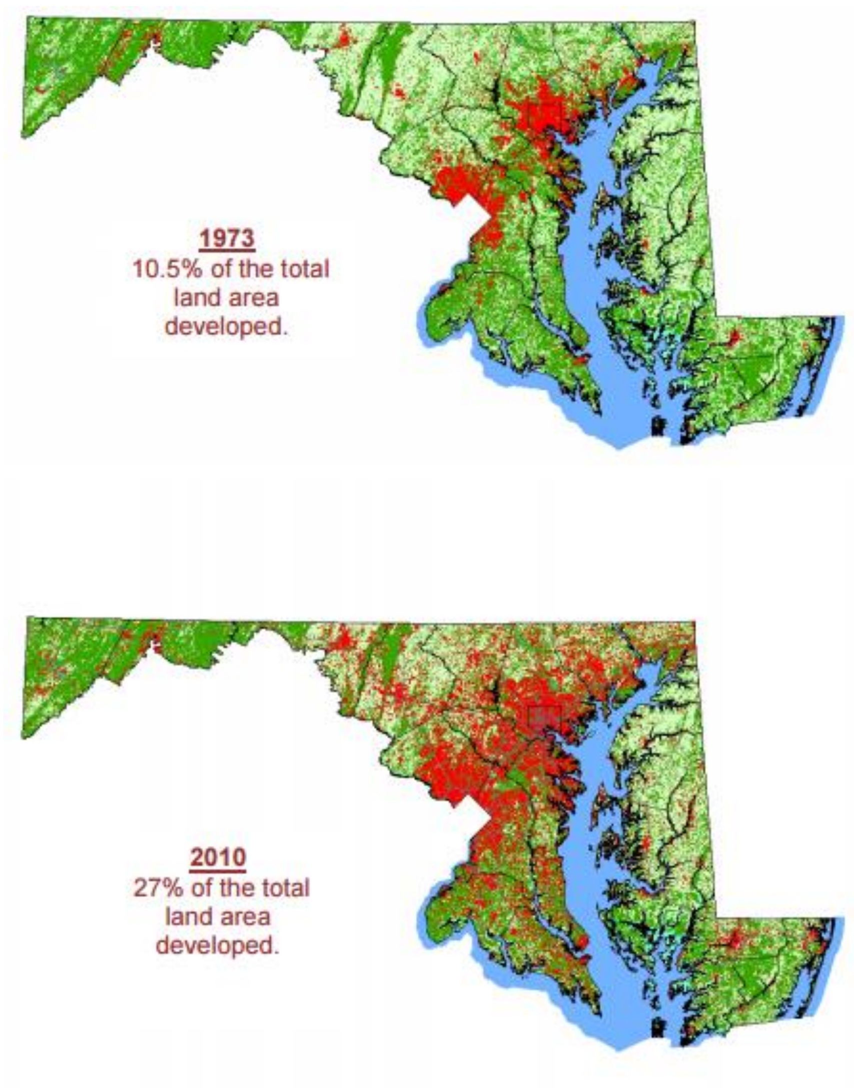


Figure 5.3 Change in development in Maryland 1973-2010 (development in red). Source: MDP

Today's trend of large single-family housing units encourages larger developments containing fewer people, resulting in more far-flung development that causes even greater habitat loss, habitat fragmentation, and loss of natural processes in these newly developed areas. Figure 5.4

shows an example of urban sprawl in Maryland caused by rapid development. The Maryland Department of Planning's website hosts a collection of interactive maps, including land use change and population growth maps.

Figure 5.4 Gilbert Pond near Hughesville, MD in 2002 (left) and in 2007 (right). Orange markers show development that occurred after 2002. Source: MD DNR

In conjunction with increases in its human population, Maryland has seen the associated development of commercial, industrial, and recreation areas. Examples of this type of development are shopping areas, businesses, shipyards, airports, sports fields, and campgrounds. Beyond loss of habitat and habitat fragmentation caused by development of places for people to eat, shop, and play, there are negative effects associated with the attraction of people to these areas, such as pollution, additional development associated with increased transportation needs, and increased carbon emissions. For example, the use of reflective materials such as window glass on city buildings and homes poses a risk to migrating and resident birds and bats, which, when they do not perceive these surfaces as solid, collide with them, and are injured or killed. Collision risk can be exacerbated when reflective surfaces are lit with artificial light, as is done on office buildings in larger cities. The Lights Out Baltimore project, which aims to reduce migrating bird mortalities caused by lights, windows, and other reflective surfaces, has found over 2,000 birds and bats dead on Baltimore City streets since the organization began patrolling Baltimore streets in 2008. Later Plan sections include information about these secondary threats.

Agriculture and Aquaculture (IUCN 2)

Maryland's landscape and waterscape support a great variety of agricultural and aquacultural operations. The fertile soil and flat geography of the Upper and Lower Coastal Plain, in particular, nurture annual and perennial crop farms *(IUCN 2.1)*, wood and pulp plantations *(IUCN 2.2)*, and livestock farms and ranches *(IUCN 2.3)*, all of which have the potential to negatively impact SGCN and their habitats. Thirty percent of Maryland's land area is currently farmed (Table 2.2, 5.2). Large expanses of land clearing for such operations after European settlement altered the habitats of many SGCN that require large contiguous forests and grasslands, such as the broad-winged hawk and a range of other birds, mammals, reptiles, amphibians, and invertebrates.

Freshwater and marine aquaculture *(IUCN 2.4)* can take advantage of Maryland's wealth of aquatic resources but can also have negative consequences. This type of development includes fish farms and hatcheries that may impact natural fish habitat in different ways. Fish farms and shellfish beds, which raise aquatic species commercially in enclosed areas, require infrastructure that expands into natural aquatic habitat. Fish hatcheries breed and raise juvenile fish to be transferred to fish farms or released into natural areas, where the habitats of SGCN or the species themselves may be affected. Aquaculture in Maryland produces a variety of fish and shellfish such as hybrid striped bass, tilapia, catfish, crayfish, trout, oysters, and soft crabs, in ponds or recirculating tanks. As of 2010, 71 commercial aquaculture producers operated in Maryland, alongside individuals who grew fish and shellfish for their own use. More than 50 schools, nature centers, government agencies, and private organizations raise fish, shellfish, or aquatic plants for educational or restoration purposes (summary from Maryland State Archives 2013).

Energy Production and Mining (IUCN 3)


Active surface mining site, Allegany County, Maryland (MDE)

Maryland produces just over half of the electricity it uses in-state (U.S. Energy Information Administration 2014). Maryland's potential energy resources include coal deposits and natural gas reserves in the mountainous western region, hydroelectric potential in some rivers, solar energy, and wind energy potential on western mountain ridges and in coastal areas. Energy-associated infrastructure, such as pipelines running through the state *(IUCN 3.1.1)*, deliver refined petroleum products and natural gas from northern states. The Port of Baltimore receives tankers carrying imported energy products such as coal and petroleum. Liquefied natural gas (LNG) can enter or leave the state at Maryland's recently expanded LNG terminal at Cove Point on the western shore of the Chesapeake Bay (U.S. Energy Information Administration 2014).

Maryland's westernmost counties lie above the Marcellus Shale, a productive source of natural gas that is extracted in nearby Pennsylvania and West Virginia. After evaluating hydraulic fracturing, or "fracking," *(IUCN 3.1.2)* as a possible energy extraction method, the State of Maryland placed a two-year moratorium on hydraulic fracturing until 2017, at which point regulations must be promulgated, possibly allowing hydraulic fracturing operations to take place. The fragmentation of forest lands, as well as other potential ecosystem damage from gas line installation, are factors being considered in this decision (MDE & MD DNR 2015).

Maryland has over 20 surface and underground mines *(IUCN 3.2)*, all in western Maryland, and coal is the leading export commodity by tonnage leaving the Port of Baltimore. Electricity generating facilities in Maryland include coal-fired plants, natural gas-fired plants, hydroelectric generators, the state's only nuclear power plant at Calvert Cliffs on the western shore, and an increasing number of renewable energy producers. Construction of several natural gas-fired facilities is planned for the next decade, while many coal-fired facilities are being phased out due to age and higher running costs (U.S. Energy Information Association 2014).

The largest sources of renewable energy *(IUCN 3.3)* in Maryland are biomass facilities and hydroelectric plants, with most energy currently generated at the Conowingo Dam on the Susquehanna River. Maryland's Renewable Portfolio Standard calls for 20% of all Maryland energy production to be derived from renewable sources by 2022, including targets for 2% solar and up to 2.5% cost-effective offshore wind production (American Council on Renewable Energy 2014). As of 2014, less than 10% of Maryland's energy portfolio is derived from renewable sources. The increasing prevalence of renewable energy infrastructure, driven by state incentives and federal tax credits, introduces new land conversion challenges in regards to industrial solar, wind, and geothermal power installations. For example, developing industrial land-based wind power can include placing facilities in a way that removes or fragments habitats .Facility operation can cause an increase in bird and bat fatalities in movement corridors. Energy installations offshore, including wind installations like those that may be developed in the 80,000-acre Wind Energy Area off the Maryland coast, could cause mortality due to collisions with the turbines themselves, loss or degradation of habitat, disruption of movement corridors and feeding areas, and/or an increased risk of collisions with and pollution from vessels operating during construction and facility maintenance. Geothermal installations pose the potential problem of impacting groundwater hydrology in areas with cave systems or seepage wetlands. Construction of large-scale solar energy facilities can fragment habitats, and designs that include "power towers" can cause direct mortality to birds.

Conowingo Dam (Wendy McPherson, USGS)

Transportation and Service Corridors (IUCN 4)

The Northeast region contains 71 million people and 732,000 miles of permanent roads, but people and roads are not distributed randomly across the region. Permanent roads are the primary fragmenting features that provide predator access into interior habitat areas and that can act as pathways for the spread of invasive plants. Heavily-used paved roads create noisy disturbances that many species avoid, and the roads themselves may be barriers to the movement of small mammals, reptiles, and amphibians. Fragmentation subdivides contiguous acres of natural land into smaller patches, with each patch having more edge habitat and less interior. Because edge habitat structure contrasts strongly with interior habitat structure, edge habitats tend to surround and isolate interior habitat regions, contributing to the interior habitat's degradation. Thus fragmentation can lead to an overall deterioration of ecological quality and a shift in associated species from interior specialists to edge generalists (Terwilliger & NEFWDTC 2013).

Connecting Maryland's commercial and industrial developments, agricultural installations, and energy-obtaining infrastructure is a network of roads, railroads, shipping lanes, flight paths, and utility and service lines. As urban sprawl shifted Marylanders from cities to suburbs, state and local highways and road systems and railways *(IUCN 4.1)* were developed and expanded, with associated development such as parking lots, sidewalks, bridges, toll plazas, and train stations. Commercial trains and trucks rely on these systems, as do many forms of public transportation. Over 30,000 miles of state, county, and municipal roads traverse the state (Maryland State Highway Administration 2014), changing the landscape by fragmenting habitat, degrading the interior forest habitat required by some species, and providing corridors for the dispersal of invasive species (Figure 5.5). Habitat fragmentation disrupts wildlife movement corridors, which species use for post-breeding dispersal, new territory establishment, and additional food source location. Migratory anadromous fish spawning is easily disrupted by the improper placement of road culverts that block upstream movements. In addition to impeding migration and movement corridors, Maryland's transportation routes cause direct mortality of many animal species in almost all taxa through collision with cars and trains. Amphibians in particular become "roadkill" primarily because they often migrate in large groups to or from breeding wetlands. Many snakes are killed as they bask on warm roads and turtles are at risk of being killed as they travel to upland nesting habitats.

