CHAPTER 2

DELAWARE'S WILDLIFE HABITATS

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

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CHAPTER 2, PART 1: DELAWARE'S ECOLOGICAL SETTING

Introduction

Delaware is the second smallest of the United States with a land area of 1,982 mi^2, or just over 1.25 million acres. Despite its small size, the state is home to a wide diversity of terrestrial and aquatic habitat types that harbor an equally diverse flora and fauna.

Delaware is situated in an ecological transition zone where a number of northern species reach their southern limit of natural distribution, and an even greater number of southern species reach their northern limit of distribution (see *Delaware Habitats in Regional Context* below). The state also contains migratory bird staging and concentration areas of global significance.

Historically, Delaware, like most of the Northeast, was largely forested. Natural, permanent grasslands were probably uncommon, except for scattered openings that existed along river floodplains, wetlands, beaver meadows, salt marshes, and grasslands, and shrublands on sandy soils of coastal and inland dunes. Other forested areas opened periodically due to fires set by lightning strikes, and burning and clearing of forest by Native Americans.

Delaware was almost entirely cleared for agriculture over a period of perhaps 150 years after European settlement. In areas where farming was not practical or productive, there has been significant re-growth of forest in areas with poor soils, poor drainage or steep terrain. Today, approximately 30% of the state's land area is forested (Delaware Forest Service 2010) and approximately 25% of the state is covered by wetlands (Tiner et al. 2011). There is significant overlap in these two classifications, since the majority (over 64%) of wetlands in Delaware are forested.

Agriculture remains Delaware's dominant land use, with about twice as much land in agriculture as in forest. However, land in farms has declined somewhat in recent decades, with a concurrent increase in residential and commercial development.

Delaware's Bayshore is widely recognized as an area of global ecological significance. Its expansive coastal marshes, shoreline, agricultural lands, and forests provide diverse habitat to many species, including migratory shorebirds. Birders and biologists from around the world come to central Delaware to witness the annual spring spectacle of more than a half million shorebirds taking a rest stop to dine on eggs laid by spawning horseshoe crabs. The Delaware Bayshore has been protected by Delaware's Coastal Zone Act for the past 40 years, and more than half of the Delaware Bayshore's acreage remains undeveloped.

Delaware Habitats in a Regional Context

U.S. Northeast Region

Delaware falls within the U.S. Fish and Wildlife Service's Northeast Region, which encompasses 13 states from Maine to Virginia. About 70 million people, nearly a quarter of the nation's population, live within this area. The Northeast Association of Fish and Wildlife Agencies (NEAFWA), the professional association that serves as the collective voice of the Northeast states, also works at this level. The North Atlantic Landscape Conservation Cooperative (NALCC) is an applied science and management partnership that works closely with the NEAFWA states on landscape-level conservation planning for the region. Delaware represents a very small proportion of the region (less than 1% by area), but has disproportionate responsibility for populations of many species of greatest conservation need.

A conservation status assessment of regionally significant fish and wildlife species and habitats was completed by The Nature Conservancy (TNC) in 2011 with support from NEAFWA (Anderson and Olivero Sheldon 2011). TNC applied key indicators and measures for tracking the status of wildlife populations that were developed by the NEAFWA Monitoring and Performance Reporting Framework and detailed in the report "*Monitoring the Conservation of Fish and Wildlife in the Northeast: A Report on the Monitoring and Performance Reporting Framework for the Northeast Association of Fish and Wildlife Agencies*" (NEAFWA 2008) (refer to Chapter 5). The conservation status assessment reports the condition of key habitats and species groups (e.g., bird population trends) in the region, and this information is summarized below. *http://www.rcngrants.org/sites/default/files/final_reports/Conservation-Status-of-Fish-Wildlife-and-Natural-Habitats.pdf*

Another recent regional project is the geospatial condition analysis conducted by Anderson et al. (2013b), which assesses several important metrics of the condition of 116 terrestrial and aquatic habitats across the Northeast using standardized region-wide habitat mapping data of streams (Olivero and Anderson 2008) and terrestrial ecosystems (Gawler 2008) developed through the Regional Conservation Needs (RCN) Grant Program. The geospatial condition report and a set of companion Northeast Habitat Guides present additional information on the condition and levels of human impact on the habitats in the region *http://nature.ly/habitatguides*.

The Northeast is more than 60% forested, with an average forest age of 60 years. It contains more than 200,000 miles of rivers and streams, 34,000 water bodies, and more than 6 million acres of wetlands. Eleven globally unique habitats, from sandy barrens to limestone glade, support 2,700 restricted rare species. Habitat fragmentation is one of the greatest challenges to regional biodiversity, as the region is crisscrossed by more than 732,000 miles of roads. The region also has the highest density of dams and other obstacles to fish passage in the country, with an average of 7 dams and 106 road-stream crossings per 100 miles of river (Martin and Apse 2011). Conversion to human use has also impacted much of the northeast landscape, with one-third of forested land and one-quarter of wetlands already converted from the natural state to other uses through human activity. Total wetland area has expanded slightly in the Northeast over the past 20 years, although 67% of wetlands are close to roads and thus have likely experienced some form of disruption, alteration, or species loss (Anderson et al. 2013a).

One-sixth (16%) of the region is conserved and five percent of that land is secured explicitly for nature (GAP Status 1 or 2). The secured land is held by more than 6,000 fee owners and 2,000 conservation easement holders. State governments are the largest public conservation land owners, with 12 million acres, followed by the federal government, which holds 6 million acres. Private lands held in easements account for 3 million acres and land owned by private, non-profit land trusts accounts for another 1.4 million acres. Land conversion, however, outweighs land conserved by roughly 2:1 (28%:16%) (Anderson et al. 2013a).

Approximately 23% of terrestrial habitats and 63% of mountain habitats are conserved in the Northeast. A few low-elevation coastal habitats including the Central Atlantic Coastal Plain Maritime Forest (89%) and Great Lakes Dune and Swale (69%) are also well conserved. Piedmont habitats were the least conserved habitats in the region, especially the Southern Piedmont Mesic Forest (3%), Southern Piedmont Dry Oak-Pine Forest (3%), Piedmont Hardpan Woodland and Forest (2%) and Southern Piedmont Glade and Barrens (0%). Among wetlands, the Atlantic Coastal Plain Peatland Pocosin and Canebrake (99%) and Atlantic Coastal Plain Northern Bog (72%) were habitats with a high percentage of conserved acreage (Anderson et al. 2013a).

U.S. Southeast Region

Although Delaware is part of the Northeast region of the U.S. with respect to agency subdivisions, the Coastal Plain of Delaware is part of the same ecoregion and has strong ecological affinities with the southeastern U.S. Coastal Plain. With climate change, these affinities can be expected to increase as northern species move northward out of Delaware and southern species move northward into the state. Therefore, despite the lack of a formal regional administrative affiliation, Delaware's role in conserving the wildlife diversity of the southeast region of the U.S. is also critically important.

Many species of sandy coastal plain areas reach the northern limit of their distribution on the Delmarva Peninsula. For example, the flora of Delmarva Coastal Plain Seasonal Ponds contains 78 species of native plants, of which 43 (55%) are of southern affinities, while only 10 (13%) are of northern affinities (McAvoy and Bowman 2002). Due to these similarities in sandy soils and plant life, highly disjunct Delaware populations of southeastern animal species, especially invertebrates, continue to be regularly discovered (e.g., Heckscher 2014).

The North American Coastal Plain (from Long Island to Texas) has recently been recognized as a global biodiversity hotspot, with high levels of endemism in plants, amphibians, reptiles, and freshwater fishes, among other taxa (Noss et al. 2015). Delaware's low elevations and relatively simple topography would seem to limit the state's potential for high biodiversity and rates of endemism. However, Noss et al. (2015)

hypothesize that "modest topographic heterogeneity" has interacted with fluctuating sea levels to generate high levels of endemism throughout the North American Coastal Plain.

In addition to resident species, many migratory species link Delaware with the southeast region, including marine and estuarine organisms that travel regularly between Delaware waters and the warmer waters of the Georgia Bight to the south, as well as migrant birds that winter primarily in the southeast, such as rusty blackbird.

The South Atlantic Landscape Conservation Cooperative (SALCC) covers the Atlantic Coast from Virginia Beach south to Jacksonville, FL. The SALCC provides cooperative conservation planning across the region, including their digital mapping effort, Conservation Blueprint. Communication between the North Atlantic and South Atlantic LCCs as well as the Atlantic Coast Joint Venture (ACJV) is occurring as of 2015, helping to facilitate coast-wide cooperation in conservation planning.

Delaware Habitats in a Watershed Context

Delaware's land area drains to three major watersheds, and contains four main drainage basins: the Piedmont, Delaware Bay, Chesapeake Bay, and Inland Bays/Atlantic Ocean basins (Figure 2.1 and Figure 2.2).

Figure 2. 1 Delaware's major drainage basins.

Delaware Department of Natural Resources and Environmental Control (DNREC) has been implementing a drainage basin approach to assess, manage, and protect Delaware's natural resources.

This approach, known as Whole Basin Management, encourages the various programs from throughout DNREC to work in an integrated manner to assess different geographic areas of the state defined on the basis of drainage patterns. Between 1997 and 2005, the DNREC published preliminary assessment reports for each of Delaware's four major drainage basins.

DNREC's Watershed Assessment and Management Section oversees the health of the state's water resources and takes actions to protect and improve water quality for aquatic life and human use. The Watershed Assessment and Management Section houses the Wetland Monitoring and Assessment Program, which assesses the condition, or health, of wetlands and the functions and ecosystem services that wetlands provide. For more information, see Wetland Condition.

Delaware River Watershed

The Piedmont Basin and the Delaware Bay Basin are both part of the larger Delaware River Basin (a total of 642,560 acres in Delaware). The entire Delaware River Basin contains 13,539 square miles, draining parts of Pennsylvania (6,422 square miles or 50.3 percent of the basin's total land area); New Jersey (2,969 square miles, or 23.3%); New York (2,362 square miles, 18.5%); and Delaware (1,004 square miles, 7.9%). Included in the total area number is the 782 square-mile Delaware Bay, which lies roughly half in New Jersey and half in Delaware.

Since 1961, a regional body, the Delaware River Basin Commission (DRBC), has overseen a unified approach to managing the river system without regard to political boundaries. The DRBC's programs include: water quality protection, water supply allocation, regulatory review (permitting), water conservation initiatives, watershed planning, drought management, flood loss reduction, and recreation.

The Delaware Estuary (the Delaware Bay and tidal reach of the Delaware River and its tributaries) comprises three states (Pennsylvania, New Jersey, and Delaware), 13 counties, and 2 EPA regions. The Partnership for the Delaware Estuary (PDE), a nonprofit established in 1996, is one of 28 National Estuary Programs. PDE published its *Technical Report for the Delaware Estuary and Basin* in 2012 (Partnership for the Delaware Estuary 2012).

Piedmont Basin

The Piedmont Basin, considered separate from the Delaware Bay Basin because of its unique geology, empties into the Delaware River and is part of the Delaware Estuary. The Piedmont Basin contains the Brandywine Creek, Red Clay Creek, White Clay Creek, Christina River, Naamans Creek, and Shellpot Creek watersheds.

Delaware Bay Basin

The Delaware Bay Basin is located in eastern New Castle, Kent, and Sussex counties. The basin is part of the Coastal Plain province and drains approximately 520,960 acres, or 814 square miles, encompassing the following watersheds: Delaware River, Army Creek, Red Lion Creek, Dragon Run Creek, Chesapeake & Delaware Canal East, Appoquinimink River, Blackbird Creek, Delaware Bay, Smyrna River, Leipsic River, Little Creek, St. Jones River, Murderkill River, Mispillion River, Cedar Creek, and Broadkill River.

Chesapeake Bay Watershed

The Chesapeake Bay, the largest estuarine system in the contiguous United States, has a watershed of almost 64,000 square miles, one sixth of the eastern seaboard, and includes parts of Maryland, Virginia, West Virginia, Pennsylvania, New York, Delaware and the District of Columbia. Delaware's 451,268 acres of Chesapeake Bay drainage, spanning the western border of the state in all three counties, is about 1% of the land area of the entire Chesapeake Bay Watershed.

Chesapeake Bay Basin

Despite its relatively small contribution to the overall area of the Chesapeake Bay Watershed, Delaware contains the headwaters of many of the rivers of the Chesapeake's eastern shore. These ecologically important and sensitive areas provide important ecosystem services and host many species that are not otherwise found in Delaware. The Delaware DNREC Division of Fish and Wildlife (DFW) manages over 20,000 acres in the watershed, including 7 wildlife areas and 10 millponds.

In 2000, the State of Delaware entered into a Memorandum of Understanding with other jurisdictions in the U.S. Environmental Protection Agency's Chesapeake Bay Program to encourage participation in the restoration of the Chesapeake Bay by improving water quality in tributary rivers and creeks. The maximum amount of pollutant that a water body can receive and still support healthy environmental conditions is called its Total Maximum Daily Load (TMDL). Watershed-based TMDLs were established by the U.S. Environmental Protection Agency (EPA). In order to meet these TMDL goals, Delaware was required to develop a Watershed Implementation Plan (WIP). Phase I WIPs were due to EPA in 2010, and Phase II WIPs in 2012. Phase III WIPs must be received by EPA in 2017. With each successive WIP, the detail of load goals and actions to achieve those goals becomes increasingly more specific.

On June 16, 2014, representatives from each of the watershed's six states signed the *Chesapeake Bay Watershed Agreement*, a new accord to create a healthy Bay by accelerating restoration and aligning federal directives with state and local goals. This agreement guides the work of the Chesapeake Bay Program and its science-based goals help partners track the health of the Chesapeake Bay.

The Nanticoke River is a major tributary of the Chesapeake Bay. Its watershed drains over 800 square miles in Maryland and Delaware and is widely recognized for its unique biological communities. In 2009, a Nanticoke River Watershed Restoration Plan was developed to improve water quality and wildlife habitat in the Nanticoke River Watershed.

Inland Bays Watershed

Delaware's three inland bays, Rehoboth Bay, Indian River Bay, and Little Assawoman Bay are separated from the Atlantic Ocean on the east by a narrow barrier dune system. Rehoboth Bay and Indian River Bay are tidally connected to the Atlantic Ocean by the Indian River Inlet. Little Assawoman Bay is connected by the Ocean City Inlet 10 miles to the south in Maryland. The inland bays are generally less than 7 feet deep, except in dredged channels, and are thus susceptible to pollution and eutrophication. The watershed of the Inland Bays includes 292 square miles of land that drains to 35 square miles of bays and tidal tributaries (Delaware Center for the Inland Bays 2011).

Inland Bays Basin

The Inland Bays Comprehensive Conservation and Management Plan (CCMP), originally published in 1995 (Delaware Inland Bays Estuary Program 1995), was recently revised and updated by a 2012 Addendum (Delaware Center for the Inland Bays 2012a). Only three major point sources of nutrient loading to the Bays remain of the 13 point sources identified in 1990. Nutrient management plans have been implemented for nearly all the farms in the Inland Bays drainage system, and thousands of acres of land have been placed under protection.

However, numerous challenges associated with development pressure and nutrient inputs to the watershed remain. In 2011, the State of the Delaware Inland Bays report was published (Delaware Center for the Inland Bays 2011), updating a previous 2004 report and outlining the condition of the bays using 31 environmental indicators.

The Inland Bays are critical spawning areas for numerous species of estuarine fishes, as well as blue crabs and other aquatic life. The Bays are an important stopover and wintering ground for at least 25 species of waterfowl.

A habitat protection action plan for the Inland Bays (Delaware Center for the Inland Bays 2012) was developed as a result of the CCMP process. This plan identifies eight Priority Areas for habitat protection and restoration within the Inland Bays Basin.

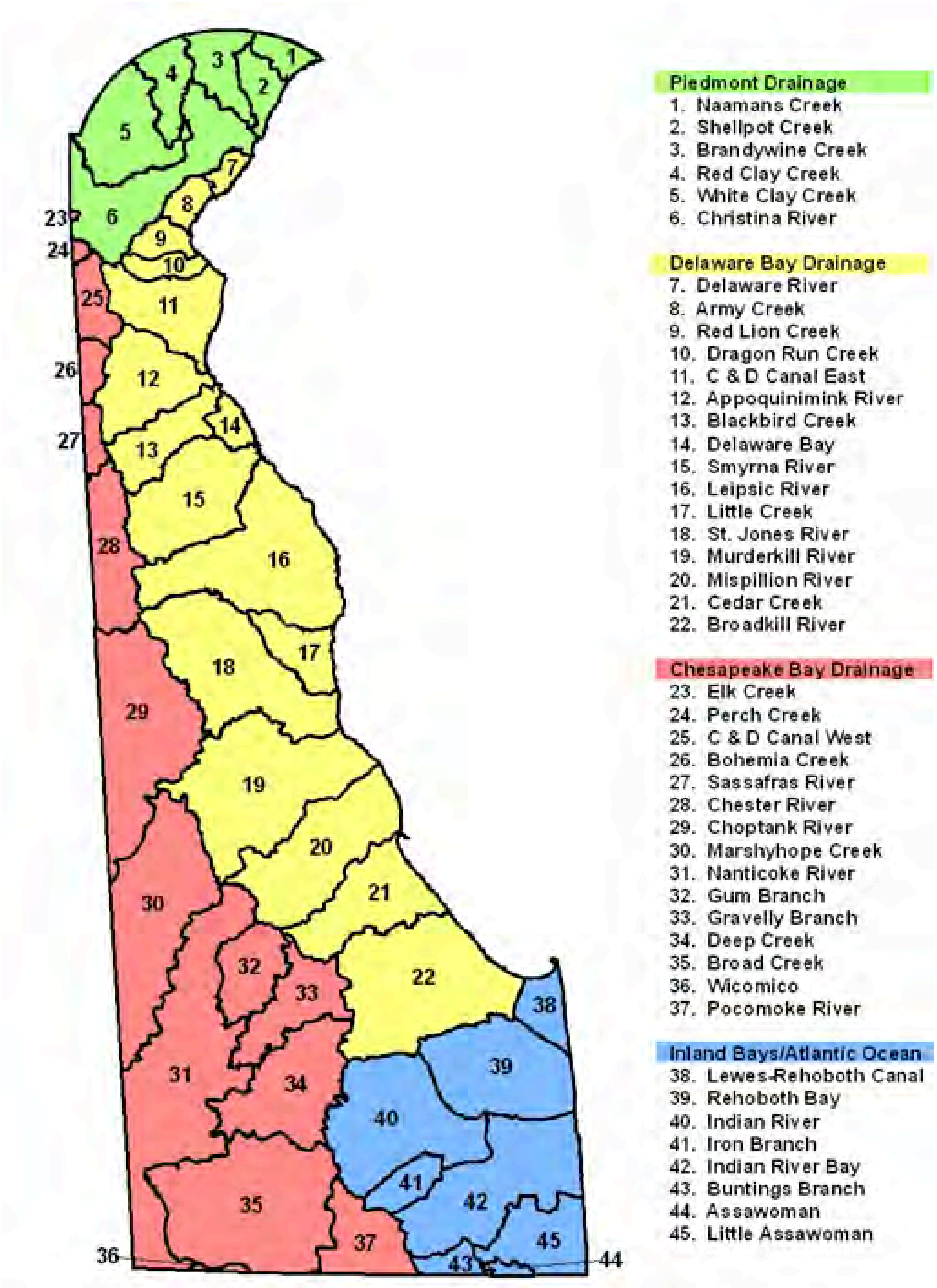


Figure 2. 2 Watersheds of Delaware

Geology and Soils

The Delaware Piedmont is composed of crystalline metamorphic and igneous rocks. These include a variety of rock types (predominately gneisses and amphibolites) that were formed by heating deep in a subduction zone, mostly in the early part of the Paleozoic Era (400-500 million years ago), and later uplifted. Also present are both extrusive igneous rocks (basalts) and intrusive igneous rocks (gabbros) that indicate the volcanic history of the region.

The Fall Zone, or Fall Line, is the dividing point between the Piedmont and Coastal Plain, and is characterized by areas of high stream gradient, exposed bedrock, islands, falls, and a mixture of metamorphic and sedimentary rock.

The Coastal Plain of Delaware is underlain by unconsolidated Quaternary sands, silts, and gravels that were laid down as beach, dune, barrier beach, saline marsh, terrace, and nearshore marine deposits.

Soils

Delaware has 80 described soil series and 195 discrete soil types (map units) (DE Natural Resources Conservation Service, NRCS). Soils of the Piedmont are generally deep, well-developed Alfisols and Ultisols of moderate to excellent fertility. Soils derived from quartzite are commonly stony and are often forested. Chrome soils from serpentinite occur locally and are low in calcium and high in magnesium, chromium, and nickel.

Coastal Plain soils are generally sandy, with a variety of different formations of varying ages that have been deposited, eroded, or blown to form their current configurations. The occurrences of each are spatially variable because of complex relationships between original thickness and extent and post-depositional erosion (Andres and Howard 2000).

Extremely sandy soils of the coastal plain are of particular importance in structuring wildlife assemblages, because these dry, infertile soils support unique plant and animal communities. In particular, the Parsonsburg Sand, Quarternary-age remnants of an ancient sand dune (Denny et al. 1979; Denny and Owens 1979), supports dry pine-oak forests and woodland, home to a number of plants and animals that are absent from other areas of the state with more mesic, fertile soils.

Physiography

EPA Ecoregions

Woods et al. (1999) described the USEPA Ecoregions of the Mid-Atlantic (Table 2.1). Delaware contains parts of three Level III EPA Ecoregions: the Northern Piedmont (64), the Middle Atlantic Coastal Plain (63), and the Southeastern Plains (65) (Figure 2.3).

Table 2. 1 Delaware's EPA Ecoregions

Level III Ecoregion	**Level IV Ecoregion**	**Approximate Acreage**
Northern Piedmont	Piedmont Uplands (64c)	60,617
Southeastern Plains	Chesapeake Rolling Coastal Plain (65n)	7,662
Middle Atlantic Coastal Plain	Delaware River Terraces and Uplands (63a)	197,398
Middle Atlantic Coastal Plain	Virginian Barrier Islands and Uplands (63d)	84,349
Middle Atlantic Coastal Plain	Delmarva Uplands (63f)	934,214

Piedmont Uplands

The Northern Piedmont in Delaware is represented by one Level IV Ecoregion, the Piedmont Uplands (64c). This ecoregion is characterized by rounded hills, low ridges, relative high relief, and narrow valleys and is underlain by metamorphic rock. The dominant historical vegetation was oak and oak-hickory forest, with a lesser extent of mixed mesophytic forest. An important ecological feature of the ecoregion is the occurrence of scattered serpentine barrens that support specialized flora and fauna (see Serpentine Barrens). The boundary of the Piedmont Uplands follows the limit of ancient metamorphic rock, distinct from the largely sedimentary rock of the surrounding ecoregions.

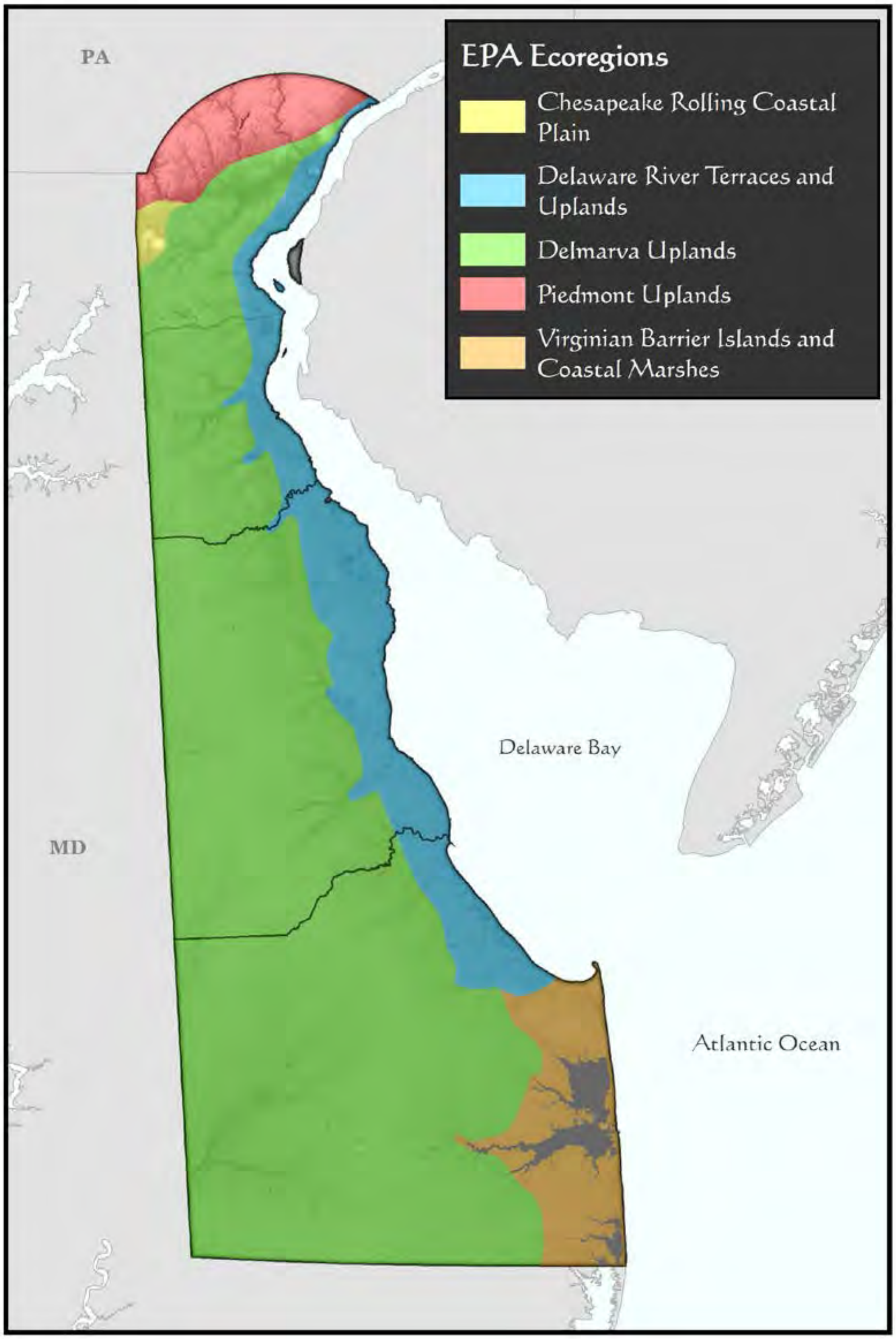


Figure 2. 3 EPA Ecoregions of Delaware

Chesapeake Rolling Coastal Plain

The Southeastern Plain Ecoregion (65) is represented in Delaware by a small area of the Chesapeake Rolling Coastal Plain (65n) Level IV Ecoregion, a hilly upland with narrow stream divides, incised streams, and well-drained loamy soils. It is hillier and better drained than the Middle Atlantic Coastal Plain (63) Ecoregion (see below), with older sedimentary rocks. Stream channels are relatively low in gradient and are often swampy-margined and sandy-bottomed. The most common soils are low-nutrient Ultisols that support oak-hickory-pine forests.

Middle Atlantic Coastal Plain

The majority of the state falls within the Middle Atlantic Coastal Plain (Ecoregion 63), which consists of three Level IV ecoregions, as detailed below.

Delaware River Terraces and Uplands

The areas adjacent to the Delaware River and Bay, the Delaware River Terraces and Uplands (63a), are narrow, marshy, nearly level to rolling lowlands dominated by tidal marshes and meandering, low gradient streams, which are often tidally influenced. Saline marsh deposits and alluvial and estuarine sand and silt are underlain by unconsolidated and easily eroded Quaternary gravels, sands, and silts.

Barrier Islands – Coastal Marshes

The Barrier Islands-Coastal Marshes Ecoregion (63d) is composed of beaches, dunes, low terraces, beach ridges, and barrier islands that are fringed by lagoons, bays, tidal salt marshes, mudflats, tidal channels, or ocean. The vegetation is mostly salt marsh, which contrasts with the natural hardwood vegetation of the Delmarva Uplands (63f). Oak-Hickory-Pine Forest occurs in better drained, higher areas. The western boundary with the Delmarva Uplands (63f) generally follows a long, often poorly defined, east-facing scarp that parallels the present shoreline at about 20 feet (6 m) above sea level. The presence of this scarp is an impediment to inland migration of tidal marshes in response to sea level rise (see Chapter 3).

Delmarva Uplands

The Delmarva Uplands (63f) Ecoregion include sandy ridges, swales, and the central ridge of the peninsula. Marshes and swamps are far less extensive than in 63a and 63d above, but do occur and include the Great Cypress Swamp of southern Delaware. Many wet, shallow elliptical depressions (Delmarva Bays) occur in this Ecoregion.

Parsonsburg Sand covers broad areas; its surface consists of sinuous, low sand ridges and broad, seasonally-wet, swales (Delcourt and Delcourt, 1986, Denny and others, 1979). Ultisols are common, supporting a natural vegetation of mostly oak-hickory pine forest. Sandy soils are nutrient poor and have a limited water holding capacity (White, 1997).

Streams and rivers are low gradient, often tidally influenced, and have wide valleys. Many have been straightened and deepened to improve drainage. Streams on the well-drained uplands have riffle sections with gravelly bottoms.

TNC Ecoregions

TNC has classified North American terrestrial ecoregions to incorporate concepts of conservation biology and ecology when developing meaningful biodiversity conservation plans (Groves et al. 2002). Characteristic species of flora and fauna and examples of characteristic natural communities have been used to develop conservation priorities for each ecoregion. According to the TNC classification, Delaware is divided into three ecoregions, the Chesapeake Bay Lowlands, the Lower New England/Northern Piedmont, and the North Atlantic Coast. TNC has drafted conservation plans for these ecoregions, describing the vegetation communities and biological resources of each.

TNC has also classified freshwater (Abell et al. 2008) and marine (Spalding et al. 2007) ecoregions. Delaware falls within the Virginian Ecoregion of the Cold Temperate Northwest Atlantic Marine Province (Spalding et al. 2007). Delaware's Chesapeake drainages are included in the Chesapeake Bay Freshwater Ecoregion and its Delaware River and Atlantic Ocean drainages fall within the Northeast US and Southeast Canada Atlantic Drainages Freshwater Ecoregion (Abell et al. 2008).

US Forest Service Ecoregional Provinces

The U.S. Forest Service (USFS) classification system places most of Delaware in the Outer Coastal Plain Mixed Forest Province, with the Piedmont in the Eastern Broadleaf Forest (Oceanic) Province (Bailey 1995).

Climate

Delaware is in a transition zone between humid subtropical climate conditions to the south and humid continental conditions to the north. The moderating effects of the Chesapeake and Delaware Bays and the state's proximity to the Atlantic Ocean lessen temperature extremes compared to nearby interior locations. Even so, the state has a continental climate, with cold winter temperatures, hot summers, and ample precipitation throughout the year (Leathers 2015).

Mean annual temperatures across the state range from 54.0 °F in northern New Castle County to 58.1 °F along the Atlantic coast of southern Delaware. Average annual precipitation is approximately 45" statewide (Leathers 2015).

The State is often affected by seasonally occurring severe weather including winter and spring nor'easters that can drop heavy snow and cause coastal flooding, autumn tropical systems with high winds, coastal flooding and heavy rainfall, and spring and summer severe thunderstorms.

Historical Trends

Observed historical data indicate that temperatures across Delaware have been increasing since 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 have also been increases in the frequency of warm temperature extremes, and decreases in the frequency of cold temperature extremes. Statewide precipitation has shown no significant changes since 1895, except for a significant upward increasing trend during the autumn season.

The Manomet Center for Conservation Sciences and the National Wildlife Federation (MCCS and NWF 2012), and NatureServe (2014) have assessed the vulnerability of northeastern fish and wildlife and their habitats to climate change and published a series of reports to help effectively plan conservation efforts at state and regional scales under a changing climate regime. Their work identifies species and habitats that may be especially vulnerable to climate change and predicts how these species and habitats will adapt under different climate scenarios. The results of these studies relevant to Delaware habitats are detailed in Chapter 3. In addition, the reports outline potential adaptation options that can be used to safeguard vulnerable habitats and species, and this information is detailed in Chapter 4.

To better understand the current and future vulnerabilities and risks of climate change, DNREC Division of Energy and Climate conducted a statewide climate change vulnerability and risk assessment (Love et al. 2013). The Delaware Climate Change Vulnerability Assessment reflects the best available climate science, climate modeling, and projections to illustrate the range of potential vulnerabilities that Delaware may face from the impacts of climate change. The Division of Energy and Climate contracted with Dr. Katharine Hayhoe to produce a report detailing downscaled climate projections for Delaware (Hayhoe et al. 2013), which will be reviewed in detail in Chapter 3.

Land Cover

Beginning in 1974, aerial photos of Delaware land cover have been digitized, mapped and interpreted. Land use change summaries are available for the periods: 1974-1984 (Mackenzie 1989), 1984-1992 (Mackenzie and McCullough 1994), 1992-1997 (Delaware Office of State Planning Coordination n.d.), 1997-2002 , and 2002-2007 (Mackenzie 2009). Land Use/Land Cover (LULC) data layers for Delaware were updated as of late 2014, but 2007-2014 land use change summary statistics were not available at the time of this writing.

A study by the American Farmland Trust found that between 1984 and 2002, 118,000 acres of agricultural lands and forests were replaced by 96,000 residential housing units (1.23 acres per house) – nearly equal to all of the acres converted in the previous 300 years. Prior to 1984, the state's 260,000 housing units consumed 125,000 acres of land (0.48 acres/house) (American Farmland Trust 2006). Over the 28-year period, almost 143,000 acres were developed into urbanized uses (an average of more than 5,000 acres per year).

Natural Disturbance Regimes in Delaware

Patterns of natural disturbance are vital in understanding the distribution of species and habitats on the landscape. Numerous birds (Hunter et al. 2001), invertebrates, and other species depend on habitats shaped and maintained by disturbance, including early successional habitats, floodplains, coastal systems, and fire-maintained systems. These periodic disturbances create habitat heterogeneity, promote species diversity, and alter plant species composition. Restoration of historic natural disturbance regimes that our native wildlife evolved with should be a high priority. Recent studies, however, suggest that restoration of plant species diversity via these disturbance regimes may not be effective without concurrent reduction in herbivore browse levels (Nuttle et al. 2013, Thomas-Van Gundy et al. 2014).

Fire

The Mean Fire Return Interval (MFRI) layer of LANDFIRE quantifies the average period between fires under the presumed historical fire regime. Using this vegetation-based fire return interval model, much of Delaware falls within a fire return interval range of 36-45 years, with large areas of coastal marsh and maritime forest and shrubland falling within a short (0-5 year) interval (SEM 2012). Data from the Mid-Atlantic region on historic fire regimes based on dendrochronological studies indicates an even shorter historical fire regime, with estimates of fire frequency in oak-dominated forests in the region ranging from 7-30 years (Abrams 2000; Lorimer 2001). Cessation of major fire began after 1900 and brought a concurrent decrease in oak recruitment (Abrams 2000).

Delaware Forest Service operates a prescribed fire program to help landowners manage their lands, a program that in 2014 conducted nine burns on 184 acres, including 95 acres at U.S. Fish and Wildlife's Prime Hook National Wildlife Refuge (Delaware Forest Service 2014). While many prescribed burns are still conducted on the Coastal Plain, fire as a grassland management tool has only recently returned to the Delaware Piedmont, with prescribed burns conducted at Brandywine Creek State Park, Delaware Nature Society's Coverdale Farm Preserve, and the private Flint Woods Preserve near Centreville.

Inland Flooding, Wind, and Ice

Windthrow and other natural disturbance events that fell trees in forested areas are important for maintaining heterogeneity at a small to medium scale in forested habitats. Since Delaware's forests are all relatively young, the rate of tree mortality due to senescence is low, and thus the role of disturbance events may be of even greater importance than in an older forest.

Inland flooding events help to create early successional habitat in dynamic riparian systems, and flooding, along with ice scour, is important in maintaining key riparian microhabitats like cobble bars and shrub thickets.

Beaver-created wetlands were an important source of disturbance on the landscape in pre-settlement times. Beaver dams created pools in low-gradient streams, generating habitat heterogeneity for fish and other aquatic organisms, at the same time creating emergent freshwater floodplain wetlands used by many species of wildlife. The beaver (*Castor canadensis*) was apparently extirpated from Delaware by the mid-1800s. It was reintroduced to the state in 1935 with the release of 1 pair in each county. Since then, additional animals have moved in from Maryland. By the mid-1980s, the beaver was beginning to come into conflict with humans, primarily because of road and field flooding and destruction of trees. In 1990, Delaware Division of Fish and Wildlife captured and relocated 28 beavers in Sussex and southern Kent Counties. A 1991 survey of beaver colonies found 126 statewide. There is an active program to trap and remove beavers from areas where they are causing conflicts. From 1997-2000, approximately 300 beaver per year were harvested statewide (DNREC 2005).

