CHAPTER 3

ISSUES AFFECTING SGCN AND WILDLIFE HABITAT IN DELAWARE

"Keeping Today's Wildlife from Becoming Tomorrow's Memory"

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Introduction

Delaware's Species of Greatest Conservation Need (SGCN) and their habitats face numerous issues that may adversely affect them and compromise their status in the state. Some of these are global or national in scale, while others may be regional, statewide, or local. Identifying issues affecting Delaware's SGCN and habitats is an important component in developing effective conservation actions. Once identified, issues can be addressed through actions that Delaware Department of Natural Resources and Environmental Control Division of Fish and Wildlife (DNREC DFW) and its partners have developed throughout the Delaware Wildlife Action Plan (DEWAP) process. The previous two chapters identified Delaware's SGCN (Element 1) and their habitats (Element 2); this chapter addresses the issues affecting these important conservation targets (Element 3).

Wildlife Action Plans (WAPs) are required to identify the "problems which may adversely affect species of conservation need and their habitats." 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. The word "issue" is used in this document as an umbrella term referring to all aspects of the process by which human actions or natural events may jeopardize fish and wildlife species and their habitats. Issues may be species-specific, affecting a species by a direct action or through indirect impacts by limitation of a particular habitat condition, or limiting factor.

This DEWAP uses the International Union for Conservation of Nature (IUCN) categories (Salafsky et al. 2008) crosswalked with the Tracking and Reporting Actions for the Conservation of Species (TRACS) system (USFWS 2014) to describe and present issues in a consistent way, as recommended by the Northeast Lexicon and Synthesis (Crisfield and NEFWDTC 2013; Terwilliger and NEFWDTC 2013).

All fish and wildlife have been impacted by human activities in some way. Some species have taken advantage of the conditions found in developed areas; alien and invasive species such as European starling, rock pigeon, tree-of-heaven, and many others have thrived. A few native species have found a surrogate habitat in urban areas as natural habitats have diminished. Some examples of these opportunists include the common nighthawk, chimney swift, and peregrine falcon. Delaware's wildlife populations are vulnerable to multiple threats associated with human activities, and the SGCN list identifies the most vulnerable.

Issues in the Northeast Region

There is no comprehensive assessment of conservation issues across the northeastern region. However, numerous threats to fish, wildlife, and their habitats have been identified by the northeastern states as part of their individual WAPs. After the completion of the 2005 plans, a survey was conducted to identify common threats listed by states (AFWA 2011) and the most frequently identified issues are listed in Table 3.1 in descending order. The 13 northeastern states and the District of Columbia identified 37 common, recurring threats to SGCN or their habitats (AFWA unpublished and 2011). The most frequently mentioned threats included invasive species (mentioned by 100% of northeastern states) and industrial effluents (pollution); commercial and industrial areas; housing and urban development; and agricultural and forestry effluents (all of which were mentioned by at least 83% of northeastern states). Other important challenges mentioned by 50% or more of the northeastern 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 WAPs, recent work by the northeastern states has emphasized the importance of additional, emerging threats such as climate change, exurban developments, new invasive species, and disease.

Table 3. 1 Key Issues Identified by Northeastern States in Their Wildlife Action Plans

Issue Category	Specific Issue
Invasive & Other Problematic Species & Genes	Invasive non-native/alien species
Pollution:	Household sewage & urban waste water
Pollution:	Industrial & military effluents
Pollution:	Agricultural & forestry effluents
Residential & Commercial Development	Housing & urban areas
Residential & Commercial Development:	Commercial & industrial areas
Human Intrusions & Disturbance:	Recreational activities
Natural System Modifications	Dams & water management/use
Climate Change & Severe Weather:	Habitat shifting & alteration
Climate Change & Severe Weather	Storms & flooding
Climate Change & Severe Weather:	Temperature extremes
Barriers/Needs	Lack of biological information/data gaps
Climate Change & Severe Weather:	Droughts
Transportation & Service Corridors:	Roads & railroads
Biological Resource Use:	Harvesting/collecting terrestrial animals
Biological Resource Use:	Logging & wood harvesting
Natural System Modifications:	Other ecosystem modifications
Invasive & Other Problematic Species & Genes:	Problematic native species
Biological Resource Use:	Harvesting aquatic resources
Pollution	Air-borne pollutants
Barriers/Needs: Natural Resource Barriers:	Low population levels, insufficient habitat requirements, etc.
Pollution:	Garbage & solid waste
Agriculture & Aquaculture:	Wood & pulp plantations
Pollution:	Excess energy
Barriers/Needs	Lack of capacity/funding for conservation actions
Barriers/Needs:	Lack of education/outreach with public and other stakeholders
Natural System Modifications	Fire & fire suppression
Agriculture & Aquaculture:	Non-timber crops

Residential & Commercial Development	Tourism & recreation areas
Barriers/Needs	Lack of monitoring capacity/infrastructure
Barriers/Needs	Lack of capacity/infrastructure for data management
Barriers/Needs	Administrative/political barriers
Transportation & Service Corridors	Shipping lanes
Biological Resource Use	Gathering terrestrial plants
Energy Production & Mining	Renewable energy
Energy Production & Mining	Mining & quarrying

Identifying Issues Affecting Species of Greatest Conservation Need and Key Habitats in Delaware

Conservation issues, sometimes known as "threats" or "stresses," are human actions that adversely impact wildlife, native plants and natural communities, and the ecological processes that sustain them. Conservation actions are the measures taken to eliminate or minimize these impacts, or to mitigate their effects. For this plan, determination of conservation issues and actions began with the preparation of standardized "taxonomies" for organizing information. Taxonomies developed by the Northeast Lexicon were used to best reflect circumstances in Delaware and coordinate with the region. The initial list of issues and actions was then derived from a review of over 50 existing state, regional, and national plans. While many Conservation Issues had their origins in the 2006 DEWAP or plans mentioned above, most of them were modified by partners and stakeholders through a series of workshops to make them applicable to particular circumstances in Delaware. These specific issues, arranged by category, are depicted in Figures 3.1,-3.3 and described in the sections below.

The Revision Development Team converted each of the 2007 Issues and Actions to the IUCN and TRACS systems, using the categories identified in Appendices 3 and 4, respectively. Members of the Technical Review Team did the initial round of review, updates, and ranks of these 2007 issues. They were asked to provide six ranks, each on a whole number scale of one through three, which were then averaged to create the final rank for each issue. The ranking criteria, adapted from the Northeast Lexicon and Synthesis (Crisfield and NEFWDTC 2013; Terwilliger and NEFWDTC 2013), can be found in Appendix 3.

During the workshops, teams of experts, partners, and stakeholders identified and contributed to the ranking of the 2007 issues, particularly where there were data gaps and thus issues left unranked by the Technical Team. Participants at these workshop, and those who contributed via phone calls and emails, provided additional updated information on previously unidentified threats to SGCN. Teams then grouped and condensed these issues, where similar, for species suites, habitat associations, or broader taxa applicability. A similar process was conducted for identifying and updating issues at the statewide level and to each key habitat. Habitat issues were also grouped and condensed to higher tier habitat groupings whenever possible to reduce redundancy and highlight common issues. Issues that were identified to be relevant for all habitats were moved to the statewide level and removed from each individual habitat group to avoid redundancy.

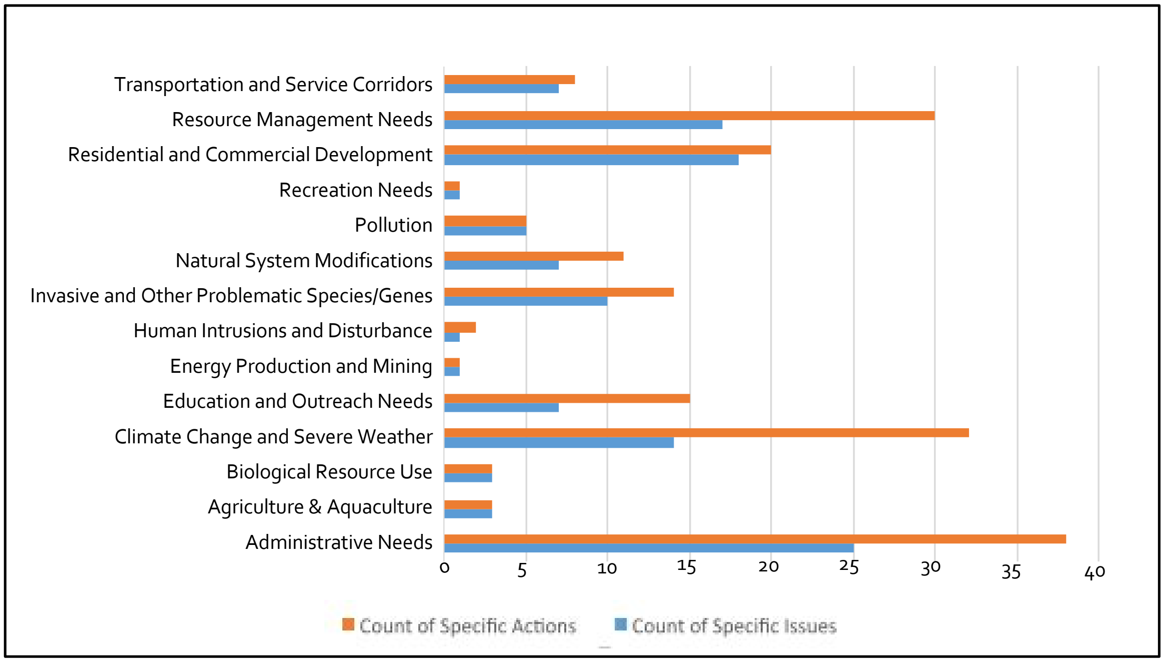


Figure 3. 1 Statewide Issues and Actions

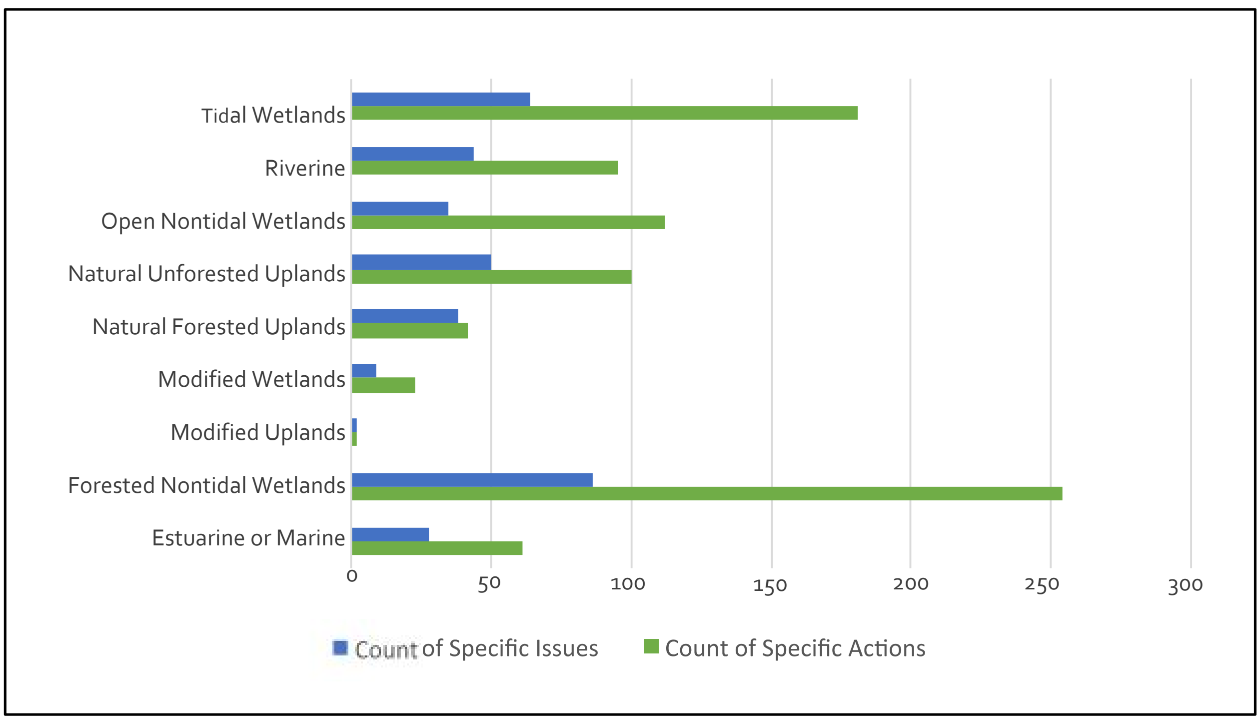


Figure 3. 2 Habitat-specific Issues and Actions

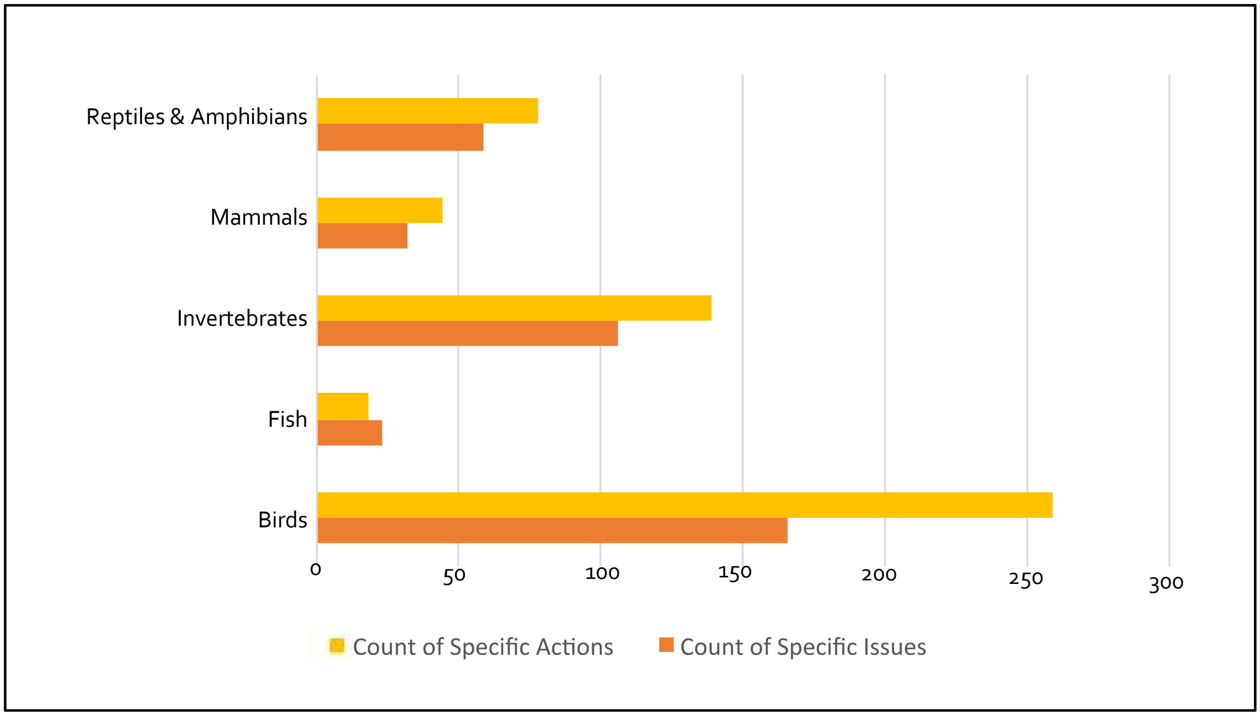


Figure 3. 3 Taxa-specific Issues and Actions

Issue Categories (IUCN)

Residential and Commercial Development

Regionally, over 88% of native vertebrate species (307 of 348) modeled in a habitat suitability (GAP) analysis of Maryland, Delaware, and New Jersey had less than 10% of their predicted occupied habitat occurring on land that is permanently protected from development and remaining in a natural state without disturbance from extractive uses such as logging or mining (GAP Status 1 or 2 lands) (McCorkle et al. 2006). One study of the northeastern U.S. found that over one third of the core habitat identified had no protection, and another 42% was subject to motorized recreation or timber extraction (Goetz et al. 2009). Most SGCN in the state are dependent to some extent on lands that are subject to habitat loss and fragmentation from residential and commercial development.