Figure 5.5 Maryland's roads. Sources: MDP, State Highway Administration, USGS

Similarly, shipping lanes, flight paths, and service lines cross many different habitat types as they transport people and goods within and outside the state. The movement of ships *(IUCN 4.3.1)* in shipping lanes in the Chesapeake Bay and Atlantic Ocean is a known cause of mortality for endangered species such as the North Atlantic right whale and Atlantic sturgeon. Ship movements can disrupt corridors important for feeding and migration of aquatic species. Harbor and channel dredging *(IUCN 4.3.2)* alter natural habitats and can cause mortality of shellfish and negative impacts from inappropriate placement of dredge spoil containment facilities. Airplane movement within flight paths *(IUCN 4.4)* causes direct fatalities and can disrupt bird migration corridors. Service line installation *(IUCN 4.2)* can degrade and fragment habitats, encouraging the spread of invasive species and reducing breeding success of forest interior SGCN due to increased exposure to predators and parasites. Finally, service lines can open up natural areas to further development activities.

Biological Resource Use (IUCN 5)

Maryland is renowned for the excellent opportunities offered for outdoor activities. Hunting and fishing draw nearly 500,000 Maryland residents to the state's natural areas every year (U.S. Department of Interior, U.S. Fish and Wildlife Service and U.S. Department of Commerce 2011). Hunting terrestrial animals, fishing for aquatic animals, and harvesting wood and plant species can be beneficial in managing biological systems in addition to providing recreational opportunities and maintaining cultural practices. For example, Maryland's state-regulated white-tailed deer hunt is intended to reduce state herd numbers to near carrying capacity, especially in ecologically significant areas. If not managed carefully, however, these activities can pose unintentional threats to Maryland's biological resources. In the past, Maryland has seen several native species pushed to the brink of extinction due to resource overuse and over-collection of wildlife *(IUCN 5.1.2)*. The Atlantic sturgeon (federally-listed as Endangered) and northern diamond-backed terrapin (of regional concern) are examples of SGCN that are recovering today under no-harvest laws after being impacted by overharvest. Wildlife today face threats less obvious than direct overexploitation, which has been largely addressed and reduced through passage of federal and state legislation to regulate hunting and fishing activities (Stein et al. 2000).

The indirect effects of harvesting animals and plants (*IUCN 5.1.2* e.g., bycatch and accidental mortality of non-targeted animals) are often complicated and difficult to address. For example, American beavers create a mosaic landscape of wetlands and upland early successional habitat used by a variety of SGCN species. When beavers are completely removed from an area, other biological resources in the system are affected. Biological resource use thus can be a threat affecting many levels of aquatic and terrestrial systems.

An excluder device, pictured here, fits into the entrance funnel on crab pots to reduce diamond-backed terrapin bycatch (MD DNR).

Certain species are also subject to persecution *(IUCN 5.1.3)* on the grounds of dangerous or troublesome behavior, leading to eradication of large numbers of individuals. Centuries ago this was true of the black bear (*Ursus americanus*), wolves, and other predators that once controlled a now-booming white-tailed deer population, itself hunted to near-extirpation in the early 1900s. Today, the copperhead *(Agkistrodon contortrix)* and timber rattlesnake, as well as "look-alike" snakes, are subject persecution leading to mortality, as are species perceived as "pests" such as bats and native forest rodents. Persecutory hunting and other human-animal conflict is especially an issue in urbanized and developed areas with higher human populations.

Overfishing *(IUCN 5.4)* is a potential issue in Maryland, which supports an immense fishery industry. In the past, the horseshoe crab, American shad, and multiple species of sunfish have been affected by overfishing. Species subject to indirect loss through bycatch today include shortnose and Atlantic sturgeons and three skates listed as SGCN. Far out at sea, marine birds and sea turtles are also subject to becoming bycatch mortality from large fishing operations. Crab pots and eel pots can cause bycatch losses of northern diamond-backed terrapins in shallow brackish environments if they do not include exclusion devices. Conservation and management strategies for these and other species are important to their survival in Maryland (see Chapters 3 and 7).

Plants can also be threatened by excessive biological resource use *(IUCN 5.2)*, both by direct harvesting in the case of desirable flowers, herbs, fungi, and medicinal plants, and through indirect harm by trampling or non-purposeful plant destruction. To limit harvest impacts, one species, American ginseng *(Panax quinquefolius)*, is managed by Maryland's Department of Agriculture, which requires purchase of a permit to harvest this increasingly rare herb. Ginseng harvesting was banned on state lands in 2013 due to concerns about the declining Maryland population (Maryland Department of Agriculture 2015). The forest products industry is one of the state's most productive industries – logging produces over $4 billion per year in wood products, including lumber, piling, paper products, furniture, pallets, and chemicals. In comparison with other renewable product-based industries in Maryland, the forestry and wood-derivative industry is more economically productive than either seafood or animal processing industries, each under $900 million per year, but less productive than agriculture at $8 billion per year. Forestry supports over 10,000 jobs, and secondary processing and manufacturing of wooden products manufacturing adds an additional 40,000 jobs to the state economy (MD DNR 2013).

Woody biomass, pictured here left over from a logging operation, can be important to nutrient cycling in commercially logged forests (U.S. Forest Service).

Over 2.5 million acres of forest (41% of Maryland's landmass) grow in the state of Maryland (Kittler & Beauvais 2010). A valuable resource, these lands are protected by a suite of regulations and incentives such as the Sustainable Forestry Act of 2009. In addition, 211,000 acres of high-quality forest are set aside in the Maryland State Forest System. Maryland has committed to practice sustainable management on its State Forests, which are certified as sustainable under both Forest Stewardship Council and Sustainable Forestry Initiative standards. However, even careful harvesting of trees and other woody materials may threaten the habitats of some SGCN through habitat loss, fragmentation, introduction of invasive species, and other consequences of forest disturbance *(IUCN 5.3)*. For example, access roads built during forestry operations can be a major cause of fragmentation. Additionally, fully 76% of Maryland's forests are privately owned and are sometimes subject to the sale of small-acreage forest lands for timber harvest (MD DNR 2010).

The harvest of smaller, individual lots can also disturb forest corridors important to species living or migrating within these forests.

Minimizing impacts on SGCN forest habitats should also be considered in light of the growing market for woody biomass, or low value wood (e.g., small trees, treetops and limbs, undesirable tree species, logging slash). The taking of smaller forest components along with traditional timber harvests can upset soil nutrient cycling, remove buffers that maintain water quality, and eliminate important animal habitats (Pinchot Institute for Conservation 2010).

Human Intrusions and Disturbance (IUCN 6)

Non-consumptive human activities can also upset and even destroy natural habitats. Often, these intrusions into natural lands are for recreational purposes *(IUCN 6.1)*. Motorized and non-motorized off-road vehicles such as all-terrain vehicles (ATVs) and bicycles can kill smaller organisms and plants, increase erosion in fragile communities such as dunes and riverbeds, and transport non-native species into sensitive areas. Boats and boating activities in areas that are not normally used as transportation corridors can cause direct mortality of aquatic species and disrupt bird nesting habits. Natural areas that attract humans for recreational activities include beaches, caves, and cliffs. Rock-climbing and other human activities in caves and on cliffs can disrupt the activities of birds, bats, and other organisms exclusive to these habitats. Bats are particularly vulnerable to impacts from human disturbance in caves during hibernation periods. Of particular concern for shorebirds is human disturbance of beach habitats during the nesting season and when these areas provide critical stop-over habitat during migration.

All-terrain vehicles disrupt natural communities and can transport non-native species into sensitive areas (Protect the Adirondacks, Inc.).

Day-to-day military and other work-related activities can also impact Maryland's SGCN and their habitats. Terrestrial and aquatic species and habitats near military installations such as Aberdeen Proving Ground and Naval Air Station Patuxent River can be affected by actions related to military objectives *(IUCN 6.2)* such as the use of loud or destructive equipment, ordnance trials, training maneuvers, and off-road travel. Other potential sources of disturbance related to occupational activities include loud noises and the extended presence of construction crews working on projects in natural areas. Noise impacts are further discussed below under "Pollution- Excess Energy (IUCN 9.6)".

Natural Systems Modifications (IUCN 7)

Although periodic fire, flooding, and sediment deposition are natural ecological processes needed to maintain some habitats, the effects of these natural occurrences are often minimized by measures put in place to protect or improve human welfare. Other natural processes are affected when a desired resource use causes modifications in natural systems, such as water flow changes in dammed streams, loss of surface water and groundwater through withdrawal, and wave action interrupted by shoreline stabilization. While environmental compromises are sometimes necessary to meet human needs, new technologies and land use planning can still aim to maintain the natural ecological processes that support SGCN species and their habitats as much as possible.

Historically, ground fires commonly occurred in Maryland's wildlands due to Native American activity. Historical and scientific researchers have corroborated that Native American fires complemented lightning fires and played a role in the distribution of plant and animal species. Today, the much larger human population has changed where and when fires occur. Maryland sees about 500 ground fires a year, only 3% of which begin naturally with lightning striking dry plant material. Most begin due to improper burning of debris (29%) or arson (26%). Other causes for fire in Maryland include improperly discarded cigarettes and ash, campfires, railroads, fireworks, and children playing with fire (MD DNR 2012). For the safety of people and their property, ground fire suppression has become commonplace. As a result, some habitats and species in Maryland are suffering due to *lack* of ground fire *(IUCN 7.1)*, as fire actually rejuvenates the soil and plant life of natural areas. Serpentine barrens, pitch pine forests, Delmarva bays, and other key wildlife habitats across Maryland rely on periodic fires to return nutrients to the soil, maintain open space, and redistribute plant life. Today, fire ecologists turn to prescribed burns to reestablish these natural ground fire regimens, as in the case of a recent prescribed burn in a shale barren in Maryland's Green Ridge State Forest described below.

Case Study: Restoring Fire to Maryland's Shale Barrens

Because most of Maryland's fires historically originated from indigenous human activity, plants and animals evolved in certain microclimates (climate conditions in the immediate surroundings of plants and animals) resulting from and maintained by frequent Native American ground fires. As well as serving human purposes, such as increasing the success of hunting and agriculture, these periodic landscape fires maintained good growing conditions with high levels of sunlight and essential nutrients, low acidity, and sparse leaf litter. Animals inhabiting these microclimates similarly adapted to periodic burning and coevolved with the high diversity of plants these fires supported. Fire exclusion and suppression in such fire-dependent ecosystems as shale barrens have caused deterioration in growing conditions by limiting sunlight (too much shade), reducing nutrient levels, increasing litter, and exacerbating summer droughts. Many shale barren species grow poorly in these fireless conditions and eventually disappear, including rare and endangered taxa. For example, the Endangered Kate's Mountain clover, endemic to mid-Appalachian shale barrens, thrived under Native American

Kate's mountain clover
(Chris Frye, MD DNR)

land use practices, but is slowly disappearing from fireless shale barrens.

Also called savannas, shale barrens are characterized by lush growths of grasses, sedges, and wildflowers, and they support a selection of rare plants able to withstand the harsh summer drought conditions typical of this habitat. Shale barren communities in Maryland exist on the steep slopes of the Appalachian Mountains in western Maryland, and provide habitats for SGCN such as the Appalachian cottontail, eastern coal skink, and several important bee species. These plants and animals evolved to prosper in areas that are periodically rejuvenated by fire. As fires can be dangerous and difficult to control, people have interfered with these natural burning processes in Maryland. When the Maryland Forest Service was founded in 1906, regulations were passed to prevent human-made forest fires and to control ground fire in Maryland.