Coastal Flooding and Coastal Storms

Hurricanes, nor'easters, and other coastal storm events are important in shaping Delaware's wildlife habitats. Severe coastal weather has affected both coastal landforms and the position of the shoreline itself. In the last 10,000 years, the overall trend for the sandy coastline has been westward retreat. From the mid-1950s or mid-1960s to the early-1980s, net shoreline erosion averaged five feet (1.5 m) per year (Bloom, 1983b).

Hurricanes are more powerful than coastal storms, but the latter are more frequent in Delaware. While hurricane season generally runs from June through November, coastal storms can occur at any time of year, but are most common between fall and early spring. Storm surge, strong winds, and torrential rainfall associated with these storms can cause extensive flooding and coastal erosion.

Delaware's Flora

Delaware's plant species play a key role in supporting wildlife diversity. Delaware is home to over 2,300 plant taxa, of which about 69% are native to the state. Thirty-seven percent (37%) of our native taxa are restricted to the coastal plain, while only about 14% are restricted to the Piedmont. The remaining 49% of taxa are found in both physiographic provinces. Delaware's native flora is highly threatened by the same stressors that affect wildlife species (see Chapter 3). Table 2.2 summarizes the conservation status of the state's flora.

Table 2. 2 Conservation Status of Delaware's Flora

State Conservation Status Rank	Number of Species	% of Native Flora
S1 and S2 (rare, extant)	384	24
SH and SX (historical and extirpated)	192 (142 SH, 50 SX)	12
S3 (uncommon)	152	9
SU (status undetermined)	128	8

Globally Rare (G1,G2,G3)	33	2
Federally Listed (LE, LT, C)	9	1

The Flora of Delaware Online Database (McAvoy 2015) is a web-based reference containing basic information on the status, habitat, and distribution of plants in Delaware. The database contains a wealth of information about each species listed and is available to planners, wildlife and land managers, stewardship ecologists, restoration ecologists, research biologists, landscapers, naturalists, educators, and home gardeners.

CHAPTER 2, PART 2: HABITAT CLASSIFICATION

Species - Habitat Associations

Background

The concept of habitat in ecology includes geographic, biotic, and abiotic factors that determine the occurrence of a species at a given place and time. In its simplest form, the habitat of a species can be defined by the relative presence or absence on the landscape of resources necessary for survival and reproduction of individuals, a so-called "fitness landscape" (Mitchell 1996). This "fitness landscape" includes aggregations of resources critical to various life stages and at various seasons. Especially for species with complex life cycles, such as holometabolous insects (insects that undergo complete metamorphosis), multiple resources within multiple habitats are likely to be used by various life stages (eggs, larvae, pupae, and adults) (Dennis 2010; New 2014)

Thus, while habitat for a given species is often thought of in terms of vegetation communities and physical habitat features, the resource needs of a species often require individuals to cross boundaries between these defined units. Recent studies have shown that vegetation communities are an imperfect surrogate for species distributions (Robinson 2012) so assumptions should not be made that conservation of special natural communities will adequately conserve all SGCN. In addition, in human-altered landscapes, some species may choose lower quality habitats over higher quality habitats, with the former functioning as ecological traps (Hollander et al. 2011). In these cases, the presence of a species in a given habitat may not indicate successful reproduction or survival in that habitat.

These caveats illustrate the importance of using both coarse- and fine-scale approaches to species and habitat conservation. Conservation of land cover types at a broad scale and focused protection of vegetation associations at the narrow scale should be one of the goals of any conservation strategy, but species-specific and guild-specific approaches should also be developed. Within areas of complex adjacent habitat mosaics, species-specific research approaches such as time budget studies and stable isotope analysis can improve our understanding of the relative extent to which a species relies on a particular resource or habitat type (e.g., Brittain et al. 2012). A renewed focus on life history data for many species, especially invertebrates, is necessary in order to direct management decision-making.

Species – Habitat Associations in Delaware

A gap analysis of animal species distributions for Maryland, Delaware and New Jersey was developed by McCorkle et al. (2006). This effort developed habitat models and distribution maps for 363 animal species (206 birds, 69 mammals, 47 reptiles, and 41 amphibians). Bird habitat models and distribution maps were limited to those species that regularly nest within the project area.

The gap analysis found that habitats supporting the rare to extremely rare species that were underrepresented in GAP status 1 and 2 (protected) lands include early successional habitats, vernal pools (non-tidal, isolated, seasonally flooded wetlands) with substantial upland forest buffers, forested wetlands, and freshwater marshes, forest interior, broad riparian and floodplain forests, and beach and dune habitats. The report also found that the most significant unprotected habitats for rare species were the large concentration of coastal plain ponds (i.e., vernal pools) and surrounding hardwood forests in the Blackbird-Millington Corridor of Delaware and Maryland (McCorkle et al. 2006).

For the 2015 DEWAP revision, species-habitat associations included in the previous DEWAP were reassessed, and reassigned by taxonomic experts to the 2015 habitat types described below. Habitat associations were denoted as either Primary or Supplemental, depending on the degree of reliance of a species on the habitat at any life stage. Species-Habitat Associations for SGCN are found in Appendix 2.C.

Habitat Analysis for the 2015 DEWAP Revision

As part of the federal requirement to address conservation of the broad array of wildlife in Delaware, Key Habitats that support SGCN were identified in Delaware's 2007 Wildlife Action Plan. Beginning in March 2014, the habitats were re-evaluated, resulting in a new wildlife habitat classification scheme for the 2015 Wildlife Action Plan. This classification includes all terrestrial and aquatic habitats. See Appendix 2.A.

Habitat Classification

Since 2007, there has been a significant increase in the amount of habitat information available for use in the wildlife action planning process (Table 2.3). The original habitat classification system from the 2006 DEWAP was revised to better match several recent habitat classification standards, in accordance with guidance from the Association of Fish and Wildlife Agencies (AFWA). A crosswalk from 2007 to 2015 habitats is provided in Appendix 2.B.

Terrestrial habitats and palustrine and estuarine wetland habitats were aligned as closely as possible with NatureServe Ecological Systems and the Northeast Terrestrial Wildlife Habitat Classification (Gawler 2008). Ecological systems are recurring groups of terrestrial biological communities that are found in similar physical environments and are influenced by similar dynamic ecological processes, such as fire or flooding. They are based on biogeographic region, landscape scale, dominant cover type, and disturbance regime. NatureServe has described and mapped over 800 distinct ecological systems for the U.S. (Comer et al. 2010).

The Northeast Terrestrial Habitat Classification System (NETWHCS) (Gawler 2008) is a standardized classification of wildlife habitats based largely upon ecological systems, with the addition of classifications for anthropogenic systems. The NETWHCS aligns with a GIS map of ecological systems based on 70,000 inventory points contributed by the state Natural Heritage programs (NHPs) and the U.S. Department of Agriculture (USDA)-USFS Forest Inventory and Analysis (FIA) program. In addition, the *Northeast Habitat Guide: A Companion to the Terrestrial and Aquatic Maps* was published by TNC (Anderson et al. 2013b). It includes a profile of each habitat type in the Northeast, as well as distribution maps, state acreage figures, identification of species of conservation concern, and assessment of overall conditions in the region. For Delaware, the Anderson et al. (2013a) acreage and species associations were considered when appropriate, though state-based data were often found to be more appropriate at this scale.

Stream and river habitats were aligned with the Northeast Aquatic Habitat Classification System (Olivero and Anderson 2008) and marine and estuarine aquatic habitats were aligned with the Federal Geographic Data Committee (FGDC) Coastal and Marine Ecological Classification Standard (CMECS) and the Atlantic Coastal Fish Habitat Partnership (ACFHP) habitats. In addition, the development team worked closely with Maryland Department of Natural Resources (DNR) to maintain as much consistency as possible for habitats on the Delmarva Peninsula.

Table 2. 3 Classification Standards Used to Generate DEWAP Habitat Classification System

Habitat Classification Source	Date of Last Revision
Guide to Delaware Vegetation Communities (Coxe 2014)	Fall 2014
FGDC Coastal and Marine Ecological Classification Standard (CMECS)	June 2012
Atlantic Coastal Fish Habitat Partnership Conservation Strategic Plan	2012
Northeastern Terrestrial Wildlife Habitat Classification System (NETWHCS) (Gawler 2008)	2008
Northeast Aquatic Habitat Classification System (NEAHCS) (Olivero & Anderson 2008)	Sep 2008
Northeast Odonate Conservation Status Assessment (White et al 2014)	2014
Maryland Key Wildlife Habitats Draft (Harrison 2015)	2015

For the 2015 revision, species to habitat associations are defined in several different and complementary ways, using multiple sets of attributes (detailed in Table 2.4). Rather than consider each of the very large number of possible combinations of these attributes a discrete habitat type, the data model links species to each of these attributes separately, providing a flexible and powerful way to query species and habitat associations in the DEWAP database. This makes it easy to generate a list of the species associated with any combination of habitat attributes. For example, the database could return all the species associated with the Coastal Plain province, Maritime Forest habitat, early successional (seedling/sapling) seral stage, and the presence of exposed upland sands. It is hoped that this flexibility in querying species by habitat will prove even more useful to plan users than previous approaches.

Table 2. 4 Habitat Attributes Used to Classify Wildlife Habitat for the 2015 DE Wildlife Action Plan

Terrestrial/Wetland	Ecological System/Northeast Terrestrial Habitat Classification Type
	Seral Stage
	Microhabitat Features
	Structural Dependencies
	Physiographic Province
Riverine Aquatic	Gradient
	River/Stream Size
	Temperature
	pH
	Tidal/Non-tidal
Marine/Estuarine	CMECS Aquatic System
	Tidal Zone
	Benthic Substrate Type
	Artificial Structure
	Biotic Structure/Association
	Salinity Range

As it is not feasible to link threats and actions directly to each of these fine-level habitat attributes, we chose to link them to a simplified list of habitats, consisting primarily of habitats at the ecological system or similar level. Threats and actions are also linked to more detailed combinations of habitat attributes indirectly via species.

Habitat Condition and Extent

Numerous resources helpful to the assessment of habitat condition and extent in Delaware have been developed since the first edition of the DEWAP was completed in 2006 (Table 2.5). The entire state is covered by a GIS layer of Delaware Vegetation Communities based on the Coxe (2014) community types, allowing assessment of habitat extent by vegetation type. This layer includes classifications of vegetation community cover for all but approximately 76,000 acres (<5 %) that remain unclassified. Several broad habitat classes have relatively recent condition assessment information, including forests (Delaware Forest Service 2010) and wetlands (Tiner et al 2011).

Through an integrated effort by the Delaware Coastal Programs, the University of Delaware, and Delaware State University, a benthic and sub-bottom imaging project to identify and map the benthic habitat and sub-bottom sediments of Delaware Bay and River was initiated. This effort has resulted in many major milestones, which include: mapping over 350 square miles, identifying the spatial extent and relative density of the oyster and *Corbicula* beds, and locating key habitats for several species. In addition, the Delaware Estuary Benthic Inventory (DEBI), a cooperative project led by the Partnership for the Delaware Estuary, resulted in a significant body of information on the condition and extent of benthic habitats in the Estuary (Kreeger et al. 2010).

The Northeast Habitat Guides and GIS map products developed by TNC (Anderson et al. 2013a,b) address condition and extent of ecological systems and aquatic habitats in the northeast region.

Perhaps most significantly, a major landscape mapping and conservation prioritization effort, the Delaware Ecological Network (DEN) was developed by The Conservation Fund in 2007 (Weber 2007) and was recently updated (Weber 2013).

Table 2. 5 A Sampling of Resources for Assessing Extent and Condition of Delaware Habitats

Data Source	Date of Last Revision
Delaware Ecological Network (DEN) GIS Product	2013
TNC Northeast Habitat Guides (Anderson et al 2013a, 2013b)	2013
Delaware State Vegetation Mapping Project	2014
Delaware Bay Benthic Habitat Mapping Project	Ongoing
Delaware Estuary Benthic Inventory	2010
Delaware Forest Resource Assessment	2010
Delaware Wetlands: Status and Changes from 1992 to 2007	2011

Mapping Habitats

Habitats were mapped using a variety of available sources, primarily the vegetation community GIS data of Coxe (2014), the Northeast Aquatic Habitat data of Olivero and Anderson (2008) and Anderson et al. (2013b), state-level wetlands data, and LULC data, as well as the Northeast Terrestrial Habitat Map for some habitats that were not well-represented by state-level data.

Many habitat types are not well-represented currently by available spatial data, or the spatial data do not closely match habitat types as defined here. For these habitats, "Unavailable" appears for the Estimated Extent and the action to provide improved spatial data and extent estimates for those habitats is hereby incorporated into the DEWAP in Chapter 4.

Priority Wildlife Habitats

Nearly all of Delaware's habitats are used to some extent by at least one SGCN. For the 2015 Revision of the DEWAP, terrestrial and wetland wildlife habitats are spatially prioritized using the Delaware Ecological Network (DEN). The DEN, based on principles of landscape ecology and conservation biology, provides a consistent framework to help identify and prioritize areas for natural resource protection.

The DEN is composed of the following elements: (1) core areas, which contain relatively intact natural ecosystems, and provide high-quality habitat for native plants and animals; (2) existing corridors, which link core areas together, allowing wildlife movement and seed and pollen transfer between them; and (3) potential corridors (Weber 2007, 2013) (Figure 2.4). The DEN is built using several important layers, notably a Habitats of Conservation Concern (HCC) layer (updated in 2012) that incorporates HCCs described in the 2006 DEWAP, and a rare species element occurrence layer (updated in 2013) from Delaware's Biotics database. DEN core areas total 346,195 acres, or 27% of the state (not including offshore water). Existing corridors total 28,664 acres (2.2% of the state), and potential corridors total 43,985 acres (3.4% of the state). DEN core areas and corridors contained 85% of rare species locations and 99.6% of habitats of conservation concern.

When used in a GIS environment, in conjunction with habitat mapping, the DEN provides a powerful tool to prioritize examples of habitats on the landscape. A habitat type may be mapped, and that map, when overlaid with the DEN layer, will indicate prioritized examples of that habitat type based upon their inclusion in the DEN and their DEN score (Figure 2.5 and Table 2.6). For these reasons, the DEN is used by the 2015 DEWAP to model and map Priority Wildlife Habitat (see Figure 2.6).

Some habitat types are not well captured by the DEN model. These include early successional habitats, estuarine and marine aquatic habitats, and various microhabitat features described in this chapter. High quality examples of these habitat types should be considered priority habitats in addition to the DEN modeled terrestrial and wetland priority habitats.

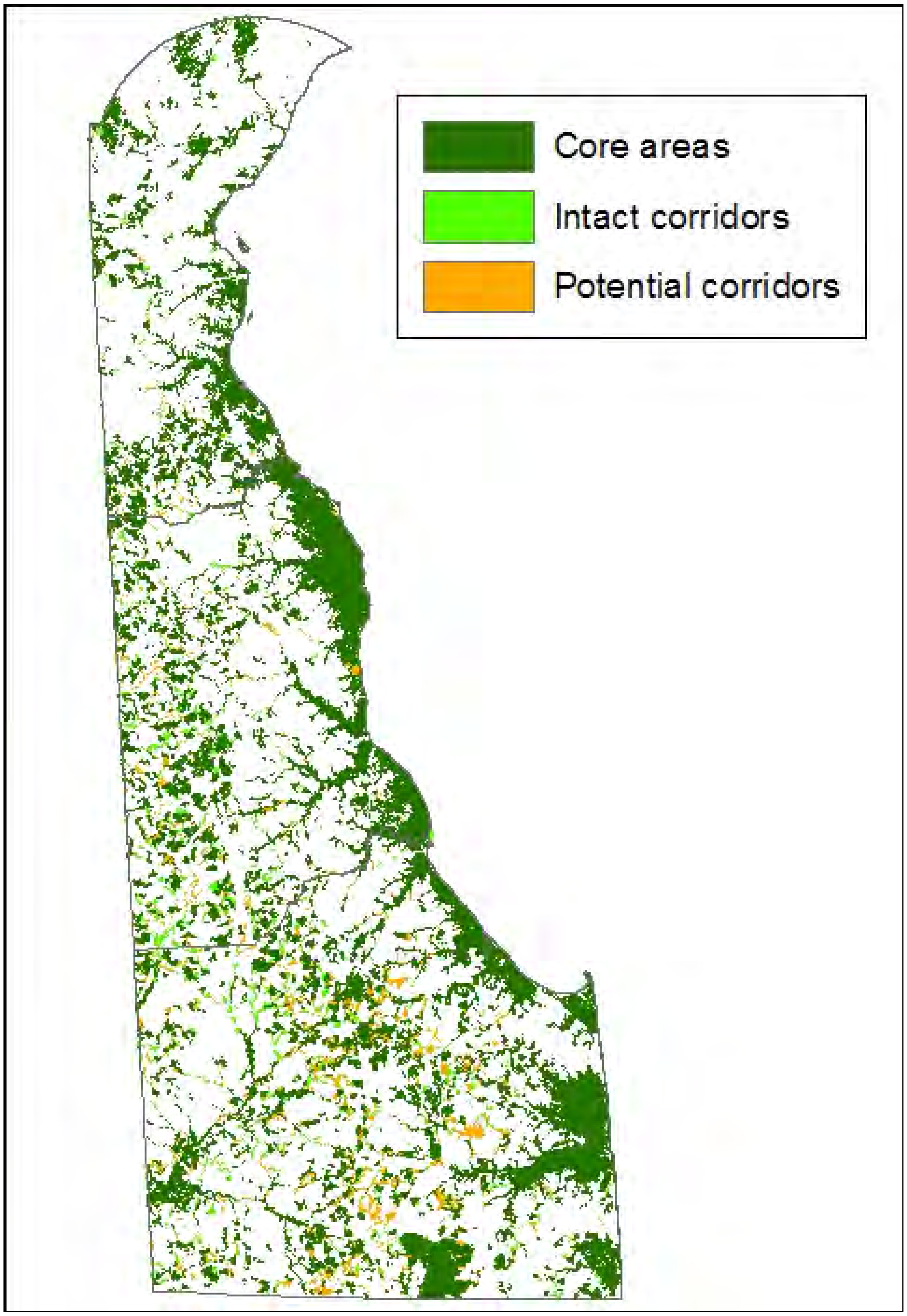


Figure 2. 4 Core areas and corridors in the Delaware Ecological Network

DEN core areas were ranked by ecoregion according to their relative contribution to biodiversity, habitat availability and condition, and landscape context. Variables used in the ranking are shown in Table 2.6. For each variable, the value for each core area was divided by the maximum value for that ecoregion, resulting in a score between 0 and 1. Variables were weighted equally, summed for each core area, and divided by the ecoregion's maximum sum to recalibrate to a 0 to 1 score. Importantly, the DEN does not currently incorporate threat mapping, including projected sea level rise or climate change resilience, in identifying or prioritizing core areas or corridors.

Table 2. 6 Variables used to rank Delaware Ecological Network (DEN) core areas

FIELD NAME	DESCRIPTION
SUM_EOR_WT	Weighted sum of rare species and community occurrence scores
HCC_AC	Area of Habitats of Conservation Concern
MATINFORAC	Area of mature interior natural forest
UNDISWETAC	Area of potentially mature, undisturbed wetlands
CORESTRMKM	Length of core streams
MAX_ACCUM	Connectivity (maximum value of any given pathway)
PROXIMITY	Measurement of proximity to other core areas (the closer to 1, the less isolated)

As of 2012, public agencies and private conservation groups had protected 44% of the DEN core areas and 42% of the network as a whole (Table 2.7). In this case, "protected" is defined as fee simple or easement restrictions on development and does not include regulatory or zoning mechanisms. Existing corridors were the least protected (22%). Only 16% of land outside the network was protected.

Table 2. 7 Protected and unprotected core areas and corridors in the DEN.

	All land and water (ac)	DEN core areas (ac)	Existing corridors (ac)	Potential corridors (ac)
Protected	**319,069**	**153,983**	**6,155**	**16,443**
Unprotected	**966,731**	**192,204**	**22,446**	**27,541**
Total land	**1,285,800**	**346,187**	**28,601**	**43,984**

	All DE (%)	DEN core areas (%)	Existing corridors (%)	Potential corridors (%)
Protected	**25%**	**44%**	**22%**	**37%**
Unprotected	**75%**	**56%**	**78%**	**63%**

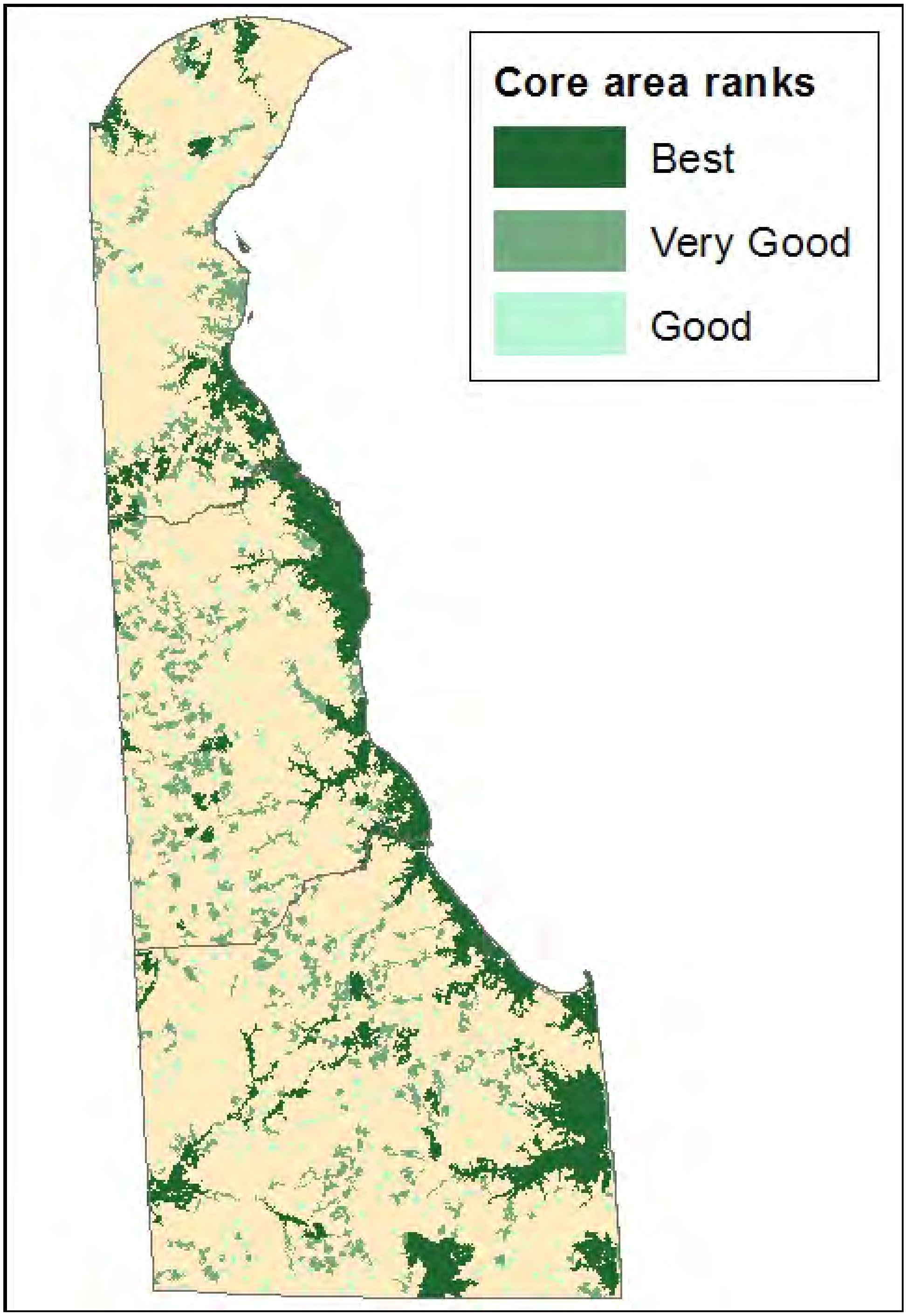


Figure 2. 5 DEN core area composite ecological ranks (in three groups by natural breaks).

The 2015 DEWAP therefore presents Priority Wildlife Habitat using the DEN model and factors described above (Figure 2.5).

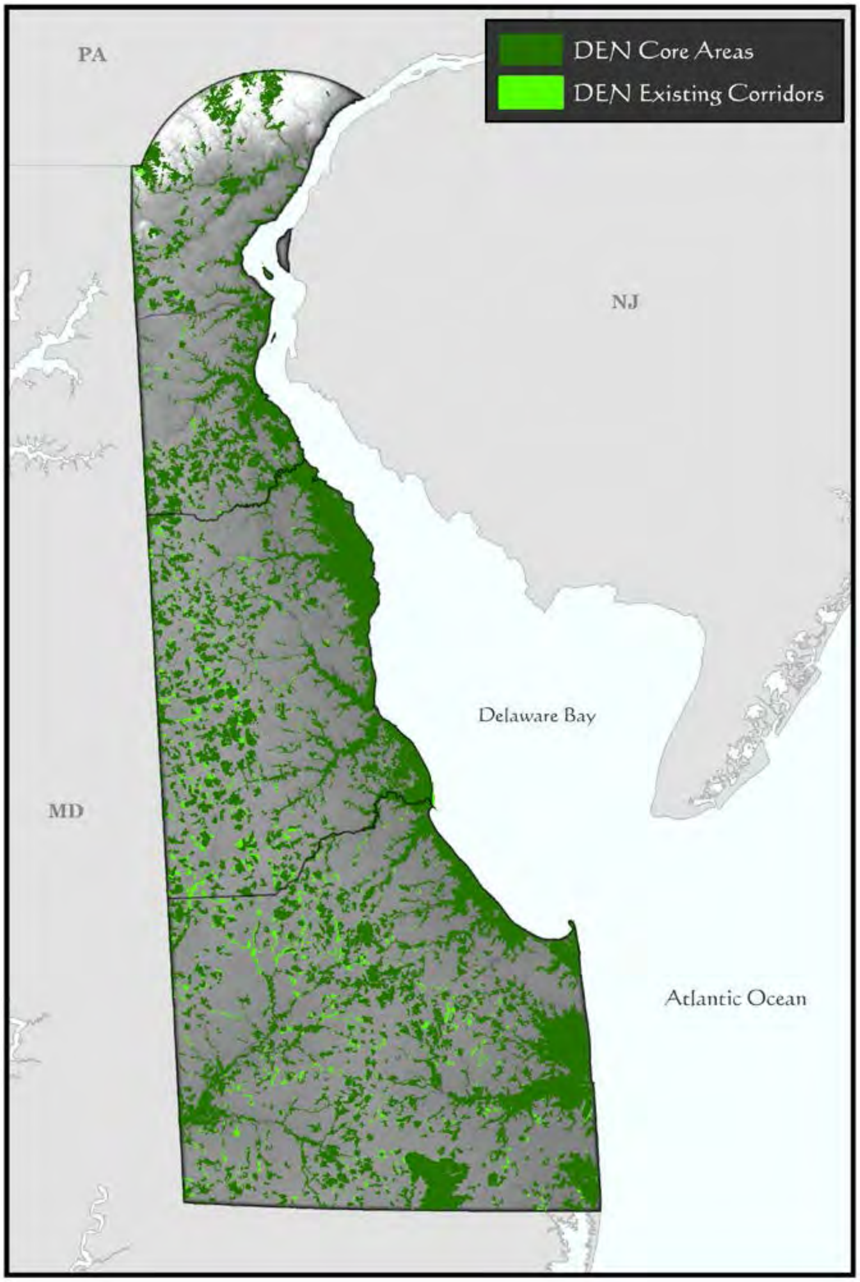


Figure 2. 6 2015 DEWAP DEN modeled Priority Wildlife Habitat

CHAPTER 2, PART 3: HABITAT DESCRIPTIONS, CONDITION, AND EXTENT

Natural Upland Habitats

Forest

Delaware contains approximately 1.25 million land acres, of which approximately 371,000 are forested. The definition of forest used to determine forest acreage includes traditional, non-urban areas with forest cover. It does not include forested areas in urban and suburban settings or very narrow "strips" of tree cover such as hedgerows in agricultural fields (Delaware Forest Service 2010). Approximately 78% of Delaware's timberlands are privately owned (Oswalt et al. 2014).

Forest Extent

Delaware was mostly forested at the time of European settlement, but has since lost over half of its forests. Historically, this loss stemmed from conversion to agriculture, but is now mostly the result of residential and commercial development and associated infrastructure. Forest loss stabilized around 1900 and Delaware's forestland area actually increased in the early 20th century. However, recent development has again resulted in a loss of forestland and forest acreage is now at its lowest point since 1907 (Table 2.8, Figure 2.7).

Table 2. 8 Forest Area in Delaware. Sources: Lister and Pugh (2014), Oswalt (2014), Delaware Forest Service (2010)

Year	Acres of Forest (x 1,000)
1907	350
1938	423
1953	454
1963	392
1977	392
1987	398
1997	389
2007	383
2009	371
2013	362

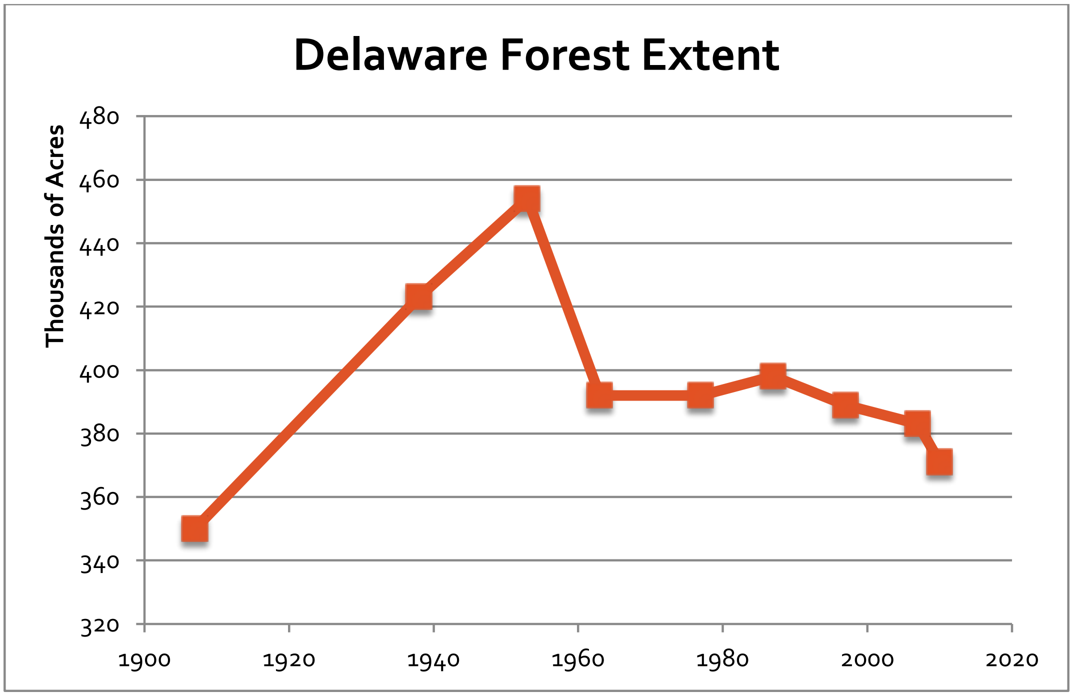


Figure 2. 7 Changes in Forest Acreage in Delaware since 1907. Sources: Lister and Pugh (2014), Oswalt (2014), Delaware Forest Service (2010)

Protected Forestland

In total, approximately 100,000 acres, or over one-quarter of Delaware's forests, are protected from development. These lands include government-owned and NGO tracts, as well as areas protected by permanent conservation easements, including over 22,000 acres of forestland protected through easements purchased by the Delaware Aglands Preservation Program (Delaware Forest Service 2010). Delaware's forested habitats are critical for migrant landbirds. In a radar study of migratory bird stopover habitat in Delaware, LaPuma et al. (2012) found that 35% of high-use stopover area was forested and 43% was woody wetland.

The Great Cypress Swamp, a large forested wetland complex spanning the border of Sussex County, Delaware and Worcester County Maryland once covered nearly 50,000 acres with forests dominated by Atlantic white cedar and bald cypress. Since the early 1800s, however, logging, ditching, draining, drought, and fire have reduced the swamp to a quarter of its pre-colonial size, and have resulted in major shifts in the dominant vegetation comprising the forests. Despite drastic changes in the swamp over the last 200 years, it is currently one of the largest contiguous tracts of forest remaining on the Delmarva Peninsula (Bennett et al. 1999).

Delaware Forest Service manages three state forests totaling over 19,000 acres: Blackbird State Forest (5,600 acres) near Smyrna, Taber State Forest (1,242 acres) near Harrington, and Redden State Forest (12,340 acres) near Georgetown.

Forest Isolation

Delaware's forested habitats are highly fragmented. Mapping of tree cover in the state completed in 2004 by the Division of Parks and Recreation delineated about 4,150 separate wooded patches larger than 10 acres (DNREC unpublished data). The median size among those patches is only 34 acres, and just 6% are larger than 250 acres. An examination of patch "thickness," which accounts for size and shape, revealed that only a few (<0.1%) patches had sufficient interior habitat to sustain area-sensitive forest species. Additional analysis indicates that the patches are highly isolated from each other, with less than 10% meeting the isolation thresholds for hooded warbler, American redstart, red-shouldered hawk, and brown creeper. Finally, calculation of perimeter/area ratio for the forest blocks highlights their very irregular shapes. Almost 90% have a ratio greater than that of a 10:1 rectangle, a configuration that produces major edge effects.

Weber (2007) used forest area of 247 ac (100 ha), in combination with other features, as a minimum threshold for "core forest." Core forest comprised 45% of total forest area, and 72% of forest-dependent rare species fell within core forest (Weber 2013). DEWAP 2006 used 250 acres as the minimum size for the "forest blocks" considered Key Habitats in the plan.

McCorkle et al. (2006), following the method of Robbins et al. (1989), mapped degree of forest isolation, using the metric of percent forest cover within 2 km of a grid cell to determine relative forest patch isolation.

Forest Condition

Field surveys of nearly 100 Coastal Plain forest blocks found about half of them to be in "Good" or "Very Good" condition, but this rating was based on vegetative characteristics, not on spatial attributes or wildlife habitat (McAvoy et al. 2006).

In Delaware and throughout the region fire suppression has led to "mesophication" of forest, a shift from fire-adapted, shade-intolerant species to fire-sensitive, shade-tolerant species (Nowacki and Abrams 2008).

In addition, the gypsy moth, which was first detected in Delaware in 1979, severely impacted oak forests throughout the state. Many of these forests now lack sufficient canopy tree regeneration potential or have experienced mesophication as a result of changes in species composition from oak to maple and gum (Delaware Forest Service 2010).

Fire suppression, mesophication, invasive plant species, and white-tailed deer overbrowsing have severely reduced the ability of northeastern forests to regenerate. As of 1999, stocking, a measure of the number and size of trees on each acre of forest, was considered medium or higher on only about half of the forestland in Delaware (Delaware Forest Service 2010, Figure 2.8). In nearby Pennsylvania, McWilliams et al. (1995) found that even using the least stringent stocking criterion (a low density of stems of any tree species) only 40% of sampled forest plots were adequately stocked to ensure forest regeneration.