Land Development in the Northeast Region

With population growth comes a need for residential development. Commercial and industrial development inevitably accompanies housing, and recent trends in commercial development have tended toward spacious "big box" developments, superstores, shopping villages, and regional distribution facilities that consume large acreages of habitat. Increases in residential and commercial development in rural areas accounts for much of the reported losses in wildlife habitat and other natural resources. Transportation infrastructure that accompanies development compounds impacts by further fragmenting habitats and interrupting wildlife travel corridors to breeding, spawning, and wintering habitats (Table 3.2).

Results of The Nature Conservancy's Geospatial Condition Analyses (Anderson et al. 2013) shed additional light on the extent of these threats in the Northeast. In general, high density development of natural habitats can change local hydrology, increase recreation pressure, introduce invasive species either by design or by accident with the introduction of vehicles, and bring significant disturbance to the area. Urbanization and forest fragmentation are inextricably linked to the effects of climate change, because the dispersal and migration of forest plants and animals are disrupted by development and roads.

Table 3. 2 State of Delaware Total Population Projections 2010-2040 (Oct. 30, 2014). Source: Delaware Population Consortium (2014).

	2010	2015	2020	2025	2030	2035	2040
Population	899,673	941,634	979,126	1,011,231	1,035,203	1,053,818	1,068,155
Population Change*	41,961	37,582	32,015	23,972	18,615	14,337	
* Represents a five-year total beginning with specified year							

Residential Development

According to the Delaware Forest Service (2010), six percent (16,000 acres) of Delaware's remaining unprotected forests (217,000 acres) were included in proposed housing developments from 2002 to 2009. From 2008 through 2013, local governments in Delaware approved a total of 32,042 residential units for future development. Of these units, 28,150 (88%) were in growth areas (defined as Investment Levels 1, 2, and 3 in the Strategies for State Policies and Spending (2011) stateplanning.delaware.gov/strategies/. In both New Castle and Kent Counties, more than 99% of all residential units approved by local governments were in Levels 1 through 3. In Sussex County by contrast, only 66 percent were located in levels 1 through 3. Sussex County is the fastest growing area in Delaware because of its popularity for primary residences as well vacation homes (Urban Research & Development Corporation 2008), and the county's population is projected to increase from approximately 198,000 in 2010 to 257,000 by 2040 (Delaware Population Consortium 2014). This projected growth, combined with the significant amount of development activity in "off-limits" areas, represents a major concern for the conservation of habitats important to SGCN in southern Delaware.

Figure 3. 4 Residential Development. Photo: DNREC, The Environment and Land Use: Sprawl and Air Quality

The economic downturn of 2008 brought a significant decrease in numbers of residential units actually permitted (built), but by 2013, the number of permitted units had rebounded (Table 3.3 and Figure 3.4). The majority of the permits issued over this period were in Sussex County, (51% of all units permitted in the state). Statewide, 84% of residential units permitted by local governments were located in Investment Levels 1, 2, or 3 as defined by the Strategies for State Policies and Spending. New Castle County jurisdictions issued permits for 97% of their residential units in Levels 1 through 3, followed by Kent with 82% and Sussex with 79%. These data reflect a significant degree of residential development activity outside of the Strategies growth zones, mainly in Kent and Sussex Counties.

Table 3. 3 Residential Units Approved by Building Permit, by County, 2008 through 2013.

	2008	2009	2010	2011	2012	2013	Total
Statewide	3,813	3,170	2,877	3,002	3,446	4,893	21,201
New Castle	960	764	779	639	787	1,569	5,948
Kent	1,159	723	574	685	778	914	4,833
Sussex	1,694	1,683	1,524	1,678	1,881	2,410	10,870

Source: Delaware Office of State Planning, 2014.

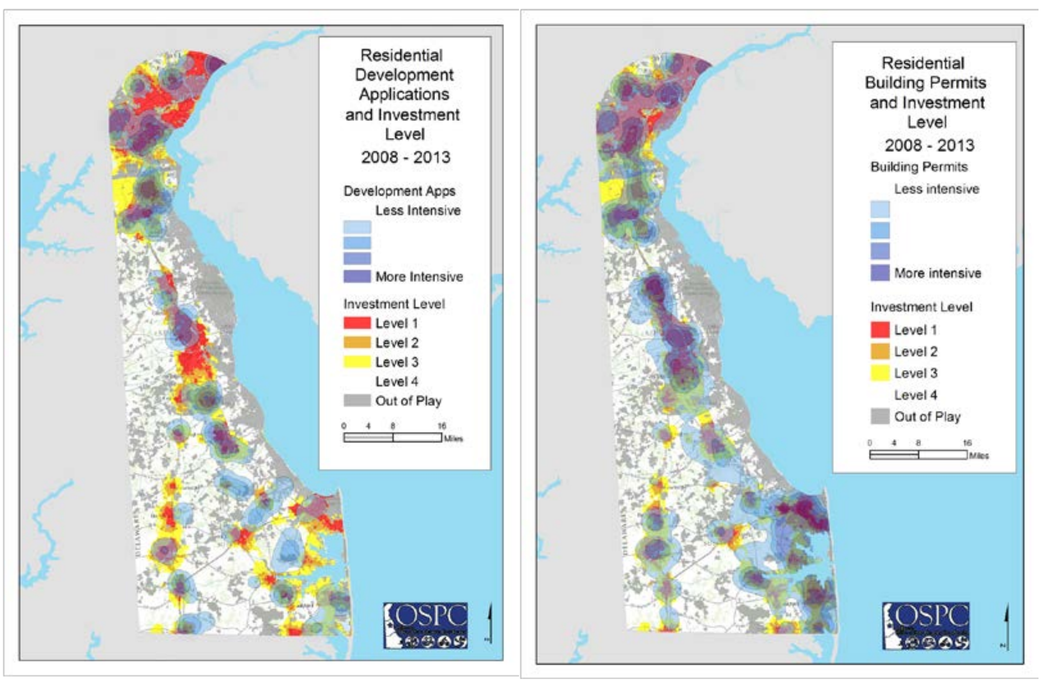


Figure 3. 4 Residential Development Applications and Investment Level 2008-2013 (left) and Residential Building Permits and Investment Level 2008-2013 (right). Source: Delaware Office of State Planning Coordination.

Non-residential Development

From 2008 through 2013, local governments approved 20,202,617 square feet of non-residential development (Figure 3.5). More than half of this development was approved in New Castle County (72%).

The remainder was split between Kent and Sussex Counties (17% and 14%, respectively). Most of the non-residential development approved by local governments in Delaware (96%) was located in Investment Levels 1, 2, or 3. From 2008 through 2013, local governments issued permits for 16,926,981 square feet of non-residential development. As with non-residential development approvals, most of the activity (nearly 61%) was focused in New Castle County.

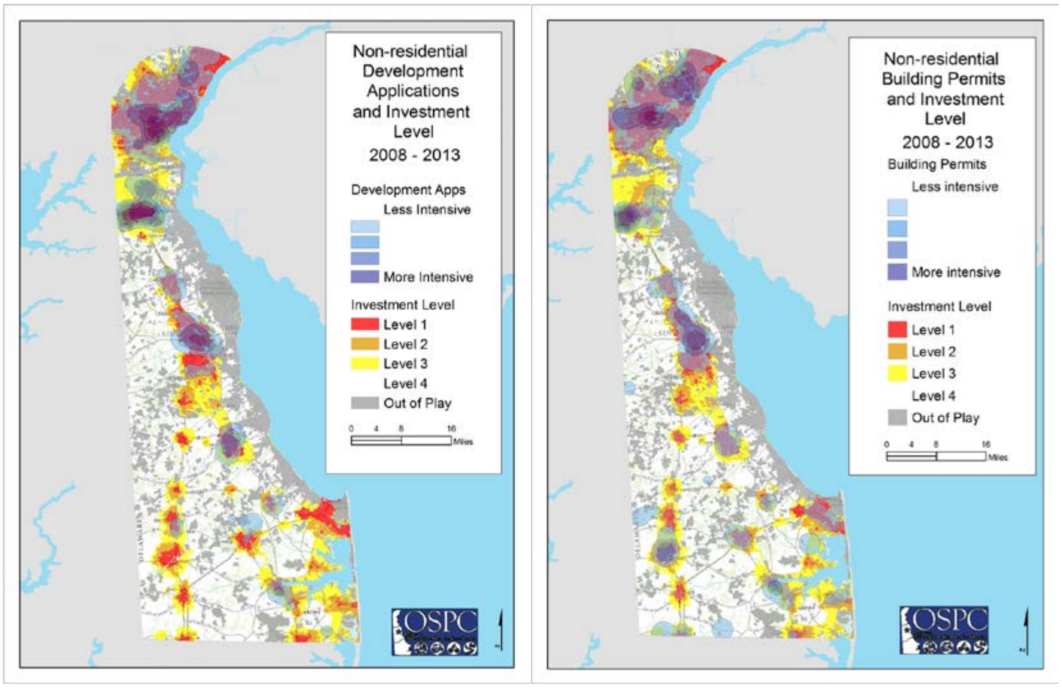


Figure 3. 5 Non-residential Development Applications and Investment Level 2008-2013 (left) and Non-residential Building Permits and Investment Level 2008-2013 (right). Source: Delaware Office of State Planning Coordination.

Development and Fragmentation of Forest Habitat

The Delaware Forest Service (DFS) (2010) reported that between 2002 and 2009, nearly 16,000 acres of Delaware's remaining 217,000 acres of unprotected forest (privately owned without a permanent conservation easement) were included within areas approved for development.

It has been estimated that by 2050, 43% of Delaware's forestland will be converted to urban areas. Only four other states are expected to experience a greater degree of forest conversion to expanding urban areas (Nowak et al. 2005).

Fragmentation subdivides large contiguous areas of natural land into smaller patches, resulting in each patch having more edge habitat and less interior. Thus fragmentation can lead to an overall deterioration of ecological quality and integrity, and a shift in associated species from interior specialists to edge generalists. Some species of wildlife require larger blocks of habitat than others and can be negatively impacted by activities that fragment habitat.

Buildings and Structures

Wildlife collisions with buildings, particularly collisions with windows, are a major anthropogenic threat to birds. A recent analysis estimated that up to 988 million birds are killed annually by building collisions in the U.S., with roughly 56% of mortality at low-rises, 44% at residences, and <1% at high-rises (Loss et al. 2014). Several species were shown to be disproportionately vulnerable to collisions at all building types, including golden-winged warbler (*Vermivora chrysoptera*), Canada warbler (*Cardellina canadensis*), wood thrush (*Hylocichla mustelina*), Kentucky warbler (*Geothlypis formosa*), and worm-eating warbler (*Helmitheros vermivorum*).

Agriculture

Agriculture is an important part of Delaware's history, culture and economy. Many Delaware farmers utilize Best Management Practices (BMPs) and are enrolled in Natural Resources Conservation Service (NRCS), Department of Agriculture (USDA), or U.S. Fish and Wildlife Service (USFWS) cost share programs that are environmentally friendly and minimize impacts to wildlife. Some agricultural practices, however, can be detrimental to wildlife and reduce available habitat.

The Coastal Plain of Delaware is characterized by expansive and intensive agricultural production, primarily dominated by row crops, particularly corn and soybeans (see Chapter 2 for a complete description). In general, agricultural use is no longer expanding in the state, with farm acreage declining as residential development increases. Future direct conversion of habitat to agricultural production is likely to be mostly limited to cropping of previously uncropped and marginal areas on existing farms, at a rate that will likely be driven by commodity prices.

The 2012 US Department of Agriculture Census of Agriculture data shows that since the last survey, in 2007, the amount of farmland in Delaware and the number of farms have both decreased slightly – farm acreage down less than 1% (1,599 acres) and the number of farms down 3% (89 farms). Delaware has taken the lead in working to halt that trend through the Young Farmers Program and the Agricultural Lands Preservation Foundation. More than a fifth – 22%, or over 116,000 acres – of Delaware farmland is permanently preserved thanks to the Foundation's work, and dozens of farmers have been able to purchase property thanks to the Young Farmers loan program.

According to the USDA Census data, there are 508,654 acres of farmland in Delaware. This is distributed among 2,457 farms (1,571 whose primary occupation is farming) with an average size of 207 acres/farm. The total market value of agricultural products sold in Delaware is $1,283,472,000, of which $429,323,000 is the market value of crops and $854,149,000 is the market value of poultry and livestock.

More than a third (183,000 acres) of Delaware's farmland acreage is in corn. According to the Delaware Extension Service (2015) Delaware corn yields have increased four-fold since the 1930s to an estimated 125 bushels per acre in 2011. Factors that have increased yields include increased breeding efforts including those that developed hybrid seed corn, commercial fertilizer manufacturing and use, modern pesticides, and the increase in irrigation (Figure 3.6).

Figure 3. 6 Water reuse, by spray irrigation on farm fields. Photo: DNREC, Division of Water, Ground Water Discharges Section

As with most technological changes, there are both costs and benefits to modern industrial monoculture cropping techniques. Modern row crop farming operations have greatly increased yields, but the impacts of these practices on biodiversity in agroecosystems have also increased. Heavily cropped lands with no BMPs and increased chemical applications can affect fish and wildlife and the availability and quality of their habitats directly and indirectly.

Installation and maintenance of conservation practices on working lands can greatly benefit SGCN. However, placing land in these practices can be costly, so additional research documenting return on investment (ROI) for these practices is needed to help facilitate their adoption. For example, a recent long-term study in an insect-pollinated crop quantified actual long-term yield increases and ROI for supplemental planting practices that encourage native pollinators (Blaauw and Isaacs 2014). While some conservation practices improve ecosystem services (e.g., pollination, pest population regulation, soil conservation) that contribute to a recognizable ROI to the individual farmer, others provide or enhance "commons" ecosystem services (e.g., water quality, carbon sequestration, wildlife habitat) that, while highly valuable to the public at large, may not have a readily quantifiable benefit to the individual producer (Stallman and James Jr. 2014). This "tragedy of ecosystem services" (Lant et al. 2008) underscores a need for strongly competitive cost-share and rental payments for conservation practices to encourage farmers to invest in practices that enhance ecosystem services even when those practices may not result in yield increases.