Native American fires occurred more frequently than lightning fires, although ecologists are still trying to determine how frequently burning occurred historically. Today, ecologists look to prescribed burning, or the planned application of fire to a specific land area, to return fire to fire-dependent ecosystems. Prescribed burning can be used to restore communities that evolved under a fire regime, and to reduce the fuel load of a system, avoiding potentially more catastrophic fires in the future. The goal of research in the still-developing field of fire ecology is to employ periodic prescribed burns to restore a fire regime to fire-dependent areas like shale barrens.

In Maryland, prescribed burns are highly regulated by the government. MD DNR and its land management partners perform prescribed burns only with trained personnel, primarily on federal- or state-owned lands. In 2010, MD DNR began a study of the effects of a prescribed burn in Green Ridge State Forest, setting in motion an effective shale barren restoration through a process designed to simulate natural fire as safely as possible. These barrens were shaped by an historic pattern of frequent, low-intensity ground fires. Under state management, fire suppression in this forest, supported by the federal Smokey Bear program in the 1940's and 1950's, permitted the spread of trees and other woody plants not normally dominant in shale barren communities. Rapid reproduction and growth of pignut hickory *(Carya glabra)* transformed the shale barrens along forest slopes to woodlands. Hickories reproduced at an extremely rapid rate in the absence of fire, threatening the existence of fire-dependent plants that require great amounts of sunlight and open space to grow, such as the native shale barren inhabitant, post oak (*Quercus stellata*). Hickory elimination through prescribed burns should allow the shale barren habitat to reestablish itself and better support rare plants such as Kate's Mountain clover *(Trifolium virginicum),* which is native to only a limited region in mountainous parts of Maryland, Virginia, West Virginia, and Pennsylvania.

Prior to burning, MD DNR staff treated pignut hickory trees in the targeted shale barren area with herbicide to ensure their elimination. Given the dearth of plant life in this community due to excessive shade from hickory tree cover, researchers were not sure fire alone would take out the trees. The shale barren community was burned in November 2011, with DNR personnel setting strips of fire alight from top to bottom of the south-facing slope. Researchers monitored regrowth in the shale barren until 2014, when they assessed effectiveness of the burn.

Results were remarkable in the short-term growth period after the burn, which, combined with herbicide application, eliminated 94% of large, and 98% of small, hickories. The published results (Tyndall 2015) demonstrate that the burn reinvigorated the shale barren community, with the adversity-loving *T. virginicum* increasing greatly in community importance and herbaceous diversity, and biomass increasing overall at the site. By removing the shady overgrowth of pignut hickories, the burn reestablished the sunny environment favored by plants of the shale barren community. Meanwhile, trees and woody plants untreated by herbicide largely survived the burn.

*Green Ridge State Forest shale barren before (left) and after (right) herbicide and prescribed fire treatment. Note thinning of forest with hickory removal and resurgence of native ground cover, including spreading sunflower (*Helianthus divaricatus) (Wayne Tyndall, MD DNR).

This prescribed burn was the first step in returning the critical natural process of fire to a fire-dependent ecosystem. Today, the Green Ridge State Forest shale barrens support a robust native plant community, providing habitat for pollinating bees and other animals. This project confirms that fire ecologists are on the right path to restoring shale barrens through periodic ground fires.

Maryland's wealth of waterbodies has presented a challenge to its citizens, who contend with streams, rivers, ponds, and bays as they establish infrastructure for transportation, development, and agriculture. Ongoing struggles to control the path of water have created threats to the habitats that support Maryland's aquatic resources *(IUCN 7.2)*. Stream ditching and channelization, the creation of artificial impoundments, and marsh management techniques for purposes of construction or species control affect the natural flow of surface water, in turn affecting species which move, live, and eat in these aquatic areas. As land is converted and human development occurs, groundwater quality and quantity are altered by residential neighborhoods, commercial areas, mining operations, and agricultural irrigation systems. Dams, culverts, and stream burials direct water to fit human needs but these changes may threaten biological processes, especially affecting fish migration paths (Figure 5.6) and sediment collection and deposition zones. Beaver dams are an important natural disturbance in many wetland and aquatic systems, as they control water flow and help reduce sediment and nutrient loads in downstream areas.

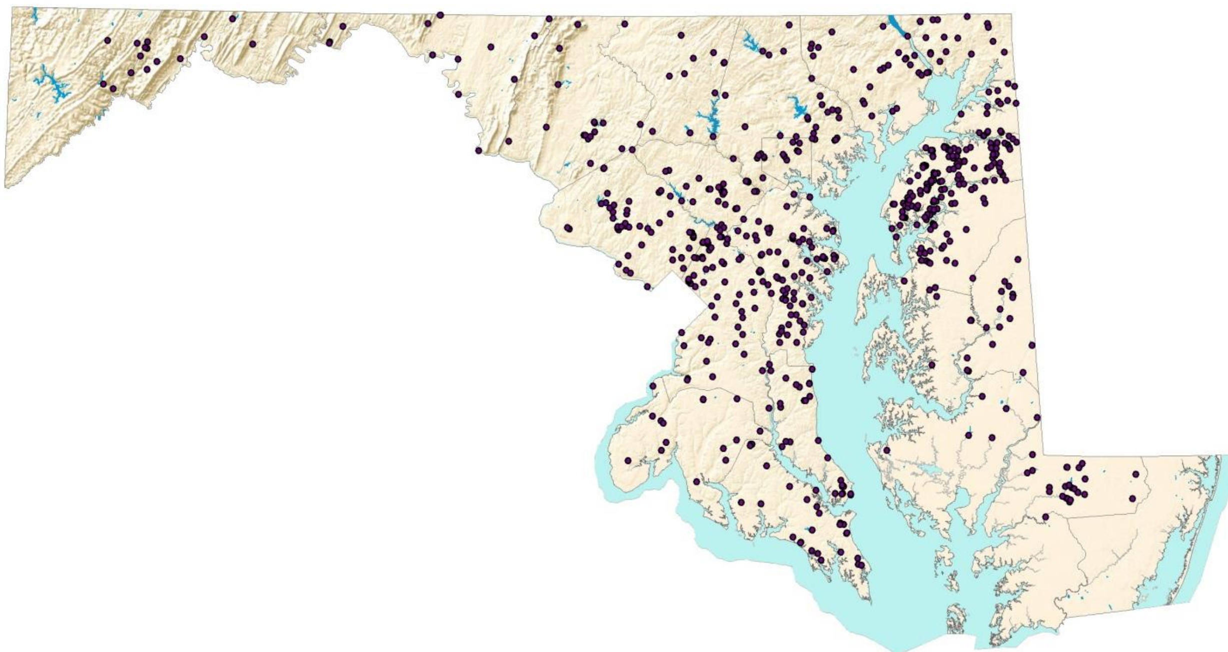


Figure 5.6 Fish passage blockages in Maryland. Source: MD DNR

The Northeast has the highest density of dams and road crossings in the country, with an average of seven dams and 106 road-stream crossings per 100 miles of river (Anderson and Olivero Sheldon 2011). Maryland's streams and rivers are crossed by roads over 14,000 times (Figure 5.7). These barriers segment and fragment both terrestrial and aquatic populations, and in many cases prevent migratory fish species from reaching their traditional spawning grounds. Dams also alter patterns of river flow, hydrology, and geomorphology. Maryland has more than 500 legacy dams – those no longer used for their intended purpose – that pose a particular threat to aquatic organisms and their habitats as well as to public safety (Terwilliger & NEFWDTC 2013)

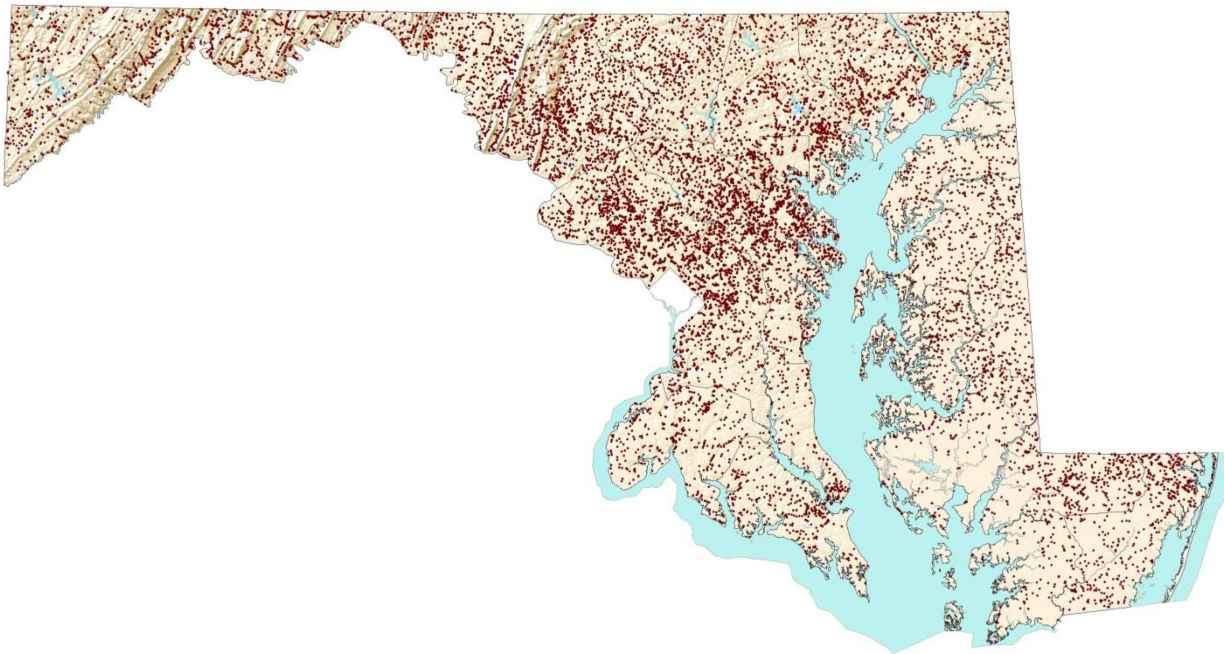


Figure 5.7 Over-stream road crossings in Maryland. Source: MDSHA, USGS

Stormwater management is also an important facet of the challenges that accompany development and natural systems modifications. The conversion of Maryland's natural lands to developed commercial and residential areas, roads, and recreation sites increases impervious surface in the state. Impervious land cover *(7.2.14)* includes hard surfaces, paved roads, sidewalks, parking lots, roofs, and land with highly compacted soils like sports fields (Figure 5.8). They prevent rain water from soaking into the ground, filtering through soils, and slowly seeping into streams. Instead, runoff from impervious surfaces rapidly enters streams and rivers, creating high velocity flows that are not well tolerated by many aquatic organisms. This change in flow also markedly increases the power of streams to move substrates and erode banks, resulting in highly modified erosion and deposition rates and widened and/or deeply cut stream channels. During non-storm periods (baseflow), the reduced groundwater input and widened channels typically produce shallow, slow velocity conditions that degrade physical habitat quality and leave the stream more susceptible to warming. Storm runoff can also affect stream water quality by introducing rapid flushes of heated water during summer, high road salt concentrations in winter, and contaminants such as hydrocarbons and antifreeze year-round.