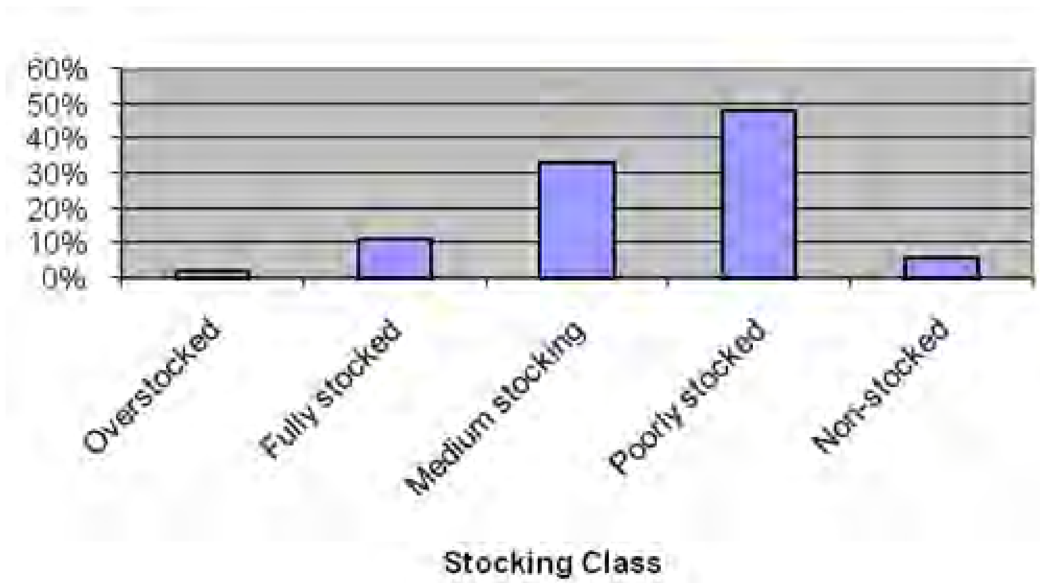


Figure 2. 8 Stocking classes in Delaware Forests, 1999. (Delaware Forest Service)

Natural Forest Types in Delaware:

Delaware Forest Service tracks forest types that are based on inventories by the U.S. Forest Service through its FIA program. More than half of the forested area in Delaware currently consists of an oak-hickory complex (Figure 2.9). Pine and oak-pine types comprise approximately one fourth of the total area. Minor hardwood components (gum, maple, etc.) occupy the remaining 15 percent of the forested acreage.

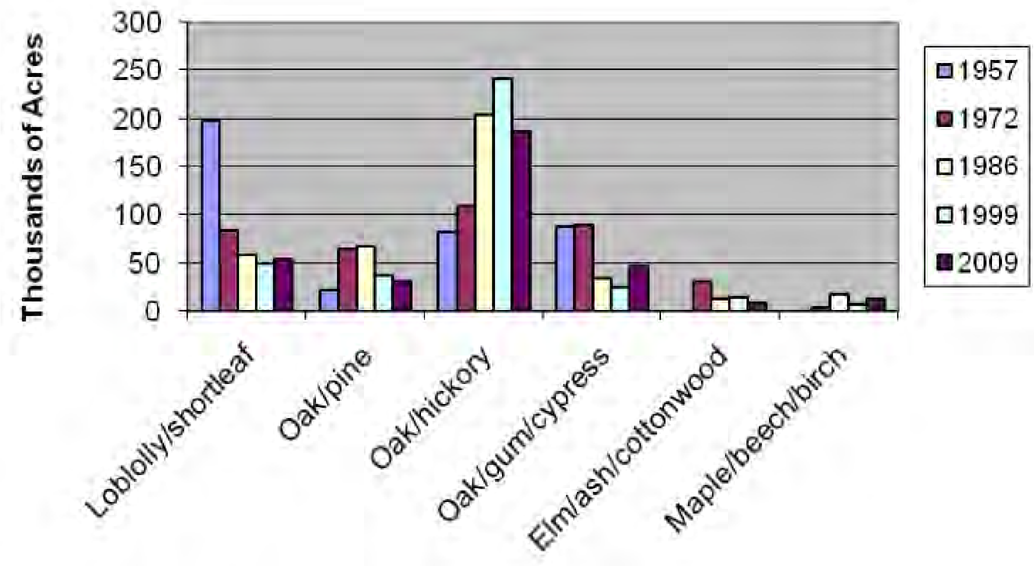


Figure 2. 9 Forest Species Composition of Delaware Forests, 1957-2009. Source: U.S. Forest Service Forest Inventory and Analysis.

While the total area of forestland has remained relatively stable over the last 50 years, significant changes have occurred within Delaware's forests. Notably, loblolly pine has steadily decreased in acreage, from nearly 200,000 acres in the 1957 FIA inventory to only 54,000 acres in 2009. Much of this decline occurred between 1957 and 1972 when significant areas of woodland were cleared for agriculture and before Delaware's Seed Tree Law. The decline of loblolly pine is due, at least in part, to trends in growth and removals. Since 1959, removals of softwood growing stock have consistently exceeded growth, while hardwood growth exceeds removal of hardwood growing stock. In many cases, natural regeneration by hardwoods such as oaks and hickories after a loblolly pine harvest results in a hardwood stand replacing a former pine stand. As a result, since 1959, the oak-hickory type has more than doubled from 80,000 to 191,000 acres (Delaware Forest Service 2010).

Tree species composition in forest habitats is important to wildlife, often in ways that have been recognized only recently. For example, insectivorous birds are known to forage more heavily on particular tree species that support favored prey invertebrates. Newell et al. (2014) found that cerulean warblers in the Midwest forage preferentially in summer on hickories because these trees support a larger volume of an important caterpillar genus that is preferred prey during the breeding season. Wood et al. (2012) found that spring migrants preferred to forage (and were more successful) on shade intolerant and moderately shade-tolerant tree species (oaks, elms, aspens, and birches) than on shade-tolerant maples and basswoods. In midwestern floodplains, the tree species most preferred by foraging birds (hickories and silver maple) were also relatively uncommon (Gabbe et al. 2002). These studies suggest that changes in forest tree species composition related to deer browse, fire suppression, timber harvest, the absence of soil mycorrhiza (due to agricultural tilling), climate change, and other factors are likely to have major effects on forest-dwelling wildlife.

Forest Seral Stage

The U.S. Forest Service FIA program is one of the most complete and comprehensive sources of forest habitat data available for the U.S. The FIA uses standard diameter thresholds to define tree size. These range from seedling/sapling (<5 inches diameter at breast height [dbh]) to poletimber (5-8.9 inches dbh for softwoods, 5-10.9 inches dbh for hardwoods) to sawtimber (>9 inches dbh for softwoods, >11 inches dbh for hardwoods). These stand size classes correspond to seral stages in forest regeneration, and have often been used to define habitat relationships for wildlife species (e.g., Hamel 1992). Areas that do not meet a minimum threshold for number of tree stems per unit area are classified as "nonstocked" and typically represent herbaceous or shrub-dominated communities.

In Delaware, sawtimber stands accounted for the majority of the forested acreage in the state as of 2009. Since 1972, as average tree diameter has increased, more stands have matured into the sawtimber size class with a corresponding decrease in the acreage of young forest (Figure 2.10).

Delaware Forest Service lands are managed to provide a mosaic of forest age classes and tree diameter distributions, with a typical "rotation age" of about 50 years or more (Delaware Forest Service 2010), providing relatively mature forest for many forest-dependent species, but not for those species dependent on senescent and very old trees and abundant coarse woody debris.

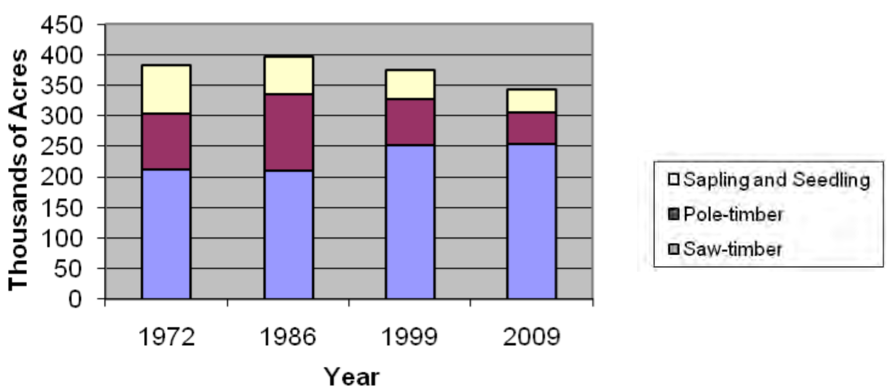


Figure 2. 10 Forest Stand Size Classes in Delaware, 1972-2009. Source: Delaware Forest Service (Data from U.S. Forest Service Forest Inventory and Analysis U.S.F.S. Resource Bulletins NE-109 & NE-151.)

Young Forest (Seedling/Sapling)

Young, post-disturbance forest can be distinguished from other early successional habitats by rapid recruitment of regenerating canopy species rather than a shift in species dominance to ruderal or "pioneer" plant species. For the purposes of the DEWAP, it is practical to consider these young forest stands as a type of early successional habitat (see Early Successional Habitats). With respect to the identification of threats and actions, young forest communities may warrant a distinction from other types of early successional habitat such as roadsides, utility ROWs, old fields, etc., as they differ from these in their conservation status and management needs. Delaware's young forest habitats have declined dramatically in acreage since 1972 (see Figure 2.9 above). Maintaining these habitats within a matrix of mature forest is important for numerous species, including even many forest interior birds that utilize young forest patches for foraging during the post-breeding period (Anders et al. 1998, Marshall et al. 2003; Stoleson 2013).

Table 2.9 shows that total acreage and average size of clearcuts has declined since the late 1990s. Smaller clearcuts may be more beneficial for some species, but research has shown increases in abundance and species richness of early successional birds in clearcuts up to 20 ha (50 acres) (Rudnicky and Hunter 1993). Further research on the effects of clearcut size on SGCN use and abundance is warranted due the largely fragmented nature of forest habitat in Delaware.

Table 2. 9 Delaware (state-wide) Timber Harvest Summary Clearcuts and Selection (1997–2012).

(Compiled by the Delaware Forest Service 2013)

Sum and Averages of Clearcut and Selection Harvests									
	Total		Type				Averages		
Year	Total Clearcut And Selection Permits	Total Clearcut and Selection Acres	Clearcut Permits	Clearcut Acres	Selection Permits	Selection Acres	Avg. Size of Clearcut + Selection Harvests	Avg. Size of Clearcut Harvests	Avg. Size of Selection Harvests
1997	126	4,526	83	3,553	43	973	36	43	23
1998	110	4,434	56	2,870	54	1,564	40	51	29
1999	96	2,999	54	1,904	42	1,095	31	35	26
2000	132	5,418	81	3,888	51	1,530	41	48	30
2001	109	4,645	62	2,344	47	2,301	43	38	49

2002	133	4,097	74	2,609	59	1,488	31	35	25
2003	135	4,636	87	3,208	48	1,428	34	37	30
2004	108	3,634	59	2,181	49	1,453	34	37	30
2005	120	3,655	74	2,446	46	1,209	30	33	26
2006	120	3,352	73	1,979	47	1,373	28	27	29
2007	114	2,944	58	1,690	56	1,254	26	29	22
2008	99	2,689	41	1,232	58	1,457	27	30	25
2009	85	2,129	40	1,211	45	918	25	30	20
2010	83	3,295	47	2,323	36	972	40	49	27
2011	88	2,298	39	876	49	1,422	26	22	29
2012	84	2,815	43	1,259	41	1,556	34	29	38

Old Growth Forest

Old growth forest represents an important habitat for wildlife, especially saproxylic invertebrates (species dependent on dead or decaying wood). Other taxa associated with old growth forest, such as tree-roosting bats, are limited primarily by roost availability, and large trees and snags provide this critical resource (Duchamp et al. 2007).

Delaware has little, if any, true old-growth forest. Some older second growth areas do exist, and these, and even younger forests might be managed for old-growth characteristics (Bauhus et al. 2009) in the future. Recent studies indicate that establishment of permanently protected and unharvested reserves (rather than long-rotation forestry) is necessary to ensure development of old-growth attributes important to species that specialize on these habitats (Bouget et al. 2014).

Upland Forest Habitat Types

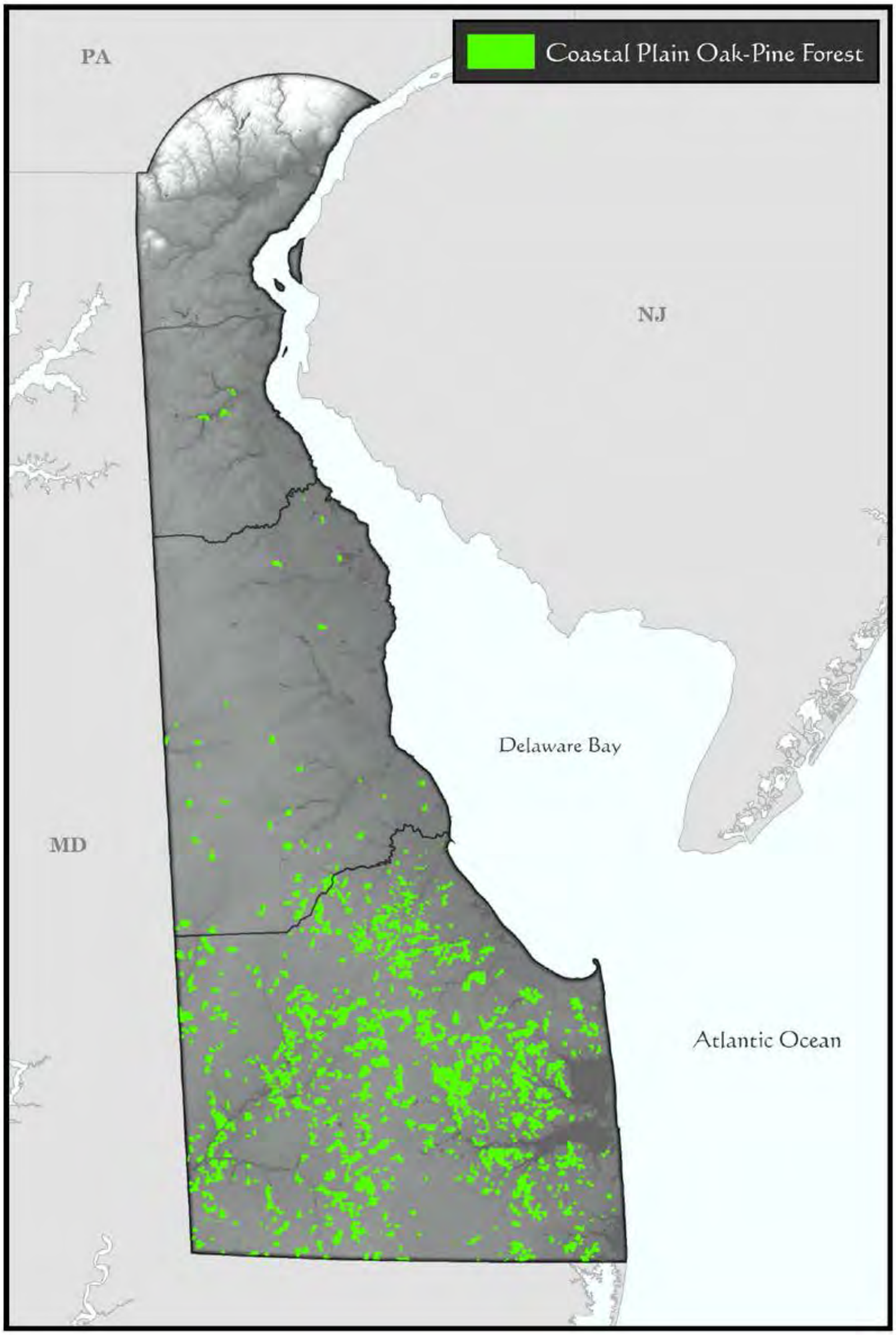
The following section describes the natural upland forested habitat types found in Delaware. With 1.0 meter or 1.5 meters of sea level rise 4% or 6% of upland forests statewide respectively would be inundated, with the highest percentage of loss being in Kent County, but the highest number of acres lost in Sussex County (Love et al. 2012).

Coastal Plain Oak-Pine Forest

These dry hardwood forests (Figure 2.11) are found on acidic, sandy soils and are largely dominated by oaks, sometimes with pine as a codominant. Typical canopy species include white oak, southern red oak, water oak, and chestnut oak. Other canopy species may include black oak, scarlet oak, sassafras, and black gum. Red maple, sweet gum, Virginia pine, and loblolly pine are also frequent in the canopy and may be locally abundant, but they usually indicate past disturbance and fire suppression. Hickories are typically a component of the understory as are dense shrub colonies of heaths such as huckleberries and blueberries. The herbaceous layer is generally not well-developed and is usually sparse and patchy throughout the forest floor. For a complete list of SGCN using this habitat, see Appendix 2.C.

Ecological System: *Northern Atlantic Coastal Plain Hardwood Forest (CES203.475) (in part)*
Estimated Extent: 37,915 acres (DNREC DFW 2015) **Habitat of Conservation Concern**

Figure 2. 11 Coastal Plain Oak-Pine Forest at Prime Hook NWR. Photo: Matthew J. Sarver



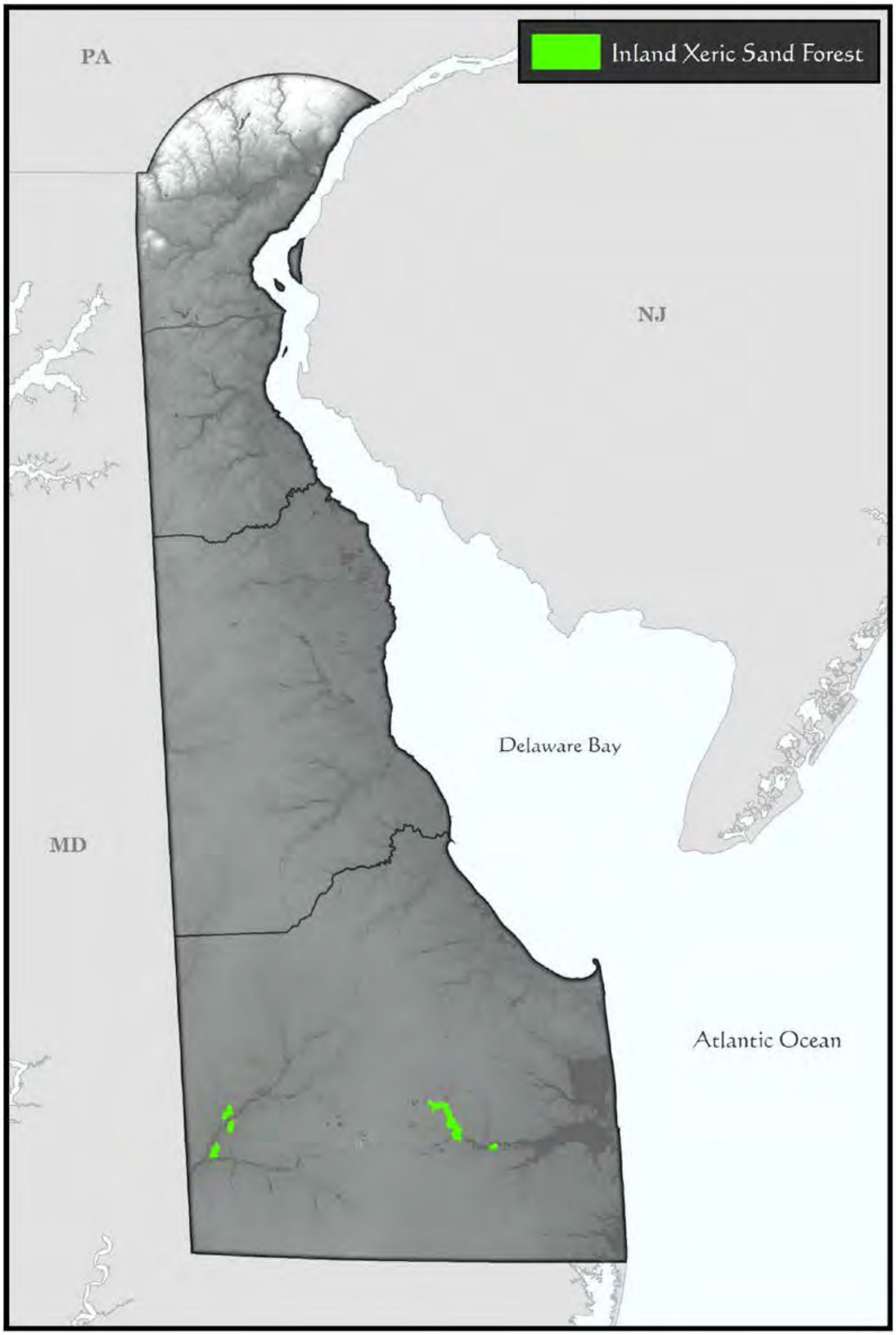
Map 2. 1 Coastal Plain Oak-Pine Forest

Inland Xeric Sand Forest

Extremely dry forests and woodlands dominated by a mix of oaks, Virginia, shortleaf, and loblolly pine, and sand hickory (Figure 2.12). In Delaware, inland sand ridges are found primarily in southwestern Sussex County in the Nanticoke watershed, and are associated with Parsonsburg Sand soils. Similar forests not located on ancient sand ridges also develop on sands of the Fort Mott-Henlopen complex. Many invertebrate SGCN are associated with this forest type, including rare invertebrates, especially wasps, bees, tiger beetles and other burrowing species associated with exposed upland sands. Fire suppression and subsequent canopy closure is an important threat to this habitat type.

Ecological System: *Northern Atlantic Coastal Plain Hardwood Forest (CES203.475) (in part)*
Estimated Extent: 895 acres (DNREC DFW 2015) **Habitat of Conservation Concern**

Figure 2. 12. Inland Xeric Sand Forest Photo: William A. McAvoy



Map 2. 2 Inland Xeric Sand Forest

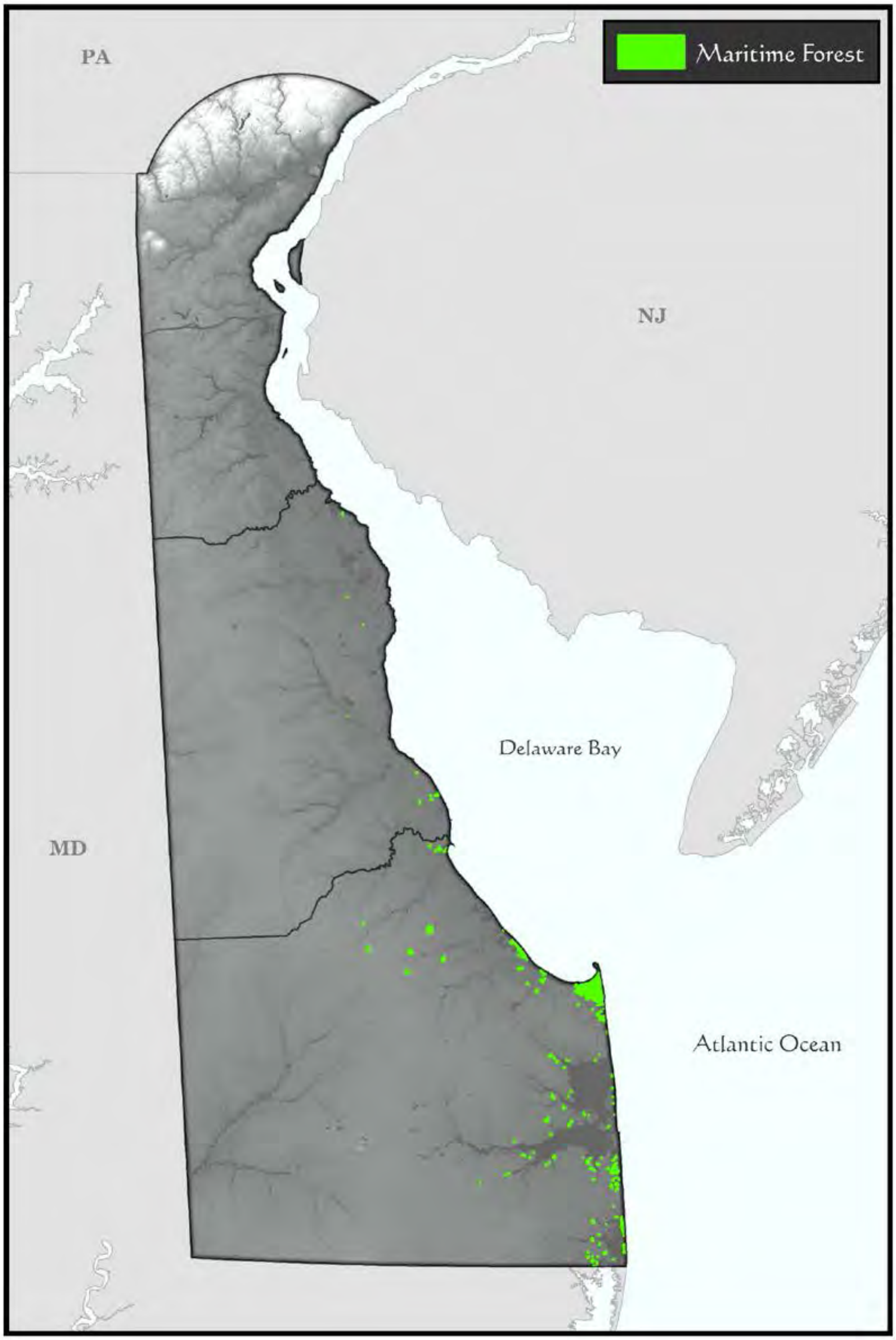
Maritime Forest and Shrubland

A forest-shrubland mosaic encompassing a range of woody vegetation defined by proximity to maritime environment (Figure 2.13). Typical forest species include loblolly pine, black cherry, sassafras, southern red oak, red maple, and American holly. Shrublands typically include beach plum, bayberry, and vines such as greenbrier and grapes. Groundwater levels vary, and have a strong influence on vegetation composition and structure. This habitat type encompasses both upland and embedded wetland environments. Maritime forest vegetation is subject to stresses like salt spray, high winds, dune deposition, sand shifting and blasting, and occasional overwash.

Maritime forests very often border and interfinger with dune, swale, and sandy beach habitats. Many species use this habitat, including: brown-headed nuthatch, prairie warbler, Eastern hognose snake, Eastern towhee, American woodcock, and Eastern whip-poor-will. For a complete list of SGCN using this habitat, see Appendix 2.C. Human disturbance and development are the primary threats to maritime forests in Delaware.

Ecological System: *Northern Atlantic Coastal Plain Maritime Forest (CES203.302) (in part)* **Estimated Extent:** 1,716 acres (DNREC DFW 2015)

Figure 2. 13 Successional Maritime Forest at Cape Henlopen State Park. Photo: William A. McAvoy



Map 2. 3 Maritime Forest

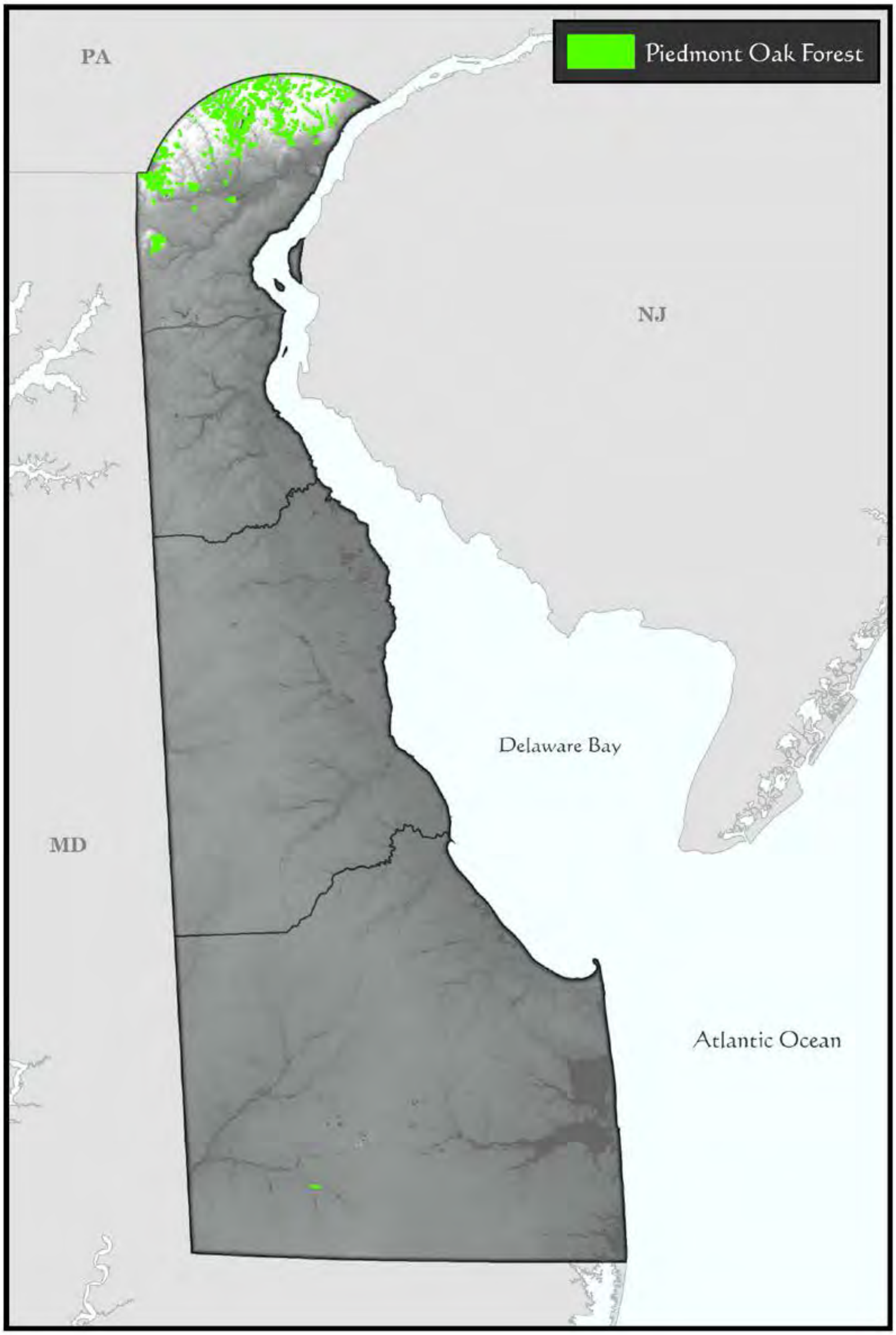
Piedmont Oak Forest

Dry to mesic oak forests of Piedmont ridges and upper slopes (Figure 2.14). This habitat combines two oak-dominated ecological systems. Oak species characteristic of this habitat type include: red, white, black, and scarlet oak. Hickories are prevalent in mature stands of this forest type. On drier ridges, chestnut oak often dominates.

These forests are the dominant forest type of the Piedmont, where they are heavily fragmented and threatened by further residential and commercial development, invasive species, and deer overbrowsing. These forests are important for many species including black-and-white warbler, Eastern towhee, Eastern wood-pewee, and ovenbird. Threats are primarily associated with direct loss to development.

Ecological System: *Northeastern Interior Dry-Mesic Oak Forest (CES202.592), Central Appalachian Dry Oak-Pine Forest (CES202.591)* **Estimated Extent:** 7,164 acres (DNREC DFW 2015)

Figure 2. 14 Piedmont Oak Forest. Photo: William A. McAvoy



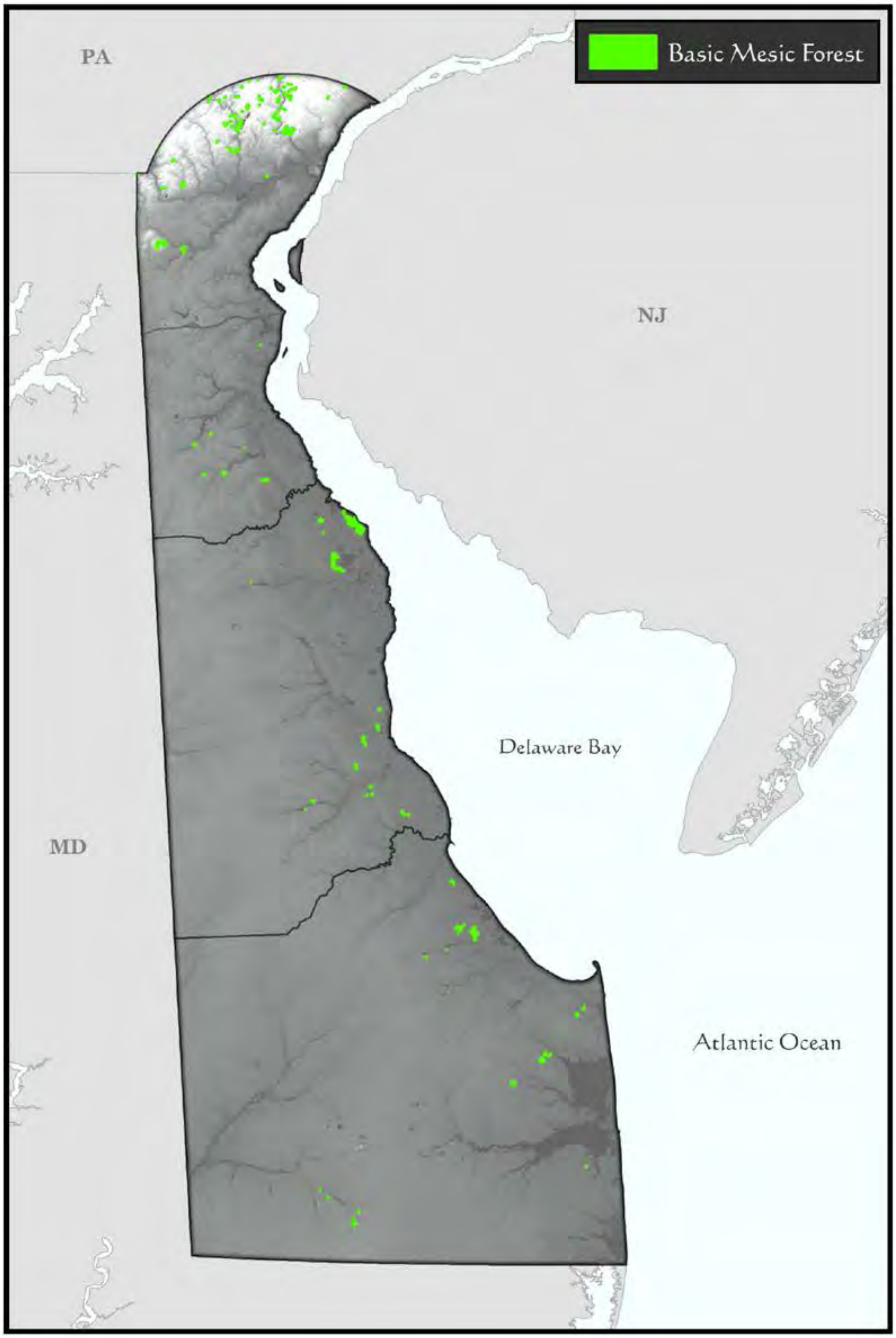
Map 2. 4 Piedmont Oak Forest

Basic Mesic Forest

Forests that develop on moist, nutrient rich soils with a near neutral or basic pH (Figure 2.15). This forest type commonly has tulip poplar in the canopy and is characterized by a highly diverse herb layer. This forest type is significant throughout the region for its high diversity of herbaceous plant species and terrestrial gastropods. In the Piedmont, Basic Mesic Forests are associated with mafic substrates such as amphibolite or diabase that weather to produce high soil concentrations of magnesium. Much of the acreage of this habitat type has been impacted by disturbance and is considered "Successional Tuliptree Forest," a nutrient-rich forest that has been invaded to varying degrees by invasive species, characterized by a greater proportion of tuliptree in the canopy. Less than 200 acres of high quality basic mesic forest are currently mapped by DNREC DFW. For a complete list of SGCN using this habitat, see Appendix 2.C.