Recent state and federal funding gaps have limited payment rate increases and capped enrollment acreage for land retirement and working-land conservation practices nationwide (Stubbs 2014). Of the 6,080 Delaware acres enrolled in the Conservation Reserve Program (CRP, see Chapter 2) as of May 2014 4,549 acres (75%) had contract expiration dates of 2018 or sooner (USDA Farm Services Agency 2014). Policy actions are needed to ensure that land retirement practice enrollment remains stable or increasing despite high commodity prices.

An emerging concept that may help address SGCN conservation more effectively via conservation practices on working lands is the spatial targeting of incentives to support landscape-scale conservation initiatives (Reed et al. 2014). The Conservation Reserve Enhancement Program (CREP) is a cooperative program between USDA and state government to improve and protect water quality of streams and wildlife habitat in the watersheds of the Chesapeake, Delaware, and Inland Bays. Five practices are offered under the Delaware CREP: hardwood tree planting, wildlife habitat, grassed filter strips, riparian buffers, and wetland restoration. These practices must adjoin impaired streams or contributing drainage ditches in designated project areas. CREP combines state funding with federal NRCS funding to provide increased incentives for conserving these sensitive areas. Delaware CREP cost-share and rental rates were increased in 2014, but secure state funding for this program is limited.

At the state level, important programs that were previously available are no longer offered, largely due to lack of funding. One example of a successful incentive program is the Delaware Landowner Incentive Program (DELIP), which is administered by the DNREC Division of Fish and Wildlife. From 2005 to 2012, a total of 892.7 acres of agriculture land was converted to wildlife habitat benefitting at least 10 Tier 1 and 29 Tier 2 SGCN identified in the previous 2006 DEWAP. The U.S. Fish and Wildlife Service's Wildlife and Sport Fish Restoration Program provided federal grant funds for states to protect and restore wildlife habitats on private lands. These grant funds, administered by DELIP, provided the funding for agricultural producers so they could take agricultural land out of production in order to establish and maintain specific types of wildlife habitat for species-at-risk (later termed SGCN) for a period of 5 or 10 years. In addition to establishment costs, DELIP provided the landowner yearly incentive payments for the duration of the contract. Unfortunately, funding is currently no longer available for this program.

Many of Delaware's State Wildlife Areas (WAs) include leases to private operators for agriculture. Historically, hundreds of acres of agricultural land on WAs were removed from production for enrollment in CRP, and these areas have remained in permanent wildlife habitat once CRP contracts expired (the state is no longer eligible for CRP contracts under the current Farm Bill). Installation of buffers on all agricultural lands on WAs is nearly complete, and lease bidding now includes bonus points given for all BMPs that operators use. Some agricultural lands on WAs could be sites for future habitat restoration for SGCN.

Other forms of agriculture included in this IUCN issue category include silviculture, livestock and poultry, and aquaculture. Many forests are managed for timber production, and this type of management often selects for even-aged stands with reduced species diversity in order to maximize production efficiency. These plantations do not provide as high habitat quality for SGCN as natural forests. Delaware Forest Service's Landowner Assistance program helps develop forest stewardship plans, which may have additional objectives such as forest health and wildlife diversity. Fourteen plans were implemented on more than 1,200 acres in 2014 (Delaware Forest Service 2014). DNREC, Delaware Forest Service, and the forest industry can work together to maximize forest acreage and health in Delaware and incorporate the conservation of SGCN wildlife into forest management whenever possible.

Energy Production

The Delaware Estuary is one of the nation's largest petrochemical centers, and the potential for spills is an ever-present threat to estuarine and wetland systems and the SGCN that rely on them. The port complex of the Delaware River and Bay is the second largest oil port in the United States, handling about 85% of the East Coast's oil imports. The *Athos I* spill in 2004 near Philadelphia released some 265,000 gallons of heavy crude into the Delaware River. The cumulative effects of small spills are also of concern for SGCN.

Figure 3. 7 Indian River Power Plant on the edge of Indian River Bay in southern Delaware. Photo: DNREC

Some of the largest direct threats from energy production in Delaware are associated with cooling water intakes and discharges (e.g., from power plants, Figure 3.7), pollution events, and other causes that are covered in more detail elsewhere in this chapter.

Renewable energy is not without risks to SGCN. There are many potential impacts of new energy development on wildlife within the Mid-Atlantic states, ranging from effects of hydraulic fracturing and offshore drilling on aquatic systems, the loss of habitat to biofuel production, and the direct mortality of birds and bats from wind turbines along mountain and coastal flyways. Additionally, solar panels can be highly attractive traps for insects seeking to oviposit on the water's surface, and design modifications are required to minimize this impact to groups like mayflies, and caddisflies (Horváth et al. 2010).

A Risk Assessment of Marine Birds in the Northwest Atlantic Ocean is underway through the North Atlantic Landscape Conservation Cooperative (NALCC) and partners to develop a series of maps depicting the distribution, abundance and relative risk to marine birds from offshore activities (e.g., offshore drilling and wind energy development). This can help document and predict areas of frequent use and aggregations of birds and the relative risk to marine birds along the coast. This NALCC project is supporting several components of map and technique development by leveraging several large, ongoing projects funded by the Bureau of Ocean Energy Management (BOEM), Department of Energy (DOE), U.S. Geological Survey (USGS), and the National Oceanic and Atmospheric Administration (NOAA) and involving research groups at the Biodiversity Research Institute, North Caroline State University, City University of New York-Staten Island, the USGS Patuxent Wildlife Research Center, and the NOAA National Centers for Coastal Ocean Science-Biogeography Branch.

A recent analysis estimated that between 140,000 and 328,000 birds are killed annually by collisions with monopole turbines in the contiguous U.S., with an increase in mortality with increasing turbine hub height (Loss et al. 2013). Large populations of migrating shorebirds, waterfowl, raptors and songbirds make Delaware Bay and its shoreline a high risk location for wind turbine siting (Jenkins and Clark n.d.).

Energy transmission infrastructure in Delaware results in direct mortality of some SGCN. Recent studies estimate that between 12 and 64 million birds are killed each year at U.S. power lines, with between 8 and 57 million birds killed by collision and between 0.9 and 11.6 million birds killed by electrocution (Loss et al. 2014). Utility companies are actively taking steps to minimize these effects by installing preventive devices on transmission lines and infrastructure in areas heavily used by wildlife, especially birds.

Mining

Sand and gravel quarries are prevalent in Delaware and typically result in irreversible destruction of habitat if they are located in areas not previously developed. While some SGCN, such as bank swallow (*Riparia riparia*), use active sand and gravel pits for nesting, these modified habitats have limited value for most SGCN. Sand and gravel mines covered over 6,000 acres in Delaware as of 2009 (Mackenzie 2009). Offshore sand mining occurs in the Delaware Bay and Atlantic Ocean and can have long term effects on benthic habitats. Offshore sand resources that have been historically harvested include sandy shoals and rocky substrate habitats in the nearshore Atlantic important for supporting fisheries and marine birds. Potential direct impacts to SGCN, including sturgeon, sea turtles, and sharks, are also of concern.

Transportation-related Issues

Roads and other transportation corridors have profound effects on wildlife populations. They represent major sources of pollutant load, and they can be barriers to dispersal for many species, fragmenting habitat and leading to genetic isolation of local populations. The ecological effects of roads have been described in several reviews (Trombulak and Frissell 2000), including some focused specifically on certain taxonomic groups that are heavily impacted, such as reptiles and amphibians (Andrews et al. 2008). Recent analyses estimate that between 89 and 340 million birds die annually from vehicle collisions on U.S. roads (Loss et al. 2014). Diamondback terrapins are heavily impacted by vehicular mortality (Wood and Herlands 1997).

While total road mileage in Delaware increased by only 4% from 1980 to 1990 and 6% from 1990-2000, the rate of increase accelerated to more than 10% between 2000 and 2012, resulting in a total net increase of 1,144 miles of roads since 1980 (Table 3.4).

Table 3. 4 Total Miles of Public Roads in Delaware, 1980-2012.

Road Type	1980	1990	2000	2012
Urban	1,345	1,615	1,984	**3,021**
Rural*	3,888	3,829	3,795	**3,356**
Total	**5,233**	**5,444**	**5,779**	**6,377**

Source: US DOT 2013 *Declining mileage figures for rural roads reflects a reclassification of previously designated "rural" areas to "urban" areas, rather than a decline in the number of rural road miles.

In Delaware, the state maintains approximately 90% of roads, as compared to a national average of 20% (Delaware Office of State Planning Coordination 2014). This largely centralized maintenance system affords significant opportunity for coordinated action at the state level with regard to the impacts of roads and road maintenance on wildlife, including SGCN. Coordination and collaboration with Delaware Department of

Transportation (DelDOT) to minimize transportation impacts on fish and wildlife is an ongoing effort and priority.

Road Salt

DelDOT pretreats roads before winter storms with a liquid brine solution, then spreads road salt once snow begins to fall. Road de-icing salts are washed off of roadways by meltwater and rains and enter aquatic systems via groundwater (Gedlinske 2013) and surface runoff. Salts are also sequestered in soils and are taken up by roadside vegetation. In addition to application by the state, up to 40% of salt used in some areas is applied by private contractors (Kelly et al. 2010).

Salts from road de-icing have serious detrimental effects on wildlife, especially amphibians (Sanzo and Hecnar 2006). The amphibians most affected are often vernal pool breeders (Karraker et al. 2008), which are already some of the rarest and most threatened SGCN in Delaware due to many other factors, such as development, wetland loss, and climate change effects. Freshwater mussels, another highly imperiled group of SGCN, are highly affected by increased chloride concentrations in streams as a result of de-icing pollution (Todd and Kaltenecker 2012).

Because road salts cumulatively build in roadside soils, they influence both the plant species composition of these areas as well as the chemical composition of the plants themselves, which can in turn have serious detrimental effects on development of herbivorous insects, including butterflies and moths (Snell-Rood et al. 2014). The severe, long-term indirect effects of road salt are only recently being fully investigated (Findlay and Kelly 2011). Recent remote-sensing studies suggest that road salt contributes to tree mortality in forested systems with both immediate and delayed responses being evident in the data (Fan et al. 2014).

Figure 3. 8 Near Indian River Inlet. Photo: DNREC

Road salts can travel as much as 172 m from roads in wetland systems (Karraker et al. 2008) and potentially much further in stream systems, where salt inputs contribute to changes in water chemistry. Designation and signage of reduced salt areas adjacent to sensitive habitats, freshwater wetlands, and groundwater recharge areas has been accomplished in other Northeast states and should be explored for Delaware.

Shipping Activities

Shipping activity (Figure 3.8) is high in the Delaware River and Bay due to the presence of deep-water ports in Wilmington, DE and Philadelphia, PA. With the ongoing main channel deepening of the Delaware River navigation channel from 40 to 45 feet, an increase in the volume and relative size of ship traffic is expected in the future. Direct effects of shipping activity include the potential for spills of oil and other toxic products as well as the possibility of vessel strikes of fish, turtles, marine mammals, and other SGCN. Vessel strikes are reported to be a major factor in marine mammal and sea turtle mortality and injury from the Atlantic coast states. Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) are at especially high risk for vessel strikes due to their preference for the deeper waters of the shipping channel (Brown and Murphy 2010). Dead sturgeon with injuries consistent with vessel strikes have been found in a number of locations along the Delaware River. Studies indicate that sturgeon spend much of their time near the channel bottom and do not exhibit avoidance of dredges (Reine et al. 2014), so annual maintenance dredging of the shipping channel may also be a significant cause of mortality. NOAA Fisheries Service's Greater Atlantic Regional Fisheries Office is currently conducting an ongoing salvage network project to document mortality of shortnose sturgeon (*Acipenser brevirostrum*) throughout the region as well. Indirect effects of main channel deepening associated with shipping on the Delaware River include an estimated 4 km upstream shift in the salt front, with concurrent shift in the turbidity zone, both of which will significantly impact Atlantic sturgeon spawning habitat (Breece et al 2013).

Biological Resource Use

Hunting & collecting terrestrial animals

This category includes threats from the consumptive use of biological resources, including deliberate and unintentional harvesting, as well as the persecution or control of specific species (Salafsky et al. 2008). This threat has been identified as an issue for many reptile and amphibian SGCN primarily due to the collection of these animals for the pet trade.

Collecting of reptiles and amphibians for the pet trade is a potential threat in Delaware, especially for the following SGCN: bog turtle (*Glyptemys muhlenbergii*), spotted turtle (*Clemmys guttata*), red corn snake (*Pantherophis guttatus*), Eastern kingsnake (*Lampropeltis getula*), Eastern milk snake (*Lampropeltis triangulum*), and tiger salamander (*Ambystoma tigrinum*).

Overharvesting or bycatch of aquatic resources

Overharvest or bycatch in legal harvest can be issues that affect many aquatic SGCN. However, regulations on harvest set by the state, as well as Atlantic States Marine Fisheries Commission (ASMFC) and Mid-Atlantic Fishery Management Council (MAFMC) are helping to ameliorate these threats for most managed fisheries. Nevertheless, both recreational and commercial fishermen (fin and shellfish) should take precautions to minimize impacts on nontarget species to maintain healthy ecosystem function and balance in aquatic food webs.

Figure 3. 9 Horseshoe crab being 'bled' for the biomedical industry. Photo: A still from the PBS Nature documentary *Crash: A Tale of Two Species, 2011* (PBS)

A particularly important example in Delaware is the horseshoe crab (*Limulus polyphemus*). Despite a male-only harvest limit for the fishery, the coastwide harvest for biomedical use has recently approached the same magnitude as the bait fishery, but only the latter is regulated by ASMFC quotas. ASMFC collects data on the biomedical harvest from the states as a requirement of Addendum III to the Horseshoe Crab Fishery Management Plan (FMP). Since 2007, the estimated annual mortality from biomedical harvest has exceeded the ASMFC's suggested action threshold for this metric. ASMFC is not currently accounting for horseshoe crab mortality from biomedical harvest (Figure 3.9), which continues to grow, in their annual regional stock assessment. The biomedical harvest takes a large percentage of female crabs, despite the fact that male-only harvest is currently regarded as the best management alternative for the fishery. In 2011, the biomedical harvest consisted of at least 34% female crabs (with an additional 18% of the harvest consisting of crabs of unknown or unreported sex) (Eyler et al. 2012).

Human Disturbance

Direct human disturbance is an issue for some SGCN and habitats in Delaware. Recreational pressure is heavy in Delaware's State Parks system, especially on beaches and coastal dunes, which are naturally susceptible to compaction and erosion. Direct disturbance of breeding, migrating, and overwintering shorebirds and waterfowl is an issue along much of the Delaware coast, especially from uncontrolled off-road vehicle (ORV) access, much of which occurs on private lands. Some groups of SGCN, including tiger beetles, shorebirds, wading birds, and colonial nesting birds, are particularly sensitive to human and vehicle traffic in coastal areas.