One of the organisms sensitive to stormwater runoff in Maryland is brook trout. Brook trout require stable, clean, cool waters, the very water conditions disrupted by increased impervious surfaces. Once numbering in the millions in the state, brook trout have declined in both abundance and range in Maryland. The species continues to be in peril due to urbanization and climate change: brook trout populations today are supported in only 50 subwatersheds, most of which are in western Maryland, and the sites where they occur exhibit varying degrees of population health (MD DNR 2006). Nearly all brook trout populations are found in streams in watersheds with less than 4% impervious surface (Stranko et al. 2008).

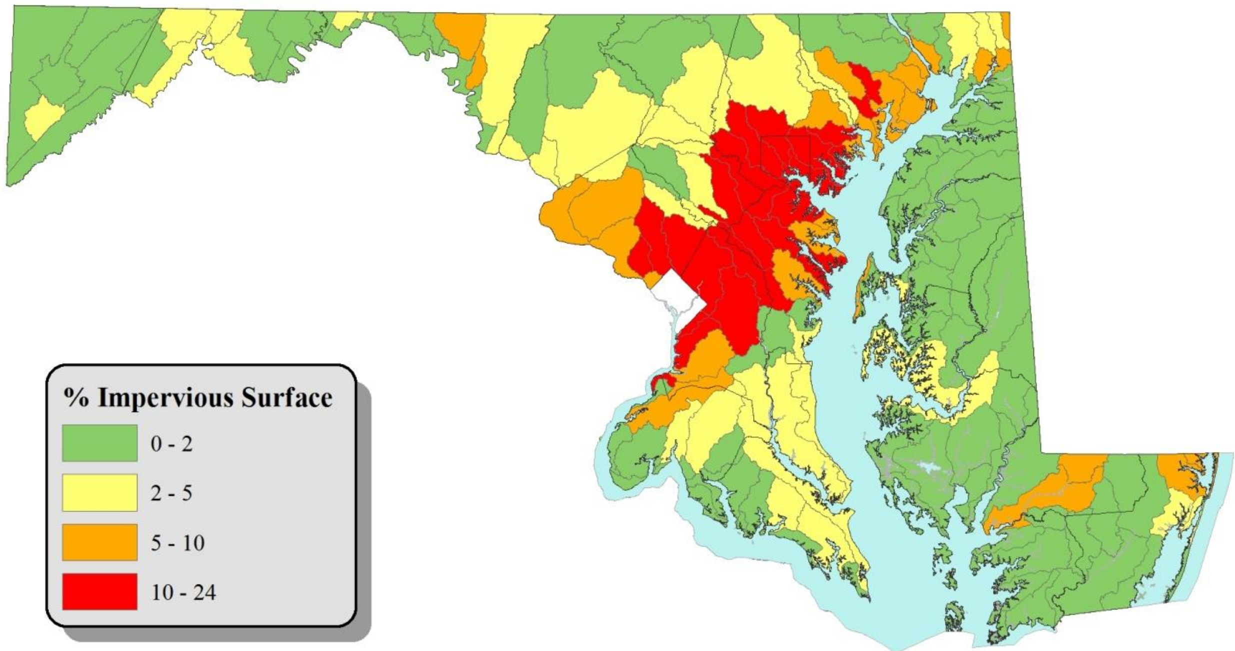


Figure 5.8 Percent of impervious surface area across Maryland. Source: NLCD, MD DNR, USGS

Other types of ecosystem modifications *(IUCN 7.3)* that may threaten SGCN or natural systems include mowing, removal of coarse woody debris, imbalance of predator-prey relationships due to loss of apex predators, and shoreline stabilization. For example, inappropriate timing of mowing can be extremely harmful to many birds, small mammals, reptiles, and amphibians in meadows, pastures, hayfields, roadsides, and powerline rights-of way, especially during the nesting seasons of these species. Removal of nesting cover during the breeding season not only causes some direct mortality of adults, eggs or young, but often leaves the habitat unsuitable for nesting until the next growing season. Native plants and grasses growing in these areas offer nutrition and protection to an array of insect species including butterflies, moths, dragonflies, damselflies, bees, wasps, and ants. Frequent mowing eliminates habitat and prevents pollinators and juveniles of many species from becoming prevalent in these potentially diverse, early successional areas.

Coastal development typically involves beach stabilization efforts to stop coastal morphology from changing. Beach stabilization interferes with natural stabilizing mechanisms, such as beach grass establishment. Stabilization of cliffs prevents natural erosion from occurring, depriving downstream beaches of their sediment supply and allowing cliff faces to become vegetated. In addition, jetties and groins interrupt shoreline sediment drift and can cause beaches to become vegetated. Although these practices may reduce shoreline erosion, they can negatively impact the survival of rare shoreline species such as the Puritan tiger beetle (federally listed as Threatened, state-listed as Endangered). Trails, roads, and walkways (*IUCN 1.3*) can exacerbate erosion by creating channels through the dunes that winds and waves can follow, overwashing the areas between the dunes with salt water (Terwilliger & NEFWDTC 2013).

Invasive Species and Other Problematic Species, Genes, and Diseases (IUCN 8)

Globalization and transportation advances have made trade and travel easier and faster than ever, but these impressive developments introduce a bevy of new organisms into unprepared systems that they may affect. Invasive species are defined as animal, plant, and pathogen species that, when introduced into an ecosystem by human activity, establish and spread, and cause economic or environmental harm to native organisms or ecosystems, or harm to human health. Alongside habitat loss, invasive species present one of the greatest threats to Maryland's wildlife and their habitats. Invasive species often exhibit a "lag time" between their introduction and their noticeably rapid dispersal and spread, so that by the time their damaging effects are recognized, they are already well entrenched in their novel habitats. This makes eradication, control, or management efforts that much more difficult. Invasive species may affect native species indirectly (e.g., habitat alteration) or directly (e.g., feral cat predation). Some major examples of invasive organisms and other problematic species in Maryland and their impacts follow.

Invasive, non-native terrestrial/wetland animal examples (IUCN 8.1.4):

Nutria (USFWS)

- **Nutria** *(Myocastor coypus)* are semi-aquatic South American rodents that were introduced from Dorchester County fur farms into nearby wetlands in 1943. These animals degrade wetland habitats as they consume the living root mat that anchors marshlands. The loss of this root mat leads to excessive erosion, further destroying the marsh. The traditional natural predators of the nutria do not exist here, so the population expanded unchecked. The nutria population recorded on the 10,000 acre Chesapeake Marshlands National Wildlife Refuge Complex (CMNWRC), Blackwater Unit was 150 in 1968. By 2000, there were an estimated 50,000 animals living in the Blackwater Unit. Wetland scientists believe that nutria are largely responsible for the dramatic change from marsh to open water at Blackwater (Figure 5.9). While the CMNWRC has recently announced the successful eradication of nutria in the entire Blackwater National Wildlife Refuge, nutria have spread across the Eastern Shore and into the Western Shore Potomac and Patuxent River watersheds in Maryland. Their destructive feeding habits harm marsh plants and animals that depend on wetlands as nurseries, habitats, and filtration complexes (USFWS 2013).

Figure 5.9 Aerial view of Blackwater Wildlife Refuge showing marsh lost from 1939 (left) to 1989 (right). Source: USFWS

- **Mute swans** *(Cygnus olor)* were introduced to Maryland in 1962, when five individuals escaped from a captive bird collection in Talbot County. These beautiful but aggressive birds were brought to the United States beginning in the 1800s to decorate estates and gardens. However, escaped swans created a wild population that, by 1999,numbered about 4,000.This swan's feeding habits threaten sensitive submerged aquatic vegetation (SAV) beds and their aggressive behavior prevents native birds from inhabiting important nesting areas

Mute swan (Bill Hubick)

- **Emerald ash borer** *(Agrilus planipennis)***,** or EAB, threatens all ash tree species *(Fraxinus* spp.*)* native to North America. The beetle was likely introduced in the 1990s in wooden materials arriving from Asia, where EAB is native. These beetles utilize ash trees as larval hosts. Eggs laid in the bark of a host tree hatch, and the larvae move into the cambium layer, where they feed on the internal transport system that carries food and water through the tree. This consumptive action kills stressed and healthy trees alike. EAB infestations have been responsible for over 50 million ash tree deaths in twenty-five states in the United States since the infestation was first detected in 2002 (U.S. Department of Agriculture [USDA] Animal and Plant Health Inspection Service 2016).

Emerald ash-borer (NPS)

Gypsy moth caterpillar (MDA)

A USDA quarantine boundary regulation, established in 2003 and updated many times since, prohibits transport of ash trees and wood products from within the quarantine area to states outside the boundaries without a permit. Control efforts by the Maryland Department of Agriculture, MD DNR, and USDA in Maryland include surveys, public outreach, and releases of biological controls. However, EAB spread continues – MD DNR detected ash borer presence on the Eastern Shore, the last region of the state to be infested, in 2015. Following this find, USDA added the entire state to the federal quarantine area in July 2015, and Maryland rescinded its own previous partial state quarantine. The EAB infestation has the potential to kill an estimated seven billion ash trees in urban and rural forests in the United States, which amounts to nearly 90% of the country's ash population (Vannatta et al. 2012). Over 18 million ash trees live in Maryland today (USDA 2014), but some foresters project that EAB could cause virtually total mortality of this species in Maryland by 2025 (DeSantis 2013).

Fuzzy masses on hemlock needles are a telltale sign of hemlock woolly adelgid infestation (NPS).

Other invasive insects that pose significant threats to Maryland's forests include: **gypsy moth** *(Lymantria dispar)*, which devours the leaves of oaks *(Quercus* spp.*)* and other hardwoods and impacts several forest key wildlife habitats; and **hemlock woolly adelgid (***Adelges tsugae)*, an insect that originated in Asia and infests hemlock trees *(Tsuga* spp.*)*, harming a basic component of cove forests and the Hemlock-Northern Hardwood Forest key wildlife habitat. Over 42,000 acres of vulnerable hemlock forests exist in Maryland, nearly all at risk of woolly adelgid infestation and eventual mortality. Maryland Department of Agriculture is working to implement a Hemlock Woolly Adelgid Treatment and Suppression Plan.

Invasive, non-native terrestrial/wetland plant examples (IUCN 8.1.5):

- **English ivy** *(Hedera helix)* was originally brought to the U.S. from Eurasia as an ornamental plant, but it quickly escaped the gardens into which it was introduced. When not pruned, English ivy is able to climb vertical structures, including trees, and reach sexual maturity. The woody vine produces berries that are distributed by birds. In natural areas, ivy thickly covers the ground, eliminating native woodland plants while avoiding herbivory from native animals, which largely do not consume ivy. The plant uses a sticky substance that holds the vine to tree bark. Mature ivy vines can smother tree canopies, and the weight of mature vines make trees more vulnerable to windthrow. Trunks blanketed by ivy can be susceptible to moisture and insect damage, as the ivy holds moisture against the bark and provides protection for borers and other insects.

English ivy (Nancy Fraley, NPS)

- **Japanese stiltgrass** *(Microstegium vimineum)* occurs in upland and wetland habitats in the eastern U.S. It is likely that the grass was introduced to the U.S. in the early 1900s from eastern Asian countries as a packing material protecting fragile products such as porcelain. Stiltgrass is established as lush green carpet in Maryland's forests, where the grass thrives in shady conditions and crowds out native plants. Because stiltgrass produces many seeds with the ability to remain dormant in soil for years, complete eradication of stiltgrass through either manual or chemical means is difficult.