Ecological System: near *Northern Atlantic Coastal Plain Calcareous Ravine (CES203.069) (In part), Southern and Central Appalachian Cove Forest (CES202.231)* (in part) **Estimated Extent:** 1,798 acres (DNREC DFW 2015) **Habitat of Conservation Concern**

Figure 2. 15 Basic Mesic Forest. Photo: William A. McAvoy



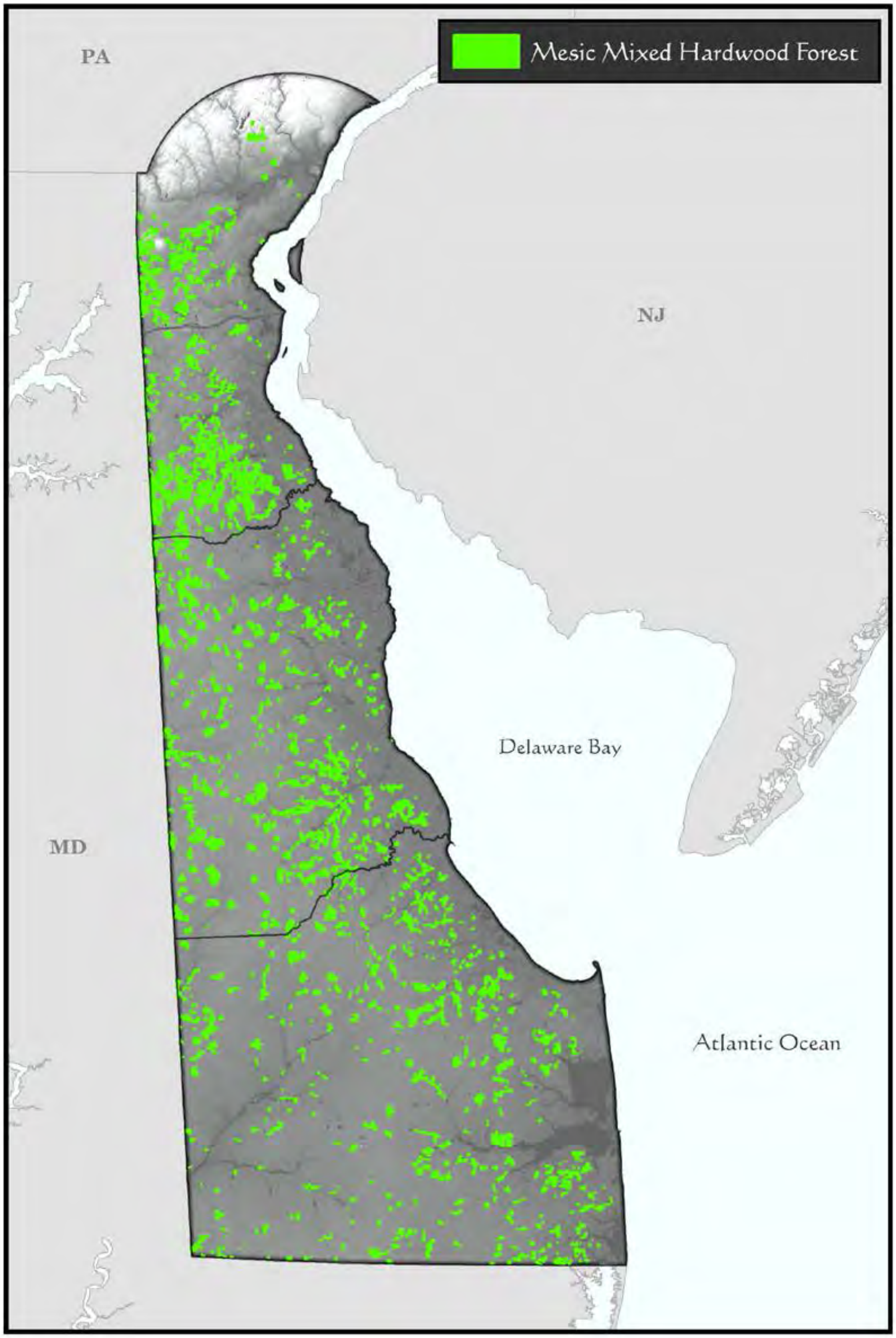
Map 2. 5 Basic Mesic Forest

Mesic Mixed Hardwood Forest

Forests that develop on moist, acidic, often nutrient-poor soils in the Coastal Plain (Figure 2.16). This forest type is associated with a variety of landforms, including ravines, lower slopes, undulating uplands, and flatwoods. These forests are characterized by a mix of tulip poplar, beech, oaks, and hickories in the canopy. This common forest type in Delaware provides habitat for wood thrush, red-shouldered hawk, Eastern whip-poor-will, Eastern box turtle, and worm-eating warbler, among many other SGCN. Delaware has high regional responsibility for this forest type, at 6% of the modeled Northeast acreage according to mapping by Anderson et al. (2013a). The extent below represents intact examples and does not include successional forests. Region-wide, these forests are highly fragmented and the vast majority are less than 80 years old.

Ecological System: *Southern Atlantic Coastal Plain Mesic Hardwood Forest (CES203.242)* **Estimated Extent:** 56,206 acres (DNREC DFW 2012)

Figure 2. 16 . Mesic Mixed Hardwood Forest. Photo: William A. McAvoy



Map 2. 6 Mesic Mixed Hardwood Forest

Beach and Dune Uplands

These coastal upland habitats are adapted to the dynamic conditions of shifting sands, strong winds, and salt spray unique to the narrow zone along the Atlantic Ocean and Delaware Bay. They range from sandy beach above the high-tide line to the grassy dunes and overwashes, to a complex of shrub-dominated back dunes. Intertidal beach areas are covered under the Tidal Wetlands section, while groundwater-controlled interdunal wetlands or swales are included in Non-tidal Wetlands.

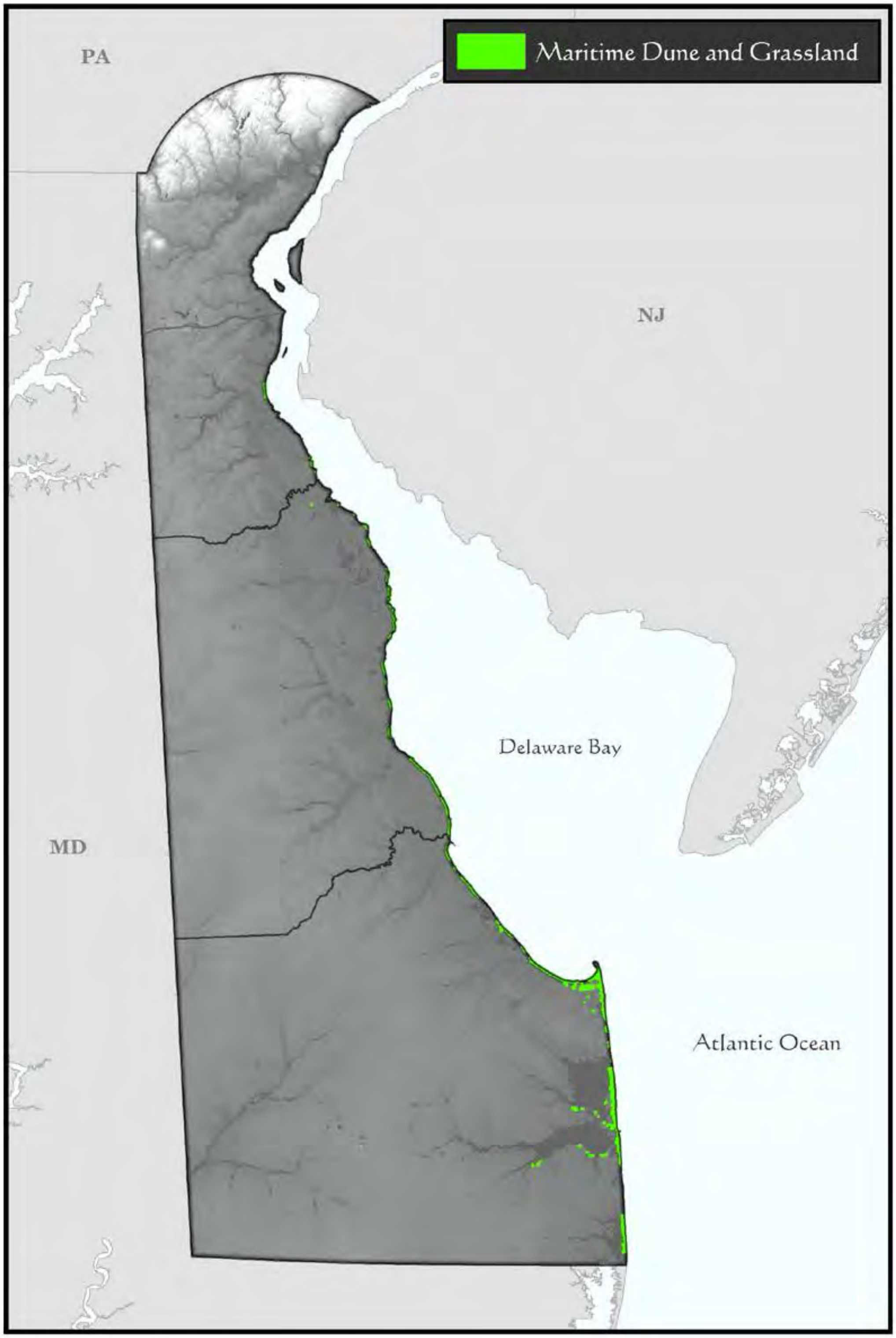
These habitats have declined significantly in extent and quality during historical times, primarily because of residential development and associated infrastructure, particularly artificial shoreline hardening and jetties and groins. In recent decades, this decline has greatly slowed on the Atlantic Coast, where most remaining habitats are on public land. Losses continue, albeit more slowly, along the shorelines of the Delaware Bay and Inland Bays. All of these habitats are subjected to on-going impacts from recreational activities, and Delaware Bay beaches in particular are occasionally impacted by oil spills. The long term prospect for beaches and dunes is potentially poor given predicted sea level rise, even though these disturbance-dependent habitats might be expected to accommodate sea level rise reasonably well by migrating inland. However, onshore and offshore coastal processes that would facilitate such a shift, especially sand transport, may have already been irreversibly compromised by the issues noted above. Efforts to stabilize dunes may also further disrupt these processes in the future, despite their seeming benefits at present. Beach replenishment is a potential solution to the loss of natural sand transport, but costs are very high and nearshore habitats that serve as a sand source, as well as intertidal habitats upon which sand is placed, may be adversely impacted.

Maritime Dune and Grassland

Coastal dunes (Figure 2.17) along the southern portion of the Delaware Bay and the entire length of Delaware's Atlantic coast support maritime grasslands. These grasslands develop within the back dune area and on the crest and faces of primary foredunes. A variety of grasses are found, but the dominant is American beach grass. Broadleaf herbaceous plants of maritime grasslands and include: seaside goldenrod, sea-beach evening primrose, and Eastern jointweed. SGCN using this habitat include a wide variety of birds, dune and beach-associated tiger beetles, numerous sand specialist native bees, and moths that feed on plants found nowhere else in the state, such as the eastern cactus-boring moth. Threats to maritime dune and grassland are primarily associated with human recreational disturbance and development, as well as potential impacts of coastal storms and sea level rise.

Ecological Systems: *(in part) Northern Atlantic Coastal Plain Dune and Swale (CES203.264)*
Estimated Extent: 1,332 acres (DNREC DFW 2015) **Habitat of Conservation Concern**

Figure 2. 17 Dunes at Cape Henlopen State Park. Photo: William A. McAvoy



Map 2. 7 Maritime Dune and Grassland

Sandy Beach

Beaches (Figure 2.18) along the southern portion of the Delaware Bay and the entire length of the Delaware's Atlantic coast are typically sparsely vegetated, and where off-road vehicles are allowed, usually unvegetated. Plant species occurring in this environment include: seaside spurge, American searocket, and purple sand grass. Beaches are critical to many species, including species such as piping plover, tiger beetles, black skimmer, common tern, horseshoe crab, least tern, piping plover, red knot, sanderling, and semipalmated sandpiper.

Delaware has approximately 25 miles of oceanfront, sandy beach, of which 11 miles is developed and 14 miles is undeveloped. Over 14 miles of oceanfront, sandy beach in Delaware are in public or NGO ownership, including three state parks, Cape Henlopen State Park, Delaware Seashore State Park, and Fenwick Island State park (Rice 2015).

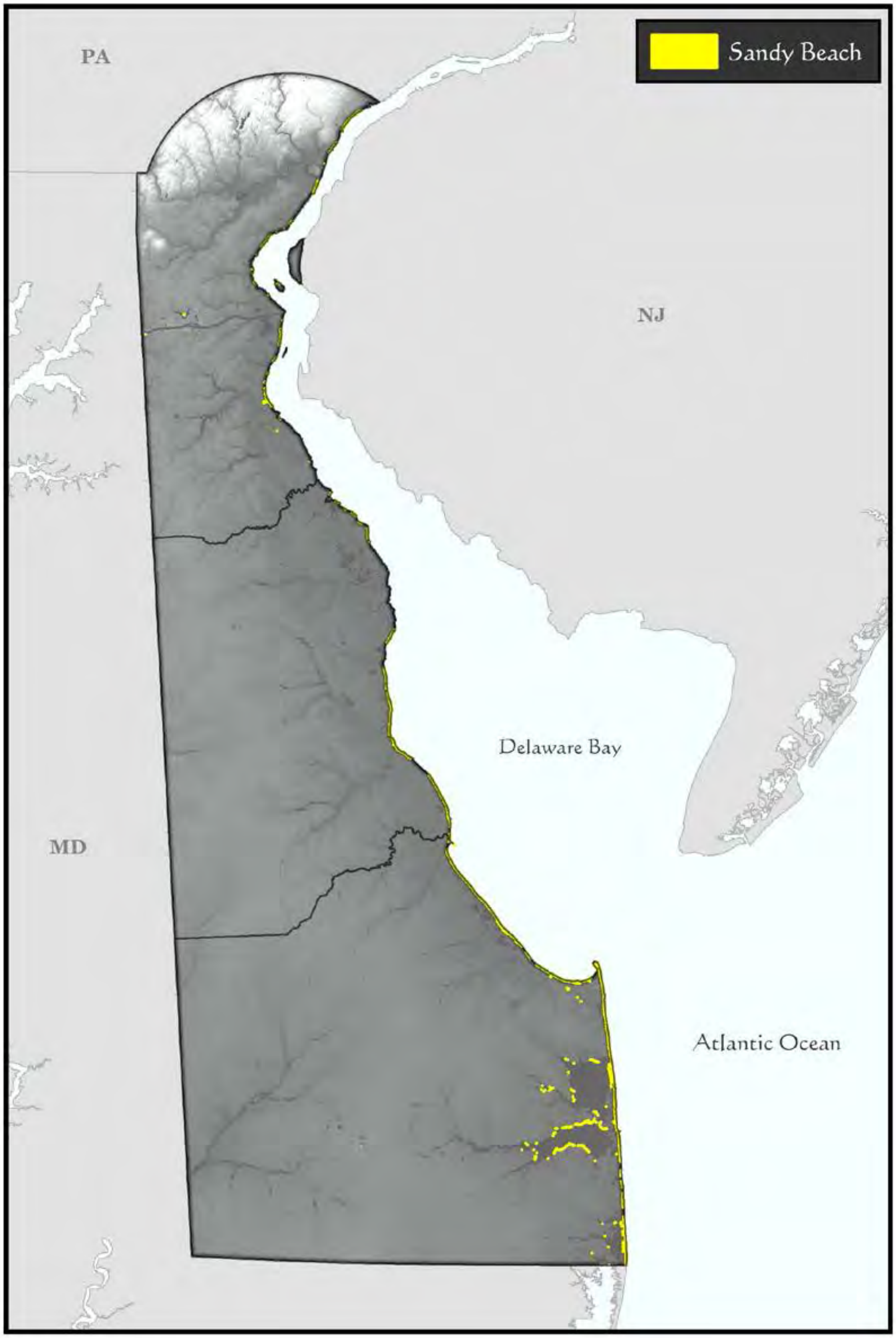
Although 57% of Delaware's oceanfront, sandy beaches are undeveloped with buildings, state Highway 1 runs parallel to much of the undeveloped beaches and modifies the habitat landward of the beaches at Delaware Seashore and Fenwick Island State Parks in particular. At least 3.68 miles of oceanfront shoreline is armored, including 29 groins, 2 jetties, and 4 bulkheads (Rice 2015).

Delaware's Bayshore beaches are largely undeveloped, but an analysis of shoreline condition for the Bayshore beaches has not been conducted. Delaware's 357 miles of river and bay shoreline are primarily flanked by sandy beach.

PSDS (2014) records indicate about half (12.59 out of 25.36 miles, or 20.26 km) of the Delaware coast received federal emergency beach fill following the destructive Ash Wednesday Storm of 1962. Precise locations are not available but exceed the length of current beach fill projects. Three federal projects place beach fill in Rehoboth Beach and Dewey Beach (since 2005), Bethany and South Bethany Beaches (since 2008), and Fenwick Island (since 2005). Prior to the start of the federal projects, widespread state-sponsored fill projects were constructed in 1989, 1992, 1994 and 1998 (Daniel 2001, Greene 2002). There is a sediment bypassing plant at Indian River Inlet that bypasses sediment (since 1990) from south to north, depositing material on 0.66 miles (1.06 km) of beach annually; periodically a larger area north of the inlet receives supplemental nourishment fill. Altogether approximately 8.66 miles (13.94 km; 34%) of Delaware's sandy oceanfront beaches have received sediment placement in recent years. Species using beach and dune habitats of the Delaware Bay were reviewed by Clancy and McAvoy (1997).

Ecological Systems: *Northern Atlantic Coastal Plain Sandy Beach (CES203.301)* **Estimated Extent:** 1,150 acres (DNREC DFW 2015) **Habitat of Conservation Concern**

Figure 2. 18 Unvegetated Sandy Beach. Photo: William A. McAvoy



Map 2. 8 Sandy Beach

Upland Barrens

Delaware has very little natural barren habitat. Small amounts of serpentine barren formerly existed in the northern Piedmont, but these have now been entirely lost or degraded. Serpentine barrens are included here because they are associated with rare plants and wildlife and because they represent a cautionary tale in Delaware wildlife conservation.

Chestnut Oak Barren

Chestnut oak barrens are a rare habitat in Delaware and occur on steep, often warm, west or south facing slopes in the Piedmont province of New Castle County (Figure 2.19). Chestnut oak is the dominant tree, forming a canopy that is often thin with occasional gaps or openings. The soils are thin, nutrient-poor, and well drained. The bedrock is close to the surface and usually exposed in areas. Cobble size rock are often scattered over the area. Low-growing shrubs such as low bush blueberry are sparsely distributed, and grasses, sedges, and broadleaf herbs can be found.

Ecological System: Undetermined **Estimated Extent:** Unavailable

Figure 2. 19 Chestnut Oak Barren. Photo: William A. McAvoy

Serpentine Barren

Serpentine barrens form over exposures of serpentinite, a greenish rock that contains high levels of magnesium, nickel, and chromium. This combination of elements in the soil makes plant growth difficult and has led to the adaptation of a specialized flora and fauna found only in serpentine sites.

Prior to settlement, as much as 500 acres of serpentinite were exposed in the Delaware Piedmont, part of a larger complex of scattered serpentine barrens that included several large sites in Chester and Lancaster Counties in Pennsylvania. Only a few acres of serpentinite exposure remain in Delaware. Rare plants such as the round-leaved fameflower, serpentine chickweed, and the serpentine aster, as well as rare moths and butterflies, including red-banded hairstreak, cobweb skipper, barrens buckmoth, mottled duskywing, and dusted skipper, are all associated with this habitat type.

The few acres of serpentine exposure that remain undeveloped in northern Delaware are on private land and are covered by either successional vegetation or manicured lawn. There is a one to two acre exposure that could be described as "old field" that has potential for restoration. The site is on private land, but a conservation easement is associated with the property, which could make restoration more likely.

Ecological System: Eastern Serpentine Woodland **Estimated Extent:** 10 acres (Anderson et al. 2013a); However, functional examples of this habitat type are no longer present in Delaware.
Habitat of Conservation Concern

Early Successional Habitats

In this plan, we follow Greenberg et al (2011) in adopting a broad definition of early successional habitats as habitats that are created by intense or recurring disturbance and are transient if not maintained by disturbance. In Delaware, naturally occurring early successional habitats would historically have been created and maintained primarily by natural disturbance regimes of either biotic (beaver meadows, insect outbreaks within forests) or abiotic (fire, windthrow, ice damage, floods, coastal storms) origin. It is difficult to estimate how much of this habitat existed at any given time in pre-settlement Delaware. Native Americans actively managed the landscape before European contact, and the disturbance regimes they created likely produced significant areas of early successional habitat in what was to become Delaware.

By the late 19th to early 20th century, with beaver extirpated by trapping, and with the advent of wildfire suppression, anthropogenic clearing for timber and agriculture became the primary generator of early successional habitats. Currently, clearcut and selection timber harvest lands and periodically managed roadside and power line corridor habitat are now the dominant types of early successional habitat in the state.

In many states, including Delaware, temporal variation in early successional habitat is essentially unstudied. Recent LANDFIRE 2010 geospatial data on disturbance and vegetation transition magnitude are available for the state, but have not been analyzed to date (SEM 2012). In other areas in the Northeast, and nationally, declines in early successional habitat have been documented. Buffum et al. (2011) found that in Rhode Island, upland early successional habitat was declining in non-coastal areas at a rate of 1.5% per year. In Delaware, land cover data trends indicate that clearcut forest acreage increased by over 45% from 6,756 acres in 2002 to 9,856 acres in 2007.

Early successional habitats are of importance not just to the guild of species that specializes in breeding in them, but, as an increasing number of studies have indicated, to forest interior species during post-breeding periods (Vega-Rivera et al. 1998) and during migration, particularly fall migration.

There are numerous small occurrences of this habitat on roadsides and utility corridors, although maintenance regimes on these areas may compromise some of their ecological value. Several public agencies and private conservation organizations are actively managing for early successional habitat, but whether or not this will ensure sufficient extent and distribution is uncertain. In addition, perpetual management is required to thwart natural succession, and costs for controlling invasive exotic plants may be especially high.

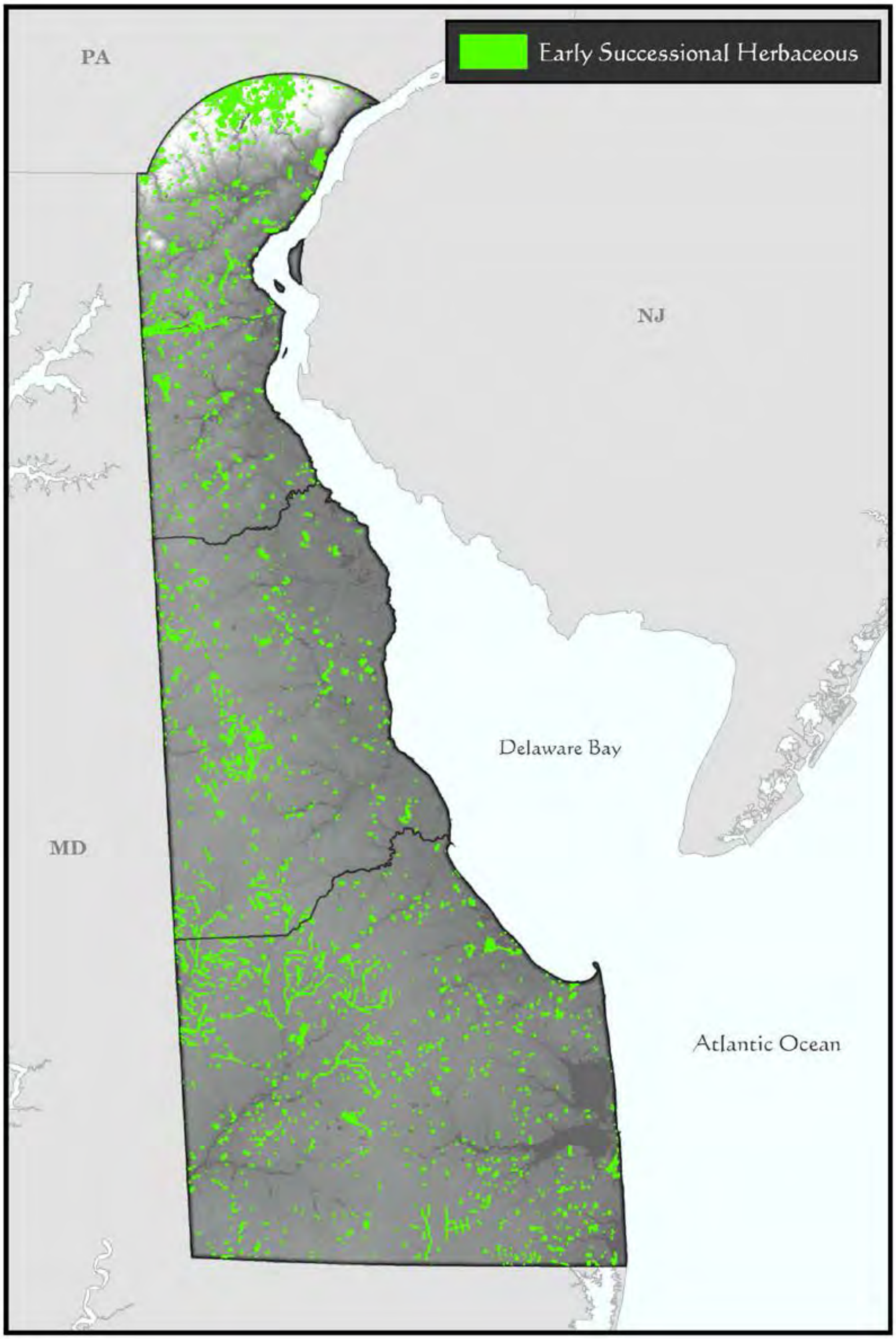
Early Successional: Herbaceous

Early successional herbaceous habitat in Delaware includes agricultural pasture and grasslands (treated separately under Agricultural Habitats) as well as managed and unmanaged grass and forb-dominated habitats in a variety of settings throughout the state (Figure 2.20). The primary vegetation type in Delaware is Northeastern Old Field, a cool-season, grass dominated community known from post-agricultural disturbed areas throughout the state.

A rare, native habitat type in Delaware, Piedmont native grasslands, is known from only a few sites in the Piedmont province of New Castle County, but additional occurrences probably exist or are in need of restoration. These native grassland sites occur on Chester Loam soils that are well drained, thin and nutrient poor. Several sites occur on warm, west facing slopes, and the dominant grass is little bluestem. Broad-leaf herbs are well represented, including milkweeds and asters, important butterfly and pollinator plants. In order to maintain grasslands, management is needed. Mowing once per year – in November or early March – seems to be effective in controlling woody vegetation. Non-native plants such as autumn olive and multi-flora rose are threats to this habitat.

Northeast Terrestrial Wildlife Habitat Classification System: Macrogroup: Ruderal Shrubland and Grassland **Estimated Extent:** 22,058 acres (DNREC DFW 2015) **Habitat of Conservation Concern**

Figure 2. 20 Early Succesional Herbaceous Habitat. Photo: William A. McAvoy

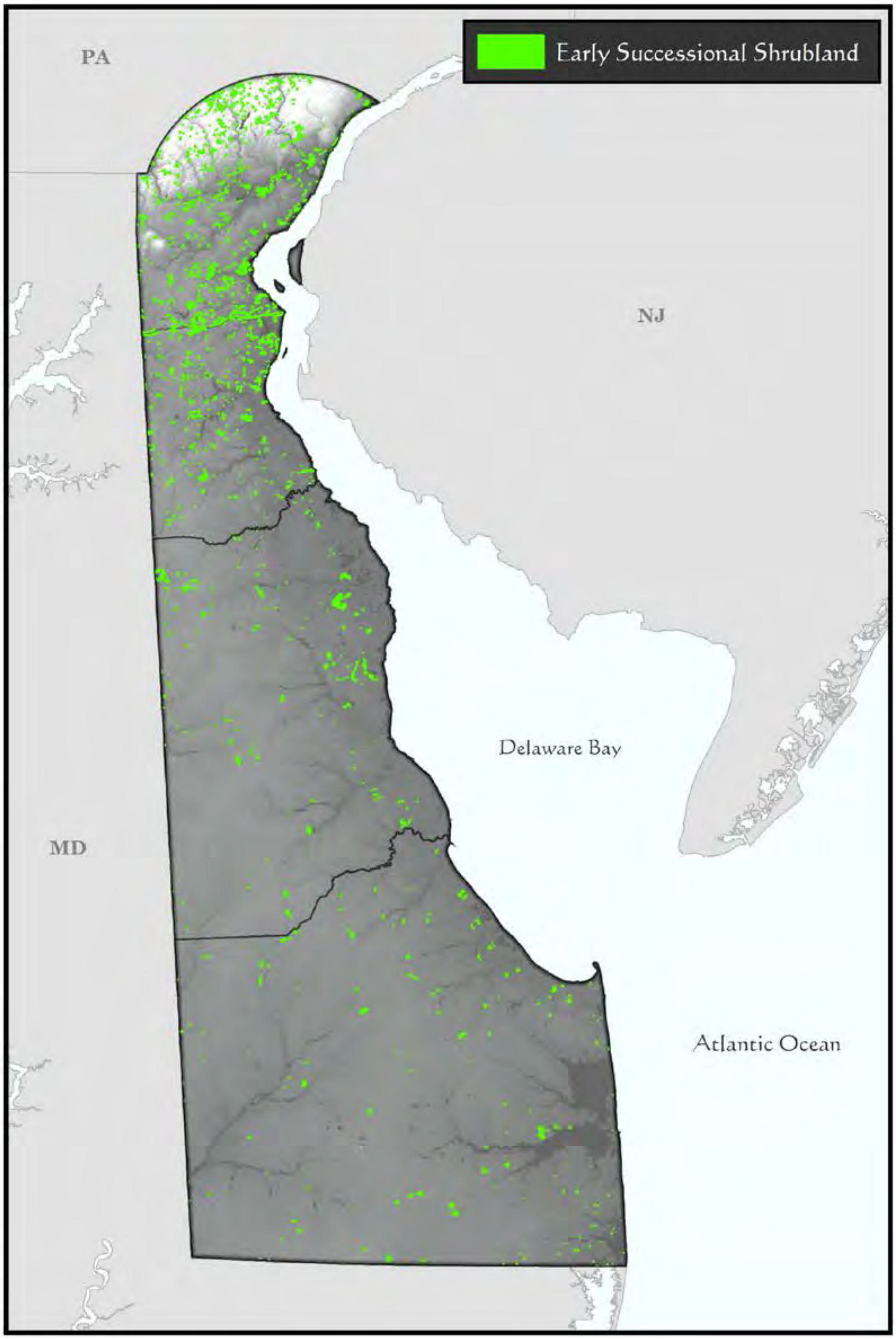


Map 2. 9 Early Successional: Herbaceous

Early Successional: Shrubland

Shrub-dominated early successional habitat in Delaware is primarily classified as Northeastern Successional Shrubland, a broadly defined association characterized by shrubby vegetation on abandoned cropland or pasture. This habitat type is important to numerous species, especially a group of declining shrubland-dependent birds including SGCN such as Northern bobwhite, yellow-breasted chat, blue-winged warbler, brown thrasher, field sparrow, and others. For a complete list of SGCN using this habitat, see Appendix 2.C. These shrublands are threatened by invasive plant species, development, and other impacts.

Northeast Terrestrial Wildlife Habitat Classification System: Macrogroup: Ruderal Shrubland and Grassland **Estimated Extent:** 6,794 acres (DNREC DFW 2015) **Habitat of Conservation Concern**



Map 2. 10 Early Successional Shrubland

Early Successional: Young Forest

Forest that is regenerating after timber harvest is now one of the most common types of early successional habitat in Delaware. This habitat type is discussed more extensively under the section on young forest habitats above. For a complete list of SGCN using this habitat, see Appendix 2.C.

Ecological System: Various **Estimated Extent:** Unavailable **Habitat of Conservation Concern**

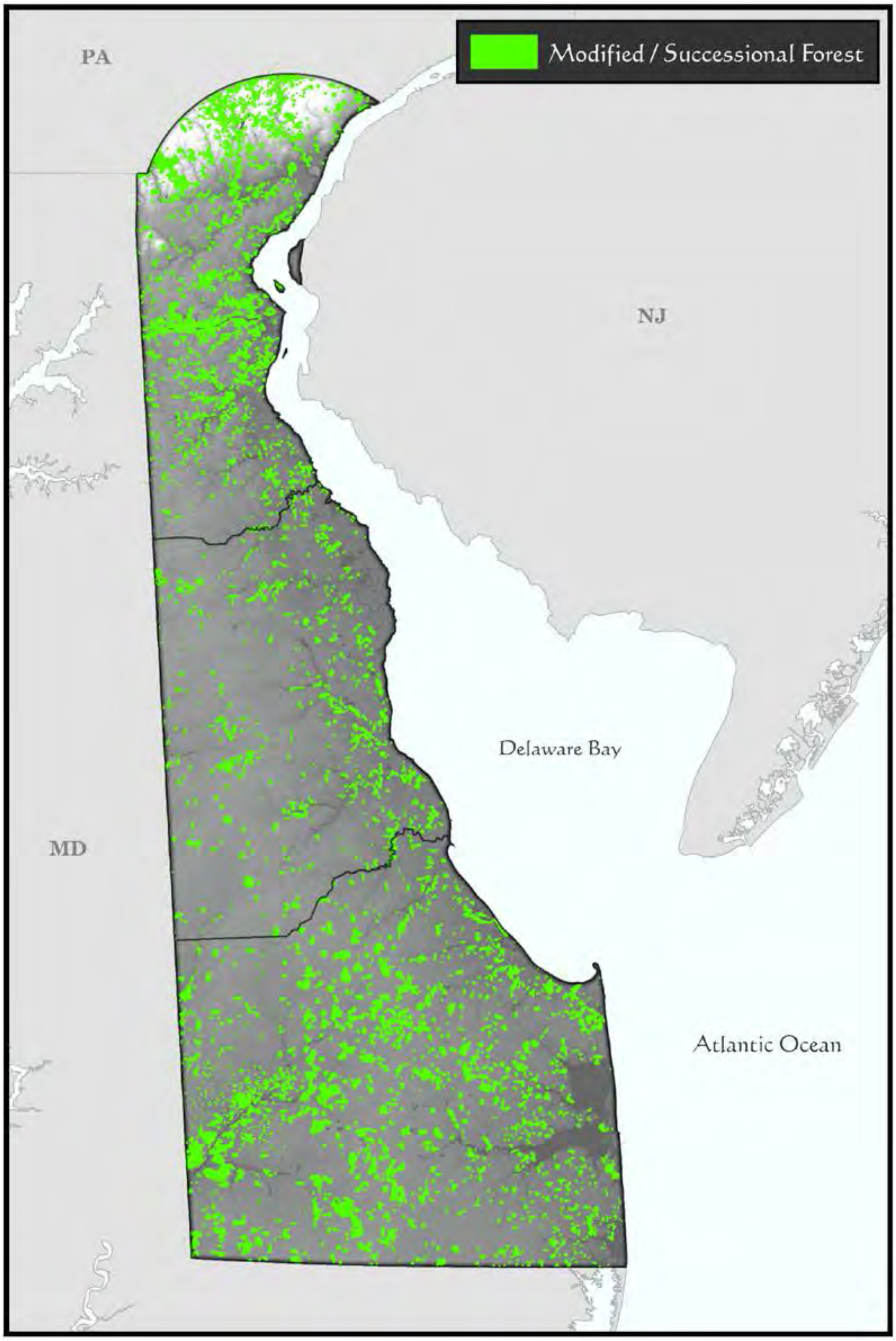
Modified Upland Habitats

Modified Forested Habitats

Modified/Successional Forests

This habitat type includes a wide variety of forests within different ecological systems that have been heavily modified in their species composition by a history of clearing and agriculture, followed by a subsequent invasion of aggressive native and non-native species of vines, shrubs, and trees. In Coastal Plain successional forests, loblolly pine and sweetgum are often the dominant trees, while Piedmont examples are often dominated by tulip poplar. Despite their decreased species diversity, these forests are nevertheless important for numerous SGCN, and should be targets for management to reduce invasive species and improve forest condition. For a complete list of SGCN using this habitat, see Appendix 2.C.

Ecological System: Various **Estimated Extent:** 50,972 acres (DNREC DFW 2015)



Map 2. 11 Modified/Successional Forests

Conifer Plantations

These plantations are typically monocultures of one tree species, with minimal understory or herbaceous layer. They are of value to some SGCN, but support significantly fewer species than natural forests.

Northeast Terrestrial Wildlife Habitat Classification System: Macrogroup: Plantation and Ruderal Forest, System: Managed Tree Plantation **Estimated Extent:** 26,110 acres (DNREC DFW 2015)

White Pine Plantation

The native white pine (*Pinus strobus*) is planted extensively in suburban neighborhoods in the Delaware Piedmont, often in monoculture stands. These can be significant for nesting raptors, including state rare breeders like sharp-shinned hawk, which nested in a white pine plantation in northern Delaware for several years in the late 2000s.