Natural system modifications

Natural system modifications are defined as threats from actions that convert or degrade habitat in service of "managing" natural systems, often to improve human welfare (Salafsky et al. 2008).

Fire Suppression

One example of a natural system modification is the suppression of fire. Natural, lightning-caused fire is a dominant force in the western and midwestern portions of the U.S. that naturally perpetuates several community types, most notably prairies and savannahs. However, in the East, lightning-strike fires have become rarer events. Instead, historical fire disturbance in this region was primarily the result of Native Americans employing fire as a land management tool. It is thought that the selective burning employed by Native Americans helped create and maintain fire-dependent habitats, especially fire-regenerated species such as coastal pine communities. Fire suppression in Delaware's natural systems has major impacts on SGCN through alteration of habitat structure and species composition. See Chapter 2: Disturbance Regimes for a complete discussion.

Dams and Water Use

Another natural system modification identified as a threat to many wetland and aquatic habitats is water management. This broad category includes dam construction, surface water diversion, withdrawals from surface water and groundwater sources, and other operations that alter water flow patterns from their natural range of variation either deliberately or as a result of other activities.

The American Industrial Revolution produced may mill dams and a long history of water management in Delaware. Of particular concern to fish and wildlife resources is the construction of dams on major rivers that has prevented the migration of anadromous fish to inland breeding locations (see Chapter 1), and have also impeded the inland flow of tidal waters resulting in the nearly total loss of the Tidal Marsh communities described in Chapter 2.

Figure 3. 10 DNREC's dam at the new Alapocas Run State Park will be demolished and five free run on that stretch of the Brandywine River to returning shad in hopes that they will spawn in the river. Photo: DNREC DFW

Delaware has 83 dams included in the U.S. Army Corps of Engineer's (USACE's) National Inventory of Dams (NID). Seventy eight of Delaware's NID dams are less than 25 feet high (Figure 3.10), and all but two are of earthen construction. Fifty one dams are owned by the state, 17 are privately owned, and 15 are owned by local governments. Seventy six percent of Delaware's dams were constructed for the purpose of recreation, with only 6 dams built for water supply and 2 for flood control. Almost a quarter of the dams in the state were built in the 1960s and only 2 dams have been built since 1980. As of 2009, Delaware had 53 state-regulated dams (DNREC 2009). Most of these 53 dams are found on the Coastal Plain of Delaware in association with mill ponds (see Mill Ponds in Chapter 2). Damming of coastal plain streams has caused extensive damage to aquatic systems by habitat degradation and blockage of passage of fish and other aquatic organisms.

Many small dams too small to be state-regulated or included in the NID are present throughout the state. Small dams are especially prevalent along Piedmont streams, where they block passage of diadromous fish, mussels, and other aquatic organisms and contribute to degradation of in-stream habitat by storing sediment (Figure 3.11).

Recently, the first dam removal in Delaware was conducted. A 40-foot portion of the historic Byrnes Mill Dam on White Clay Creek was removed in late 2014, the first of a number of obsolete, low dams on the White Clay Creek slated for partial or total removal (Figure 3.12). This removal allows access to 3.5 miles of upstream reaches by diadromous fish (including striped bass, American shad, hickory shad, and river herring) for the first time since the 18th century. Six more dams are present upstream in the Delaware reach of White Clay Creek. Likewise, Brandywine and Red Clay creeks also have numerous small dams that present barriers to movement for aquatic organisms. Delaware's many dams should be evaluated to determine feasibility of removal for those that no longer serve their intended purpose and for which removal would benefit SGCN.

Figure 3. 11 Most of the breached dam at Rockland Mills will soon be removed, which should enable American shad to get further up into the Brandywine River. Photo: DNREC DFW

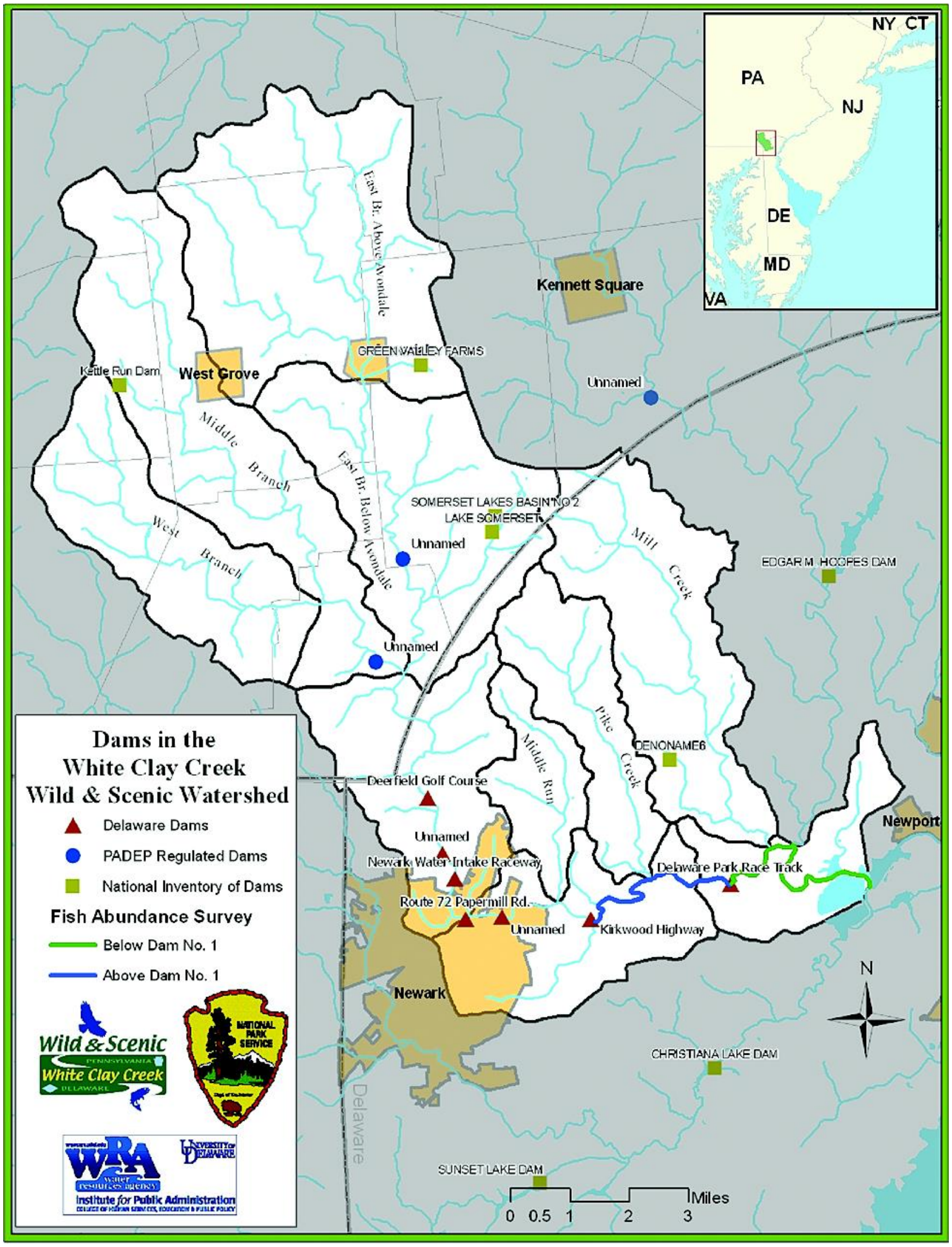


Figure 3. 12 Dams in the White Clay Creek Wild & Scenic Watershed. Source: University of Delaware Water Resources Agency and White Clay Wild and Scenic

Surface and Groundwater Withdrawals

Entrainment and impingement in cooling water withdrawals on the Delaware River are known major sources of mortality for many aquatic species, including several SGCN such as striped bass (*Morone saxatilis*) and weakfish (*Cynoscion regalis*), as well as important baitfish such as bay anchovy (*Anchoa mitchilli*) (Kahn 2008).

Groundwater withdrawals have the potential to deplete aquifers important to wetland system recharge. Simulations of water level reductions in Coastal Plain seasonal pond wetlands suggest that sustained reduction of water levels will result in vegetation shifts, notably encroachment of surrounding forest into these systems (Laidig 2012). Additionally, field observations have confirmed that impacts to groundwater hydrology associated with these systems have resulted in closed canopies and the loss of rare plant species (McAvoy pers. comm.). Other habitats potentially highly impacted by groundwater depletion include karst and seepage habitats.

In addition, excessive groundwater withdrawals in coastal aquifers can exacerbate saltwater intrusion (Sophocleous 2002). This has already occurred to some extent in Delaware, where brackish water has been drawn into the Potomac aquifer by pumping near Delaware Bay (Hodges n.d.).

The Delaware Geological Survey (DGS) currently monitors groundwater levels in a network of more than 90 wells in Delaware. In 2015, in anticipation of the need to monitor for saltwater intrusion, DGS installed salinity sensors in wells at three locations: Indian River Inlet, Fenwick Island Seashore State Park, and Woodland Beach Wildlife Area (Delaware Geological Survey 2015).

Beach Nourishment

Beach nourishment is a frequently used technique in Delaware for beach erosion control and widening (Figure 3.13). Beach nourishment can have dramatic effects on beach invertebrates and their predators that last for at least 4 years post-disturbance (Peterson et al. 2014). Brown (2009) found that beach nourishment affects establishment of *Sabellaria* tubeworm reefs. Current nourishment projects at Broadkill Beach have required extensive capture and relocation of spawning horseshoe crabs. Effects are not limited to the beach itself, but also include the borrow site and nearby areas of the water column.

Figure 3. 13 Beach Nourishment in Dewey Beach. Photo: DNREC

On the other hand, nourishing beaches helps provide greater resilience of these habitats to sea level rise and coastal storms, and may ensure the continued existence of beach habitat in areas where development precludes inland migration of the beach. In such areas, all beach habitat may be lost to erosion and sea level rise in the absence of beach nourishment.

Saltmarsh Management

Open Marsh Water Management (OMWM) is a highly effective (James-Pirri et al. 2009) larval source-reduction mosquito control practice that involves selective installation of small, shallow ponds and interconnecting ditches that allow tidal flow and movement of mosquito-eating fish between potential mosquito breeding pools in high marsh areas (Meredith 1985, Lesser 2007). The history and extent of OMWM in Delaware is provided in Meredith and Lesser (2007). The primary rationale for the adoption of OMWM practices is to reduce the need for application of chemical larvicides and adulticides in these systems.

Several studies have indicated positive effects of OMWM practices on use of marshes by waterbirds and fish, especially when implemented in degraded sites where the creation of ditches restores tidal hydrology (Rochlin et al. 2012). Some alteration of vegetation on OMWM managed sites may include reduction of *S. alterniflora* short form and *S. patens* (Mitchell et al. 2006, James-Pirri et al. 2012) and it has been suggested that this may impact obligate saltmarsh birds (Mitchell et al. 2006). In a study conducted in Delaware, relative abundance of seaside sparrows (*Ammodramus maritimus*) was 2.5 times greater on "limited" OMWM sites than on "extensive" OMWM sites, but this was the only species that differed significantly in relative abundance between the two treatment levels (Pepper et al. 2010). Seaside sparrow territory density and nesting density was also 2 times greater on "limited OMWM" plots than "extensive OMWM" plots (Pepper et al. 2010). This study used a semi-quantitative scoring system to account for relative amount of OMWM and age of OMWM system across multiple sites. Future studies employing long-term monitoring and Before-After Control-Impact (BACI) designs would help further assess the effects of OMWM installation on marsh fauna.

James-Pirri et al. (2012) found shifts from fish-dominated to shrimp-dominated nekton and modest changes in bird abundance (primarily an increase in fall use by SGCN American black duck) as measured by point count at Delaware sites. Vincent et al. (2015) found significant differences in trophic structure and fish growth for the SGCN fish mummichog (*Fundulus heteroclitus*) between ditch-plug ponds and natural saltmarsh ponds.

The effects of OMWM manipulations on SGCN are complex and vary among sites and treatments. Further research and coordination are warranted to ensure that this practice is utilized with maximum benefit to SGCN while minimizing potential negative impacts to SGCN and contributing to mosquito reduction goals.

Wetland Alteration/Drainage and Stream Channelization

Wetland drainage, especially of isolated freshwater wetlands, has severe effects on many wetland SGCN. The system of tax ditches maintained throughout Delaware was created for the purpose of facilitating the drainage of wetlands for agriculture (see Tax Ditches in Chapter 2). These systems are now largely degraded due to channelization, frequent dredging, and poor water quality.

In northern Delaware, urban and industrial activities have caused extensive habitat modification. Erosion, urban development, dredging, filling, and bulkheading have eradicated many wetlands and continue to have an impact on those that still exist. Shoreline hardening for bank stabilization is also an issue in the Inland Bays and Nanticoke watersheds.

Many efforts to restore degraded wetlands and streams have been undertaken in Delaware during the past several decades. An example of success is The Northern Delaware Wetlands Rehabilitation Program that was established by DNREC DFW in the 1990s to bring together civic and business leaders, scientists, resource managers, and property owners to develop strategies to restore nearly 10,000 acres of wetlands at 31 distinct sites along the Christina and Delaware rivers in New Castle County (Hossler 1994). Many of these sites have had successful restoration of hydrology, but funding challenges must overcome in order to ultimately meet the goal of restoring all wetlands originally targeted.

Invasive and Problematic Species and Diseases

The spread of invasive species poses a significant threat to SGCN throughout the Northeast. With Northeast Association of Fish and Wildlife Agencies (NEAFWA) funding through the Regional Conservation Needs (RCN) Grant Program, Klopfer (2012) identified 238 invasive species from 12 groups with a potential to adversely affect SGCN, while at the same time acknowledging that this is not a complete list of invasive species for the Northeast. The majority of species identified are plants (68%), and the majority of these (58%) occurred in seven or more states. There were 71 (30%) invasive species common to all states in the Northeast. The habitat identified with the greatest number of invasive species was "forest edge" with 115 species (48%), followed by pasture and grassland with 94 and 86 species respectively (39% and 36%).

The Delaware Invasive Species Council (DISC) defines an invasive species as "an alien species whose introduction causes or is likely to cause economic or environmental harm or harm to human health." This is the same definition promulgated by Executive Order 13112 (1999) that established the National Invasive Species Council.

Delaware has a series of laws and regulations designed to prevent the import and establishment of invasive species. Two state agencies, the Delaware Department of Agriculture (DDA) and DNREC, administer laws involving invasive species.

Invasive Species – Plants

The DNREC DFW has compiled a list of 78 non-native plant species known or likely to cause ecological impacts in natural habitats (McAvoy 2015). Some terrestrial invasive plant species that are particularly problematic in Delaware are: Japanese stiltgrass (*Microstegium vimineum*), lesser celandine (*Ranunculus ficaria*), Japanese honeysuckle (*Lonicera japonica*), oriental bittersweet (*Celastrus orbiculatus*), and garlic mustard (*Alliaria petiolata*).