Carpet of Japanese stiltgrass (TNC)

- **Garlic mustard** *(Alliaria petiolata)* had an early start in Maryland, as settlers brought the medicinal plant from Europe to the New World via New York in the 1880s. This flowering herb escaped to woodlands and spread like wildfire through upland forest habitats, where it outcompeted native plants including spring ephemeral wildflowers. As a mustard, it is related to the native toothworts that are host plants for certain rare butterflies. Where garlic mustard occurs, the butterflies are confused by the similar chemical signals from the plant and lay their eggs on it instead of toothwort, but then they cannot survive on garlic mustard. Garlic mustard spreads quickly and efficiently, with little or no herbivory from white-tailed deer. Once established, the plant can be difficult to eradicate, as seeds from the mature garlic mustard are able to lie dormant for up to five years.

Garlic mustard (NPS)

- **Wavyleaf basketgrass** *(Oplismenus undulatifolius)* is a more recent invader. This grass of Asian origin was discovered in the United States for the first time in 1996 in Maryland's Patapsco Valley State Park, and turned up more frequently in various Maryland parks and natural areas in the 2000s. Wavyleaf basketgrass spreads quickly, creating dense mats of shade-tolerant grass that cover the forest floor. Long bristles on the seeds produce a sticky substance that allows them to adhere to passing animals, people, and equipment, only to fall off later far from the parent plant, facilitating the grass's spread over large distances. As of Spring 2016, the grass had been documented only from Maryland and Virginia, although adjacent states continue to survey for it. Its current limited distribution in the eastern U.S. makes this a worthy target for eradication.

Wavyleaf basketgrass (Kerrie Kyde, MD DNR)

- **Purple loosestrife** *(Lythrum salicaria)* arrived in Maryland from Europe accidentally in the 19th century in ships' ballast water and attached to other materials; it was also imported purposefully as a medicinal and decorative plant. Unfortunately, this attractive plant reproduces quickly when established, crowding out other plants, establishing extensive patches and disrupting food chains and habitats in wet areas and marshes.

- **Phragmites** (non-native *Phragmites australis* var. *australis*) arrived in Maryland's wetlands in the 18th century. Transported in the ballast water of sailing ships, this tall grass dominates native wetland plants, including the native variety of *Phragmites*.

Purple loosestrife (Kerrie Kyde, MD DNR)

Case Study: Invasive Plant Control at Parkers Creek

One established invasive species in Maryland is *Phragmites australis* var. *australis*, or common reed, a European haplotype, or genetic strain, of a pan-global grass species. Also known as "Phrag", this grass spread from Europe in the 18th century in the ballast water of sailing ships.

Biologists recovered preserved Phrag roots from New England marshes showing that a native Phrag haplotype was present on the East coast of the U.S. nearly 4,000 years ago. *P. australis* var. *americanus* is a slower growing, more contained marsh grass, and is an excellent example of a native plant that grows with other natives to create a balanced habitat for wetland animals.

Unfortunately, this native grass has largely been replaced in marshes by the aggressive European subspecies *P. australis* subsp. *australis.*
Today, the European *Phragmites* has taken up residence in wetlands across the U.S., where the grass utilizes a spreading system of rhizomes to compete with native marsh plants by blocking sunlight and taking over open growing spaces. The plant reaches heights of 15 to 20 feet – in fact, the grass's name comes from the Greek word *phragma*, or fence. As *Phragmites* spreads through marshy regions, the grassy growth eliminates plant diversity and aquatic habitats. The root system fills in wetland areas, resulting in loss of habitat for wetland species, many of which are already threatened by poor water quality and habitat destruction. In Maryland, *Phragmites* control is important as the state's wetlands are of great value as habitat for birds, fish, reptiles, mammals, and an extensive range of invertebrates.

Least bittern, marsh nesting bird (George Jett)

A recent DNR-led *Phragmites* control project in southern Maryland took on nearly seven acres of established Phrag in the marsh at the head of Parkers Creek. Parkers Creek is a wildlife management area (WMA) featured in Maryland's Natural Areas Guide. In 2014, 1,756 acres of Parkers Creek WMA were designated as one of Maryland's 38 state wildlands (see Chapter 7). Parkers Creek WMA, which safeguards nearly 3,000 acres of forest and marshlands in Calvert County, is owned by MD DNR and managed by the American Chestnut Land Trust, which also owns land within the Parker's Creek watershed. Together, the lands encompass some of the most pristine wetlands on Maryland's Western Shore. *Phragmites* arrived in the Parkers Creek WMA in the 1980's and presents a threat to rare species dwelling in the marshes of Parkers Creek, including several species of marsh nesting birds, such as least bittern.

In the fall of 2012, DNR teamed up with the Chesapeake Bay Field Office of the U.S. Fish and Wildlife Service and the Maryland Department of Agriculture, with funding from the USDA Forest Service, to control *Phragmites* at Parkers Creek. Surveys of the marsh showed that the Phrag infestation was too great to pull from the marsh manually, so, for the first time, herbicides were used in Parkers Creek Wildlife Management Area. The materials were chosen carefully and applied in early fall, when other marsh plants were dormant but *Phragmites*, the resilient invader, was still growing and flowering. The control effort began in 2013, but met with technical issues that prevented the project from gaining much headway. In 2014, the Phrag control team headed into the field again, using an amphibious all-terrain vehicle (ATV) outfitted with herbicide tanks and sprayers to travel throughout the marsh. Instead of wheels, the ATV traveled on tracks that evenly distributed the weight of the vehicle, minimizing disturbance to the sensitive marshland.

The herbicide did its job, killing nearly seven acres of invasive *Phragmites*. Some grass remaining along the creek edge could not be reached by ATV. A DNR contractor treated these patches in the summer of 2015 from a small boat by motoring carefully into the creek's headwaters. This project was a promising start to a multi-year management operation, although stands of invasive Phrag remain down the length of the creek. One of these remaining stands includes the native Phrag species, *Phragmites australis* var. *americanus*. With the active management of the largest stand of invasive Phrag in Parkers Creek WMA, project leaders expect to observe a greater diversity in marsh plants repopulating the area, allowing Parkers Creek to recover its ecological character.

Invasive Phragmites plants loom up to 12 feet in Parkers Creek before the 2012 treatment (left); Desiccated Phragmites in 2013 after treatment (right)
(Kerrie Kyde, MD DNR).

Invasive, non-native aquatic animal examples (IUCN 8.1.2):

- **Zebra mussels** *(Dreissena polymorpha)* arrived in Maryland in 2012, spreading into the Susquehanna River in 2012 (Figure 5.10) from northern waterways, where the mussels were likely introduced in ships' ballast water. MD DNR resource assessment team observations from 2012 to 2015 indicate that zebra mussels appear to be increasing in abundance in the Lower Susquehanna River and the Susquehanna Flats near Havre de Grace. In 2015, this invasive species was first reported from the tidal portions of the Gunpowder and Middle rivers – likely carried by tidal currents as larvae from the upper Chesapeake Bay. (MD DNR 2015). Although dispersal into other bay tributaries is possible, establishment of this species outside of oligohaline waters will be limited by salinity. These mussels mean trouble for Maryland waters, where native mussel populations struggle to survive in sub-optimal conditions. Zebra mussels spread rapidly, are fast filter feeders capable of depleting water of the oxygen

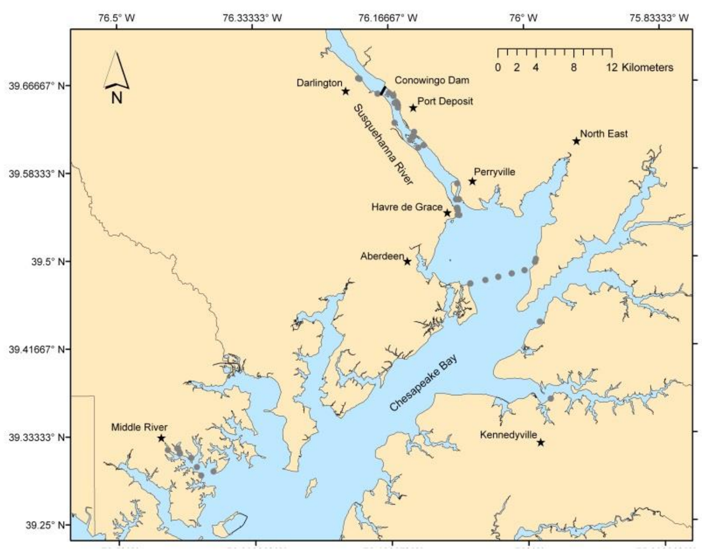
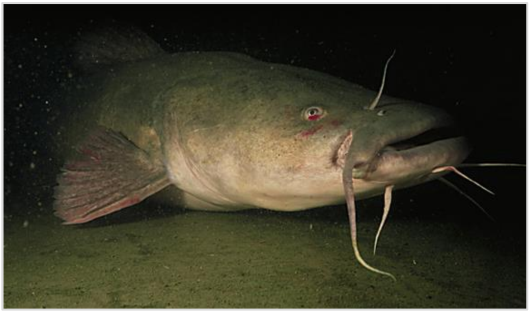


Figure 5.10 Spread of zebra mussels in the Chesapeake Bay and its tributaries.
Source: MD DNR.

and plankton needed by larval fish, and attach themselves to native mussels to steal resources. Zebra mussels have also been known to clog and damage infrastructure like intake pipes.

- **Blue catfish** *(Ictalurus furcatus)* and **flathead catfish** *(Pylodictis olivaris)* have rapidly spread into every major tributary in the Chesapeake Bay watershed. Both fishes are popular sportfish in southern U.S. rivers, and were introduced in the 1970s and 1980s to Virginia waters for recreational fishing purposes. Blue catfish is established in the Potomac River; the flathead catfish is found in less numerous quantities in Maryland's rivers. Both of these large fish are voracious predators of native species including shad, menhaden *(Brevoortia tyrannus)*, mussels, and blue crab (*Callinectes sapidus*).



Flathead catfish (Garold Sneegas, USGS)

Northern snakehead (MD DNR)

- **Northern snakehead** *(Channa argus)* is an invasive eastern Asian species that has become established in Maryland's Potomac River, and that threatens many other waterways in Maryland including the Wicomico, Patuxent, and Susquehanna Rivers. Snakeheads are remarkable in their tolerance of wide temperature, salinity, and dissolved oxygen ranges. Female fish can release up to 100,000 eggs a year, and parent fish guard young offspring. This invasive preys on native fish, crustaceans, and amphibians, and increases the risk of introducing non-native disease organisms to U.S. fisheries.

- **Invasive crayfishes** represent the single greatest threat to native crayfish diversity (Lodge et al. 2000; Taylor et al. 2007). Three invasive crayfishes, including the rusty crayfish *(Oronectes rusticus)*, virile crayfish *(Oronectes virilis)*, and the red swamp crayfish *(Procambarus clarkii)*, are established in Maryland. Reaching high densities in invaded waterbodies, these invasive crayfishes have the capacity to displace native crayfishes and to alter aquatic food webs and habitats.

Rusty crayfish (MD DNR)

The virile crayfish, first reported from the Patapsco River in the late 1950s, has become widely established in central and western Maryland primarily through its use as bait by anglers (Fig.5.11). Its spread was followed by the concomitant decline of two native crayfishes including the SGCN Allegheny crayfish. Rusty crayfish, a more recent

Maryland invader, is a formidable competitor responsible for displacing native crayfishes in other U.S. states. Further spread of this invader poses a substantial risk to native crayfish populations.