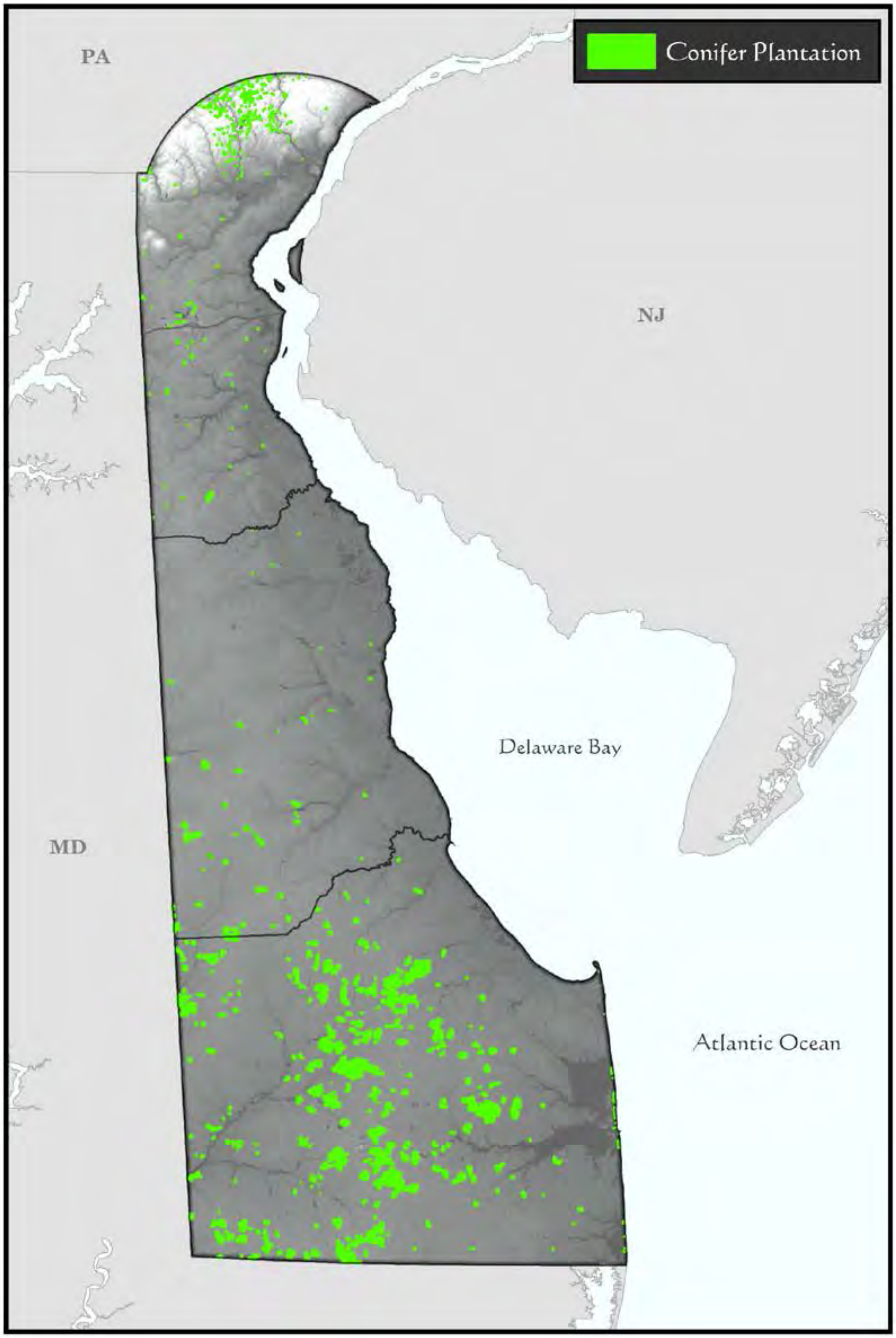
Spruce Plantation

These are plantations of non-native spruces, typically either Norway spruce (*Picea abies*) or red spruce (*Picea rubens*) that are planted in rows or stands. Norway spruce was extensively used by the Soil Conservation Service in 1950 and 1960's for reforestation.

Loblolly Pine Plantation

Loblolly pine is the most extensively planted conifer in Delaware, with large amounts of commercial timberland in the Coastal Plain planted in monocultures of this species. It is one of Delaware's most important commercial timber species and historically contributed considerably to the state's economy.

There has been a 75 percent decline in acreage of loblolly pine in Delaware from nearly 200,000 acres in 1957 to only 54,000 acres in 2009. The passage of Delaware's Seed Tree Law in 1989 was due to this precipitous loss in loblolly pine forests and requires landowners to ensure that harvests of loblolly pine (and yellow-poplar) forests greater than 10 acres are sufficiently regenerated. This law only applies to properties that will remain in forestland (it does not apply to land use changes, such as development).



Map 2. 12 Conifer Plantation

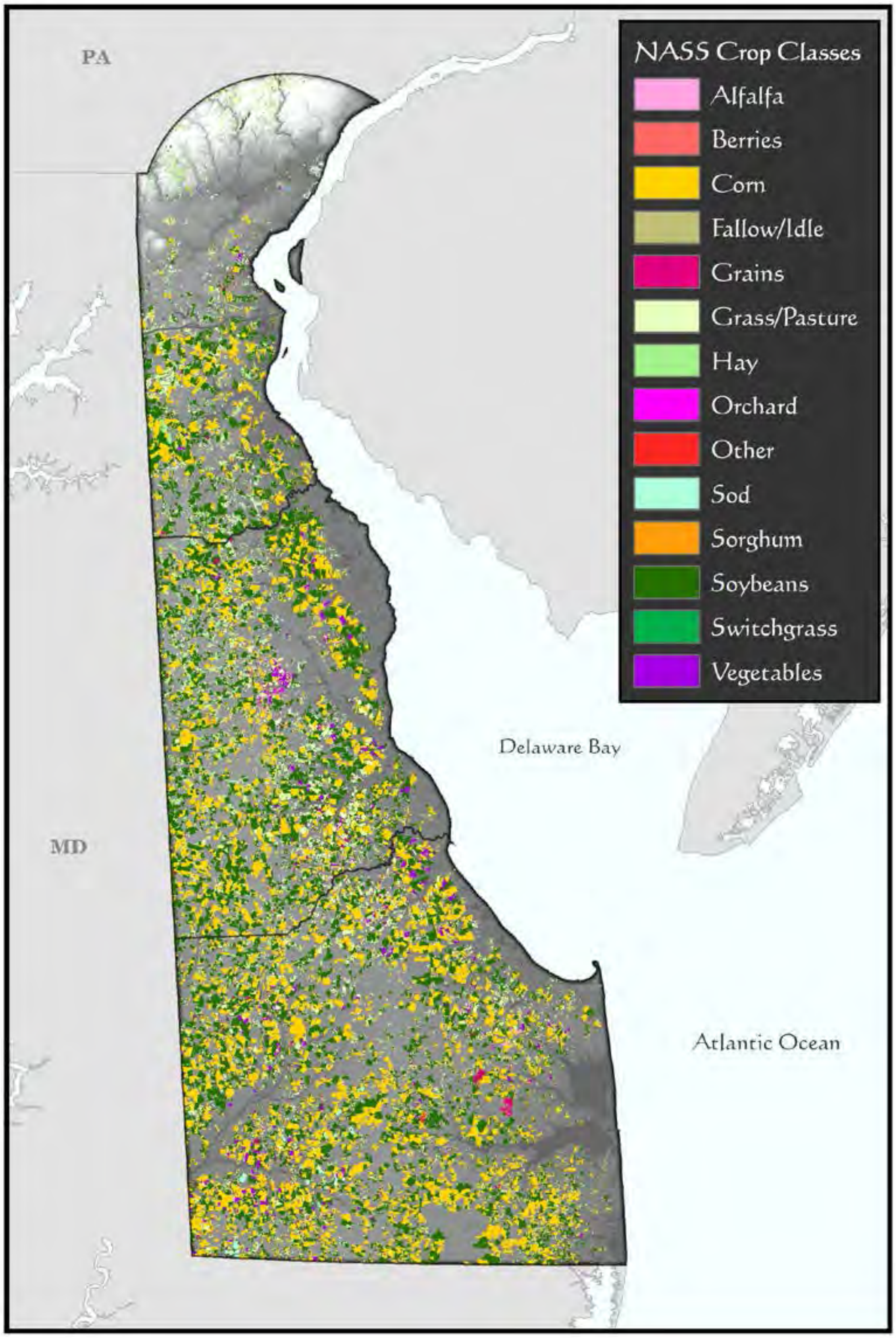
Agricultural Habitats

Delaware has a rich history of agriculture, and this land use has heavily shaped the distribution, structure, and quality of habitats in the state. Thirty-nine percent of all land in Delaware is part of a farm (Kee n.d.). As in other states, many forests and early successional habitats were previously farmed, wetlands ditched, and marshes managed for salt hay. Today's agricultural landscape in Delaware is dominated by row crops (Table 2.10). The upland areas of the Coastal Plain host the most intensive row crop agriculture on the Delmarva Peninsula, including primarily corn and soybeans. In addition, poultry farms are widespread and are highly economically important. Vegetable production accounts for fewer acres, but is nearly as valuable as corn and soybeans in terms of annual commodity marketing receipts (Kee n.d.).

Statewide, land in farms decreased from 589,107 acres in 1997 to 508,652 acres in 2012, a decrease of 13.7%. Total cropland as of 2012 was 439,157 acres, with a total of 421,321 acres harvested. Land in orchards declined over 62% from 1,200 acres in 1997 to 450 acres as of 2012 (USDA NASS 2012).

Benton et al. (2003) found that loss of habitat heterogeneity is a major factor driving observed declines in farmland biodiversity around the world. Recent studies support the generalization that farms with greater on-farm heterogeneity support higher levels of biodiversity (Belfrage et al. 2015). Throughout the country, the removal of fencerows and enlargement of fields that has accompanied agricultural intensification during the second half of the 20th century has led to decreased structural heterogeneity on working farms (Best 1983, Basore et al 1986).

Numerous species of birds make use of row crop fields, but abundance of bird species within row crop fields is influenced by surrounding land cover (Best et al. 2001). Due to the presence of crop residues, birds prefer to nest in no-till fields rather than tilled fields (Basore et al. 1986, Vanbeek 2012). Nest success for birds is typically low in row crops, on the order of 20-25%, with significant mortality from mechanical operations (Tews et al. 2013). As of 2012, Delaware had 219,138 acres of crop fields farmed with no-till practices, with a further 81,402 in conservation tillage (excluding no-till). 106,915 acres were in conventional tillage; 70,126 acres utilized cover crops, providing some additional benefit to wildlife species (USDA NASS 2012).



Map 2. 13 Agricultural Crop Types of Delaware. From USDA National Agricultural Statistics Service (NASS) Cropscape Cropland Data Layer (2014).

Table 2. 10 Delaware Crops Harvested by Acre, 2012

Crop	Acres Harvested	Acres
Corn (grain and silage)	182,994	
Soybeans	167,672	
Winter Wheat	79,658	
Vegetables	38,321	
Barley	33,455	
Hay/Forage		15,294
Permanent Pastureland		8,154
Sorghum	592	
Orchards		450
Rye	391	
Berries		98
Oats	83	

Opportunities for conservation on working lands are provided by several USDA Natural Resources Conservation Service (NRCS) programs, including the Conservation Reserve Program (CRP), Wetlands Reserve Program (WRP), Farmable Wetlands Program (FWP), and Conservation Reserve Enhancement Program (CREP). CRP is a program established by the USDA in 1985 that takes land prone to erosion out of production for 10 to 15 years and devotes it to conservation uses. In return, farmers receive an annual rental payment for carrying out approved conservation practices on the conservation acreage. The WRP, FWP, and CREP programs are included under the Conservation Reserve Program and offer landowners financial incentives for conservation practices such as filter strips (Figure 2.21). Acres in these programs declined from 9,221 in 2007 to 7,808 in 2012, a 15% decline. The number of acres enrolled in conservation programs increased with increasing age of the principal operator. See Chapter 3 for a discussion of issues and challenges associated with implementing conservation practices on private agricultural lands.

The Delaware Agricultural Lands Preservation Program was formed in 1991, and as of June 2015 the Delaware Agricultural Lands Preservation Foundation has identified 170,267 acres in 1,082 Agricultural Preservation Districts and District expansions in Delaware. Out of the acres currently in

Agricultural Preservation Districts, 808 farms encompassing approximately 116,223 acres have been permanently protected through the purchase of preservation easements (DALPF 2015). With a rise in sea level of 1.0 meter 9% of statewide Agricultural Preservation Land would be inundated (Delaware Coastal Program 2012).

Figure 2. 21. Filter strips, buffers, and other conservation practices can provide valuable wildlife habitat in agricultural systems. Photo: Jeff Gordon

Hay and Pasture

Some of the most valued and least abundant agricultural lands for wildlife are cool-season grassland habitats provided by hayfields and pastures that support a number of declining SGCN birds and insects, including the bobolink, Eastern meadowlark, grasshopper sparrow, upland sandpiper, vesper sparrow, and horned lark. By the 1800s, grasslands were widespread in the Northeast, as land was cleared for pastures and hayfields. Grassland birds undoubtedly benefited from this expanded habitat. During the 20th century, many small farms were abandoned, remaining farms became larger and increasingly industrialized, and populations of grassland birds began to decline.

Old hayfields that were traditionally harvested late in the season provided ideal breeding habitat for birds. Today, remaining hayfields are mowed earlier and more frequently in the summer, or are planted in large monoculture crop fields. Modern grassland habitats in Delaware are ephemeral and dependent on continuing agricultural practices to maintain them. In general the few managed grasslands in the state are not of sufficient size to maintain area-sensitive grassland bird species. Acres used for forage and hay declined 17% from 18,499 acres in 1997 to 15,294 acres in 2012. By comparison, a 1942 report indicated 78,128 acres of hay statewide. Although many grassland species, especially birds, require large habitat patch sizes, as of 2012, only 3,117 acres of Delaware's hay/forage was in fields of over 100 acres in size (USDA NASS 2012). Pasture acreage declined from 85,578 acres in 1942 to 8,154 acres of permanent pastureland.

Recently, a spray irrigation system was installed near Middletown Delaware to handle municipal wastewater. This site, at Levels Road, is managed as grassland habitat with periodic mowing. Since installation, the site has attracted a number grassland bird SGCN, including rare species in Delaware such as dickcissel. The Middletown site seems to be "proof of concept" that spray irrigation of municipal wastewater has the potential to provide grassland habitat capable of attracting a diverse assemblage of nesting species that are severely habitat-limited elsewhere in the state.

Northeastern Terrestrial Wildlife Habitat Classification: Macrogroup: Agricultural, System: Pasture/Hay **Estimated Extent:** 23,448 acres (USDA 2012)

For a complete list of SGCN using various agricultural habitat types, see Appendix 2.C.

Roadsides and Rights-of-Way

Rights-of-Way

With over 800 miles of electricity transmission rights-of-way and over 6,000 miles of roads, roadside and right-of-way (ROW) habitats are important in Delaware. Since these habitats are maintained in an early successional state by periodic mechanical and/or chemical vegetation management, they are often important sites for early successional plant and animal species (Figure 2.22).

Wagner et al. (2014) found that plant species richness along New England power line ROWs was twice as high as in adjacent woodland. Several plant species and species groups important for supporting higher trophic levels (especially insects) were found to be primarily associated with the intermediate disturbance levels of ROWs. Right-of-way context is also important, as ROWs in developed areas may be sinks for early successional birds, while those in more forested areas may allow greater nesting success (Askins et al. 2012). ROW vegetation management, particularly on ROWs that traverse public lands, should be targeted to benefit SGCN to the greatest extent practical.

Northeastern Terrestrial Wildlife Habitat Classification: Macrogroup: Ruderal Shrubland and Grassland, System: Power Line Right-of-Way **Estimated Extent**: 1,839 acres (DNREC DFW 2015)

Figure 2. 22 Power line rights-of-way can provide valuable early successional habitat, especially for invertebrates. Photo: Pepco Holdings, Inc.

Developed Habitats

Suburban

While not a substitute for natural lands, suburban habitats may be important for SGCN when they contain or incorporate areas of remnant natural vegetation. On older subdivisions with larger lot sizes and patches of mature native vegetation that are connected to forests and wetlands in the surrounding landscape, numerous SGCN may find habitat. However, more recent trends in building have decreased lot sizes, limited retention of natural vegetation, and are frequently landscaped with non-native species, thus providing very limited habitat for SGCN.

Suburban habitat can be productive for biodiversity, especially for highly mobile taxa such as insects and birds. Recent interest in native landscaping has the potential to transform suburban yards to valuable habitat if widely implemented. Several resources are now available that describe the relationship between native plants and biodiversity in the suburban landscape (see Tallamy 2009). New studies are elucidating the links between socioeconomic factors, wildlife diversity, and human well-being in urban and suburban residential settings (Lerman and Warren 2011).

The Delaware Nature Society, the Delaware affiliate organization of the National Wildlife Federation, provides Backyard Wildlife Habitat Certification to interested homeowners in Delaware to help improve habitat in suburban systems. New Castle County's Unified Development Code

Article 10 – Environmental Standards provides for protection of Critical Natural Areas (CNAs) from development via DNREC review.

Northeastern Terrestrial Wildlife Habitat Classification: Developed, Macrogroup: Urban/Suburban Built **Estimated Extent**: Unavailable

Urban

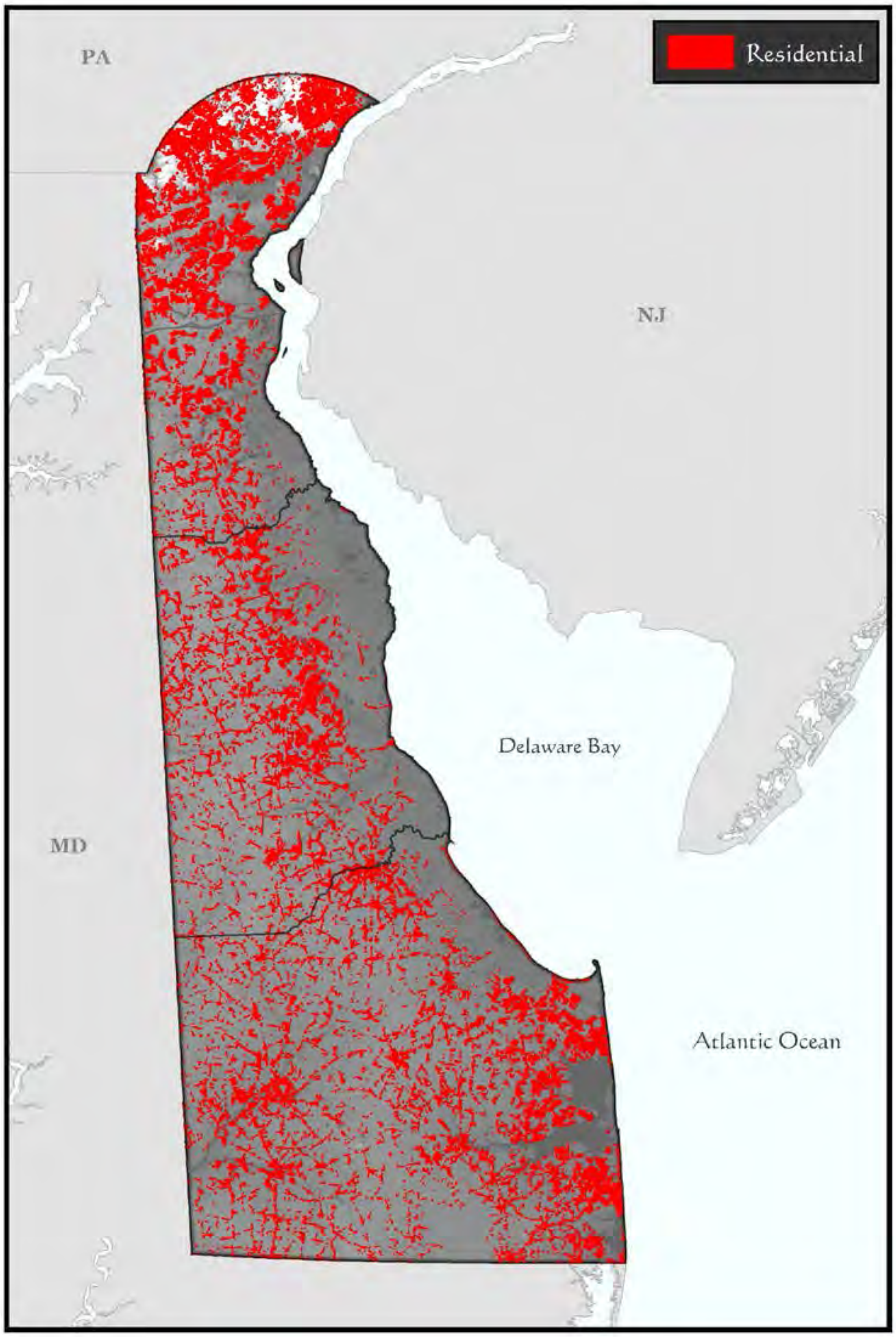
Some species of concern are heavily dependent on urban areas. Chimney swifts now nest almost exclusively in structures, and their distribution in the state is closely tied to towns and cities with numerous older buildings with uncapped chimneys used for nesting and roosting. Peregrine falcons nest on bridges and on ledges of city buildings in urban settings in and around Wilmington, and these urban habitats are important to the population rebound of this species (Altwegg et al. 2014).

Urban riparian habitats and parklands may be especially important, as they provide refugia for migratory species in an otherwise inhospitable landscape, as well as important breeding areas for resident species. Further research on breeding success of SGCN within urban fragments would help determine whether these areas function as sources or sinks for wildlife populations. Urban areas can also serve as traps for migrating bird species, as evidenced by significant numbers of SGCN migrants killed by collisions with buildings in the City of Wilmington (Delmarva Ornithological Society, unpublished data).

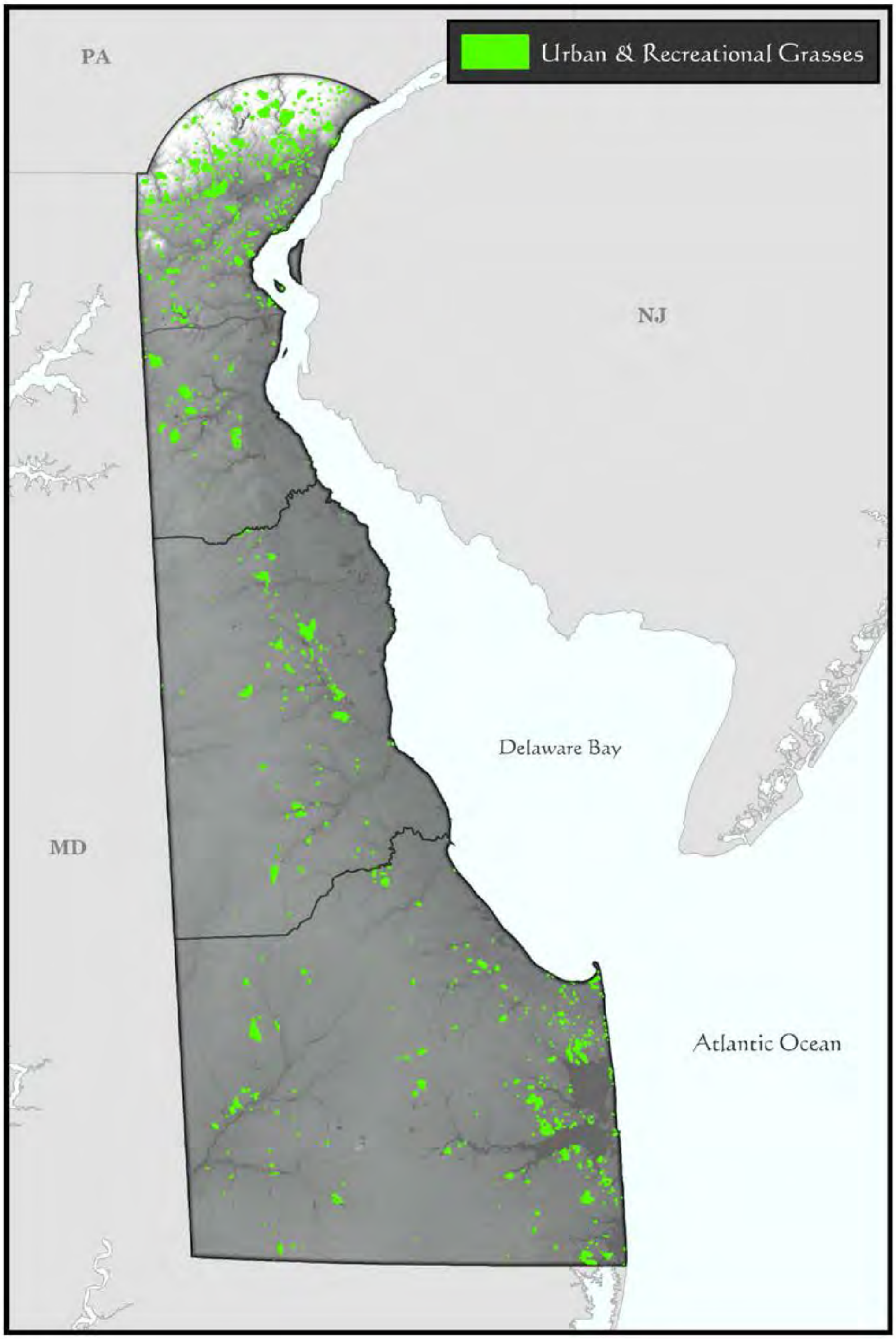
Total urban forest canopy coverage in Delaware as of 2007 was just under 17% (39,300 forested acres out of 234,000 total urban acres) (Delaware Forest Service 2010). Urban forests were assessed in northern Delaware by Nowak et al. (2009). The Delaware Forest Service provides technical assistance to local municipalities to help develop community forest management plans and street tree inventories through the Urban and Community Forestry Program. Annual Community Forestry Grants (18 grants totaling $80,647 in fiscal year 2014) help support tree planting and management on publicly owned lands.

Again, existing spatial data for Delaware did not always align with the updated habitat classification system. Therefore, a map of the coverage of urban areas would include a portion of Map 1.14 above and some of urban and recreational grasses (total coverage of 15,204 acres), represented by Map 1.15 below. Map 1.16 represents commercial and industrial areas of Delaware, which does not fit into one of the new classification systems, is not an important key habitat for SGCN. Some commercial and industrial areas, which cover a total of approximately 79,587 acres, may also be included in coverage for urban areas.

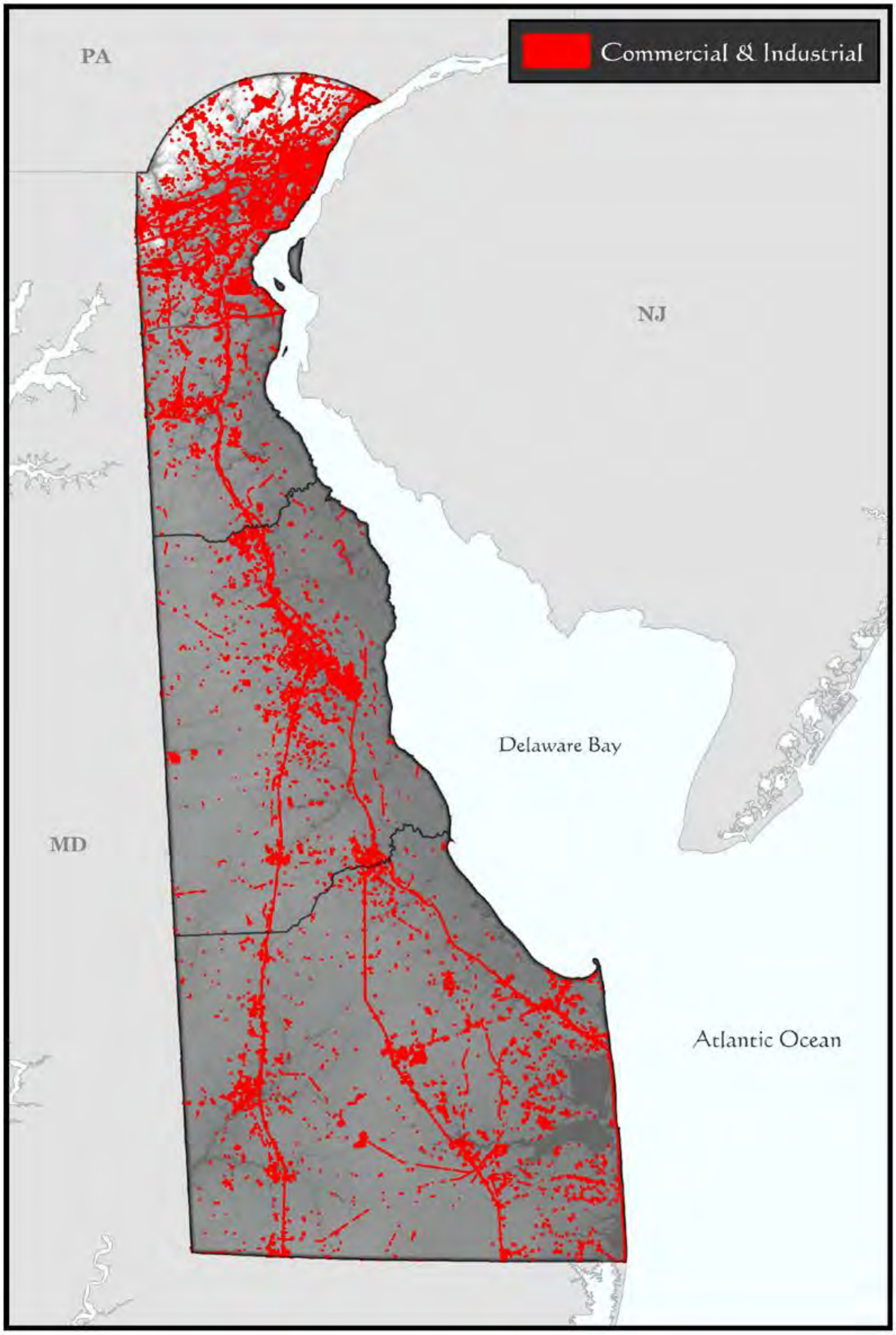
Northeastern Terrestrial Wildlife Habitat Classification: Developed, Macrogroup: Urban/Suburban Built **Estimated Extent**: Unavailable



Map 2. 14 Residential Land Cover in Delaware. Existing land use spatial data available for Delaware does not align with the DEWAP habitat classification system. For this reason, this map includes all residential land (urban, suburban and rural) in the state: a total of 175,180 acres. Source: 2012 Delaware Land Use/Land Cover.



Map 2. 15 Urban and Recreational Grasses. Source: 2012 Delaware Land Use/Land Cover.



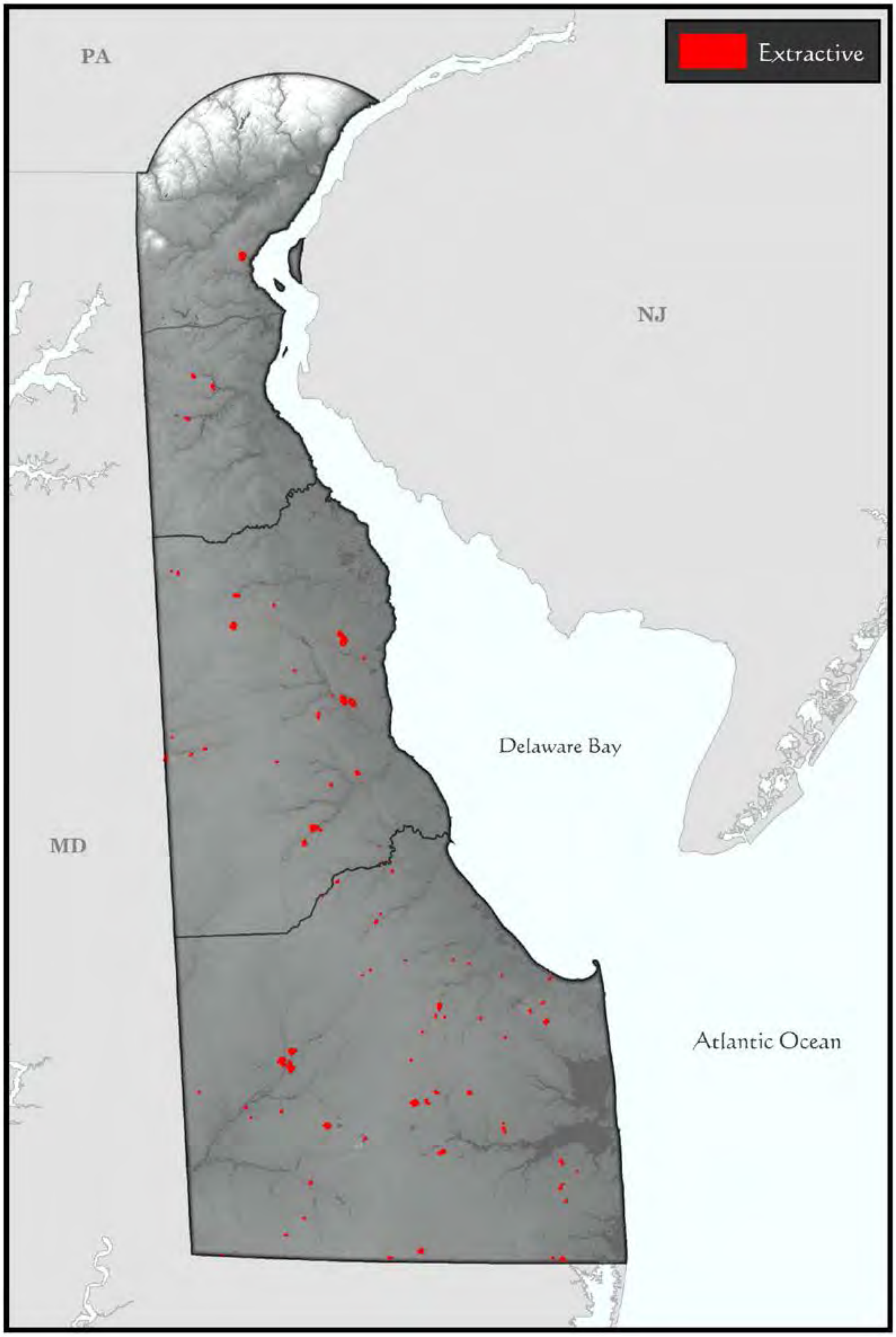
Map 2. 16 Commercial and Industrial. Source: 2012 Delaware Land Use/Land Cover.

Extractive

Land use devoted to sand and gravel extraction increased from 12,084 acres in 2002 to 22,927 acres by 2007, an increase of 89.7%, bringing this land use to just under 2% of the state's acreage. Some SGCN, such as bank swallow, are heavily dependent on extractive uses to provide habitat in Delaware.

Abandoned borrow pits from smaller sand and gravel removal operations may ultimately provide important wetland habitat for amphibians and odonates. Due to their nutrient-poor substrates, these areas may eventually be colonized by acidic bog species, as has been the case at Maryland's Idylwild Wildlife Management Area, just across the border from Bridgeville, Delaware. These anthropogenic wetland habitats are discussed in more detail under Borrow Pits in the Modified Wetlands section of this chapter. Modern sand and gravel operations, however, are heavily industrialized and operated at a much larger scale, so their potential to eventually provide important habitats for wetland species is likely limited.

Northeastern Terrestrial Wildlife Habitat Classification System: Macrogroup: Extractive, System: Quarries/Pits/Stripmines **Estimated Extent**: 1,816 acres



Map 2. 17 Extractive. Source: 2012 Delaware Land Use/Land Cover.

Wetland Habitats

Wetlands are perhaps Delaware's most significant natural feature, covering one-fourth of the state, with a total of approximately 320,000 acres. An estimated 47 percent of wetlands are located in Sussex County, 38 percent in Kent County, and 15 percent in New Castle County. Wetland habitats include a wide range of types – tidal, nontidal, freshwater, brackish, and saltwater, and include coastal wetland impoundments, vernal pools, Coastal Plain seasonal pond wetlands, peat wetlands, and Piedmont stream valley wetlands. Wetlands are found along the shores of the Delaware Bay and Inland Bays, along rivers, streams, and ponds, and in forests and fields throughout the state.

Delaware is one of only 16 U.S. states with greater than 50% loss of wetlands (Blann et al. 2009). The majority of these were freshwater wetlands that were lost to ditching, stream channelization, conversion to ponds, and filling for development. Tidal wetlands were also lost to filling for development, shoreline hardening, conversion to impoundments, and ditching for mosquito control or agricultural drainage. Fortunately, wetland regulations at both the state and federal levels have greatly curtailed these losses in the last several decades. Tidal wetland losses have slowed dramatically, but protection of isolated freshwater wetlands remains insufficient.

Delaware completed a Statewide Wetlands Mapping Project in 2007 in partnership with National Wetlands Inventory (NWI). This effort updated previous state wetland maps from 1992 and produced a Wetlands Status and Changes report (Tiner et al. 2011) for the entire state. The 2007 effort mapped 320,076 acres of wetlands across the state of Delaware, which included 62,291 acres of hydric soil map units that were naturally vegetated but did not exhibit a wetland signature on the aerial imagery, likely representing seasonally saturated wetlands.