The DDA currently designates 4 plant species as noxious weeds: Canada thistle (*Cirsium arvense*), burcucumber (*Sicyos angulatus*), giant ragweed (*Ambrosia trifica*), and johnsongrass (*Sorghum halepense*). Currently, none of the invasive species that are most prevalent and problematic in natural habitats are considered noxious weeds.

In aquatic systems, hydrilla (*Hydrilla verticillata*), an invasive, submerged aquatic plant, has heavily impacted ponds throughout southern Delaware, incurring management costs of over $200,000 in 2014 alone. It is more resistant to salinity than other aquatic freshwater plant species, outcompetes native plants, and tolerates high nutrient levels (eutrophic conditions). Hydrilla can affect fish and aquatic invertebrate communities by competition with native species and by contributing to hypoxic conditions in ponds (Bradshaw et al. 2014).

Phragmites

European reed (*Phragmites australis* ssp. *australis*) has perhaps the most dramatic impact on Delaware's natural habitats (Figure 3.14). DNREC DFW manages a Phragmites Control Program that treats over 6,000 acres annually. A number of studies have demonstrated significant impacts of European reed invasion on Delaware's estuarine species, including SGCN (Able and Hagan 2000; Able and Hagan 2003; Jivoff and Able 2003; Hunter et al. 2006). A recent assessment of Christina watershed wetlands found that European reed was the most abundant in estuarine wetlands as well as a significant stressor in non-tidal flat and riverine wetlands (Jennette et al. 2014). Well over 1000 acres of the European reed have been mapped in the Inland Bays region of Sussex County.

Figure 3.14 Phragmites invasion in a Delaware wetland. Photo: Chris Bennett

Invasive Species - Aquatic Animals

Northern snakehead (*Channa argus*), a native fish of China and Russia, was originally brought to the U.S. for the live food fish market. Unfortunately these exotic invaders escaped or were illegally stocked and now occur in at least eleven states. In Delaware, Northern snakehead have been documented in the Nanticoke and Christina River drainages, four private ponds, and in Becks Pond, which is one of the most popular public fishing ponds in Delaware. Unauthorized stocking of this species has likely contributed to its spread in freshwater impoundments in New Castle County. To curtail illegal stocking in Delaware, a regulation was passed in 2013 that prohibits the transport, purchase, sale, and possession of live snakeheads. Unfortunately once established, this species is difficult to eradicate, making preventive measures even more crucial.

Several species of non-native, invasive crabs are present in Delaware's estuarine and marine systems, including the European green crab (*Carcinus maenas*), and the Chinese mitten crab (*Eriocheir sinensis*). The Asian shore crab (*Hemigraspus sanguineus*, Figure 3.15), which was first discovered in North America near the mouth of Delaware Bay in 1988, expanded to far outnumber native crabs in rocky nearshore habitats, then recently declined in abundance (Schab et al. 2013). Some of Delaware's freshwater invasive invertebrates include the channeled apple snail (*Pomacea canaliculata*), red swamp crayfish (*Procambarus clarkii*), and zebra mussel (*Dreissena polymorpha*).

Figure 3. 15 Asian shore crab (*Hemigraspus sanguineus*). Photo: USGS

Blue catfish (*Ictalurus furcatus*) and flathead catfish (*Pylodictis olivaris*) are freshwater fish native to the Ohio and Mississippi River basins that were introduced into parts of the Chesapeake basin for sportfishing in the 1960s through the 1980s. These catfish are voracious predators now found in the Delaware River that may have major impacts on blue crabs and diadromous fish. Blue catfish are now found in the Delaware portion of the Nanticoke River system as well.

Nutria (*Myocastor coypus*), a non-native, marsh-damaging, beaver-like rodent has been documented in Delaware. A new state regulation passed in 2014 makes it unlawful to possess, buy, sell, barter, trade, or transfer live nutria to or from another person unless permitted by the Director of the Division of Fish and Wildlife.

Invasive Species – Free-ranging Cats

A study by Loss et al. (2013) estimated that free-ranging domestic cats may be the single greatest source of direct anthropogenic mortality for US birds and small mammals, killing an estimated 1.3–4.0 billion birds and 6.3–22.3 billion mammals annually. Un-owned cats, as opposed to owned pets, cause the majority of this mortality. Cat attack injuries account for over 10% of all injured bird cases brought to Tristate Bird Rescue and Research, Inc., a non-profit wildlife rehabilitation and rescue organization in Newark, DE (Tristate Bird Rescue and Research unpublished data). Free-ranging cats have been documented to kill numerous native species of birds, mammals, snakes, frogs, lizards, and invertebrates (Crooks and Soulé 1999, Dauphiné and Cooper 2009, Loyd et al. 2013), including SGCN such as star-nosed mole (Mitchell and Beck 1992) and Eastern towhee (Dauphine and Cooper 2009).

Invasive Species – Insects

As a result of globalization, many species of non-native insects have become established in the eastern U.S. Some of these species, such as emerald ash borer, gypsy moth (*Lymantria dispar*), and hemlock woolly adelgid (*Adelges tsugae*), have highly detrimental effects on native biodiversity, while many other species, such as the European noctuid moth *Noctua pronuba* have become widely established (Passoa and Hollingsworth 1996) with very little known about their effects on native species. While many of these species can be highly problematic, control of non-native insects can also have unintended effects on non-target biodiversity (e.g., Rawlins et al. 1998), so a balanced approach is needed.

Gypsy Moth

Gypsy moth populations in Delaware were reduced by the fungus *Entomophaga maimaiga* in the mid-1990s. Populations appeared to be growing somewhat from 2006 through 2009 based on aerial surveys of defoliation, with up to 800 acres per year defoliated in southern Sussex County. Defoliation has since declined to minimal levels in 2012-2014. Wet springs in 2012 and 2013 have likely increased the effectiveness of the *Entomophaga* fungus, killing a large percentage of the gypsy moth larvae that eat the leaves of oak and sweetgum trees (Delaware Forest Service 2010).

Other invasive insect threats in Delaware include the Asian tiger mosquito (*Aedes albopictus*) and Japanese rockpool mosquito (*Aedes japonicus*), with the latter being a known vector of West Nile Virus (Kaufman and Fonseca 2013).

Emerging Invasive Insect Threats Not Yet Found in Delaware

Emerald Ash Borer

This Asian pest continues to spread to numerous eastern states, including New Jersey most recently in 2014. It feeds exclusively on ash trees and, in areas where it has been established for several years, kills all ash trees. Although only about one percent of Delaware's forest trees are ash (Delaware Forest Service 2010), ashes are ecologically important and can be dominant species in sensitive freshwater wetlands and floodplains. Some ash-dependent SGCN may be highly threatened by the loss of this group of trees. For example, the larvae of the ash sphinx moth (*Manduca jasminearum*) are only known to feed on ash trees (Tuttle 2007). Host specificity testing has recently been completed for a wasp parasitoid that may prove useful as a biological control agent for emerald ash borer (Duan et al. 2015).

Asian longhorned beetle

Asian longhorned beetle (*Anoplophora glabripennis*) is an invasive insect that is killing street trees in New York, New Jersey, Massachusetts, and Ohio. Unlike other longhorned beetles, which usually attack stressed, diseased, and dying trees, *Anoplophora glabripennis* attacks and kills healthy trees. Consequently, there is concern that this exotic insect will become a major pest in North America. Asian longhorned beetles attack maple (*Acer*) trees including Norway, red, sugar, and silver maple, and boxelder. Horse-chestnut (*Aesculus*) and willow (*Salix*) trees are also attacked. The most obvious sign of a beetle infestation is the presence of characteristic circular exit holes on the trunk, branches, and exposed roots. The Delaware Forest Service continued to monitor for this pest in 2013 and 2014 with nine large panel traps placed throughout the state, focusing on areas north of Dover. To date, no ALB has been found.

Sirex wood wasp

An exotic wood wasp (*Sirex noctilio*) has been found in the wild in New York State and Pennsylvania. This wood wasp attacks pine trees and represents a serious potential threat to Delaware's loblolly pine resource. Adults can disperse 20 miles or more. A survey program was initiated in Delaware in 2006 using Lindgren funnel traps baited with chemical lures. In 2014, detection traps will be set up and monitored at nine sites throughout the state. Early detection would allow a more effective and timely response should this European pest be found here.

Invasive Species – Plant Pathogens

Beech Bark Disease

American beech (*Fagus grandifolia*) is a common tree in Delaware and is easily recognized by its smooth gray bark. Unfortunately, a non-native disease complex called beech bark disease (BBD) has killed millions of beech trees in the Northeast. Currently found from Canada down the Appalachians as far as West Virginia, BBD begins with infestation by a scale insect, followed by infection of a destructive fungus. Most of the beech trees in infested stands die within a few years.

Four sites in northern to central Delaware were surveyed for BBD in 2014 as part of a coordinated effort also involving New Jersey, Maryland, and West Virginia. At each site, at least 20 beech trees were inspected for the presence of scale and symptoms of BBD. Fortunately, beech bark disease was not found in Delaware in 2014. Surveys will continue in coming years as the disease continues its southward spread.

Other emerging plant pathogens that may occur in Delaware in the future include: thousand cankers disease, which affects walnuts (*Juglans* sp.); redbay ambrosia beetle-laurel wilt pathogen, which affects redbay (*Persea borbonia*) and related species; and sudden oak death (*Phytophthora ramorum*).

Problematic Native Species

Problematic native species include native animal species that have become overabundant due to introduction, habitat changes, and a lack of predators, all usually resulting from human activities. Some of Delaware's most important problematic native species are detailed in this section.

White-tailed Deer

In many areas of the country, including Delaware, deer have changed the composition and structure of forests by preferentially feeding on select native plant species. This bottom-up impact affects numerous SGCN, either directly (for butterflies and moths that feed on plants, and bees and other pollinators that rely on plants for pollen and nectar) or indirectly (through large-scale changes in ecosystem structure and function brought about by reduced plant diversity and regeneration).

Based on 2009 aerial survey data, statewide average deer density in Delaware was 44.3 deer per square mile. The targeted goal for deer populations statewide is 40 deer per square mile of deer habitat which includes forested, rangeland, and wetland habitats (Rogerson 2010). Studies of the effect of deer density on biodiversity suggest that in some habitats, deer densities even lower than the current goal can have negative impacts (deCalesta 1994 and Tymkiw et al. 2013). In many forest systems, deer browse interacts synergistically with invasive plant species to further reduce the cover and diversity of native plants (Williams and Ward 2006, Baiser et al. 2008, Knight et al. 2009). In addition, recent studies have found that the positive effects of natural disturbance regimes on tree species diversity do not occur in the presence of heavy browsing pressure (Nuttle et al. 2013). Legacy effects of heavy deer browse can be persistent even once deer densities have been reduced (Royo et al. 2010, White 2012).

Canada Goose

Resident, non-migratory Canada geese (*Branta canadensis*) are another problematic native species. These geese exhibit high survival (Beston et al. 2014) and reproductive rates and impact vegetation and water quality in freshwater wetlands statewide. Congregations of resident geese can remove vegetation along shorelines by feeding and trampling, resulting in bank erosion and soil sediments being carried by rainwater into lakes, ponds, reservoirs, and wetlands. Goose feces can also be a significant source of phosphorus and nitrogen into surfaces waters. (AFCTS 2011).

Resident Canada geese often become a nuisance when they occupy human-influenced landscapes, such as golf courses, parks, backyards, and agricultural fields. They can consume grasses and leave feces to the extent that it causes monetary damage and/or becomes a public health hazard. Recent concerns about the presence of highly pathogenic avian influenza in the United States have heightened public awareness and health officials' interest in the role that birds may play in transmission of diseases to captive/backyard poultry. Resident Canada geese can become dangerous when situated near airports and airfields because of the potential for bird strikes which can damage or crash aircraft.

Since 2000, DNREC DFW has been flying an annual aerial survey in July to estimate the post-breeding population size of resident Canada geese in Delaware. The most recent 5-yr mean estimate (2010-2014) from this survey is 11,300 individuals. Surveys completed as part of the Atlantic Flyway Breeding Waterfowl Survey for the same time period estimated the population at 10,327 geese (note: this is a pre-breeding season estimate). DNREC DFW has established a breeding population objective of 2,000 geese (AFCTS 2011).

Snow Goose

Beginning in the mid to late 1970s, greater snow goose (Chen caerulescens atlantica) numbers at known wintering sites began to increase and these were observed expanding into new wintering areas, especially in coastal areas of Delaware Bay and Maryland's Eastern Shore (Figure 3.16). At the same time, numbers at the traditional wintering grounds (in North Carolina and Virginia) stayed the same, indicating not only a redistribution of the wintering greater snow goose population, but an actual increase in population size. Historically, Delaware supported <1% of the total wintering population. Today, Delaware supports approximately 37% of the wintering greater snow goose population, and Delaware, Maryland, and New Jersey combined support over 85% of the wintering population.

Figure 3. 16 Flock of Snow Geese. Photo: Joey Melvin

As greater snow goose populations have continued to grow, so has damage to wetlands and agricultural fields. Rather than simply browsing on the leaves of plants, snow geese often feed on vegetation by uprooting the plant or clipping the vegetation at the base of the stem. In habitats where vegetation has yet to emerge, snow geese will "grub" for roots and tubers. These techniques are very destructive and can produce unvegetated "eat-outs" in fields and wetlands. Biologists at Bombay Hook National Wildlife Refuge (NWR), a major wintering site for greater snow geese, estimate that 500-600 acres of vegetated wetland habitat have been lost due to grazing by geese. Similarly, it is estimated that snow geese damage over 11,000 acres of wheat, barley, and rye crops every year in Delaware, especially in the months of January and February.

Management strategies for snow geese have primarily relied on hunter harvest to curb population growth. Delaware was granted a season modification in 1999 to extend the snow goose season to 107 days with a 15-bird daily bag limit. In 2009, Delaware established a Conservation Order for snow geese that eliminated daily bag and possession limits and authorized the use of special harvest methods. Despite the implementation of expanded hunting opportunities and in increase in snow goose harvest, current management strategies may be inadequate to address the problem of snow goose population increase. In 1965, the Atlantic Flyway population of greater snow geese was estimated at 25,400 birds. By 2006, the population had reached 1,016,900 geese and achieved an annual population growth rate of 8%. Since implementation of snow goose conservation orders in various Atlantic Flyway states, snow goose population estimates appear to have stabilized. The USFWS has proposed a greater snow goose population goal of 500,000 birds. At this time, it is unclear what methods will be employed to achieve to stated population objective.

Wildlife Diseases

Many wildlife diseases have emerged in recent years as critical threats to particular taxa. In some cases, climate change threatens to exacerbate the spread and severity of wildlife pathogens. A few of the most important wildlife diseases in Delaware are detailed below.