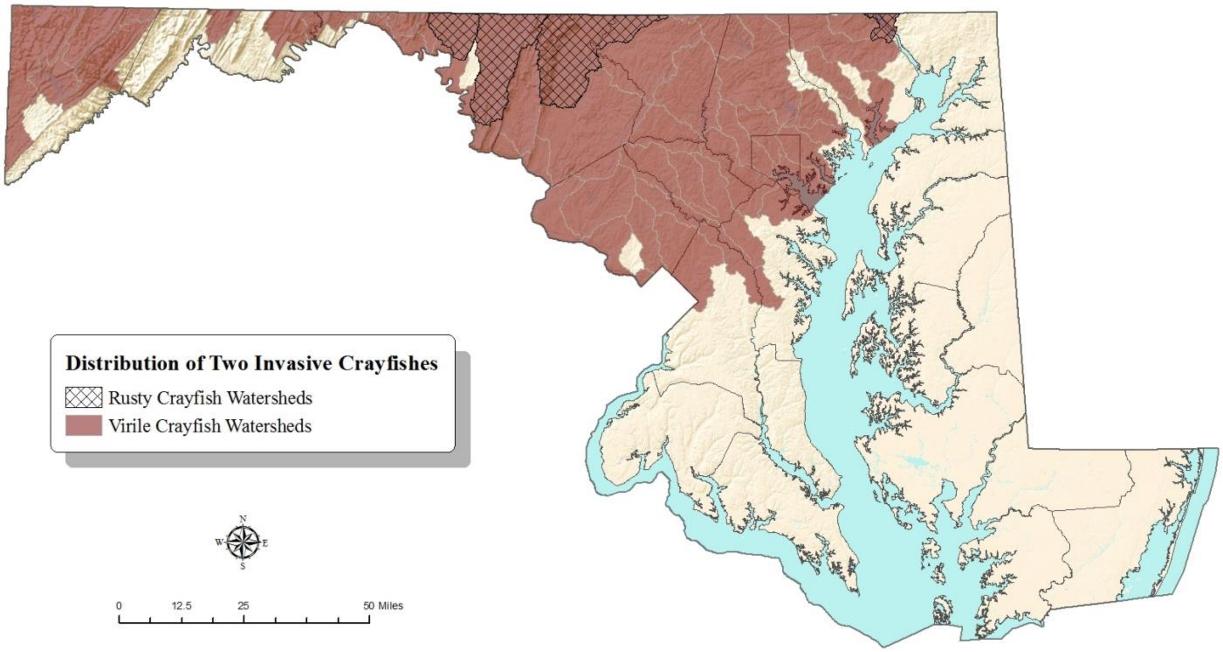


Figure 5.11 The spread of the virile and rusty crayfishes in Maryland. MD DNR

Invasive, non-native aquatic plant examples (IUCN 8.1.3)

- **Water chestnut** *(Trapa natans)* spread into Maryland's waters from northern states, where the plant was cultivated in ponds in the late 1800s. The plant, which is native to western Europe, Africa, and Asia, forms floating mats on the surface of the water, limiting the penetration of light needed by many native aquatic species. In addition to competing with native plants, the rapidly reproducing water chestnut impacts occupied zones when it dies back every year, decomposing and reducing oxygen levels in the water.

Water chestnut
(Mike Naylor, MD DNR)

- **Hydrilla** *(Hydrilla verticillata)* was introduced to the United States in the 1960s through the aquarium trade. It was first detected in the Potomac River in 1982, and by 1992, had covered 3,000 acres of the river. This floating aquatic plant, native to Korea and India, has proven to provide good habitat for fish fry, but outcompetes native grasses by blocking sunlight from smaller plants.

Hydrilla, pictured here tangled around a boat propeller (Stephen Badger, MD DNR)

Invasive, non-native fungal/bacterial disease examples (IUCN 8.1.6):

- **Bd Chytridiomycosis** is a contagious fungal disease causing amphibian die-offs in 40 countries worldwide; 36 states in the U.S. report infections. The disease is caused by the chytrid fungus *Batrachochytrium dendrobatidis,* which feeds on the skin of living vertebrates, interfering with amphibians' ability to take up water and air through the skin. Although the fungus has been present in the world since ancient times, scientists speculate that it is becoming lethal to amphibians now due to other stresses such as climate change, pollution, and habitat destruction (Lips et al. 2006). Although it is Maryland's frog species are most affected by the chytrid fungus, the eastern hellbender, a large riverine salamander experiencing precipitous declines across its range in the Northeast region, is also highly susceptible to the disease (Terwilliger & NEFWDTC 2013).

- **Bsal Chytridiomycosis** is a fungal disease that in 2013 was discovered to be the cause of a massive salamander die-off in Europe. Bsal *(Batrachochytrium salamandrivorans)* is native to Asia, where native salamanders can be carriers without showing signs of disease. The international salamander trade introduced the fungus to parts of Europe, where it has spread lethally through wild and captive populations in many countries. As of 2016, *Bsal* had not yet been identified in North America. The introduction of this fungus could be disastrous to the diverse native salamander populations, which frequently play important roles in their ecosystems (Yap et al. 2015).

- **White-nose syndrome (WNS)** is a devastating disease that has wiped out roughly 85% of the northeastern bat population since its arrival in the U.S. in the winter of 2007-2008 (USGS 2015). Named for the white fungus (*Pseudogymnoascus destructans)* that grows on the muzzle and ears of hibernating bats, this disease kills by causing bats to expend too much of their limited energy during hibernation. WNS is estimated to have killed more than 5.7 million hibernating bats in all of the Northeast region states (Terwilliger & NEFWDTC 2013). WNS is affecting more than bats, however; bats are important insectivores that benefit not only their ecosystems, but also human neighborhoods and farms through insect consumption.

Bats exhibiting white-nose fungus (Nancy Heaslip, NY Department of Environmental Conservation)

Native Threats to Wildlife (IUCN 8.2)

Native species can be problematic as well, although these problems are often a result of anthropogenic changes to an ecosystem. A well-known problem in Maryland is the overabundance of white-tailed deer, as the species breeds with little natural control in the absence of mountain lions and other predators that were historically present. Deer present in high densities in Maryland's natural areas damage sensitive ecosystems, such as Soldiers Delight

Natural Environment Area. These native ungulates have the potential to devastate ecosystems if not controlled through public hunting and other means. Deer are prodigious browsers that are capable of wiping out the forest understory, which is an important habitat of native plants and wildlife. Deer consumption of native plants facilitates the spread of exotic, invasive plant species like wavyleaf basketgrass, Japanese stiltgrass, and garlic mustard, establishing harmful monotypic stands that do not support a variety of wildlife as native plants do (Tallamy 2004). Deer-denuded forest understories cannot perform the crucial function of slowing down and cleaning surface runoff, thus maintaining water quality. Deer present problems to Maryland's human population more directly as hosts of the ticks that vector Lyme disease, consumers of gardens and crops, and a frequent cause of automobile accidents (MD DNR 2008).

Maryland wildlife are also threatened by native diseases such as species of *Baylisascaris*, a roundworm that affects the intestinal tracts of animal hosts like raccoons, rabbits, skunks, and birds. *Baylisascaris* species take up residence in a variety of animals, causing tissue damage. Worm eggs are excreted to infect other animals, including humans, through accidental consumption of worm larvae. This is thought to be one of the primary reasons for the loss of many Allegheny woodrat (*Neotoma magister*) populations in western Maryland, causing it to be currently listed as Endangered in Maryland.

Other threats related to problem species include introduced genetic material *(IUCN 8.3)* and viral diseases *(IUCN 8.5)*, two important research areas that are not yet fully understood. One example of a threat from genetic manipulation is the impact of genetically engineered herbicide resistant crops. While these plants permit reduced production costs, the herbicide treatments used to clear fields without harming crops removes all but the resistant plants. One important native devastated by this practice is common milkweed (*Asclepias syriaca*). Milkweeds *(Asclepias* spp.) are the only plants on which the monarch butterfly, a Maryland SGCN, will lay its eggs. The monarch butterfly, and the declining milkweed on which it depends, have become the figurehead for a movement focused on sustainable agriculture in the United States (Center for Food Safety 2015).

A final significant threat is the increasing prevalence of viral diseases affecting native animals *(IUCN 8.5)*. Examples of these diseases include West Nile Virus, which affects mosquitoes, birds, and mammals; *Ranavirus* species, which affect reptiles and amphibians; and sudden oak death, caused by a contagious pathogen *(Phytophthora ramorum)*. These diseases are spread more easily around the world through modern transport and travel systems. Such diseases threaten not simply individual species, but entire ecosystems of which those species are a part. *Ranavirus*, which includes six species of viruses in the same genus, is known to affect over 100 reptile and amphibian species and subspecies. This disease is especially dangerous as the virus can live for weeks outside the host in aquatic conditions, and is usually fatal to juvenile individuals, although adults can also be susceptible to or transmit *Ranavirus*. Relatively little information is known about the origin, extent, and frequency of the virus due to the disease's pattern of rapid onset and mortality. In populations that tend to congregate in large groups,the disease can spread quickly, with some infected populations suffering 90% mortality (Northeast Partners in Amphibian and Reptile Conservation 2014).

Pollution (IUCN 9)

Wastewater, runoff, and other effluent sources (IUCN 9.1, 9.2, and 9.3)

Three major groups of pollutants flow into Maryland's waters, and eventually into the Chesapeake Bay, due to wastewater pollution. Nitrogen, phosphorus, and excessive sediments are pollutants that originate from a variety of sources and are released into the natural landscape and waterscape. Runoff with excessive levels of road salt can impact soils, groundwater, and aquatic systems by increasing chloride to toxic levels. Nitrogen and phosphorus are both beneficial to wildlife in small quantities, but the flood of nutrients introduced to Maryland's waters by wastewater plants and agricultural and residential runoff has negative impacts on wildlife and their habitats. In large quantities, these nutrients can trigger harmful algal blooms that reduce sunlight and oxygen in aquatic environments and can even be toxic to plants and animals. Sedimentation, the addition of large amounts of sand, silt, and clay particles to waterways, can cloud the water, reducing sunlight needed for photosynthesis by growing submerged vegetation, which in turn harms shellfish and young fish that depend on these plants for food and shelter. These pollutants can cause dead zones, areas with little or no dissolved oxygen in the water, in the deeper water portions of the Chesapeake Bay (Figure 5.12). Without oxygen, aquatic organisms suffocate in great die-offs. This interactive graphic depicts causes of nitrogen, phosphorus, and sediment pollution entering the Bay.