Palustrine forested wetlands make up 64%of the state's wetlands. Estuarine emergent wetlands comprise 23 percent of the wetlands statewide. Forty-seven percent of Delaware's wetlands are located in Sussex County, 38%in Kent and 15%in New Castle County. Forty-two percent of Delaware's wetlands fall within the Delaware Bay Basin, 42%in the Chesapeake Basin, 14%in the Inland Bays Basin, and 2% in the Piedmont Basin (Tiner et al. 2011).

The majority of Delaware's wetlands are equally split between the Chesapeake Bay drainage basin (133,283 acres) and the Delaware Bay drainage basin (133,544 acres). An ecologically significant, but smaller fraction (44,098 acres) are within the Inland Bays drainage basin in Sussex County. Finally, about 2.6% of the state's wetlands (8,412 acres) are found in the Piedmont (Tiner et al. 2011).

Wetland Condition

Many wetlands in the state suffer from degradation caused by sedimentation, nutrient enrichment, and invasive plant species. These problems are exacerbated by insufficient natural buffers around many wetland blocks. Tidal wetlands, which constitute the great bulk of wetland blocks, are almost all threatened by sea level rise, especially given the lack of buffers to accommodate migration.

The Delaware Ecological Network (DEN) identified intact and ecologically important "core" wetlands in Delaware. Core wetlands comprised 53% of total wetland area in the state. Assuming a 10 m positional error, 760 of 880 (86%) wetland-dependent rare species or community Element Occurrences fell within core wetlands (Weber 2013).

The DNREC Wetland Monitoring and Assessment program is tasked with the job of assessing the health of Delaware's Wetlands. To complete this task, each summer season a field crew assesses the health of wetlands on a watershed level. They will complete the entire state and begin again by 2019. Completed Watershed Assessments to date include the Nanticoke (Jacobs and Bleil 2008); Inland Bays (Jacobs et al. 2009, Rogerson et al. 2009); St. Jones (Rogerson et al. 2010); Murderkill (Rogerson et al. 2011); Broadkill (Rogerson et al. 2013); and Christina (Jennette et al. 2014) watersheds (Figure 2.23).

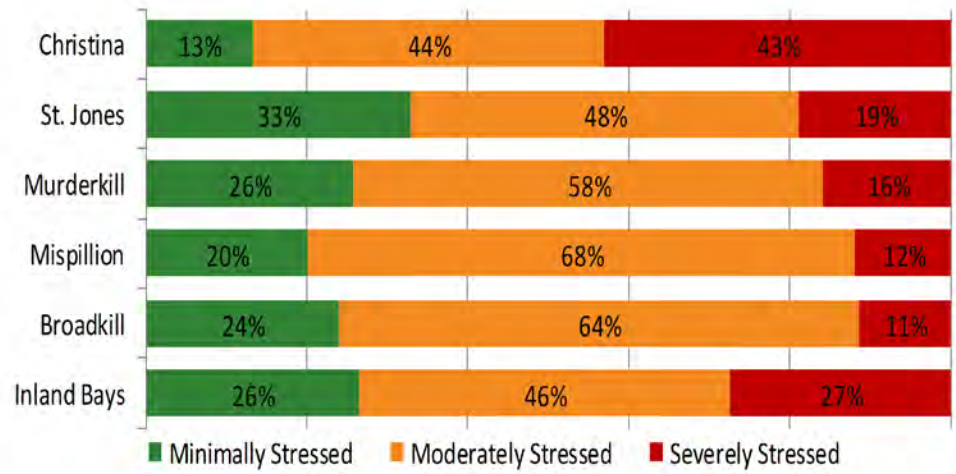


Figure 2. 23 Combined condition of tidal, tidal freshwater, flat, and riverine wetlands in the Christina, St. Jones, Murderkill, Mispillion, Broadkill, and Inland Bays watersheds.

The 2015 Delaware Wetland Conservation Strategy (DNREC 2015) was produced by DNREC and the Delaware Forest Service, updating the 2008 version and identifying seven main goals and related action items for improving wetland Delaware's wetland programs. The 2015 strategy highlights accomplishments over the last 7 years such as updating wetland maps, advancements in assessing the health of all wetland types, the development of methods to monitor natural and restored wetlands, and bringing awareness and appreciation through education and outreach.
However, Delaware remains the only Mid-Atlantic state with no state conservation program for freshwater wetlands;, many residents are unaware of the valuable services wetlands provide to the economy and our well-being; there is room to improve restoration techniques; and research is needed on how to protect our coastal systems from the threats of sea level rise.

The 2015 strategy was crafted with the input from a team of experts and lays out seven major goals and forty-one action items related to mapping, monitoring, restoration, conservation, education, collaboration, and climate adaptation. The leading agencies will revisit the strategy in 2020 to discuss accomplishments and determine new objectives.

Natural Non-tidal Wetlands

Delaware's non-tidal wetlands are critically important to SGCN. The following wetland habitats are natural or semi-natural non-tidal wetlands. For modified non-tidal wetlands, see Modified Wetlands.

Non-tidal Freshwater Wetlands

Non-tidal freshwater wetlands are by far the most abundant wetland type by acreage in Delaware, at just over 230,000 acres mapped (Tiner et al. 2011). These wetlands support a large percentage of the biological diversity and rare species found in Delaware. Though sea level rise is not as great a threat to non-tidal wetlands as tidal wetlands, significant loss of these habitats will occur. Thirty-three percent of non-tidal emergent wetlands, 8% of non-tidal forested wetlands, and 22% of non-tidal shrub wetlands would be inundated at 1.0 meter of sea level rise (Delaware Coastal Program 2012).

Piedmont Stream and River Floodplain

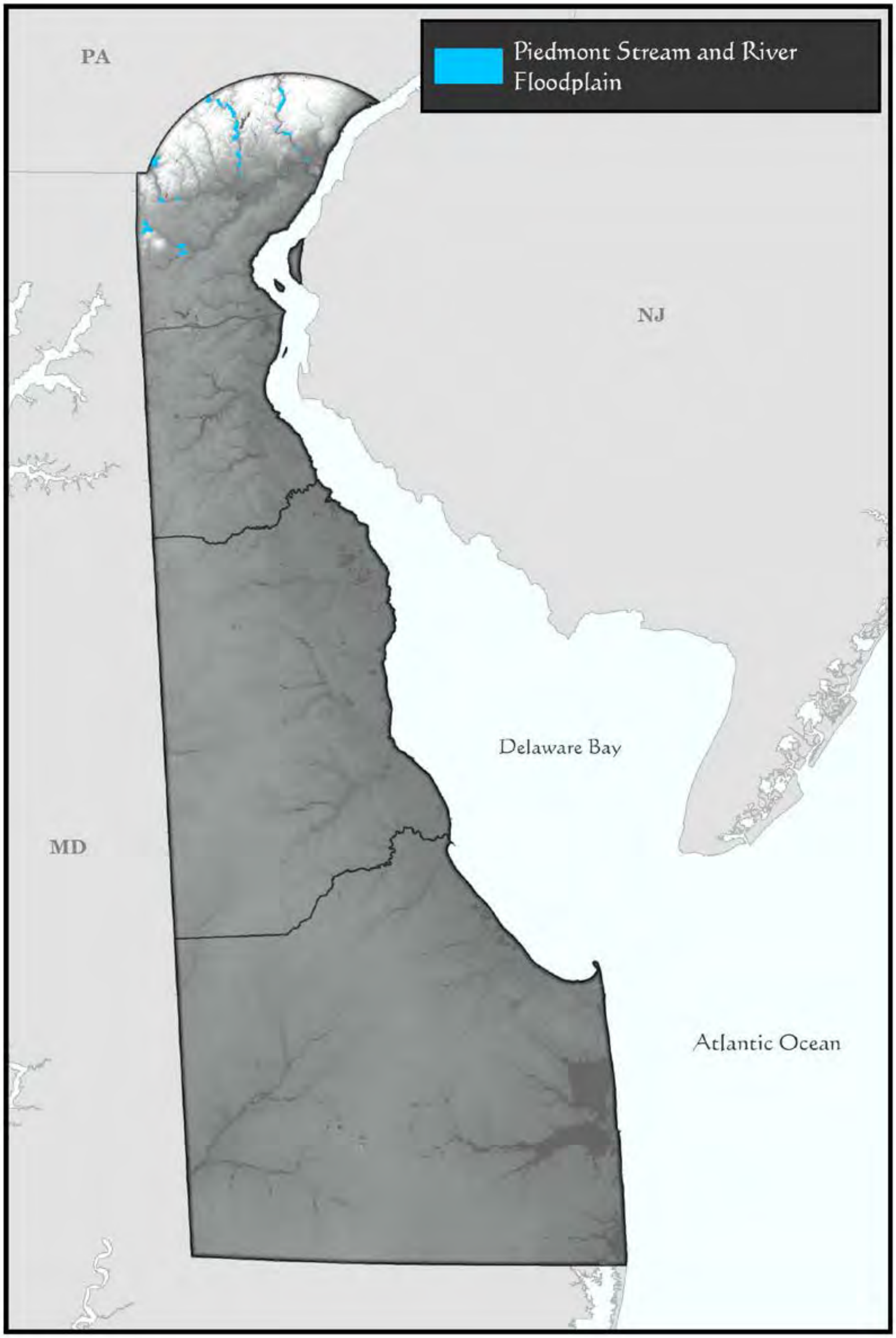
Intermittently flooded forests and woodlands of Piedmont stream and small river valleys, dominated by characteristic floodplain species like sycamore, silver maple, willow, ash, river birch, and box elder (Figure 2.24). This habitat is the matrix floodplain system within which small-patch habitats like Piedmont Seepage Swamps and Piedmont Seepage Meadows may be found.

Most of these floodplain habitats are generally not subject to direct loss as a result of residential development or other habitat conversion. Impacts to seepage wetlands from groundwater withdrawal, to streamside wetlands from changes in flow regimes, and to both types from nutrient enrichment are of concern over the long term. A number of Piedmont floodplains and streamside wetlands are heavily degraded by invasive plants. Disruption of natural hydrology and floodplain connections are common as a result of dams as well as accumulation of legacy sediments the in floodplain.

This habitat supports numerous SGCN, including breeding birds like cerulean warbler, warbling vireo, Louisiana waterthrush, and yellow-throated vireo. Temporary floodplain wetlands are important breeding sites for eastern newt and other amphibians. Numerous species of invertebrates are associated with this habitat, including moths, butterflies, odonates, and aquatic invertebrates.

Ecological System: Central Appalachian River Floodplain (CES202.608), Central Appalachian Stream and Riparian (CES202.609) **Estimated Extent:** 228 acres (DNREC DFW 2015) (Additional Mapping Needed)

Figure 2. 24 Piedmont Stream and River Floodplain along White Clay Creek. Photo: William A. McAvoy



Map 2. 18 Piedmont Stream and River Floodplain

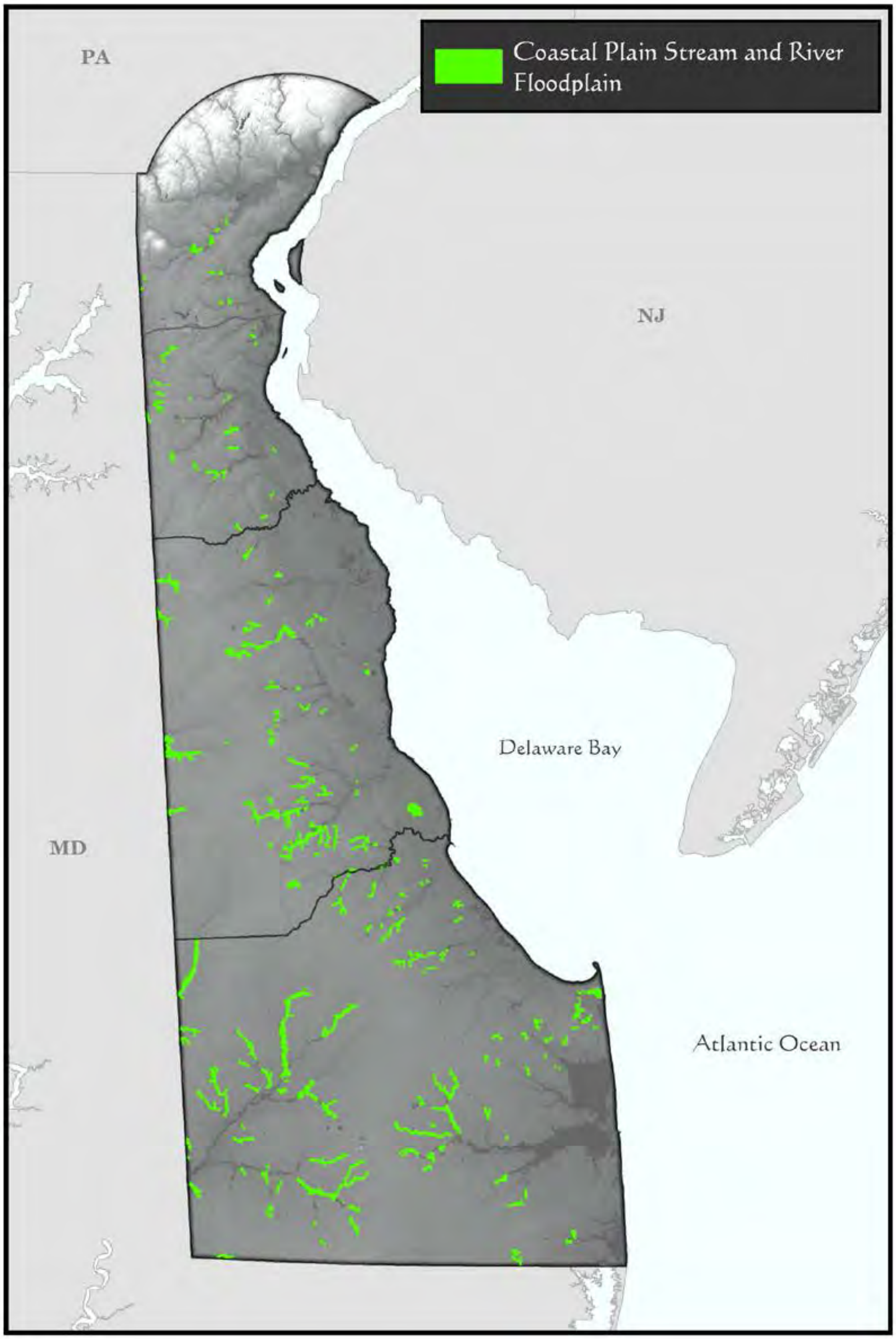
Coastal Plain Stream and River Floodplain

Intermittently flooded habitat mosaics of low-gradient coastal plain floodplains, supporting canopy species of green ash, swamp gum, and red maple (Figure 2.25). These habitats support numerous riparian forest-dependent SGCN, including Louisiana waterthrush, Kentucky warbler, prothonotary warbler, yellow-throated warbler, and yellow-throated vireo. Breeding amphibians in these habitats include marbled, spotted, and mud salamander.

Primary threats to these habitats include nutrient enrichment and eutrophication, and hydrological alteration due to ditching and drainage. Protection of pristine examples and restoration of degraded sites are high priorities for conservation of SGCN.

Ecological System: Northern Atlantic Coastal Plain Riverine Peat Swamp (CES203.070) **Estimated Extent:** 10,830 acres (DNREC DFW 2015)

Figure 2. 25 Coastal Plain Floodplain at Cow Bridge Branch. Photo: William A. McAvoy



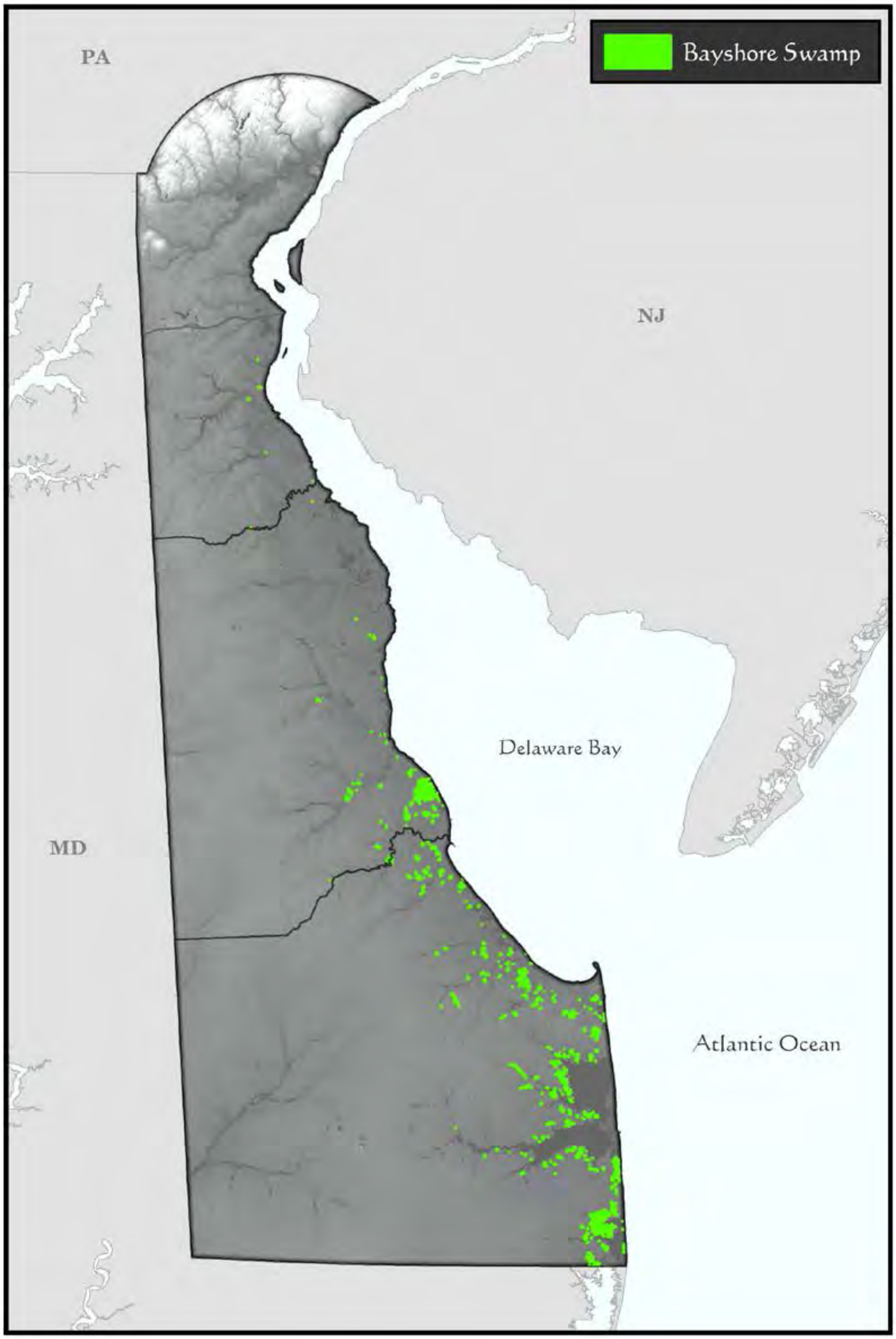
Map 2. 19 Coastal Plain Stream and River Floodplain

Bayshore Swamp

This habitat includes freshwater forested or shrub-dominated wetlands of back-dune depressions and low-lying flats bordering tidal marsh. It is typically dominated by red maple in the canopy, bayberry, chokeberry, highbush blueberry, and sweet pepperbush in the shrub layer, and ferns and sedges in the herbaceous layer. Back-dune depressions of barrier islands and low-lying flats bordering tidal marsh of estuaries further inland are characterized by a dominance of loblolly pine and a saturated hydrology. These fringing pine forests are nearly level and may contain areas of standing water. These habitats are important for many SGCN, including as stopover habitat for Neotropical migrant songbirds.

This habitat is limited in distribution and is highly threatened by saltwater intrusion and sea level rise.

Ecological System: Northern Atlantic Coastal Plain Maritime Forest (CES203.302) (in part)
Estimated Extent: 4,175 acres (DNREC DFW 2015)



Map 2. 20 Bayshore Swamp

Piedmont Seepage Swamp

These forested seepages on floodplains and lower slopes of the Piedmont are characterized by typical dominance of skunk cabbage and occur where groundwater reaches the surface at the bases of slopes in valleys and along floodplains (Figure 2.26). This is a small-patch habitat within the larger Piedmont Stream and River Floodplain system. In the Maryland Piedmont, shallow seepages known as "hypotelminorheic" habitats have been found to support unique assemblages of invertebrates, including previously undescribed species (Culver et al. 2012). The presence of similar shallow groundwater habitats in Delaware is to be expected. Threats to Piedmont seepage swamps are primarily associated with development of adjacent uplands and include excess inputs of nutrient and sediments, invasive plant species, and loss of sufficient upland buffer to support SGCN.

Ecological System: North-Central Appalachian Acidic Swamp (CES202.604) **Estimated Extent:** 358 acres (Anderson et al. 2013a) **Habitat of Conservation Concern**

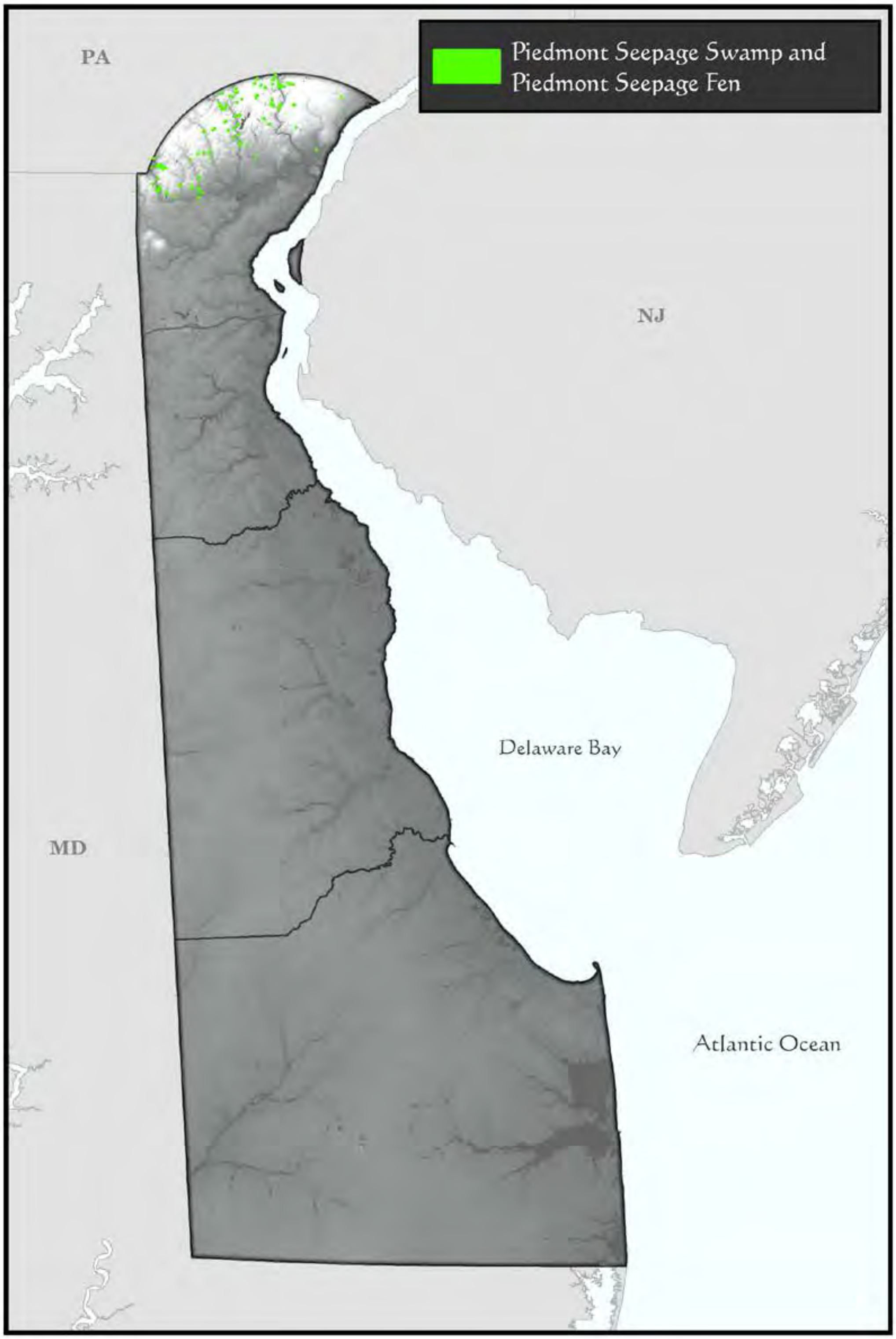
Figure 2. 26 Piedmont Seepage Swamp. Photo: William A. McAvoy

Piedmont Seepage Meadow

Open, graminoid-dominated meadows scattered throughout low stream valleys of the Piedmont (Figure 2.27). These wetlands develop where groundwater seepage flows from the base of steep slopes in stream valleys and along floodplains. They are usually open and sunny, but often have a patchy distribution of shrubs and occasional trees. They typically support a diverse suite of grasses, sedges, rushes, and broadleaf herbs. Piedmont seepage meadows are the primary habitat for the federally threatened bog turtle and they support a variety of state-rare SGCN, especially butterflies and moths. Threats to this habitat include sediment and nutrient inputs, invasive plants such as reed canary-grass, and isolation of this already patchy habitat by intervening development.

Ecological System: Laurentian-Acadian Wet Meadow-Shrub Swamp (CES201.582) (in part)
Estimated Extent: 57 acres (DNREC DFW 2015) **Habitat of Conservation Concern**

Figure 2. 27 Piedmont Seepage Meadow. Photo: William A. McAvoy



Map 2. 21 Piedmont Seepage Meadow

Karst

Karst landscapes are created where water flow dissolves layers of soluble rocks such as limestone, dolomite and gypsum, creating sinkholes, caves, and underground drainage systems. While not strictly a wetland, this habitat is included here because of its potential relationship to groundwater-influenced wetlands and seepage springs. A small and poorly known area of karst geology occurs in the Hockessin Valley of Delaware, where weathered Cockeysville dolomite marble has dissolved enough to store groundwater (Talley 1981). The Cockeysville marble is estimated to be 400 to 800 feet thick, with weathered depth to 150 feet or more based on quarry exposures (Plank et al. 2000). The subterranean groundwater habitats of this system have never been surveyed, and may host rare assemblages of aquatic subterranean-adapted invertebrates, known as stygobionts. Both deep karst aquatic habitats and shallow (typically less than 10 m below the surface) "epikarst" habitats may host assemblages of amphipods, isopods, and other invertebrates (Culver and Pipan 2014). Impacts to this system include water withdrawal for residential wells, contamination of the aquifer, and reduced recharge and nutrient leaching to the epikarst due to increases in impervious surface cover.

Northeast Terrestrial Wildlife Habitat Classification System: Modifier: Karst **Estimated Extent:** 960 acres (estimated based on Talley 1981)

Coastal Plain Seepage Swamp

These are forested, groundwater-fed wetlands that occur where seepage flows from the base of moderate slopes within narrow stream corridors (Figure 2.28). Red maple, swamp chestnut oak, sweetbay magnolia, sweet pepperbush, highbush blueberry, and a suite of sedges, particularly in the genus *Carex*, are often found. Black ash seepage swamps, a rare plant community in Delaware, are included in this group. Numerous SGCN of coastal floodplain forests use this habitat type, with some species, such as mud salamander, relying primarily on forested groundwater seepage habitats. Threats to this habitat are similar to those for Coastal Plain Stream and River Floodplain.

Ecological System: (in part) North-Central Interior and Appalachian Rich Swamp (CES202.605)

Estimated Extent: 31 acres (DNREC DFW 2015) **Habitat of Conservation Concern**

Figure 2. 28 Coastal Plain Black Ash Seepage Swamp. Photo: William A. McAvoy

Coastal Plain Seepage Fen

Coastal Plain seepage fens are rare, open habitats characterized by groundwater seepage through acidic, sandy, or gravelly soils along margins of headwater coastal plain streams, at the base of slopes, and in artificially created or maintained settings such as millpond edges, power line ROWs and abandoned sandpits. The typically small openings often support pitcher plants, orchids, and a diverse array of sedges (Figure 2.29). An extremely globally rare community, twig rush peat mat, also known as a Delmarva poor fen (Harrison and Knapp 2010) is known only from two sites in Delaware and two in Maryland. This community is dominated by twig rush and supports a large number of rare plants. These habitats are threatened by encroaching tree canopy, eutrophication, hydrological changes, and in some cases sea level rise.

Ecological System: (in part) Northern Atlantic Coastal Plain Basin Peat Swamp (CES203.522)
Estimated Extent: 33 acres (DNREC DFW 2015) **Habitat of Conservation Concern**

Figure 2. 29 Coastal Plain Seepage Fen. Photo: William A. McAvoy

Sea Level Fen

Sea-level fens (Figure 2.30) are globally rare wetlands associated with higher landscape positions in tidal salt marsh and shrubland systems. These small seepage wetlands develop at the upland edge of salt marshes where abundant groundwater discharges at the bases of gentle slopes. The hydrology of these sites are best characterized as saturated, although shallow standing water and small, muck-filled pools are locally present at most sites. The soils are organic and extremely nutrient-poor. Because of the freshwater groundwater seepage the vegetation of these features exhibit characteristics of both inland acidic seepage bogs and oligohaline tidal marshes. Stands are generally a physiognomic mosaic of open woodland, scrub, and herbaceous patches. Some Delaware SGCN, including the odonates seepage dancer and elfin skimmer, are found nowhere else in the state. Sea-level fens are globally rare natural communities threatened by sea-level rise, encroachment of non-native species (e.g., phragmites, *Phragmites australis* subsp. *australis)*, and excessive nutrient input via agricultural runoff. Examples have already been lost due to sea level rise.

Figure 2. 30 Sea Level Fen. Photo: William A. McAvoy

Ecological System: *Northern Atlantic Coastal Plain Tidal Salt Marsh* (CES203.519) (in part). Sea level fens are considered to be within this ecological system, but they are treated as a distinct habitat here due to their extreme rarity and unique species associations. In addition, despite their landscape position, they are classified here with non-tidal freshwater wetlands on the basis of their groundwater-driven hydrology. **Estimated Extent:** 6 acres (DNREC DFW 2015) **Habitat of Conservation Concern**

Coastal Plain White Cedar Peat Swamp

Known at present only from southern Delaware, these wetlands are characterized by stands of Atlantic white cedar on poorly drained, mucky soils along slow-flowing streams and at the headwaters of millponds (Figure 2.31). They feature hummock and hollow microtopography, with cedars often growing on hummocks. Numerous rare plant species, such as swamp pink, pitcher plant, and orchids, may be found in the herbaceous layer of some types. Other tree species present may include red maple and swamp black gum.

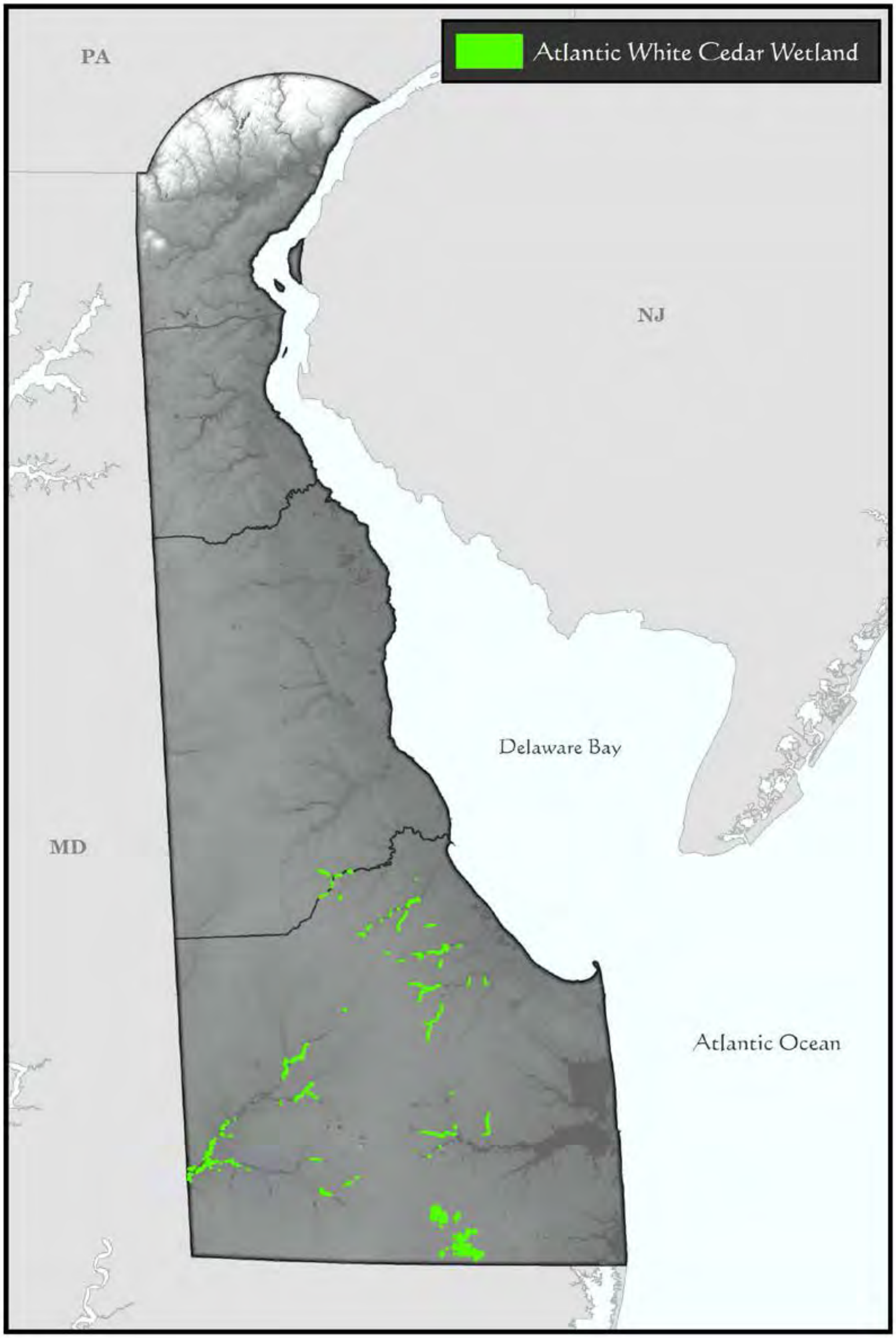
Figure 2. 31 Coastal Plain White Cedar Swamp. Photo: William A. McAvoy

The current distribution of Atlantic white cedar wetlands is primarily restricted to one major (Nanticoke River) and several minor drainages in Sussex County (e.g., Mispillion River, Cedar Creek, Broadkill River, and several streams emptying into the Inland Bays), with a few additional sites in Kent County. Historically, Atlantic white cedar wetlands were much more extensive in the state, comprising a portion of Sussex County's Great Cypress Swamp, and dominating the Cedar Swamp Wildlife Area at the edge of the Delaware Bay in New Castle County until a hurricane in 1878 breached the barrier beach (Fleming 1978).

Beginning more than 200 years ago, timber harvest and wetland draining for agriculture eliminated most of these swamps. With the near-cessation of Atlantic white cedar logging in the last century, this habitat is in relatively stable condition at present. However, natural regeneration of white cedar is often inhibited by competition from red maple and other hardwoods that are presently more common than in the past, probably due to fire suppression and deer browse. Also, as with other forested wetlands discussed above, loss of buffers is resulting in some short term impacts from sediment and nutrient runoff, and will exacerbate long term impacts from sea level rise.

Atlantic white cedar is the host plant for the globally rare butterfly, Hessel's hairstreak, and this habitat is also the primary habitat for the rare firefly *Photuris mysticalampas*.