White-Nose Syndrome

White-nose syndrome (WNS) has caused unprecedented mortality among cave bats in the Northeast and beyond and its rapid expansion appears likely to affect populations throughout North America. With greater than 90% cave bat mortality in many sites, this large-scale bat die-off represents a huge challenge to wildlife agencies. Most states are tasked with collecting data on WNS and working cooperatively to find solutions for safeguarding bat populations. Delaware, despite its small size and lack of many winter hibernacula, has documented WNS and *Pseudogymnoascus destructans* (formerly known as *Geomyces destructans)* in winter and summer roosts.

WNS has been detected in hibernating bats in Delaware and *P. destructans* has been detected on bats returning to two maternity colonies (Figure 3.17). In early April 2010, wing biopsies from two little brown bats (*Myotis lucifugus*) that had just returned to their maternity colonies were sent the National Wildlife Health Center for analysis; both were polymerase chain reaction (PCR)-positive for *P. destructans*. Severe population declines have been documented at both of these colonies. One colony had a minimum of 290 bats in 2009. That number dropped to 52 in 2010, nine in 2011, two in 2012 and zero in 2014. The other colony declined from a 2010 maximum count of 122 to a 2011 maximum count of 28 bats. The abandoned house that maintained this colony was demolished in June 2011 so no further data could be collected.

Figure 3. 17 Little brown bat (*Myotis lucifugus*) with White Nose Syndrome (WNS). Photo: Ryan von Linden/New York Department of Environmental Conservation

Delaware has no caves or mines suitable for hibernating bats; however, hibernating bats have been documented at Fort Delaware State Park, a Civil War-era fort situated on an island in the Delaware River. The fort is made primarily of brick and concrete and parts of it provide temperature and humidity levels similar to what is found in caves. Bats were also documented using small ammunition bunkers in Fort DuPont State Park located on the mainland near Fort Delaware. Surveys conducted in the winter of 2011-2012 documented the presence of WNS at both Fort Delaware and Fort DuPont and changed the status of WNS in Delaware from *Suspect* to *Confirmed*. Subsequent surveys confirmed that WNS was still present.

Species impacted by WNS included big brown bats (*Eptesicus fuscus)*, tri-colored bat (*Perimyotis subflavus)*, little brown bats (*Myotis lucifugus)*, silver-haired bats *(Lasionycteris noctivagans)* and northern long-eared bats *(Myotis septentrionalis).* Swabbing studies at Fort Delaware documented the presence of *P. destructans* year round.

Species potentially impacted by WNS include: Northern long-eared bat *(Myotis septentrionalis*), little brown bats (*Myotis lucifugus*), big brown bats (*Eptesicus fuscus*), tri-colored bats (*Perimyotis subflavous*), Eastern small-footed bat (*Myotis leibii*), and silver-haired bat (*Lasionycteris noctivagans*).

Ranavirus and other diseases affecting Herpetofauna

Ranaviruses are a group of viruses (genus *Ranavirus*, family Iridoviridae) affecting fish, amphibians, and reptiles. They are highly infectious, often lethal, and can cause mass die-offs, especially in aquatic populations. These viruses are found nearly worldwide.

Delaware participated in a regional ranavirus SWG grant from 2013-2014. The goal of this project was to better understand the geographic distribution of ranavirus in the Mid-Atlantic, its potential effects on amphibian and reptile populations, and to develop and test a sampling protocol that could be used throughout the Northeast region. This was accomplished by focusing sampling at wood frog (*Lithobates sylvaticus*) breeding ponds (typically vernal pools). Mortality rates are 50-99% in the larval life stage compared to low mortality rates in adults; thus larvae are the appropriate life stage to sample to increase the probability of detection of the disease.

Ranavirus was detected in thirteen of twenty-three sampled ponds (56%) and wood frog die-offs were documented in two of those ponds in Delaware in 2013. It was documented in every county in Delaware (even though there were only two sites in Sussex County) and all the Blackbird State Forest sites were positive for ranavirus.

In 2014, all sites that were positive in 2013 (and had wood frogs present in 2014) were revisited and samples taken to determine if ranavirus was still present. Ranavirus was documented at seven of the 13 populations sampled (54%). Ponds that were negative for ranavirus in 2013 were also visited in the spring of 2014 to look for signs of ranavirus in tadpoles. A die-off was observed in 2014 at one of these sites and a sample was sent to the National Wildlife Health Center (it came back positive for ranavirus). In 2014 die-offs were documented (and samples were collected) at four of the 13 sites that were positive for ranavirus in 2013.

Ranavirus was also detected in bog turtles (*Glyptemys muhlenbergii*), snapping turtles (*Chelydra serpentina*) and a box turtle (*Terrapene carolina*) in 2013 but not in 2014. Herpesvirus was detected in bog turtles in 2013 and 2014. Spotted turtles (*Clemmys guttata*) and snapping turtles tested negative for herpesvirus. Twelve out of 18 bog turtles and all box turtles (two) tested positive for *Mycoplasma*. It should be noted that no outward symptoms were seen on turtles that tested positive for disease and all nine bog turtles that had transmitters still working in spring 2014 had survived the winter and spring without incident.

Species Potentially Impacted: Any frog, salamander or turtle species

Some of these pathogens may be dormant in the animal's systems and may not cause problems unless other stresses are present. Continued research is needed to determine the effects of pathogens in Delaware. Large scale die-offs of some species (including box turtles, frogs, and salamanders) have been documented in other places due to ranavirus. Continued monitoring and research is necessary to determine long-term impacts of diseases on amphibian and reptile populations in Delaware.

Snake fungal disease (see http://northeastparc.org/snake-fungal-disease-faq/ for background information) has not been documented in Delaware, but one Eastern ratsnake (*Pantherophis alleghaniensis*) was observed with symptoms and was tested (results are pending).

Species Potentially Impacted: Any snake species

Other Wildlife Diseases

Many other existing and emerging wildlife diseases present significant threats to SGCN. Of particular note is emerging evidence that pathogens prevalent in managed or introduced invertebrates are actively transmitted to wild invertebrates, and may pose major threats to SGCN. This has been demonstrated in the case of native bumblebees (*Bombus* spp.) becoming infected by pathogens of the managed, non-native honeybee (*Apis mellifera*) (Fürst et al. 2014).

Other emerging wildlife diseases of note include West Nile Virus (birds), highly pathogenic avian influenza (HPAI) viruses (birds), chytrid fungus (*Batrachochytrium dendrobatidis*) (amphibians), and fibropapillomatosis (sea turtles). Since climate change may affect the spread and effects of wildlife diseases, additional emerging diseases are likely to become problematic in the future.

Pollution

Urban wastewater includes stormwater runoff and sewage. Increases in stormwater occur concurrently with high levels of impervious surface and changes in land use associated with development. In older cities, including Wilmington, outdated, combined sewer and stormwater infrastructure can result in sewage flows into streams and rivers, and problems with sewage backup during flooding events. Efforts to address these issues are being made, but projects are costly.

Delaware has a long legacy of industrial pollution. Currently, 13 sites in Delaware are on the USEPA's National Priority List (see Table 3.5) (US Environmental Protection Agency 2015). Remediation work has been completed on all but three of these sites.

Table 3. 5 Delaware Sites on the US EPA National Priority List

Site Name	Location	Final Listing Date	Site Score	Status
Army Creek Landfill	New Castle County	09/08/1983	69.92	Construction Complete
E.I. du Pont de Nemours & Co., Inc. (Newport Pigment Plant Landfill)	Newport	02/21/1990	51.91	Construction Complete
Delaware Sand & Gravel Landfill	New Castle County	09/08/1983	46.60	Construction Complete
NCR Corp. (Millsboro Plant)	Millsboro	07/22/1987	38.21	Construction Complete
Chem-Solv, Inc.	Cheswold	08/30/1990	37.93	Construction Complete
Dover Air Force Base	Dover	03/13/1989	35.89	Construction Complete
Dover Gas Light Co.	Dover	10/04/1989	35.57	Construction Underway
Standard Chlorine of Delaware, Inc.	Delaware City	07/22/1987	35.42	Construction Underway

Koppers Co., Inc. (Newport Plant)	Newport	08/30/1990	33.56	Design Underway
Halby Chemical Co.	New Castle	06/10/1986	30.90	Construction Complete
Harvey & Knott Drum, Inc.	Kirkwood	09/08/1983	30.77	Construction Complete
Delaware City PVC Plant	Delaware City	09/08/1983	30.55	Construction Complete
Tybouts Corner Landfill	New Castle County	09/08/1983		Construction Complete

Source: US Environmental Protection Agency. 2015. *Final National Priorities List (NPL) Sites - by State*. As of 9 February 2015. http://www.epa.gov/superfund/sites/query/queryhtm/nplfin.htm - DE

With respect to toxic substances that affect Delaware's water resources, the Division of Waste and Hazardous Substances and the Division of Watershed Stewardship have developed a Watershed Approach to Toxics Assessment and Restoration (WATAR). WATAR is a holistic (watershed scale), integrated, and systematic approach to the evaluation of contaminant sources, transport pathways, and receptors, and a mechanism to implement restoration actions based upon site prioritization.

Nutrients from agriculture and development are a problem for aquatic systems, especially in the Inland Bays watershed. Nitrate in the Coastal Plain unconfined aquifer may exceed 10 mg/L as nitrogen in areas affected by agriculture or domestic sewage (Hodges n.d.). Delaware NEMO (Nonpoint Education for Municipal Officials), coordinated by the University of Delaware's Delaware Sea Grant Program, is an educational program for local decision makers that addresses the relationship between land use and natural resource protection, with a focus on watersheds. The Chesapeake Bay Watershed is also designated a Critical Conservation Area (CCA) by the NRCS Regional Conservation Partnership Program (RCPP), with the goal of reducing nitrogen, phosphorus, and sediment loads coming from private lands by strategic implementation of conservation practices (USDA NRCS 2013).

Pesticides, including fungicides and insecticides, present an issue for many invertebrate SGCN. Recent research on declines of honey bees (*Apis mellifera*) implicates both insecticides and fungicides in bee declines (Pettis et al. 2013, Fairbrother et al. 2014), and these results are likely applicable more broadly to other native bee species, especially bumblebees (*Bombus* sp.) Studies indicate that foraging bees are acquiring pesticides not just from foraging on the flowers of treated crops, but also from non-crop species at field margins and other areas within agroecoystems that may be subject to overspray. Widespread use of neonicotenoid insecticides, such as imidacloprid, in agricutural systems represents a threat to non-target invertebrates (reviewed by Pisa et al. 2015), including SGCN, as well as a potential threat to vertebrate SGCN via both direct and indirect impacts (reviewed by Gibbons et al. 2015).

Widespread use of non-selective herbicides to treat weeds in herbicide-tolerant (e.g., Roundup Ready®) crops reduces diversity of native plants in the vicinity of field margins and may lead to increased herbicide resistance of some plant species (VanGessel 2001), potentially including invasives.

In residential settings, use of pesticides continues to occur at a large scale. Recent popularity of private backyard mosquito control treatments, especially those utilizing adulticides as barrier sprays, has the potential for negative impacts on native invertebrate species, including SGCN bees, butterflies, and moths. Coordination, information dissemination, and technical assistance with the landscaping and pest control industries are important in minimizing impacts to non-target wildlife and water quality.

Excess Energy

Thermal, Noise and Light Pollution

Thermal pollution of the Delaware Estuary from cooling water discharges at industrial complexes along the Delaware River and Bay is a potential issue for aquatic SGCN, especially since river temperatures are already rising globally as a result of climate change (Kaushal 2010, Van Vliet et al. 2011) and thermal impacts of discharges may contribute to local exacerbation of these effects (Coulter et al. 2014).

Recent studies indicate that there are negative effects from noise pollution on breeding birds (Ortega 2012, Schroeder et al. 2012) and these effects are more pronounced in insectivorous species and species with lower frequency vocalizations that overlap to a greater extent with ambient noise frequencies from highways, air traffic, and other sources (Francis 2015). Delaware's extensive road transportation network and location within the flight paths of several major airports are sources of excess noise. In-water noise (such as from pile driving, excavation, drilling, etc) can create an impediment to upstream migration for anadromous fish species. American shad (*Alosa sapidissima*), blueback herring (*Alosa aestivalis*), and alewife (*Alosa pseudoharengus*), collectively known as alosines, are especially sensitive to changes in their natural environment and noise and vibrations can interrupt their upstream migration to spawning areas. Marine noise also has detrimental effects on marine mammal SGCN. The National Oceanic and Atmospheric Administration (NOAA) is developing acoustic guidance for assessing the effects of anthropogenic sound on marine mammal species under their jurisdiction (NOAA 2013).

Light pollution (Figure 3.18) is thought to be a major problem for biodiversity, especially insect diversity (Newport et al. 2014). A recent study by Pawson and Bader (2014) suggests that widespread adoption of energy-efficient LED outdoor lighting may exacerbate this problem due to its closer match to nocturnal invertebrate visual sensitivity range. Excess lighting in cities and unsuitable types of lighting on bridges and communication towers have been implicated as important factors influencing avian strike mortality at these structures.

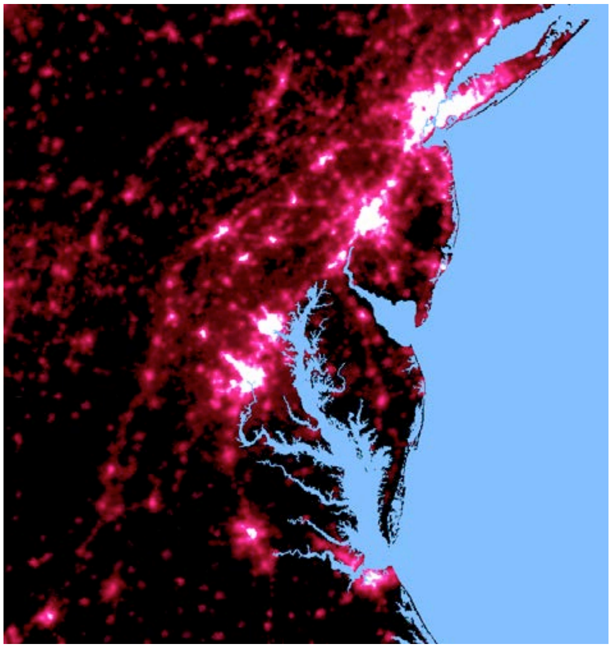


Figure 3. 18 Nighttime Light Pollution Intensity in the Mid-Atlantic Coast Region. **Source: https://catalog.data.gov/dataset/nighttime-lights-of-north-america-direct-download**

Climate Change

Introduction and Regional Perspective

Climate change is now recognized as a major threat to fish and wildlife habitats, populations, and assemblages. There is evidence that climate change is already affecting ecosystems as distributions of animals and plants change, phenology is disrupted, and community compositions and structures are altered. Species and populations likely to have greater sensitivities to climate change include those with highly specialized habitat requirements; species already at or near physiological temperature limits or having other narrow environmental tolerances; isolated, rare, or declining populations with poor dispersal abilities; and taxa especially sensitive to pathogens. Species with these traits will be even more vulnerable if they have a small population, a low reproductive rate, long generation times, low genetic diversity, or are threatened by other factors (NFWPCAP 2014).