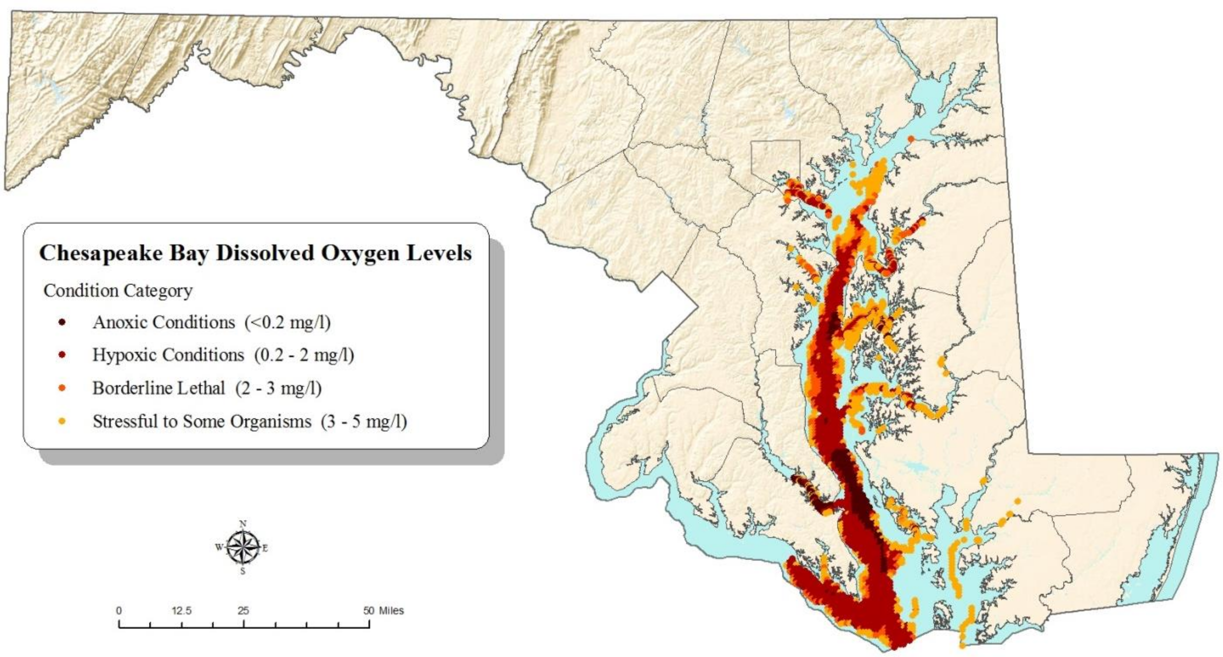


Figure 5.12 Dead zones in the Chesapeake Bay. Sources: USGS, MD DNR

The sources of these pollutants are separated into two broad classes: point and nonpoint sources. Point source pollution enters natural systems from specific entry points, such as municipal sewage and industrial discharges. Nonpoint pollution enters systems from unidentifiable sources or from numerous different entry points, such as agricultural and residential runoff and groundwater discharges. The nature of pollution often makes identifying entry points and pollution sources difficult, especially when dealing with a polluted body as large as the

Chesapeake Bay. To address this problem, scientists developed the concept of Total Maximum Daily Load (TMDL) to track and regulate pollution reaching the Bay. The U.S. Environmental Protection Agency's (EPA) TMDL for the Chesapeake Bay was announced in 2010 and is referred to as a "pollution diet" for the Bay, designating the maximum amount of pollution the Bay can receive and still meet state water quality standards designed to keep the Bay swimmable and fishable (EPA 2010). TMDL is an accountability framework for jurisdictions within the Bay watershed, identifying pollution limits that, if reached by 2025, will reduce nitrogen input by 25%, phosphorus by 24%, and sediment by 20%. The 2010 report identifies required reductions in the three classes of pollutants for multiple jurisdictions within each state in the Chesapeake Bay watershed. The TMDL denotes limits, or "waste load allocations" for point sources and "load allocations" for nonpoint sources, that jurisdictions will strive to meet through their own Watershed Implementation Plans (EPA 2013). To learn more about TMDL goals and pollution allowances for Maryland's jurisdictions, see the Chesapeake Bay Program's TMDL tracking program.

Discharge from wastewater treatment plants *(IUCN 9.1)* and industrial sources makes up the majority of Maryland's point source pollution *(IUCN 9.2)*. Wastewater treatment plant discharge alone makes up nearly 20% of nitrogen pollution in the Chesapeake Bay (CBF 2015). Mandatory monitoring of these pollution discharges, performed by the dischargers themselves and audited by Maryland Department of the Environment (MDE) under the National Pollutant Discharge Elimination System, aims to reduce wastewater emissions to meet TMDL standards. Point source pollution also includes industrial and military effluents from oil spills, acidic mine seepage, industrial toxin settling ponds, and wastewater ponds such as those used for hydraulic fracturing processes, toxic chemicals from factories, and accidental sewage spills from wastewater treatment plants. MDE tracks and has mapped the location of regulated facility outfalls in in the state (Figure 5.13).

Acid mine drainage *(IUCN 9.2.2)* affects surface waters across the mid-Atlantic region. Formed by chemical reactions between water and rocks containing sulfurous minerals, acidic drainage from abandoned and operating mines flows into streams as runoff if sufficient control mechanisms are not in place. Although unmined mineralized areas can produce acidic runoff, mines, where mining activities have exposed rocks containing sulfur-bearing pyrite, are the most frequent origins of acidic drainage. These acidic contaminants pollute drinking water, disrupt the health and growth of plants and wildlife in streams and wetlands, and corrode human-made and natural features. Acid mine drainage can be alleviated with the installation of alkaline dosers that neutralize acid in water by adding alkaline compounds, but doser operation is often limited by lack of financial resources (Maryland State Water Quality Advisory Committee 2010).

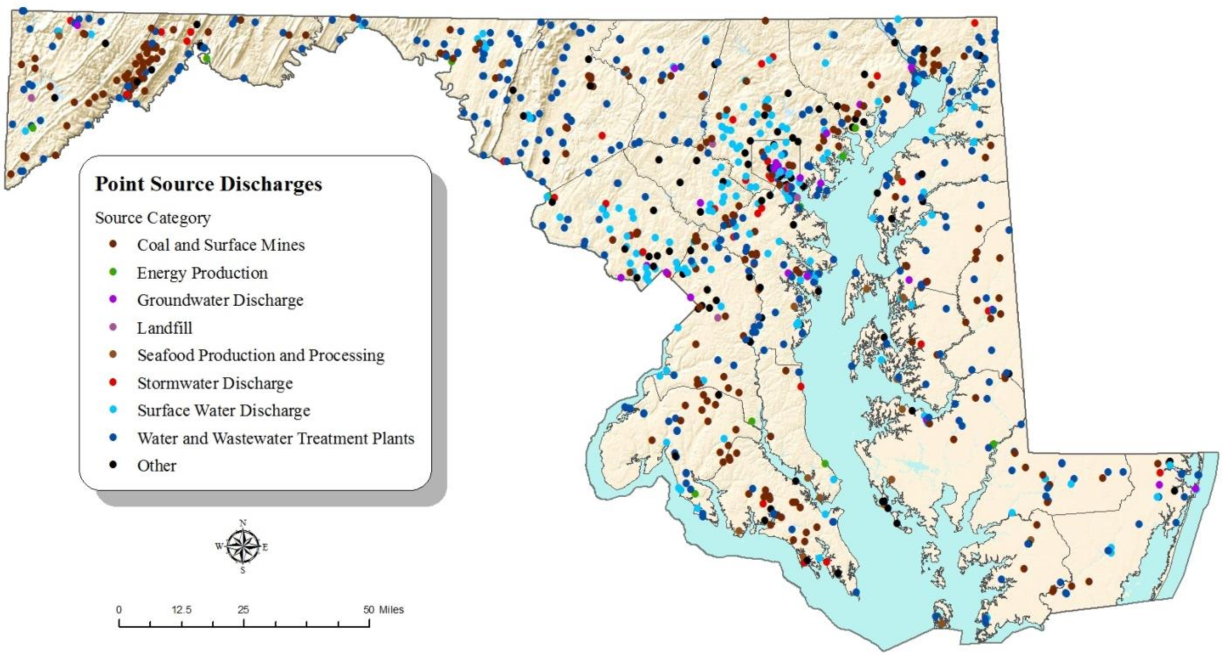


Figure 5.13 Sources of point source pollution in Maryland. Source: MDE

Nonpoint source pollution is more difficult to track to specific sites of origin as it often occurs in runoff when rainwater washes water across land, collecting contaminants and nutrients that end up in waterways. Regular water quality sampling regimens, such as those administered by MD DNR's StreamWaders program and others detailed in Chapter 8, are the key to locating and limiting Maryland's greatest sources of nonpoint pollution. The greatest source of Maryland's nonpoint source pollution is agricultural runoff, which introduces over 40% of nitrogen pollution and roughly 50% of phosphorus pollution into the Chesapeake Bay (CBF 2015). Agricultural pollutant sources *(IUCN 9.3)* include fertilizer runoff; manure seepage from animal enclosures or accidental spills from manure holding tanks; excess chemicals from aquaculture operations; sedimentation caused by overgrazing, clearcutting, and soil erosion; and pesticide runoff. Urban and stormwater runoff makes up 15 % of nitrogen pollution that reaches the Bay. Major contributors to nitrogen overload are the runoff of herbicide from lawns and golf course treatment chemicals. Oil, sediment, and salt from roads also flow into Maryland's streams and rivers and the Chesapeake Bay as a result of runoff. Nonpoint source pollution can be reduced by restoring natural filters such as riparian forest buffers and wetlands in areas with excessive stormwater, urban, and agricultural runoff. Maryland's Nonpoint Source Pollution Management Plan identifies targets for Maryland's research and management of statewide nonpoint source pollution.

Garbage and solid waste (IUCN 9.4)
Poor waste disposal practices can have disastrous results for wildlife and their habitats. Discarded solid waste can pollute groundwater and surface water, entangle and injure wildlife, and cause mortality when consumed. Debris in marine systems is of particular concern for sea turtles, seabirds, and marine mammals. Although now strongly regulated and strictly managed,

older landfills can contaminate water, air, and soil with toxic and noxious chemicals and liquids. Major sources of solid waste pollution in Maryland include municipal waste, trash from cars and boats, and construction debris. Heavy rainfall events can cause localized flooding and the subsequent transport of trash and debris downstream. Trash accumulates in larger rivers and the Chesapeake and Coastal Bays, with some debris making its way into the ocean. Marine environments also receive discarded solid waste directly from vessels at sea from derelict fishing gear and improper trash disposal.

Airborne pollutants (IUCN 9.5)
Maryland has historically exhibited some of the highest ozone levels in the eastern U.S., due not only to a highly concentrated population, but also to a "perfect storm" of meteorological and geographic conditions that transport airborne pollutants from power plants in the west and air pollution from highway traffic in states south of Maryland, trapping airborne contaminants at the western edge of the Chesapeake Bay. MDE research indicates that states upwind of Maryland are responsible for about 70% of Maryland's air quality problem (MDE 2015). The EPA now requires "Good Neighbor" plans from states whose emissions significantly affect other states, which includes most states east of the Mississippi River.

For the first time in more than three decades, EPA found that the metropolitan Baltimore area met the health-based federal standard for ground-level ozone in 2015. Also, for the first time since measurements began in 1980, 90% of air quality monitors serving Maryland met the EPA ozone standard. As part of the federal Clean Air Act, states are required to monitor and report air pollution levels on a yearly basis. Ozone is created by a chemical reaction between substances released into the air chiefly by industrial facilities and motor vehicle exhaust. This compound is very harmful to respiratory systems of wildlife and humans and can negatively affect sensitive ecosystems.

Maryland exhibits one of the highest rates of death due to air pollution in the U.S., where an estimated 200,000 deaths are attributed to air pollution every year (Caiazzo et al. 2013). More than one-third of the nitrogen pollution entering the Chesapeake Bay comes from the air (MDE 2011). In addition to ground-level ozone, air pollution problems include smog, which is formed from a mixture of fine particles from motor vehicle emissions, wood smoke, other combustion processes, and methane gas, a potent greenhouse gas that is emitted from natural gas operations like hydraulic fracturing. Maryland's Healthy Air Act, enacted in 2009 and praised as the toughest power plant law in the eastern U.S., has greatly reduced chemical emissions from power plants since its inception (MDE 2011). While these regulations are in place largely to improve human health in Maryland, wildlife and plants share the benefits of cleaner air.