Ecological System: *Northern Atlantic Coastal Plain Basin Peat Swamp* (CES203.522), *Northern Atlantic Coastal Plain Stream and River* (CES203.070) (in part) **Estimated Extent:** 4,272 acres (DNREC DFW 2011) **Habitat of Conservation Concern**



Map 2. 22 Coastal Plain White Cedar Peat Swamp

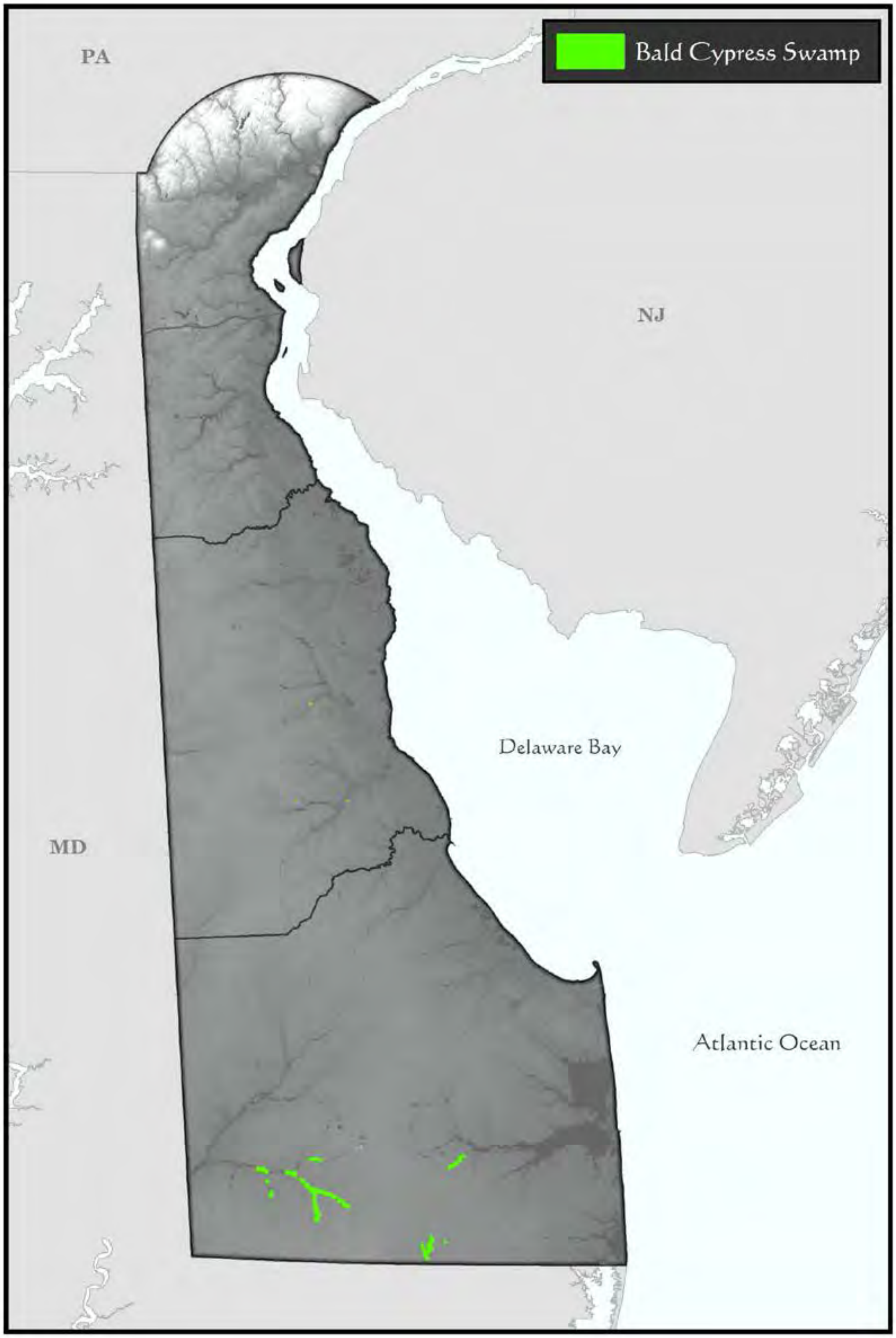
Bald Cypress Swamp

Bald cypress reaches the northern limit of its range in Delaware, where it occurs in both tidal and non-tidal wetlands, primarily on seasonally inundated floodplains (Figure 2.32). It is often an emergent canopy tree, with a sub-canopy of red maple, swamp black gum, and green ash, and this swamp type serves as habitat for various species including the Eastern red bat, Louisiana waterthrush, Kentucky warbler, marbled salamander, and prothonotary warbler.

Figure 2. 32 Bald Cypress Swamp. Photo: William A. McAvoy

Bald cypress is the host plant for the cypress looper moth and the cypress sphinx moth. The latter species has not yet been identified in Delaware, but is found in association with bald cypress throughout the southeast and is state listed in Maryland and Virginia.

Ecological System: *Northern Atlantic Coastal Plain Stream and River* (CES203.070) (in part) **Estimated Extent:** 784 acres (DNREC DFW 2011) **Habitat of Conservation Concern**



Map 2. 23 Bald Cypress Swamp

Coastal Plain Flatwood and Depression Swamp

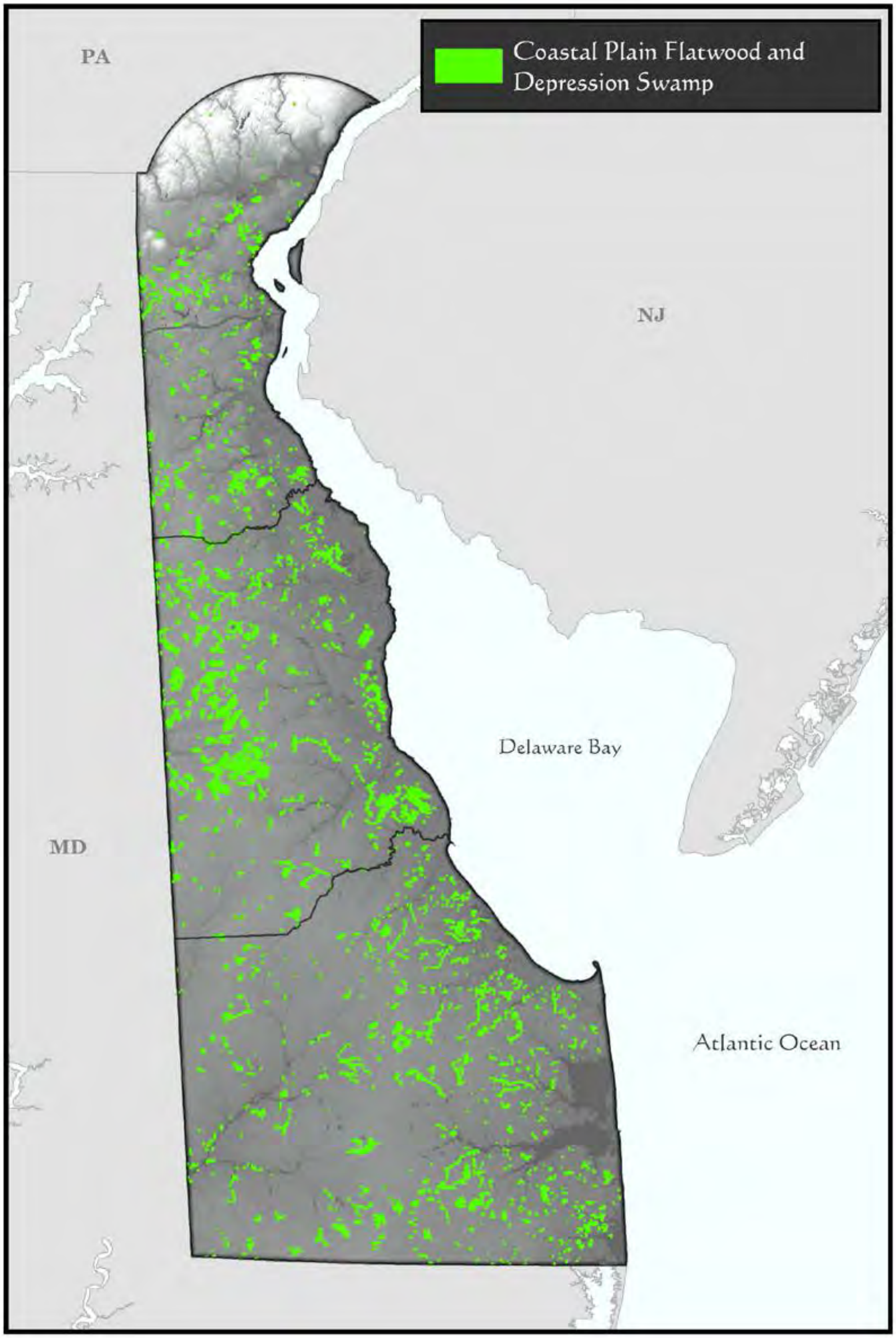
Forested swamps and flatwoods of poorly drained, relatively shallow depressions that are often groundwater-influenced, but are also often configured in large patches along streams and rivers, especially in headwater settings (Figure 2.33). They occur on mineral soils overlain by a variable organic but non-peaty layer. Characteristic tree species include red maple, sweet gum, swamp black gum, willow oak, and green ash.

Delaware has high responsibility for this habitat in the Northeast, with 16% of the modeled acreage for the region (Anderson et al. 2013a). Forest inventory data for the Northeast indicates that almost all of these forests have been harvested in the past century, with over 80% less than 60 years old (Anderson et al. 2013a).

These wetland forests are important habitat for a wide array of SGCN, including plain-bellied watersnake, spotted turtle, four-toed salamander, and hooded and Swainson's warblers, among many others. Threats to this habitat include timber harvest, draining, and development, since the isolated wetlands within this habitat are not protected by state wetland regulations.

Ecological System: *Northern Atlantic Coastal Plain Basin Swamp and Wet Hardwood Forest* (CES203.520) **Estimated Extent:** 66,490 acres (DNREC DFW 2015)

Figure 2. 33 Coastal Plain Flatwood and Depression Swamps feature depressional wetlands in a forested matrix. Photo: William A. McAvoy



Map 2. 24 Coastal Plain Flatwood and Depression Swamp

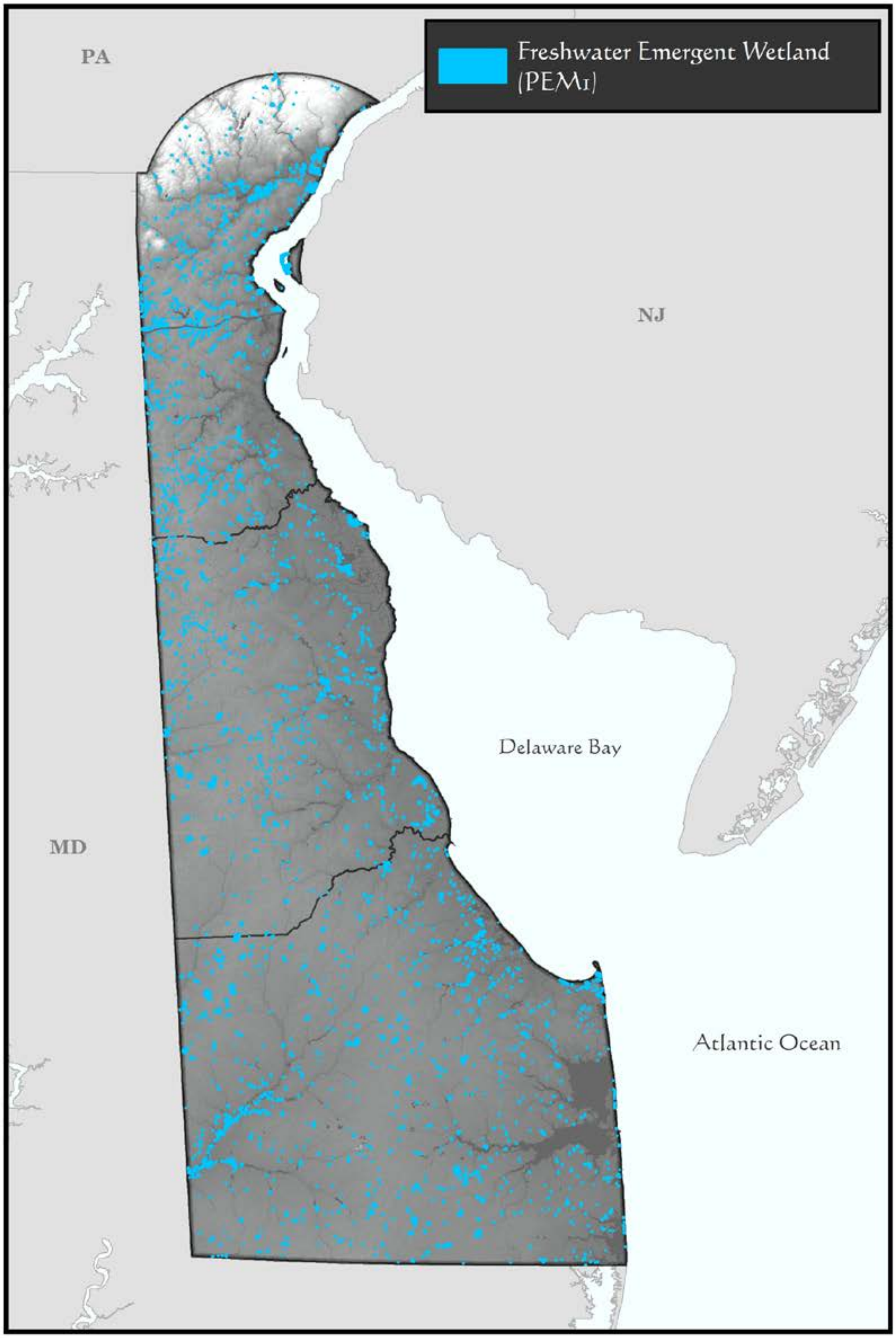
Emergent Freshwater Marsh

Herbaceous freshwater marshes that occur in closed or open basins are generally flat and shallow (Figure 2.34). They are associated with lakes, ponds, slow-moving streams, and/or impoundments or ditches and are generally permanently or semi-permanently flooded. Typical plants include cattails, marsh fern, touch-me-not, pondweeds, water lilies, pickerelweed, and rushes, species that tolerate sustained inundations and do not persist through the winter. King rail, least bittern, marsh wren, Northern pintail, herons, waterfowl, and many other species inhabit these marshes.

Because this habitat is broadly defined in terms of vegetation composition and landscape setting, it potentially overlaps with other habitats defined in this Plan. Essentially any freshwater emergent marsh in a non-tidal basin setting falls into this category. Thirty-three percent of non-tidal Emergent Wetlands would be inundated with 1.0 meter of sea level rise (Love et al. 2012).

Ecological System: *Laurentian-Acadian Freshwater Marsh* (CES201.594) **Estimated Extent:** 6,440 (DNREC/NWI 2007)

Figure 2. 34 Emergent Freshwater Marsh Photo: William A. McAvoy



Map 2. 25 Emergent Freshwater Marsh.

Freshwater Shrub Swamp

Shrub-dominated freshwater wetlands occurring in a variety of settings, often associated with impoundments, ponds, and other artificial settings, which are permanently or semi-permanently flooded. Smooth alder is often the dominant shrub. This is a dynamic system that may return to marsh in beaver- or artificially-impounded areas or succeed to wooded swamp with sediment accumulation or water subsidence. Twenty-two percent of non-tidal shrub wetlands would be inundated with 1.0 meter of sea level rise (Love et al. 2012).

These wetlands are important habitats for several SGCN, including rusty blackbird, hooded merganser, great blue heron, spotted turtle, Eastern ribbonsnake, and great purple hairstreak. Threats to this habitat include eutrophication from adjacent land uses, loss of upland buffer, and hydrological alteration.

Ecological System: Laurentian-Acadian Wet Meadow-Shrub Swamp (CES201.582) (in part)
Estimated Extent: 1,592 (DNREC DFW 2015)

Ephemeral Non-tidal Wetlands

Vernal Pools

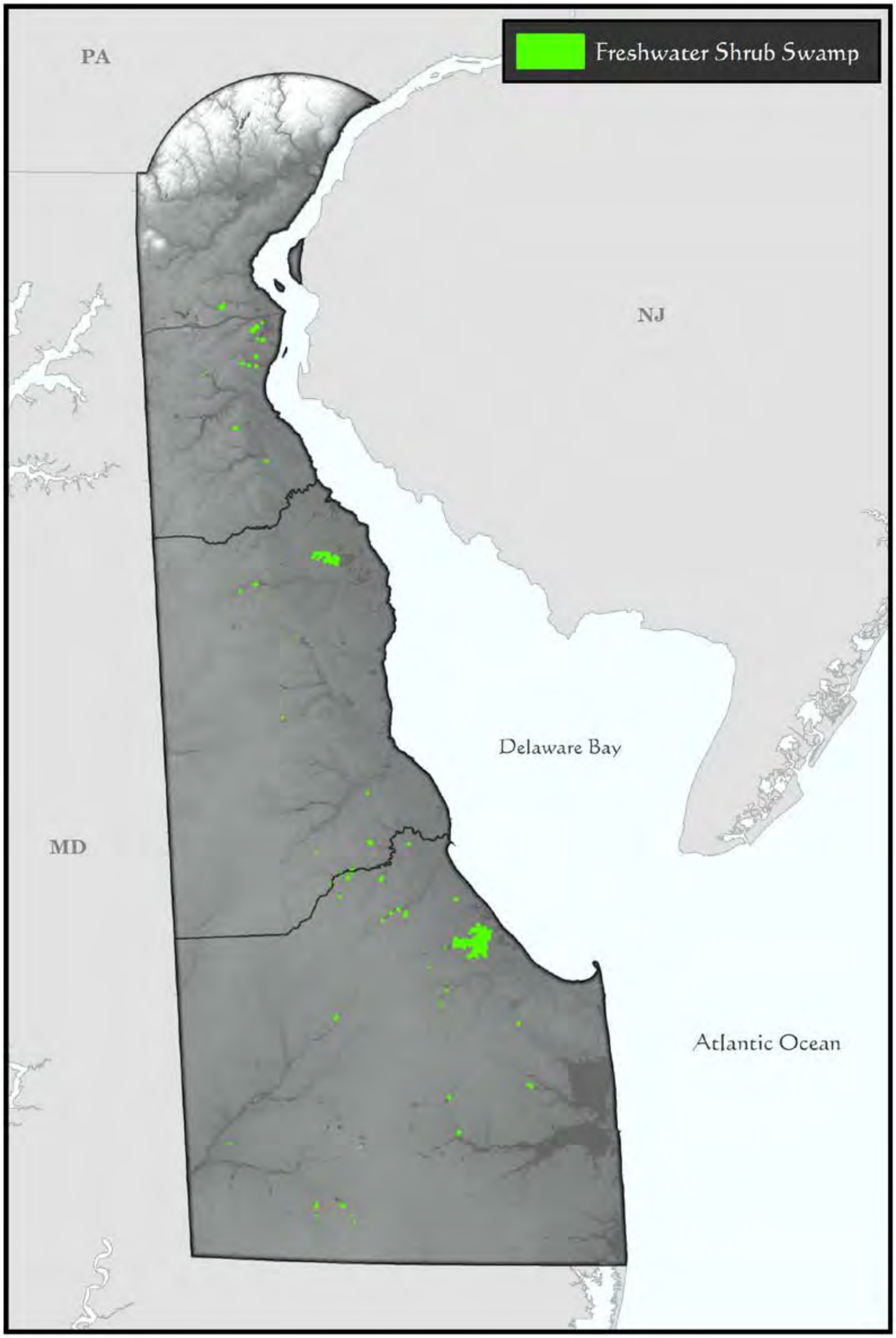
These small, ephemeral wetlands occur as small-scale features in forested systems and are thus treated in the DEWAP habitat data structure as a "microhabitat feature." Efforts are currently underway by DNREC DFW to develop methods to map Delaware's vernal pools.

Vernal pools differ from Coastal Plain Seasonal Ponds by being much smaller in size, shallower, and often have a closed canopy. They also have a much shorter hydro-period then the larger, deeper Coastal Plain Seasonal Ponds. Due to their closed canopies, they are usually devoid of herbaceous vegetation.

Vernal pools provide critical habitat for several species of breeding amphibians, including spotted salamander, marbled salamander, and wood frog. Water beetles are diverse and important inhabitants of vernal pools. The SGCN predaceous diving-beetle *Agabetes acuductus* is found in leaf litter at the bottom of forested vernal pools (Colburn 2004). A handful of very small, shallow, forested vernal pools are the only known habitat for the highly imperiled Seth Forest water scavenger beetle (*Hydrochus spangleri*) (McIntosh and Short 2012).

The primary threats to vernal pools are direct loss due to development of the forest matrix within which they occur as well as adjacent upland buffers.

Ecological System: multiple **Estimated Extent:** Unavailable



Map 2. 26 Freshwater Shrub Swamp

Coastal Plain Seasonal Ponds

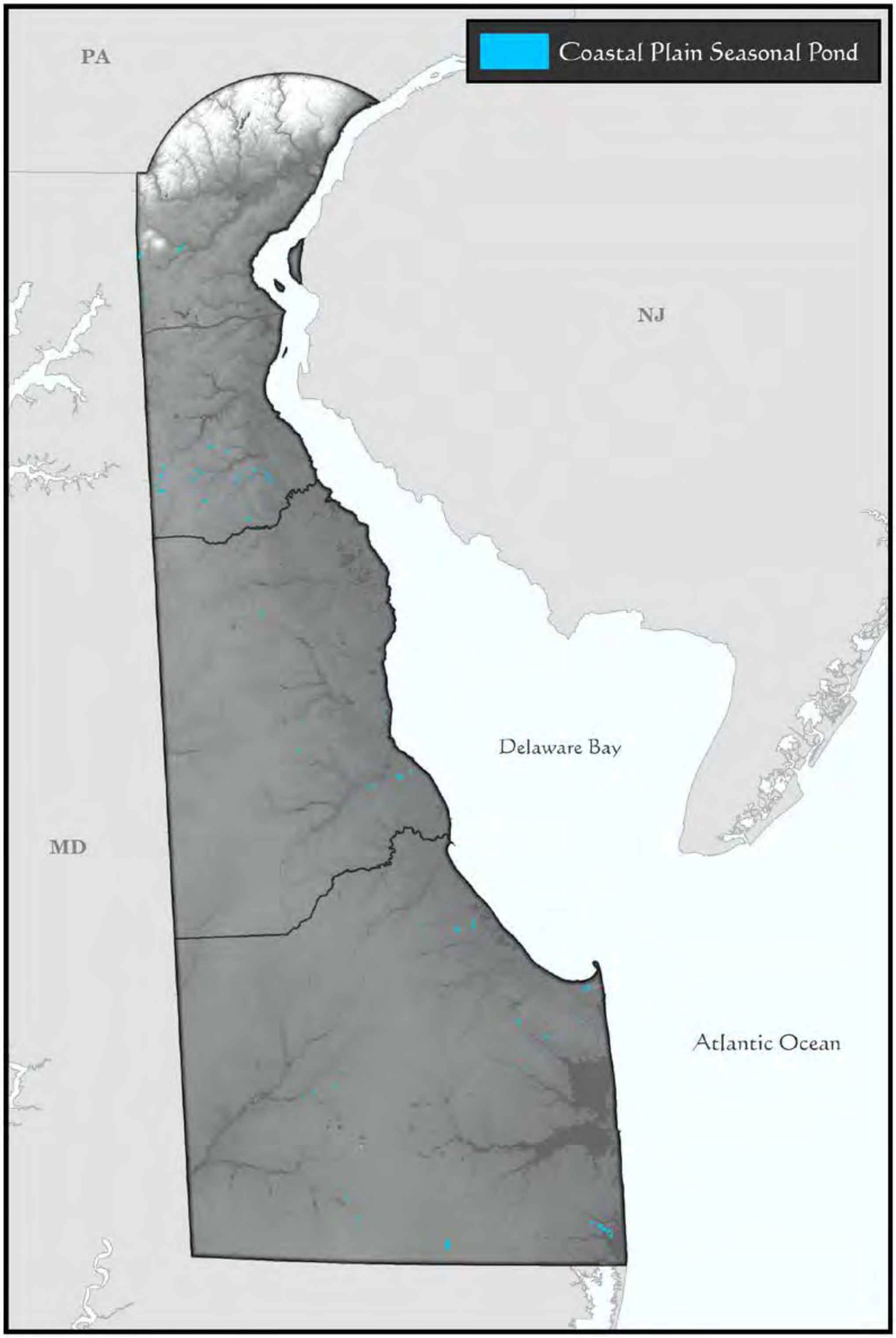
More than 1,000 of these small depressional wetlands, typically flooded by groundwater and precipitation in the winter and spring but dry in the summer and fall, are scattered throughout the Coastal Plain province of the state (Figure 2.35). It is thought that they may have been formed some 15,000 – 20,000 years ago as wind-blown depressions in what were then sandy dune areas (Stolt and Rabenhorst 1987b). The majority of these ponds are small (most less than one acre), but they often occur in groups or complexes that may share a common groundwater source and among which pond-dwelling animal species freely travel. Although the ponds naturally occur imbedded in a forest matrix, they usually contain only herbaceous and shrub vegetation within their boundaries. Because Coastal Plain seasonal ponds are not permanent bodies of water, they do not support fish. For this reason they are important breeding locations, sometimes the only locations, for a number of frogs and salamanders that inhabit the surrounding forest. Over 30 rare plant species are found in these ponds, including five that are globally rare (McAvoy and Bowman 2002). Coastal plain seasonal ponds are typically quite acidic , and may be of either a "basin-fill" type that is deeper and less sandy, or a "sandy-bottom," shallower type (Stolt and Rabenhorst 1987a).

Delaware's Coastal Plain Seasonal Ponds were mapped by Zankel and Olivero (1999). A status assessment in the Blackbird-Millington corridor (Bowman et al. 2005) determined that many pond complexes in this area (which has the largest concentration of ponds in the state) are in relatively good condition, based on pond density and forest buffer. This is due, at least in part, to the protection of some ponds on state forest lands. However, hundreds of other ponds elsewhere are not in conservation ownership and have been significantly impacted by draining, tilling, loss of forest buffers and invasive plant species. A statewide analysis of Coastal Plain ponds found that about 25% of pond habitat is surrounded half or less by a forested buffer adequate for the conservation of typical pond-breeding salamanders; less than 20% are completely surrounded by such a buffer.

Fluctuating groundwater levels are the driving force behind the ecology of Coastal Plain seasonal ponds. The effect on pond hydrology of groundwater withdrawals for drinking water and crop irrigation is uncertain, although there is substantial pumping for irrigation in the vicinity of many ponds. Even in locations where hydrology is intact, the need to conserve ponds in large complexes interconnected by extensive forests complicates protection efforts on both public and private property.

Ecological System: *Northern Atlantic Coastal Plain Pond* (CES203.518) **Estimated Extent:** 1,013 acres (DNREC DFW 2011) **Habitat of Conservation Concern**

Figure 2. 35 Coastal Plain Seasonal Pond in early spring (above) and late summer (below). Photo: William A. McAvoy



Map 2. 27 Coastal Plain Seasonal Pond

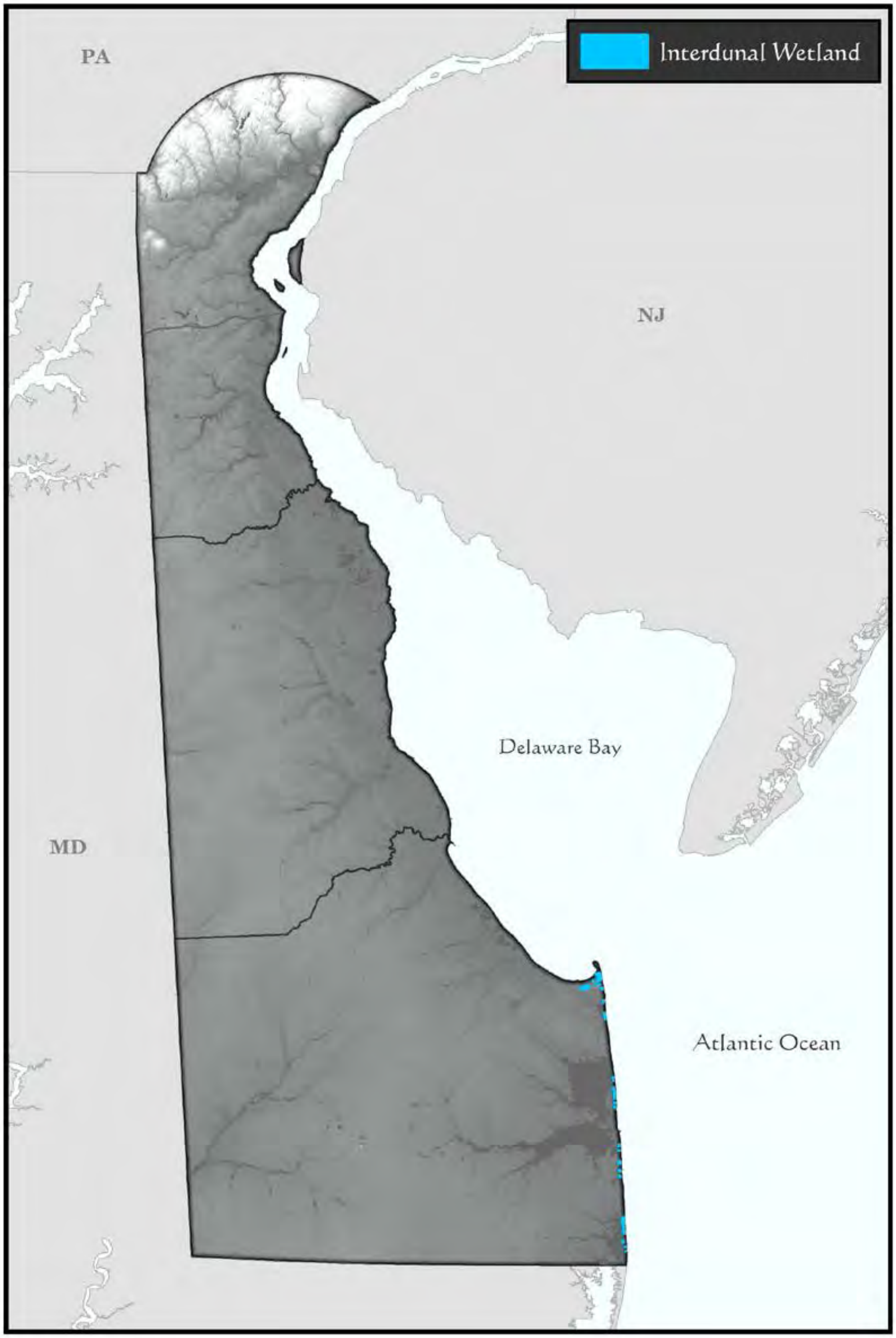
Interdunal Wetlands

These small wetlands occur in low, shallow depressions behind primary dune ridges along the Atlantic Coast (Figure 2.36). They are typically less than one acre in size, and are often irregularly shaped. Despite their proximity to the ocean, their seasonal flooding is driven by groundwater and precipitation. As dynamic as many other beach and dune habitats, these swales are periodically created or destroyed by major storms. Some types have purely herbaceous vegetation, while others are dominated by shrubs. More than 20 species of rare plants are found in these wetlands.

At present most of these habitats are relatively stable, and the great majority are protected on state parkland. Most of those not on state land have been degraded by loss of upland buffers, changes in hydrology and invasive plants, all of which result from encroaching residential development. Impacts from sea level rise, made worse by disturbance of normal coastal processes, could be substantial. Note that although interdunal wetlands are part of a very dynamic coastal ecosystem, their recovery from disturbance – including sea level rise – is believed to be fairly slow. Eighty-one percent of interdunal wetland acreage would be inundated at 1.0 m of sea level rise (Love et al. 2012). Interdunal wetlands are the only habitat for the globally imperiled Bethany Beach firefly.

Ecological System: *(in part) Northern Atlantic Coastal Plain Dune and Swale (CES203.264)*
Estimated Extent: 162 acres (DNREC DFW 2011) **Habitat of Conservation Concern**

Figure 2. 36 Interdunal Wetland. Photo: William A. McAvoy



Map 2. 28 Interdunal Wetland

Modified Wetlands

Modified Freshwater Wetlands and Lentic Habitats

A variety of human-modified wetland habitats occur in Delaware. While these habitats may not serve the same ecological functions as natural wetlands, they are nevertheless important to various SGCN. Because these modified lentic water bodies serve as "catch basins" for pollutants, nutrients, and sediments from the surrounding area, they are especially susceptible to water quality impairment. DNREC has found that 74% of Delaware's fresh water ponds and lakes do not fully support the fish and wildlife designated use as defined by water quality criteria (DNREC 2013).

Lakes and Reservoirs

Since the state was not glaciated, Delaware's lakes are all man-made. In the Piedmont, two reservoirs, Newark Reservoir and Hoopes Reservoir (Figure 2.37), provide deepwater lotic habitat used by a variety of species, particularly migratory and wintering waterfowl. A Delmarva Ornithological Society survey of Hoopes Reservoir found 187 species using the reservoir and surrounding forest. Delaware SGCN that use these habitats include American black duck, red-throated and common loons, horned and pied-billed grebes, and other waterfowl, primarily during migration and winter (Falk 1971, Sarver pers. obs.).

Water depth in the 192-acre Hoopes Reservoir reaches a maximum of 100 feet and it is classified as a warm, mesotrophic, medium alkalinity lake (Olivero-Sheldon et al. 2014). Hoopes Reservoir was constructed in 1932. Completed in 2006, the recently-constructed, 317-million gallon Newark Reservoir pumps water from the White Clay Creek into a 30-acre basin, with a maximum depth of 56 feet.

Northeast Terrestrial Wildlife Habitat Classification: Ponds, Lakes and Reservoirs **Estimated Extent:** 222 acres

Figure 2. 37 Hoopes Reservoir, Greenville, Delaware. Photo: Jim White

Small Ponds

Farm ponds and other small man-made ponds or small impoundments that contain fish and are thus unsuitable for species that rely on ephemeral or fishless wetlands. These habitats are of some value as supplemental habitat for SGCN, but are often subject to stressors from the surrounding environment, including eutrophication, low dissolved oxygen, and algal blooms.

Northeast Terrestrial Wildlife Habitat Classification: Ponds, Lakes and Reservoirs **Estimated Extent:** Unavailable

Borrow Pits/Fishless Ponds

Often the result of small-scale or isolated sand, gravel, or fill removal, these are small, usually sandy-bottomed, artificial ponds that are not colonized by predatory fish and are often very important habitats for breeding odonates and amphibians, including SGCN such as comet darner, Eastern spadefoot, carpenter frog, and others. For many very rare odonates, such as Martha's Pennant, the only known records in the state are from this habitat. Threats include eutrophication and invasive plants.

Northeast Terrestrial Wildlife Habitat Classification: N/A **Estimated Extent:** Unavailable

Mill Ponds

A characteristic feature of Delaware's Coastal Plain are the many "millponds," coastal plain streams that have been dammed to create large lentic habitats (Figure 2.38). The creation of these millponds meant destruction of important coastal plain forested wetlands and floodplain habitats, including in some cases rare habitats such as Atlantic white cedar wetlands. However, the created mill ponds are now popular fishing and recreation destinations. Some 36 ponds, ranging in size from 5 to 189 acres, are owned and managed by the Delaware DFW. These ponds are routinely surveyed every five years by electrofishing. Some rare natural communities occur at millpond fringes, and these communities support several SGCN insects as well as freshwater mussel species.

The dams at the downstream end of mill ponds create barriers to fish passage for diadromous fish, and will also prevent future inland migration of freshwater tidal wetland habitats.

Northeast Terrestrial Wildlife Habitat Classification: Ponds, Lakes, and Reservoirs **Estimated Extent:** 3,790 acres

Figure 2. 38 Fleetwood Pond. Photo: Rob Gano

Dredge Spoil Disposal Areas

Dredge disposal areas can be significant habitats for a variety of bird species. The Dredged Material Containment Areas (DCMAs) of the Savannah Harbor Confined Disposal Facility (CDF) in coastal South Carolina hosted over 1,663,000 individual birds of 299 species over 19 years of survey effort, including large numbers of migrating and wintering waterfowl, shorebirds, and other waterbirds, as well as species of conservation concern (J.S. Calver, personal communication). Locally, a Delmarva Ornithological Society survey of the disposal facility adjacent to the Port of Wilmington found that between May 1995 and October 1996, the 225-acre spoil area was used by 29 species of shorebirds (Smith 1996a).

The fitness tradeoffs potentially associated with nutrient or contaminant loads in these sites are not known. A case of significant shorebird mortality suspected to be caused by avian botulism was reported for the Wilmington site in August 1996 by Smith (1996b). Data on the use of CDFs by taxa other than birds is generally lacking.

Because CDFs eventually fill up with material, the wetland habitat is ultimately lost as each cell in the CDF reaches capacity. The 2013 Delaware Estuary Regional Sediment Management Plan calls for the conversion of existing upland Confined Disposal Facilities (CDFs) to Confined Management Facilities (CMFs), in which dredged material is placed, dewatered, and then excavated and beneficially reused (Delaware Estuary Regional Sediment Management Plan Workgroup 2013). Coordination regarding wildlife habitat uses of such sites would be beneficial. CMFs may have more long-term potential for habitat, but operations would ideally be carefully timed to avoid wildlife impacts.