Climate modeling analyses for the northeastern region of the U.S. have projected major changes over the rest of this century, although the magnitudes of these changes are likely to vary spatially across the region. Using recent modeling studies, the Manomet Center for Conservation Sciences (MCCS) projected the following changes in the climate of the Northeast by 2070-2099 (Table 3.6; NWF and MCCS 2014).

Table 3. 6 Projected Changes in the Climate of the Northeast by 2070-2099. Source: NWF and MCCS (2014).

Average Temperature	The annual average air temperature across the region will increase by 2-5 °C (3.6-9.0 °F) depending on the emissions scenario. The annual average temperature increase will have seasonal and geographical components, being greatest in the winter months and at higher latitudes.
Extreme Temperature	The number of extreme heat days per year (>50 °C, 90 °F) will increase from the current 10 to 20-40 days depending on the emissions scenario.
Precipitation	Precipitation levels will increase by about 7-15%, most falling as rain during the winter months.
Growing Season	The length of the plant growing season (days between last and first killing frosts) will extend by 30-50 days, depending on the emissions scenario, and plant hardiness zones will advance north.
Soil Moisture	Soil moisture content (percent saturation) will decrease, particularly during the summer months (by about 1-2%).
Extreme Weather Events	Winter and spring floods will be of shorter duration but higher intensity and more frequent.
Ice	Ice formation will occur later in the year and melting will be earlier; many lower elevation lakes and rivers might no longer have sustained ice cover.

Climate Projections for Delaware

For Delaware, future climate models were statistically downscaled by Hayhoe et al. (2013) using historical weather station data from 14 Delaware stations.

Delaware is likely to experience projected increases in annual and seasonal temperatures, high temperatures, and heavy precipitation, all of which show greater increases under higher as compared to lower scenarios and by end of century as compared to more near-term projections. The ***lower scenario*** represents a future in which people shift to clean energy sources in the coming decades, reducing emissions of carbon dioxide and other greenhouse gases. The ***higher scenario*** represents a future in which people continue to depend heavily on fossil fuels, and emissions of greenhouse gases continue to grow. (All climate projections and graphs are based on Hayhoe, et al, 2013.)

Annual and Seasonal Temperatures

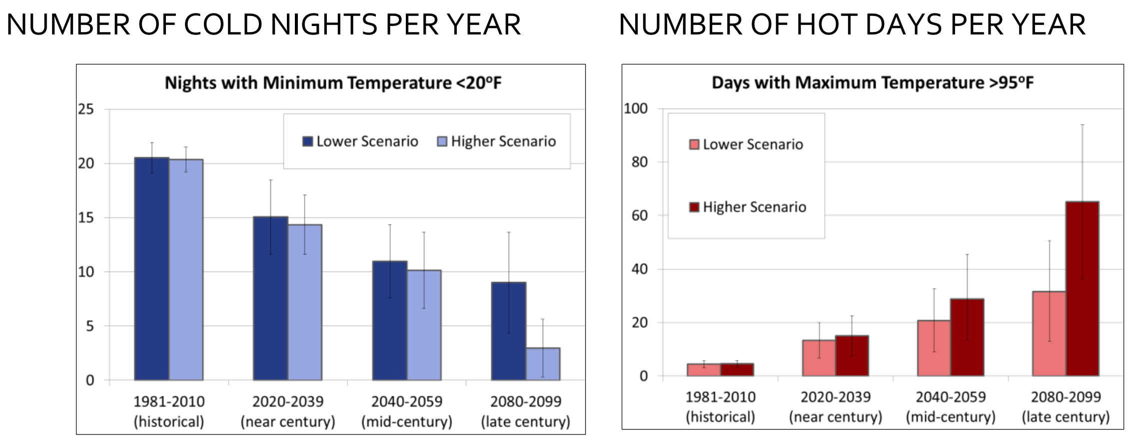
- Temperature increases of 1.5 to 2.5°F are projected for 2020-2039 across all scenarios. By mid-century or 2040-2059, increases under lower scenarios range from 2.5 to 4 °F and around 4.5 °F for higher scenarios.
- Relatively greater temperature increases are projected for spring and summer as compared to winter and fall.
- The range of spring temperature (calculated as the difference between daytime maximum and nighttime minimum temperature) is projected to increase, while the range in fall temperature is

projected to decrease, and temperatures ranges in summer and winter are not predicted to change appreciably.

- The growing season is also projected to lengthen, with slightly greater changes in the date of last spring frost as compared to first fall frost.

Extreme Temperatures

- The number of very cold days (minimum temperature below 20 °F) is projected to drop from 20 to 15 by 2020-2039, to just over 10 days per year by 2040-2059, and to a minimum of 10 days per year under lower scenarios and only 3-4 days per year under higher scenarios by 2080-2099 (Figure 3.19).
- The number of hot days (maximum temperature over 95 °F) is projected to increase from the current average of less than 5 days per year to as many as 15 to 30 days by mid-century.
- All simulations show large increases in average summer heat index, potential evapotranspiration, and the number of hot and dry days per year.

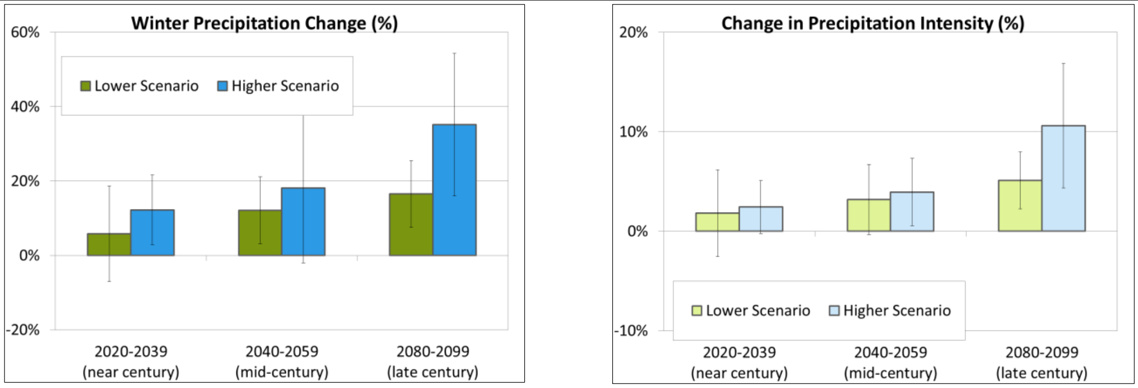


Projections for **temperature extremes** indicate an increasing number of very hot days and decreasing number of very cold days and nights. Differences between the high scenario and low scenario are greater by mid-century and end of century. Source: Hayhoe et al. (2013).

Figure 3. 19 Projections for Temperature Extremes

Precipitation Changes

- Precipitation is projected to increase, particularly in winter (Figure 3.20).
- By end of century, nearly every model simulation shows projected increases in the frequency of heavy precipitation events, indicating an increase in precipitation intensity.



Precipitation increases are projected, primarily for winter and fall. Increasing precipitation intensity reflects projected increases in the frequency of heavy rainfall. Source: Hayhoe et al. (2013).

Figure 3. 20 Projected Precipitation Increases

Potential Impacts to Ecosystems and Wildlife

Effects of climate change in Delaware on ecosystems, natural resources, and infrastructure are detailed in the Delaware Climate Change Impact Assessment (DNREC Division of Energy and Climate 2014).

Many of Delaware's wildlife species will face changes in habitat quality, timing, and availability of food sources, abundance of pests and diseases, and other stressors related to changes in temperature and precipitation. Species with very restricted ranges and isolated populations are likely to be most vulnerable to climate change impacts, compounded by other stressors. Changes in temperature and precipitation will affect species that depend on wetland and aquatic habitats.

The ways in which species and populations respond to climate changes can vary widely. Differences in how organisms respond to climate change — their adaptive capacity — will lead to some species benefitting, by expanding their range and/or increasing population, and other species declining. In the northeastern United States, for example, some forest types such as oak-hickory are expected to expand, while maple-beech-birch forests are expected to contract.

Responses to climate change that have already been observed include changes in geographic range and the timing of life cycle events such as migration and reproduction. Numerous studies show shifts in the geographic range of species in response to increasing temperatures. As the climate warms, species may shift poleward (north in the northern hemisphere) or to higher elevations. For example, winter bird counts taken in the United States over the past 40 years showed a significant shift northward for more than half of the species tracked (177 of 305); nearly 20 percent of the species recorded had shifted more than 100 miles to the north (Staudinger et al. 2012). These northward shifts are also being observed in ocean habitats. In U.S. waters, marine species are shifting northward, and changing distributions of both cold- and warm-water fish species have been recorded (Janetos et al. 2008).

Changes in bloom time, migration, and nesting are also well documented. Some changes in life cycle activities are triggered by the increasing length of the growing season. Global satellite data show that the onset of spring across temperate latitudes has advanced by 10 to 14 days over the past two decades (Janetos et al. 2008). However, a species' ability to adjust geographically or temporally does not guarantee survival. The timing of these shifts can be critical for ecologically linked species, potentially resulting in a mismatch between species and the resources they need to survive. Migratory birds, for example, depend on food supply in breeding territories, wintering grounds, and throughout their migratory path. The earlier onset of spring may alter the optimum timing for arrival of birds that rely on peak food availability to support their breeding cycle.

In addition to being an existing external stressor, new invasive species and diseases may emerge as they benefit from changing climate conditions, readily establishing in new areas and outcompeting native species for resources. The spread of new diseases and pathogens may also be enhanced by changing climate conditions, potentially affecting native species and humans. Table 3.7 summarizes the potential ecological impacts in response to climate change.

Table 3. 7 Potential Ecological Impacts in Response to Climate Change

Observed or projected physical change	Examples of potential impacts on biodiversity
Increased temperature	Species and population range shifts Changes in phenology leading to alteration or loss of biotic interactions
Changes in annual and seasonal precipitation	Changes in species composition of communities and habitats
Increased frequency of extreme events	Mortality resulting from flooding after storms Damage or mortality resulting from drought or heat waves
Changes to hydrologic regimes	Reduced streamflow affecting species population persistence and community composition
Changes to fire regimes	Changes in species composition of communities
Ocean acidification	Change in water chemistry affecting calcification rates of marine organisms
Sea level rise	Habitat loss and fragmentation from coastal erosion or inundation
Increases in ocean stratification	Reduced productivity of pelagic ecosystems
Changes in coastal upwelling and/or ocean temperatures	Changes in productivity of coastal ecosystems and fisheries Species and population range shifts and/or changes in phenology leading to alteration or loss of biotic interactions

Adapted from: National Climate Assessment (Staudinger et al. 2012).

Climate Change Effects: Habitat Shifting and Alteration

Delaware's ***beach and dune ecosystems***, including beaches, maritime dune and grasslands, interdunal wetlands, and tidal sand flats, are already vulnerable to coastal storms. If sediment input into the system is unbalanced, the combined effects of sea level rise and severe storms may lead to increased erosion and loss of beaches and dunes. Barrier beaches and dunes may be subject to more frequent overwash from storm surge, and may be increasingly vulnerable to breaching and formation of new inlets (DNREC Division of Energy and Climate 2014). Interdunal wetlands, rare habitats that support several SGCN, including the Bethany Beach firefly (*Photuris bethaniensis*), will be mostly inundated at 1 m of additional sea level rise (Love 2013b). Regional impacts of sea level rise vulnerability for fish and wildlife in the Northeast U.S. were summarized by the National Wildlife Federation (NWF) and MCCS (2014).

Delaware's diverse range of ***wetland and aquatic ecosystems***, including tidal, nontidal, freshwater, brackish, and saltwater wetland habitats, as well as stream and riverine habitats, will be vulnerable to sea level rise and increased storm surge from extreme weather events. Climate change impacts will likely accelerate erosion in tidal marshes, leading to further wetland losses, landward migration of marsh habitat, or conversion to open water. Increased temperatures and higher variance in precipitation intensity will stress freshwater habitats, including streams, rivers, and ponds. Higher water temperatures are likely to increase the incidence of harmful algal blooms (DNREC Division of Energy and Climate 2014).

Delaware's ***forest ecosystems*** may experience shifts in the range of forest species and composition of forest communities, triggered by changes in temperature. Temperature and moisture changes are likely to contribute to plant stress, resulting in decreased productivity and greater susceptibility to pests and diseases for some species (DNREC Division of Energy and Climate 2014). Loblolly pine (*Pinus taeda*) and some species of oaks (*Quercus stellata*, *Quercus nigra*) and hickories (*Carya cordiformis*) are expected to increase their abundance in Delaware's forests, while red maple (*Acer rubrum*), white oak (*Quercus alba*), tulip poplar (*Liriodendron tulipifera*), and others are expected to decrease (Prasad et al. 2007-ongoing).

Climate Change Effects: Sea Level Rise

Accelerating rising sea levels are another manifestation of the changing climate. Under rising global temperatures, sea water is undergoing thermal expansion, and ice caps and glaciers are melting and contributing to rising sea levels. Sea level rise (SLR) poses significant threats to coastal ecosystems that may become inundated, resulting in habitat changes and losses, and adverse impacts to species or communities that depend on these habitats.

The *Third National Climate Assessment* (2014) estimated a range of additional SLR from about 2 feet to as much as 6 feet by 2100, depending on emissions scenario (Walsh et al. 2014). Locally, in Lewes, Delaware, the rate of existing SLR has been estimated to be 3.41 ± 0.25 mm/year (NOAA, Figure 3.21). This is almost double the average global linear trend of 1.7 mm/yr (Church and White 2011).

The DNREC Sea level Rise Technical Workgroup developed projections for local SLR of 0.5, 1.0, and 1.5 meters, which served as the basis for the state's *Sea Level Rise Vulnerability Assessment* (Love 2013b). on researching and developing recommendations that will build the state's capacity to adapt, rather than pinpointing adaptation measures that should be used in specific locations (Love 2013a,b; Love 2014).