Although agriculture and acid mine drainage are important sources of acid to streams, atmospheric deposition (more commonly known as acid rain) is the largest source of acid settling in Maryland waters. Formed when sulfur dioxide and nitrogen oxides reach the air and combine with water vapor, acid rain can impact terrestrial and aquatic ecosystems. Acid rain is especially dangerous to aquatic life, impacting metabolic processes, immune systems, growth rates, and abundance of aquatic animals from mayfly larvae to large fishes. Acid rain can also mobilize aluminum and other metals from surrounding soils and can increase concentrations of these elements to toxic levels in streams and lakes. Acid rain is considered a major threat to the Chesapeake Bay ecosystem (MDE 2013). Approximately 13% of streams in Maryland are impacted from acid rain (Versar, Inc. 2011). Streams with low acid neutralizing capacity, such as those of the Coastal Plain, are particularly vulnerable to this source of pollution.

Finally, the presence of both herbicidal and insecticidal compoundscan be very damaging to wildlife and their habitats, especially when these chemicals are applied in adverse weather conditions and are blown into nearby non-target natural areas and waterways. Pesticides are generally applied to agricultural operations and lawns, targeting troublesome species like beetles, maggots, or aphids, but they often kill other beneficial species. Bees and other pollinators are declining in part due to widespread use of neonicotinoids and other pesticides, which combine with other stresses to cause mass pollinator deaths and disrupt essential pollination activities.

Excess energy (IUCN 9.6)
Light, thermal, and noise pollution are less noticeable to humans and are often overlooked. However, these forms of pollution can have serious impacts on the functioning of biological systems. Light pollution affects primarily major cities and urban centers, and to a lesser extent, suburban residential areas. Light pollution disturbs wildlife's normal movement patterns: lamps attract insects, beach lights confuse nesting turtles, and tower lights disorient migrating birds, causing mass mortality events. More ecologically-friendly light sources, like motion-detecting streetlamps and downward-directed lighting, are important investments that many urban areas are making to cut down on light pollution. Artificial lighting can be deceptive to migrating birds, which navigate by the moon and stars, especially under low visibility conditions like foggy nights. Artificial light shining on reflective surfaces, such as the windows on tall city buildings, can increase the risk of collision for migrating birds and bats.

Thermal pollution sources include power plant-heated discharge water and hot road surfaces, the latter a feature of areas with extensive impervious cover. The introduction of heated water into aquatic systems can create conditions that disrupt reproductive and metabolic processes, and curtail aquatic plant life and other native species pushed beyond their heat tolerances. Rapid changes in temperature that can occur when heated water discharge is discontinued can shock fish, amphibians, and invertebrate species that cannot adjust to fluctuating water temperatures.

Noise pollution includes noise from airplanes, highways, and construction zones in terrestrial areas. Many animals depend on an elevated sense of hearing that allows them to perceive important environmental indicators, such as mating calls and distress signals, which can be masked by excessive human-made sound. Noise also causes stress reactions such as elevated heartbeat, blood pressure, and respiration (Francis & Barber 2013). SGCN in the Chesapeake Bay and Atlantic Ocean are known to be negatively affected by sonar from submarines and research stations as well as offshore construction projects such as wind power development. These technologies threaten marine species, including marine mammals. Potential effects of such human-generated noise to SGCN include physical injury, loss of hearing sensitivity, changes in foraging or habitat use patterns, separation of mother-calf pairs, and the inability to hear important environmental signals. Some strandings of marine mammals on land or in shallow waters may be due to noise pollution disrupting navigational processes such as echolocation in toothed whales and dolphins (Marine Mammal Commission 2007).

Geological Events (IUCN 10)

Natural geological events such as earthquakes and landslides are rare in Maryland, but, when they occur, such forces can be incredibly destructive to natural habitats. There is a greater likelihood that landslides will present a threat in Maryland where slopes and mountainsides are developed or mined.

Climate change (IUCN 11)

The phrase "climate change" is often used as an umbrella term to refer to long-term alterations of climate patterns. Climate change threatens species and their habitats due not only to warming temperatures and changes in precipitation patterns, but also to the exacerbation of already present stressors. Numerous climate-related alterations are already affecting Maryland SGCN and their habitats, including sea-level rise, changes in rainfall and temperature patterns, increased storms and flooding, and shifts in timing of plant and animal activities. An additional concern is the likelihood of reaching a "tipping point", a point beyond which, without decisive action, it will not be possible to reverse ecosystem damage. As research into the effects and scope of climate change continues, our ability to react in a way that conserves important species and natural lands should improve. Given the importance and relevance of climate change to a wide range of today's conservation actions, Chapter 6 of the SWAP is dedicated to this threat category and related information.

Lack of Planning, Integration, Research, and Resource Management

Many threats to Maryland's wildlife are present not because of directly-harmful human behavior or environmental influences, but rather because of other issues affecting conservation, management, and restoration of natural lands, as well as species populations. These issues include the need to effectively address data collection, resource management, recreation, education and outreach, and administration of conservation programs in a way that sustains biological diversity on a large scale. MD DNR is a large, multifaceted entity that must work to increase program integration in order to be maximally effective in conserving Maryland's wildlife. Towards this end, SWAP needs, goals, and objectives should actively influence program activities and expenditures. By outlining areas that must be improved to best protect Maryland's wildlife, especially in the face of numerous other threats outlined in this document, MD DNR hopes to increase connectivity and transparency between the agency and private and public stakeholders in the conservation of Maryland's wildlife and natural lands.

Resource Management Needs (IUCN 12)

Inventories, surveys, and monitoring projects play a vital role in our understanding of Maryland's wildlife and the habitats that support them. These projects are instrumental in collecting the information required for important conservation actions such as writing and implementing wildlife management plans, designing easements, and other projects for purposes of land conservation, as well as for modifying annual hunting and fishing regulations. Monitoring is a critical tool of "adaptive management" or learning from management outcomes to better manage resources. While some species with important populations in Maryland receive regular attention in this area (e.g., piping plover, nesting colonial waterbirds), the lack of focus on smaller organisms, such as many classes of invertebrates, threatens not only the survival of these species, but also the species that depend on their presence in the ecosystem. Many SGCN in the SWAP, particularly hundreds of invertebrates, are species for which we lack basic knowledge and understanding of their specific habitat needs, life histories, vulnerabilities, and distribution. These species are marked as data deficient in Chapter 3 and Appendix 3h. Unfortunately, funding for the necessary statewide monitoring programs to better understand wildlife, particularly aquatic resources, is often lacking, causing knowledge gaps.

Also included in this category are threats stemming from inappropriate or unsustainable management decisions. As Maryland's main source of information about state wildlife, MD DNR has an important responsibility to guide development actions with technical assistance, environmental project review, and wildlife and habitat planning. Landowners, public and private land managers, private industries, and government agencies rely upon services offered by MD DNR and other state agencies to support Maryland's human population with as little resultant harm to Maryland's wildlife as possible. The creation and regular review of species and land management plans are needed to support sound management decisions.

Recreation Needs (IUCN 13)

Outdoor recreation is an important pursuit in Maryland not only for entertainment and educational purposes but also for the state's economy, which is bolstered by revenues from recreational activities. Maintaining this human-wildlife link is important for both humans and animals, as increases in conservation awareness and funding are generated through recreational activity. However, proper support is required from MD DNR and other conservation stakeholders to ensure recreational activities are safe and adequately utilized by the public, and are positive for both humans and wildlife. Staff must be able to convey and practice laws, rules, and safety procedures guiding recreational activities. Our ability to meet the public's need for recreation can be compromised by a lack of habitats for desired pursuits (e.g., ponds and streams for fishing and watercraft use, forests for hiking and camping), public access, facilities, and information on locations of facilities and resources.

Education/Outreach Needs (IUCN 14)

As leading stewards of Maryland's natural areas and the many species that live in the state, MD DNR has a responsibility to educate the public about the environment and the need for environmental health in Maryland. This education can come in many forms, including outreach to schools and local communities, awareness of wildlife-related projects, utilization of wildlife through hunting and fishing, and other MD DNR actions. Maryland species are threatened by insufficient education in that human-wildlife conflict frequently arises from a lack of knowledge. For example, lack of understanding about and appreciation for Maryland's snakes leads to many incidents in which harmless snakes are killed. Construction and development companies can threaten rare key wildlife habitats such as vernal pools if they do not recognize their significance before construction, and attendant habitat destruction is initiated. Other important educational goals that need to be met include understanding the needs of native plants and wildlife, maintaining resources and facilities for educational programs, and sustaining contact with a large constituent base. Outreach by MD DNR in the form of education empowers Maryland's citizens to be knowledgeable stewards of wildlife and their habitats. A strong base of informed constituents across Maryland provides MD DNR more resources to use in conservation activities, including citizen science projects like the Maryland Amphibian and Reptile Atlas, completed in 2014, or the volunteer assistance of trained Maryland Master Naturalists.

Administrative Needs (IUCN 15)

Infrastructure Needs (IUCN 15.1)
The work of a variety of organizations contributes to the persistence and health of Maryland's wildlife and their habitats, including governmental (state, federal, county, city) and non-governmental organizations. To effectively and efficiently carry out this work, workspaces and laboratories; basic equipment for field studies, communication, habitat restoration and management, and data processing and storage; and software packages for data management, mapping, and analysis are needed to use data for conservation purposes. When these resources and other forms of infrastructure are lacking, Maryland SGCN and their habitats face an indirect threat that could be thought of as inadequate administrative support.

Programming and Planning Needs (IUCN 15.2)
Planning has long been recognized as an essential element of good practice for the protection, conservation, management, and restoration of wildlife and their habitats. On a local scale, planning might take the form of a series of goals and strategies for a state Wildlife Management Area; on a larger scale, planning might involve setting the direction for an entire agency program based on its mission. Operating without a plan can mean that activities are not carried out in a way to meet identified needs, and can result in a threat to species and their habitats.

Coordination and Regulatory Needs (IUCN 15.3)
Resource limitations and insufficient leadership support can impact an organization's ability to carry out even basic functions in support of wildlife conservation. Likewise, inadequate coordination may represent a threat when it leads to a loss of opportunities, redundant efforts, or the creation of negative consequences as people and their organizations go about their work individually rather than in partnership with others. Governmental policies, legal protection, and law enforcement can be critical to the persistence and recovery of fish and wildlife populations. When policies change, or legal protections in the form of laws and regulations are lacking, fish and wildlife species can be directly affected by loss of habitat, illegal harvest or collection, direct mortality, or impacts on other resources that they need to survive. Laws and regulations also need to be current in order to function as they were intended. Threats to SGCN and their habitats can result when government policies, laws, and regulations are insufficient or detrimental, are outdated, or are inadequately enforced.

This chapter reviewed threats facing Maryland's wildlife species and their habitats (**Element 3**). The comprehensive list of threats was derived from the IUCN Threats Classification Scheme and developed by MD DNR and their many federal, state, and local conservation partners. Please see Appendix 5a for a complete matrix of Maryland's threats**.** Chapter 6 continues the discussion of threats due to climate change, and Chapter 7 will discuss the many conservation actions and strategies to address the threats outlined in Chapters 5 and 6.

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