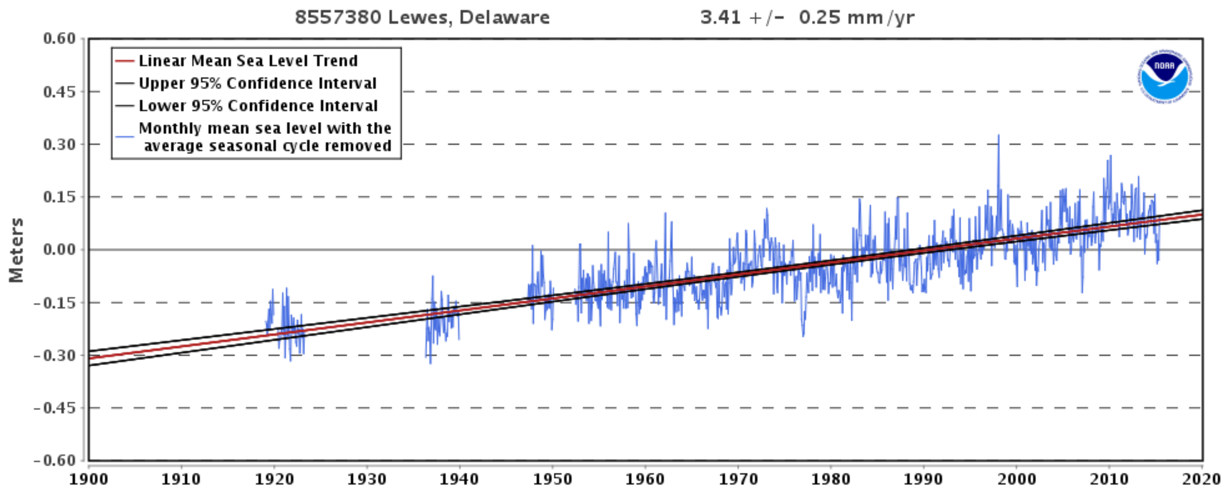


Figure 3. 21 Mean Sea Level Trend Lewes, Delaware. (Source NOAA: Accessed August 2015)

Coastal ecological resources are likely to be among the most sensitive to the changing climate (Frumhoff et al. 2007; Karl et al. 2009, IPCC 2014). As sea levels rise, tidal marshes will be inundated and convert to shallow open water habitats. Some non-tidal wetlands, as well as most freshwater and brackish tidal wetlands, may be converted to higher salinity marshes. Assuming a modest scenario for sea level rise (0.5 m), bathtub models predict 9% of nontidal wetlands and 98% of tidal wetlands will become inundated by the year 2100 (Love 2013b).

The Prime Hook National Wildlife Refuge 2013 Comprehensive Conservation Plan (CCP) identified the conversion of forested areas to emergent wetlands and a displacement of wildlife as predicted impacts of sea level rise at the refuge (USFWS 2013). As discussed in the 2013 CCP, the Delaware Coastal Program conducted a Sea Level Rise Affecting Marsh Model (SLAMM) exercise and predicted that, by the year 2050, half of the current upland area of Prime Hook NWR will be lost (either converted to wetlands or open water), decreasing from 20 percent to, at most, 12 percent of the current land base. Under the worst case scenario, by the year 2100, up to 88 percent of Prime Hook NWR could be open water or tidal mud flats and only one percent of Prime Hook NWR would be uplands.

Coastal development and hardened shorelines reduce the ability of wetlands to migrate inland with increasing sea level, restricting these systems until they convert to open water. As sea level rises, salt water will intrude further upstream into freshwater systems and disrupt natural processes. Najjar et al. (2000) predict significant upstream migration of the salt front in Delaware Bay. Salinity of the Delaware Estuary has already increased significantly, with further increases predicted regardless of changes in stream flow (Ross et al. 2015)

SLR will also have complex effects on future tidal range. Model runs for Delaware Bay indicate a spatially complex behavior with tidal-range changes of up to 10% (Hall et al. 2013). SLR will dramatically affect many SGCN in Delaware, including beach-nesting birds like piping plover (*Charadrius melodus*) (Seavey et al. 2011) and saltmarsh species, especially those whose life history makes them especially vulnerable, such as saltmarsh sparrow (*Ammodramus caudacutus*) (Bayard and Elphick 2011) and black rail (*Laterallus jamaicensis*).

Climate Change Effects: Storms and Flooding

Figure 3. 22 Old road and Indian River Inlet, Hurricane Sandy. Photo: DNREC.

Storms and Coastal Flooding

Future projections of tropical storm and hurricane frequency in the Atlantic remain uncertain due to complex interactions with sea surface temperature and atmospheric phenomena (Oouchi et al. 2014, Walsh et al. 2014). Although the most recent models do not currently indicate a significant increase in frequency, some models (especially those incorporating sea surface temperature) indicate that these storms may become more intense (Ting et al. 2015) with heavier rainfall (Maloney et al. 2014). As sea levels increase, higher storm surges will occur in coastal areas (Anthes et al. 2006).

Storm effects on beach systems have shown sensitivity to compounding impacts of human disturbance (Figure 3.22 and Figure 3.23). Macroinvertebrate communities on Gulf coast beaches showed negative effects on community recovery post-hurricane in beaches that were subject to high vehicular traffic (Witmer and Roelke 2014).

Flooding

Tebaldi et al. (2012) projected future change in frequency of today's 100-year flooding events through the year 2050 and estimated significantly higher return frequencies of these extreme events. Diffenbaugh et al. (2013) projected an increasing likelihood in severe thunderstorm environments. While the uncertainty surrounding projections of extreme precipitation events is relatively high (Walsh et al. 2014), these events have the potential to significantly impact many SGCN and their habitats. Impacts on freshwater aquatic systems may include increased input of sediment and pollutants, mechanical disturbance due to highly varied flow rates, and increased turbidity. Estuarine systems may be impacted by increases in freshwater flow rates, as illustrated by large oyster die-offs during periods of prolonged low salinity at beds in the upper estuary after Hurricane Irene and Tropical Storm Lee in 2011. This salinity perturbation produced such significant oyster mortality that ecological models predict that these stocks will take on the order of 10 years to recover from the event (Munroe et al. 2013).

Climate Change Effects: Temperature and Precipitation Changes

Observed historical data indicate that temperatures across Delaware have been increasing since record-keeping began in 1895. This warming trend includes all seasons and is asymmetrical, with greater increases in minimum temperatures, especially in more recent years, than in maximum temperatures. There has also been a continuing global increase in the frequency of warm temperature extremes since 1998 (Seneviratne et al. 2014). Across the Northeast and Mid-Atlantic region, heavy precipitation has already increased significantly over the last 60 years (Walsh et al., 2014).

Predicted increased frequency of very warm days in summer will result in warmer summer water temperatures in shallow estuarine habitats and may lead to decreased water quality and lower dissolved oxygen content as well as changes to food availability and heat stress to aquatic organisms. This warming could also promote the spread of parasites and other pests in aquatic environments (Pyke et al. 2008; Najjar et al. 2010). Moore et al. (2014) predict that increasing frequency of short-term summer temperature spikes may lead to near-complete eelgrass die-offs, which, combined with continued spread of widgeongrass (*Ruppia*) into these areas, may result in the extirpation of eelgrass in the region. In freshwater aquatic systems, multiple existing stressors may interact with warming to impact SGCN (Pinkney et al. 2014). Marine aquatic species are also affected by changing sea surface temperatures, acidification, and other factors (Doney et al. 2012; Bopp et al. 2013; Byrne and Przeslawski 2013; Hobday and Evans 2013).

Temperature increases may also be problematic for terrestrial species at the edge of their ranges, whose physiological temperature tolerances may be exceeded (Pyke et al. 2008). Species that are restricted in pursuing their climate niche by barriers to dispersal may be capable of limited adaptation in place via genetic and phenotypic plasticity (Urban et al. 2014). For example, some *Plethodon* salamanders in rapidly drying and warming habitats have responded with body size reduction over the past half century (Caruso et al. 2014). It is unclear whether such plastic metabolic responses can keep pace with climate change.

Warming temperatures will also lead to changes in plant phenology, as has already been observed (Ellwood et al. 2013; Polgar et al. 2013). These changes may have significant impacts on ecosystems by permitting spread and increasing competitive advantage of invasive species (Polgar et al 2013).

Predicting Responses of SGCN to Climate Change

Much research effort has been devoted to attempts to predict species' responses to the climate change impacts discussed above in order to inform and prioritize species conservation. Much of the recent research has involved bioclimatic envelope modeling (e.g., National Audubon Society 2013), an extension of species distribution modeling. However, this type of model considers only the abiotic niche of the species as defined by factors such as temperature and precipitation. Also highly important, but much more complex and poorly understood, are the ways in which multiple species interact to influence distributions, helping to determine "realized niches" or actually occupied areas versus "fundamental niches," the area the species could occupy in the absence of competition. The importance of biotic interactions in mediating species responses to climate change is reviewed extensively by Post (2013).

As species shift in response to temperature and moisture changes and associated habitat alterations, novel species assemblages will lead to unpredictable interactions between species (Herstoff and Urban 2014), making prediction of effects difficult for many species.

In addition, the suitability of the landscape for supporting species movement and reorganization in response to climate change is important. This encompasses not just habitat connectivity in the traditional sense, but also geophysical landscape complexity (heterogeneity in slope, aspect, elevation, etc.) as well as landscape permeability (the number of barriers and degree of fragmentation within a landscape). Both of these metrics were analyzed for the northeastern U.S. by Anderson et al. (2012). Delaware predictably exhibited low landscape complexity due to minimal elevation relief and relatively uniform geology. However, in contrast to adjacent areas of the Atlantic Coastal Plain, such as southern New Jersey, the extremely high degree of fragmentation of natural habitats on the Delmarva Peninsula led to below average landscape permeability for much of Delaware in this analysis.

Providing increased areas of suitable habitat and connecting existing natural habitats with corridors are logical approaches to facilitating species range shifts in response to climate change, especially given high levels of fragmentation. However, a recent study of British butterflies suggests that species with already declining populations may be limited in their ability to expand or shift their ranges as a result of low population abundance, even in the presence of available habitat (Mair et al. 2014). Thus, for declining species, it may be equally important to improve core habitat condition in addition to restoring new habitat or establishing corridors.

Importantly, Mair et al. (2014) and other studies (Angert et al. 2011; Fox et al. 2014, Hunter et al. 2014) have shown limited importance of species traits in explaining observed range shifts, relative to population abundance and availability of suitable habitat and land use changes. Widely used species prioritization systems (such as the NatureServe Climate Change Vulnerability Index) often emphasize species traits (such as dispersal ability and habitat specialization), but species with similar traits may not respond consistently.

For these reasons, a broad approach to mitigating the effects of loss of habitat from SLR to the greatest extent possible, while improving the quality and connectivity of existing habitats, may be the most efficient statewide actions to address the effects of climate change on Delaware's SGCN.

Figure 3. 23 South Bay Drive, Kitts Hummock, dune damage Hurricane Sandy. Photo: DNREC.

Need for Information and Planning

Although not direct threats, gaps in information and lack of appropriate conservation planning are considered issues (action drivers in TRACs) that call for important actions to address conservation of SGCN and key habitats. Lack of information on the distribution, status, and ecology of SGCN and key habitats is considered critical because of the importance of having accurate information to respond appropriately and meaningfully to impending threats.

It is important to point out that the original DEWAP first identified these as important needs a decade ago. However, primarily due to budgetary and staffing constraints, large gaps in data exist and not all of these actions have been accomplished in regard to the collection and management of data. The same is true with the need for outreach and education and the need for dissemination of these data to the targeted audiences and the public, who can help reverse these impacts on wildlife.

The action to identify and map Delaware's habitats has been partially completed through DNREC DFW's vegetation community survey project described in Chapter 2, although additional ground truthing would provide more detailed mapping of all rare communities, and rectify any data discrepancies.

One of the greatest threats to SGCN in Delaware is lack of detailed knowledge of species distribution, biology, and ecological interactions. This is especially true of invertebrates, which present a number of special challenges. The vast number of species and taxonomic complexity of invertebrates renders their identification difficult and often requires the attention of a specialist. In addition, the large number of taxa and exceptionally small number of specialists translates into great difficulty in obtaining authoritative identifications. Finally, few groups are understood well enough systematically to make it possible to identify them without retention of voucher specimens. The number of experienced systematists is declining as the number of students training for careers in systematics decreases, and the availability of systematic expertise will remain one of the more limiting factors for invertebrate study in the foreseeable future.

Details of habitat and microhabitat needs and associations as well as interspecies interactions are lacking for many SGCN across taxonomic groups.

Need for Education and Outreach

The growing indifference of the public toward fish and wildlife conservation (Mccallum and Bury 2013) can pose an obstacle to implementing conservation. To further complicate this issue, public perceptions, concerns, and attitudes about species are not equal across taxa, with public awareness of invertebrates in particular often lacking. In general this lack of knowledge results in the public not recognizing or valuing many ecologically and economically significant taxa.

DNREC environmental and outdoor education programs introduce children to nature for their own health and well-being and for the future of environmental conservation in Delaware. DNREC recognized that children were not connecting with nature and may not become part of the next generation of environmental stewards. In 2012, DNREC and the Delaware Department of Education launched the Children in Nature/No Child Left Inside® Initiative. The report of the Children in Nature/No Child Left Inside® Initiative Task Force included goals and recommended actions for improving connection of children with the outdoors and the natural world (State of Delaware 2012).

Several other education and outreach programs are not fully implemented due to lack of funding. For example, the Children in Nature/No Child Left Inside® Initiative Task Force report recommended hiring a full-time naturalist at each State Park to provide educational programming. Project WILD® and Project WET® programs were previously offered via DNREC, but are no longer offered due to lack of available funding.

Need for Funding

The lack of stable funding for wildlife and habitat conservation, education, and research at both state and federal levels creates challenges or obstacles that can be interpreted as a threat to implementing conservation. These underlying fiscal challenges interfere with the capacity of DNREC DFW and its conservation partners to fully implement the DEWAP. In 1842, a U.S. Supreme Court ruling resulted in the Public Trust Doctrine that said that wildlife resources are owned by no individual, but instead are held in trust by government for the benefit of present and future generations. In short, most of the authority for managing wildlife rests with the states and the public bears responsibility for providing funding (AFWA 2011). The lack of appropriate dedicated funding, especially for wildlife diversity, severely constrains the ability of state fish and wildlife agencies to plan, build capacity, conduct long-term monitoring, and manage at landscape scales, all necessary in order to ensure success (AFWA 2011).

For example, Delaware reported an unmet need of $15.5 million for its parks system alone (U.S. National Park Service 2011). Many SGCN are protected largely or in some cases exclusively by Delaware’s State Park system, especially Atlantic coast beach and dune species that occur in Cape Henlopen and Delaware Seashore State Parks. Management budgets for Delaware's state WAs are also stretched very thin.

Funding for protection of lands containing important habitats and SGCN occurrences is a major limitation for wildlife conservation in Delaware and is true for both public and private lands. Since its inception in 1991, Delaware’s Open Space program has protected over 50,000 acres, including much SGCN habitat, at a total cost of $291 million ($229 million of state funds). By law the Open Space Program is to receive $9 million per year from Realty Transfer Taxes, but this funding has decreased significantly in recent years, and was cut to zero in the FY2016 state budget.

Delaware also initiated a Forestland Preservation Program (FPP) in 2006 to purchase conservation easements on working forestlands, modeled after the very successful Agricultural Lands Preservation Program. With an initial allocation of $1 million in FY08 and $500,000 from TNC, conservation easements were purchased on 9 tracts totaling 835 acres. The DFS, working with TNC and other partners, continues to seek additional funding for the FPP, which does not have a dedicated funding source.

Research and monitoring funding is also limited, and the funds available to study and conserve biodiversity are often not distributed equally among taxa, with invertebrates in particular receiving a disproportionately small allocation for research and management. Populations of many SGCN, including state endangered species, are not monitored on a frequent or regular basis due to lack of resources.

These funding issues must be corrected if Delaware is to continue to enjoy the diversity of wildlife and habitats it currently supports.

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