Northeast Terrestrial Wildlife Habitat Classification: Developed **Estimated Extent:** Unavailable

Wastewater Treatment Wetlands

Wastewater treatment wetlands, while no substitute for natural wetlands, are often used by waterbirds (Figure 2.39). Many treatment facilities maintain open water during winter when many other water bodies are frozen, thus making them attractive to wintering waterfowl and gulls. The fitness tradeoffs potentially associated with nutrient or contaminant loads in these sites are not well-studied, but are reviewed in Murray and Hamilton (2010). These wetlands are likely of limited importance for non-avian SGCN.

Northeast Terrestrial Wildlife Habitat Classification: Developed **Estimated Extent:** Unavailable

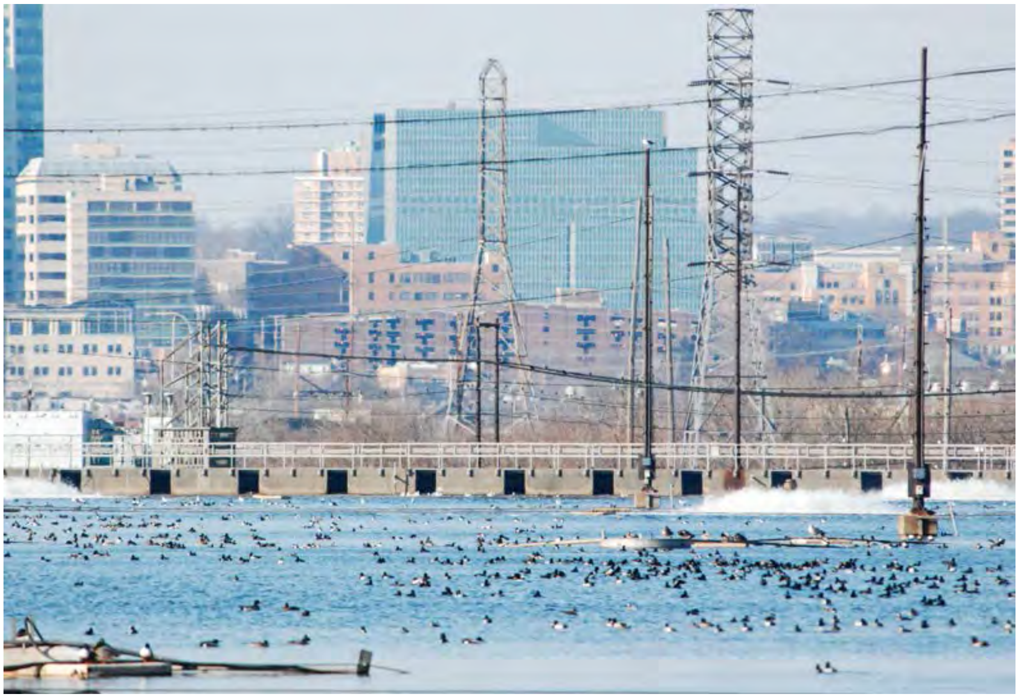


Figure 2. 39 Wastewater Treatment Wetland in Wilmington, DE, with a large aggregation of wintering waterfowl. Photo: Jim White

Stormwater Management Wetlands

This land use has become increasingly common in Delaware due to a boom in residential development. Tiner et al. (2011) found that between 1992 and 2007 the state experienced a net gain of 2,285 acres of ponds and tidal mudflats, with about two-thirds (65%) of the new pond acreage built on former agricultural land for use as stormwater ponds for new residential and commercial developments (Figure 2.40).

Stormwater management ponds are often relatively deep, unvegetated or minimally vegetated wetlands that do not provide the same wildlife habitat or ecosystem services that natural, vegetated wetlands provide. Thus, while the creation of stormwater pond acreage may improve the numerical appearance of net wetland loss, these wetlands tend to provide only modest wildlife value.

Nevertheless, Sparling et al. (2007) found that in suburban Washington, DC, red-winged blackbird nesting success in cattail stands at the edges of stormwater wetlands was comparable and in some cases higher than the rates reported in studies of natural wetlands, suggesting that these wetlands can serve as suitable source habitats for common species in otherwise degraded systems. A total of 47 species of birds used stormwater wetlands in the Sparling et al. (2007) study, with highway wetlands being somewhat more attractive and suitable than residential or commercial wetlands. Massal et al. (2007) found as many as six species of frogs and toads using stormwater basins in

Baltimore County, MD. The only Delaware SGCN amphibian found in the Baltimore County study was Cope's gray treefrog, but the habitat-sensitive wood frog was also found at two sites. Nitrate levels in these basins were such that nitrogen pollution represented "little or no direct risk to developing embryos and larvae of pond-breeding amphibians, although indirect effects and interaction of inorganic nitrogen with other pollutants warrant further investigation." Stormwater retention wetlands can provide habitat for dragonflies and damselflies. A recent record of the SGCN dragonfly band-winged meadowhawk from a retention basin in northern Delaware was the first record for the state in a decade (White 2014). This species is a specialist on spring-associated floodplain meadows, so whether it was able to breed in the retention basin is unknown.

Significant regional progress has been made toward improving design guidelines and best management practices for stormwater management, including technologies for more ecologically functional stormwater conveyances and infiltration areas, mostly featuring increased vegetation cover and diversity and shallower water levels, but these practices have not yet been widely adopted by the industry or codified in the stormwater permitting process in Delaware. Design and planting improvements using native plants have the potential to provide suitable habitat for some SGCN in stormwater wetlands, but concomitant protection of upland buffers of native vegetation as well as corridors to natural habitats are needed in most residential and commercial areas in order to maximize the potential of these anthropogenic wetlands.

Northeast Terrestrial Wildlife Habitat Classification: N/A **Estimated Extent:** Unavailable

Figure 2. 40 Stormwater Management Wetland. Photo: Jim White

Impoundments

Coastal impoundments are human-modified and managed wetland habitats where low-level dikes and water-control structures have been constructed to restrict, retain, or exclude water over a selected area. Delaware has an extensive complex of coastal impoundments along the Delaware Bay, Atlantic Ocean (Gordons Pond), and Little Assawoman Bay (Figure 2.41). Impoundment habitats vary from fresh to brackish, depending on how the water depths and flows are controlled. Water-level management often varies seasonally to benefit particular species or meet specific conservation goals. For example, water levels may be kept high in winter and drawn down slowly to support invertebrate populations, an important food source for migratory waterfowl and shorebirds in spring. In summer, water levels are often kept low to allow vegetation to grow; the impoundments are then flooded to provide food and habitat for waterfowl on their return migration in fall.

The first documented active management of tidal marshes using dikes to control water levels occurred in Delaware in the mid-seventeenth century, with the construction of what is now known as the Broad Marsh Dike at New Castle sometime prior to 1675 (Catts and Mancl 2013). Impounding of estuarine marshlands for production of salt hay was a common early practice that continued through the 19th century. Then, in the 20th century, wildlife managers initiated the practice of impoundment construction to create habitat for migratory waterfowl and to help control populations of saltmarsh mosquito (Meredith 2000). As of 2007, there were 5,366 acres of estuarine tidal wetlands in Delaware that were cut off from full tidal connection in some way by a road, dike, or other structure (Tiner et al. 2011).

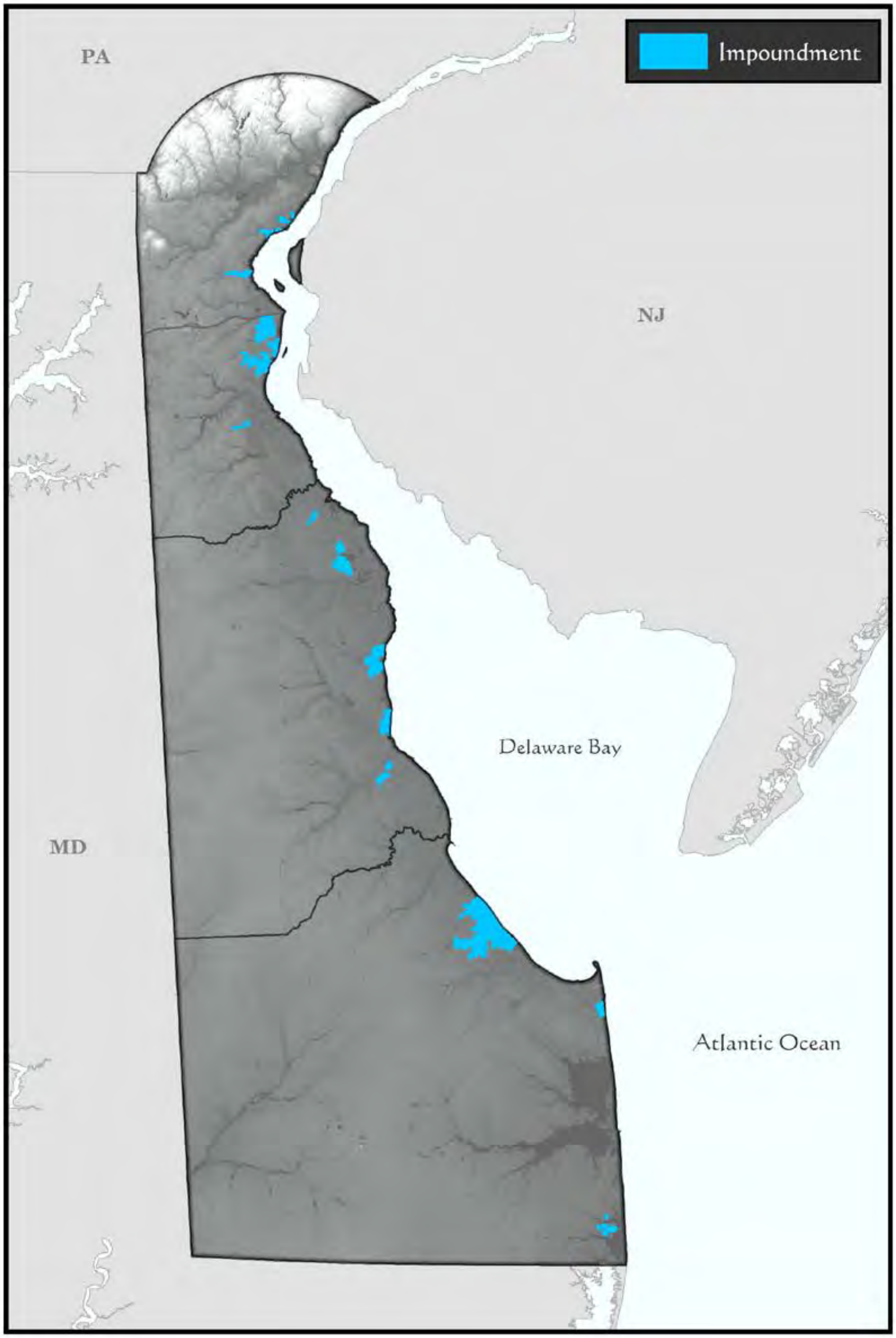
The large impoundments at Bombay Hook National Wildlife Refuge were constructed between 1939 and 1961 and total 1,135 acres (Meredith 2000). An even larger impounded area occurs at Prime Hook National Wildlife Refuge, where approximately 4,000 acres were created or restored between 1981 and 1988. This series of impoundments was breached near its northern end by coastal storms, beginning in 2008. A current restoration plan calls for the creation of tidal saltmarsh and brackish marsh in place of the damaged impoundments (USFWS 2013).

The system of State Wildlife Areas managed by Delaware DFW contains 14 coastal impoundments, totaling approximately 2,400 acres. DFW continues to refine management of these impoundments and has created a structured decision making model to assist with water level management of state-owned impoundments to maximize benefits for wildlife, including juvenile fish, migratory shorebirds, and migrating and wintering waterfowl. Multiple restoration projects are planned for state-owned impoundments in response to aging infrastructure (dikes and water control structures) and projected sea level rise.

Estimates of privately owned and managed impoundments in the state indicate that around 70 impoundments total some 2,500 acres (Meredith 2000). Delaware's coastal impoundments are heavily used by wading birds (Parsons 2002) and others, like the King rail, least bittern, marsh wren, and northern pintail. The primary threat to these habitats is sea level rise. With only half a meter of sea level rise, 81% of Impoundments in Delaware will be inundated, and 99% will be inundated with 1.5 meters of rise (Love et al. 2012).

Northeast Terrestrial Wildlife Habitat Classification: Macrogroup: Modified/Managed Marsh
Estimated Extent: 11,735 acres (DNREC DFW 2011) **Habitat of Conservation Concern**

Figure 2. 41 Impoundment - Muddy Neck Pond, Assawoman Wildlife Refuge. Photo: Rob Gano



Map 2. 29 Impoundments

Tax Ditches

Delaware has over 2,000 miles of tax ditch channels, ranging in size from approximately 6 to 80 feet wide, and 2 to 14 feet deep. Size variation is due to the number of acres that drain to a particular site, and the topography of the area. These ditches are managed by 228 individual tax ditch organizations, ranging in size from the 56,000 acre Marshyhope Creek Tax Ditch in southern Delaware to a two-acre system in Wilmington. Taxes are levied by the tax ditch organizations on adjacent landowners who receive drainage benefits. Taxes pay for the maintenance of the channels and spoil disposal areas. A ROW allows the tax ditch association to keep the ditch clear of sediment bars and woody debris. For a detailed description of the history of tax ditches in Delaware, see Delaware Department of Natural Resources and Environmental Control (2005).

In otherwise inhospitable landscape matrices, such as agricultural and developed areas, these ditches may serve as important corridors or hydrological refugia for species, including some SGCN, and in some cases may serve as habitat for uncommon aquatic species, as was the case with freshwater gastropods in a European agricultural system (Herzon and Helenius 2008). These modified channels are, however, a poor substitute for natural systems. Nutrients conveyed by the tax ditch systems from surface runoff from agricultural or developed landscapes may negatively impact water quality in downstream aquatic systems.

In the Nanticoke drainage in Delaware, where the state's largest tax ditch organizations have been formed, 80% of the natural streams are channelized (Tiner et al. 2001). Many of these large channels traverse areas of intact forest habitat. As part of the Nanticoke River Watershed Restoration Plan (Nanticoke Restoration Work Group 2009), several restoration projects have been completed to restore these large, channelized streams to a more natural channel design that incorporates floodplain reconnection (Secrist 2013). Projects such as this should help restore wildlife value to these systems.

Northeast Terrestrial Wildlife Habitat Classification: N/A **Estimated Extent:** 521 acres (DNREC DFW 2015)

Tidal Wetlands

With nearly 76,000 acres of tidal estuarine wetlands and over 10,000 acres of tidal palustrine wetlands, Delaware's tidal wetlands in total account for over a quarter of the state's wetlands (Tiner et al. 2011).Tidal marshes are widely recognized for their ecological importance, as well as their importance to human populations. Tidal marshes filter contaminants and nutrients, improve water quality, sequester carbon, and protect coastal communities from flooding (Kreeger et al. 2010). A wide range of terrestrial and aquatic species, including birds and commercial and recreational fish and crustacean species, use tidal marsh habitats for nursery grounds and other functions during their life cycles (Boesch and Turner 1984; Nixon 1980).

The Delaware River is fringed by a contiguous band of brackish/saltwater tidal marshes from the mouth of Delaware Bay upstream to the Delaware Memorial Bridge. Beyond the tidal marsh fringe, tidal wetlands are predominately tributary-associated freshwater tidal wetlands that occur in discrete patches.

Salinities in polyhaline salt marshes near the mouth of the Delaware Bay range from 18 to 30 parts per thousand (ppt) and are dominated by two grass species, smooth cordgrass (*Spartina alterniflora*) and saltmeadow cordgrass (*Spartina patens*). Brackish (mesohaline) marshes, with higher vascular plant diversity than salt marshes, occur upstream of the bay mouth in salinity ranges from 5 to 18 ppt (Odum 1988). Oligohaline marshes with salinities less than 5 ppt support the highest species diversity and are at most risk from sea level rise. These habitats provide a critical buffer between the tidal ocean and bay aquatic environments and the upland habitats of the Delaware Estuary.

It has been estimated that the Delaware Estuary has lost more than half of its wetlands, and more than 95% of freshwater tidal wetlands, since early settlers arrived (PDE 2008). Historical losses occurred primarily because of development and conversion of wetlands for agriculture and other purposes. Despite increased regulatory oversight and "no net loss" policies that have greatly slowed rates of wetland conversion, we continue to lose all types of wetlands within the Delaware River Basin (PDE 2012).

Freshwater (Palustrine) Tidal Wetlands

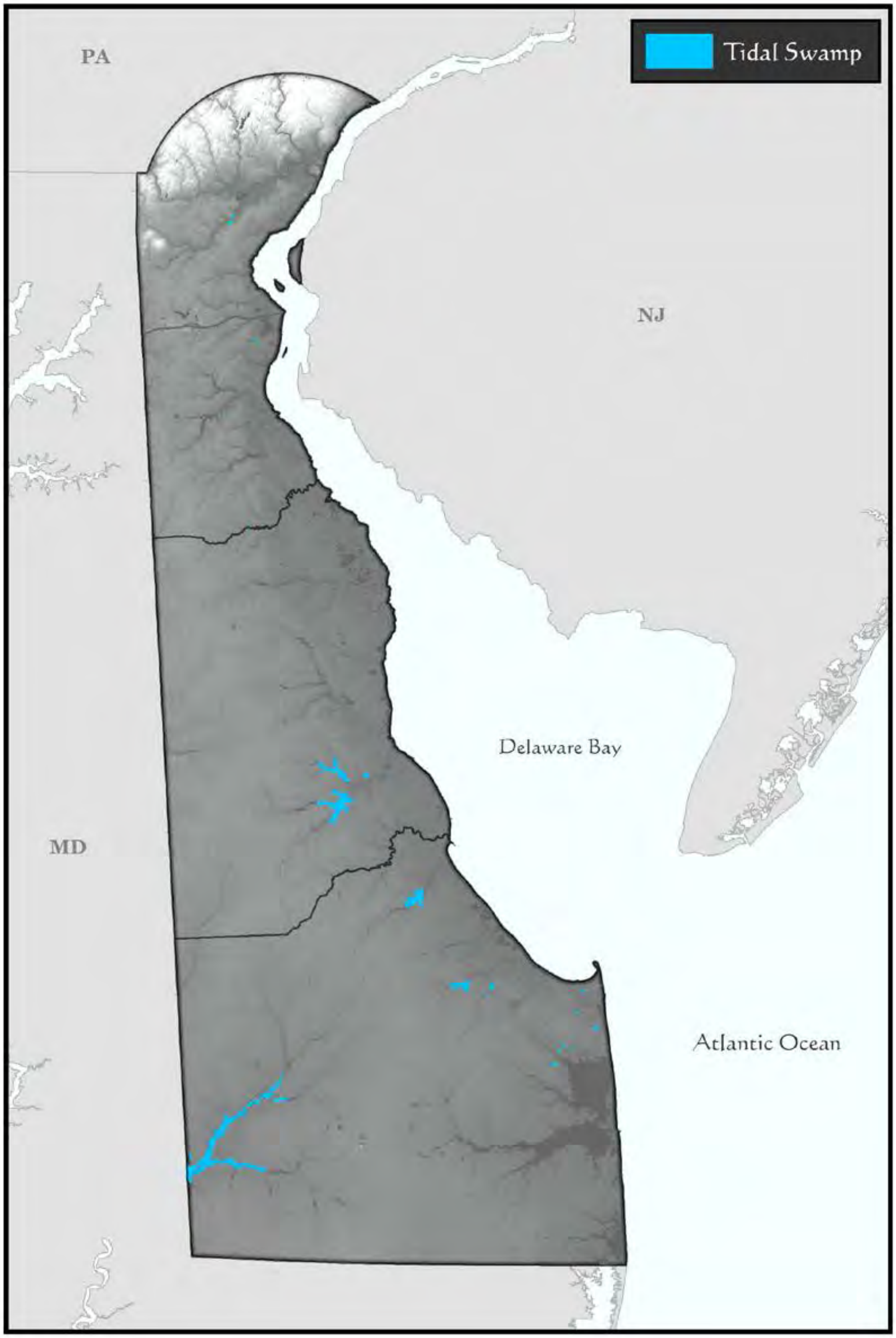
Although seldom destroyed outright, these habitats have been somewhat impacted by ditching, dredging, and channelization. They also have long been subject to incremental degradation arising from incompatible land use practices upslope, often magnified by the frequent loss of adjacent buffers. Opportunities for migration inland of this habitat in the face of sea level rise will be limited by topographic features and mill pond dams on tidal coastal plain streams. Purely fresh (0 ppt) tidal marshes in Delaware are now only found on the Christina and Nanticoke Rivers (W. McAvoy personal communication). It is estimated that between 84% and 98% of freshwater tidal wetlands will be impacted by sea level rise by 2100 (Love et al. 2012).

Freshwater Tidal Swamp

This group of wetlands ranges from thinly forested types to those dominated by small trees and shrubs. They are typically found at the head of tide or along the fringes of tidal creeks, where tidal flooding is irregular. SGCN associated closely with this habitat include numerous birds, especially foraging herons, as well as Swainson's and prothonotary warblers, many species of diadromous fish, and a variety of rare invertebrates.

Freshwater tidal swamps are threatened by sea level rise and saltwater intrusion and in many cases inland migration of this habitat type is precluded by millpond dams. Between 89% and 97% of freshwater tidal forested and shrub wetlands are likely to be inundated by the year 2100 (Love et al. 2012).

Ecological System: *Northern Atlantic Coastal Plain Tidal Swamp (CES203.282)* **Estimated Extent:** 2,221 acres (DNREC DFW 2015) **Habitat of Conservation Concern**



Map 2. 30 Freshwater Tidal Swamp

Fresh and Oligohaline Tidal Marsh and Shrubland

Tidally-influenced marsh and shrubland with salinities less than 5 ppt (oligohaline) and often less than 0.5 ppt (fresh), characterized by diverse herbaceous vegetation near the tidal channel and often bordered by a diverse shrub zone toward the upland edge (Figure 2.42). This habitat spans the border between the Cowardin et al. (1979) definitions of palustrine and estuarine. The Delaware Estuary has the most freshwater and oligohaline tidal marsh of any estuary in the U.S., but it is thought that in the Delaware River Basin these systems currently occupy only about five percent of their historical area (Kreeger et al. 2010).

Naturally high in diversity (Field and Philipp 2000), fresh and oligohaline tidal marshes contain both "high" marsh, composed of dominant species like arrow arum, spatterdock, and pickerelweed, and "low" marsh habitat, characterized by species like wild rice and cattail. Freshwater tidal marshes provide important habitat for a range of aquatic and wetland species. Numerous SGCN use the diverse array of microhabitats found in these marshes.

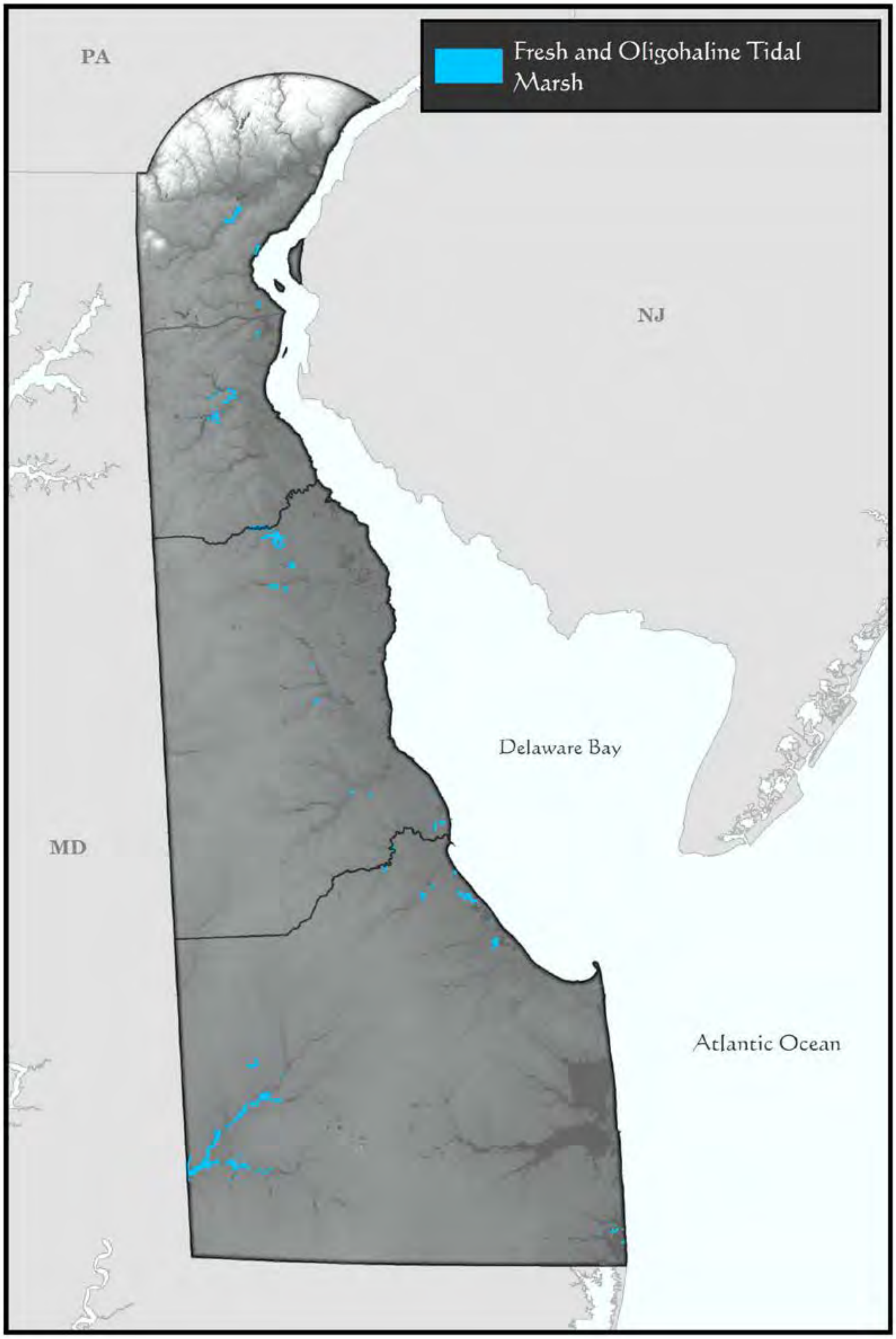
Much like salt marshes and other coastal wetlands, freshwater tidal marshes provide an array of benefits for people as well as wildlife: they maintain water quality by filtering nutrients, sediments, and pollutants (Tiner 1984); they help reduce erosion and buffer storm surges (Stedman and Dahl 2008;, and they provide nursery habitat for fish (NOAA 2001).

As important as these freshwater tidal ecosystems are, they have been subjected to a range of negative impacts resulting from human use of the surrounding land. Their position in the estuary exposes them to pollutants, sediments, and nutrients from upstream portions of the watershed (Neubauer et al.2002). The high concentration of freshwater tidal wetlands in the urban corridor of the Delaware River has been subjected to degradation and destruction via a range of activities and inputs, such as development, highway construction, dredge spoil disposal and landfills, runoff of nutrients and pollutants, chemical and oil spills, and inputs from sewage treatment facilities (Simpson et al. 1983).

These marshes have suffered relatively little outright destruction from habitat conversion, but there has been substantial contraction of their extent from sea level rise and saltwater intrusion, especially along streams draining into Delaware Bay. In many areas, inland migration of this habitat is impeded by dams or steep stream valley slopes. Thousands of acres have experienced invasion by the non-native, invasive, common reed (*Phragmites australis* ssp. *australis*).

Ecological System: *Northern Atlantic Coastal Plain Fresh and Oligohaline Tidal Marsh (CES203.516)*
Estimated Extent: 1,426 acres (DNREC DFW 2015) **Habitat of Conservation Concern**

Figure 2. 42 A pond-lily tidal marsh and adjacent shrubland on Tidbury Creek. Photo: William A. McAvoy.



Map 2. 31 Fresh and Oligohaline Tidal Marsh

Saltwater (Estuarine) Tidal Wetlands

Estuarine wetlands are systems associated with coastal salt or brackish waters. These areas extend upstream into coastal rivers to the point where salinity levels decline to negligible levels (less than 0.5 ppt).

Eighty-one percent of Delaware's estuarine wetlands occur on fringe landforms, with unobstructed connection to tidal embayments. Islands of wetland surrounded by open water account for 12%, while 7% of estuarine wetlands in Delaware are cut off from full tidal flow by roads, dikes, or similar structures and are thus considered basin landform types. These were discussed above under impoundments.

The predominant estuarine habitat in Delaware is salt marsh. Delaware has high regional responsibility for salt marsh habitat, with 9% of the salt marsh in the Northeast region (Anderson et al. 2013a), relative to only about 1% of the land area.

Salt marshes are universally considered to be among the most important wildlife habitats in North America, and Delaware's contribution to the regional distribution and conservation of this habitat is significant.

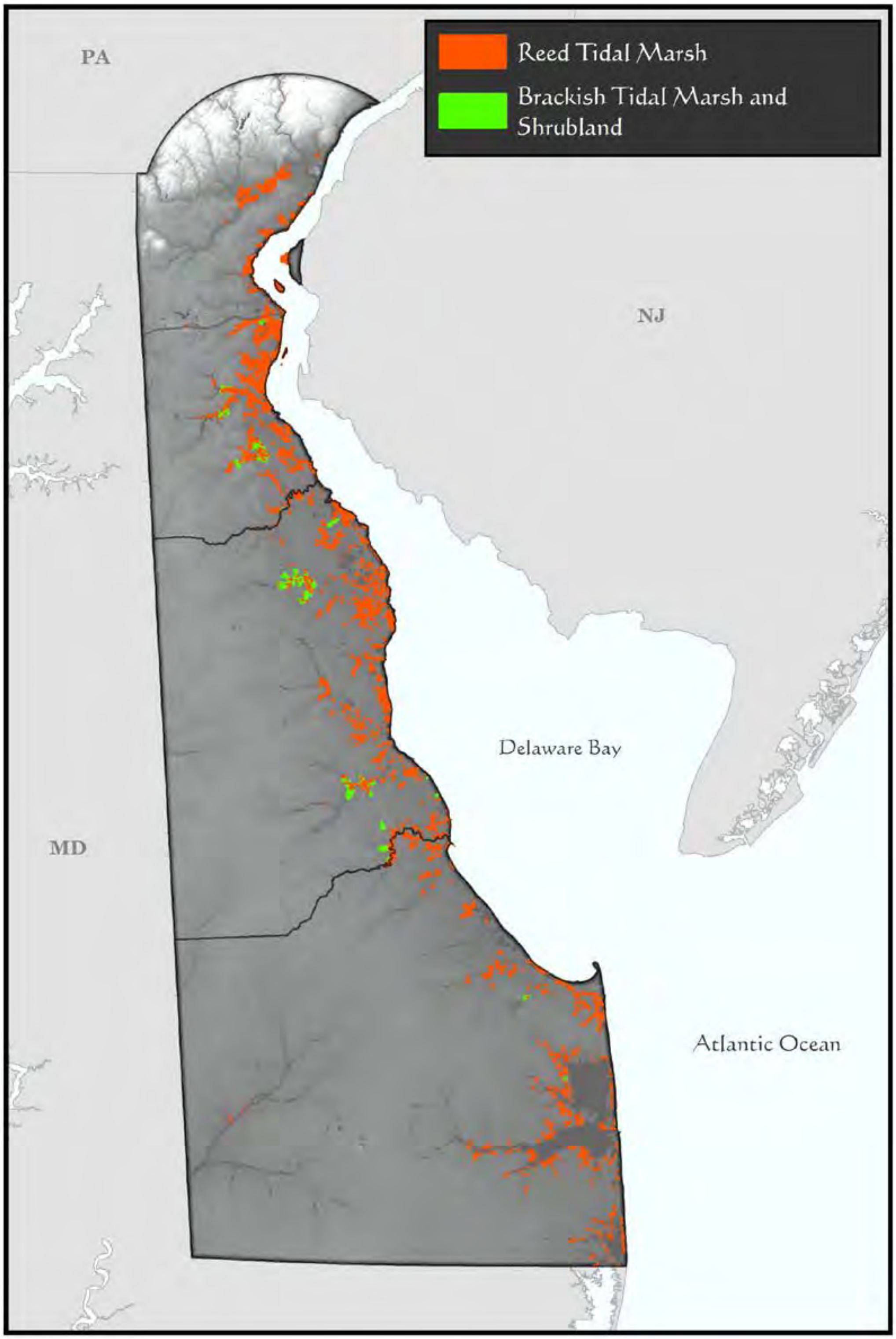
Brackish Tidal Marsh and Shrubland

Transitional wetlands between tidal fresh and oligohaline systems and salt marshes, with salinity ranging from 5-18 ppt. This wide transition zone is diverse, with species tolerant of both saline and freshwater conditions.

Lower, more regularly flooded zones consist of species such as smooth cordgrass, saltgrass, narrow-leaved cattail, Olney threesquare, saltmarsh bulrush, and extensive stands of black needlerush. Higher portions of brackish marshes may support saltmeadow cordgrass, sea-lavender, seashore mallow, saltmarsh fleabane, glassworts, switchgrass, and seaside goldenrod. Shrubby ecotones of southern bayberry, marsh elder, and high-tide bush are frequent. SGCN such as the American black duck, clapper rail, diamond-backed terrapin, saltmarsh sparrow, snowy egret, and willet use these areas.

Much of the brackish tidal marsh in Delaware has been invaded by invasive *Phragmites* and has been converted to "Reed Tidal Marsh," mapped by Coxe (2014) at over 13,000 acres in the state. Map 2.32 shows the relatively small extent of uninvaded brackish marsh relative to the large acreage of *Phragmites*-dominated Reed Tidal Marsh.

Ecological System: *Northern Atlantic Coastal Plain Brackish Tidal Marsh (CES203.894)* **Estimated Extent:** 1,502 acres (DNREC DFW 2015)



Map 2. 32 Brackish Tidal Marsh and Shrubland and Reed Tidal Marsh

Tidal High Salt Marsh and Shrubland

These are usually the more landward of the coastal low marshes, occurring at a slightly higher elevation where they are subjected to a shorter period of tidal inundation (Figure 2.43). Shorter-statured salt marshes or salt meadows are dominated by saltgrass (*Distichlis spicata*) and saltmeadow cordgrass (*Spartina patens*) and generally occur on slightly elevated surfaces where tides may be less regular and where soils may concentrate salts. High salt marsh zones often support a diverse assemblage of plants that may include species such as camphorweed, seaside gerardia, annual saltmarsh aster, perennial saltmarsh aster, sea-oxeye, sea rose-pink, and narrow-leaved loosestrife. The salinity of tidal water is usually 18-30 ppt and flooding is less regular because of slightly elevated landscapes. Embedded in salt marshes are shallow, poorly drained depressions called "salt pannes." Like the adjacent salt marsh, salt pannes are flooded by tidal water, but water does not drain freely into creeks or guts. After a panne has been flooded, the standing water evaporates and the salinity of the soil water greatly increases above the level of sea-water, thus supporting the most salt tolerant perennials and annuals such as glassworts. Salt scrub is generally species poor and composed only of plants tolerant of high salinity such as wax myrtle, high-tide bush, and marsh elder.

Even though the majority of these habitats are protected on state land, they have been subjected to a number of significant impacts in historic times, especially harvesting of "salt hay," conversion to impoundments, and grid-ditching for mosquito control or agriculture. These impacts have largely ceased, but more modern mosquito control efforts continue today and will likely continue into the foreseeable future. Most breeding of saltmarsh mosquitoes (genus *Ochlerotatus*) occurs in small, periodically flooded "potholes" within high marsh (Lesser 2011). In order to reduce rates of insecticide application, recent mosquito control efforts have used Open Marsh Water Management (OMWM), a technique 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. Potential effects, both positive and negative, of OMWM on high marsh SGCN are discussed in Chapter 3.

The particular topographic setting of these marshes, adjacent to uplands, makes landward migration in the face of sea level rise highly problematic. In the next 85 years, between 97% and 99% of existing tidal wetlands may be inundated (Love et al. 2012), eliminating habitat for the array of SGCN that depend on these tidal areas, such as the clapper rail, Nelson's sparrow, saltmarsh sparrow, seaside sparrow, snowy egret, and willet.

Ecological System: *Northern Atlantic Coastal Plain Tidal Salt Marsh (CES203.519) (in part)*
Estimated Extent: 7,227 acres (DNREC DFW 2015) **Habitat of Conservation Concern**

Figure 2. 43 Tidal High Salt Marsh. Photo: William A. McAvoy

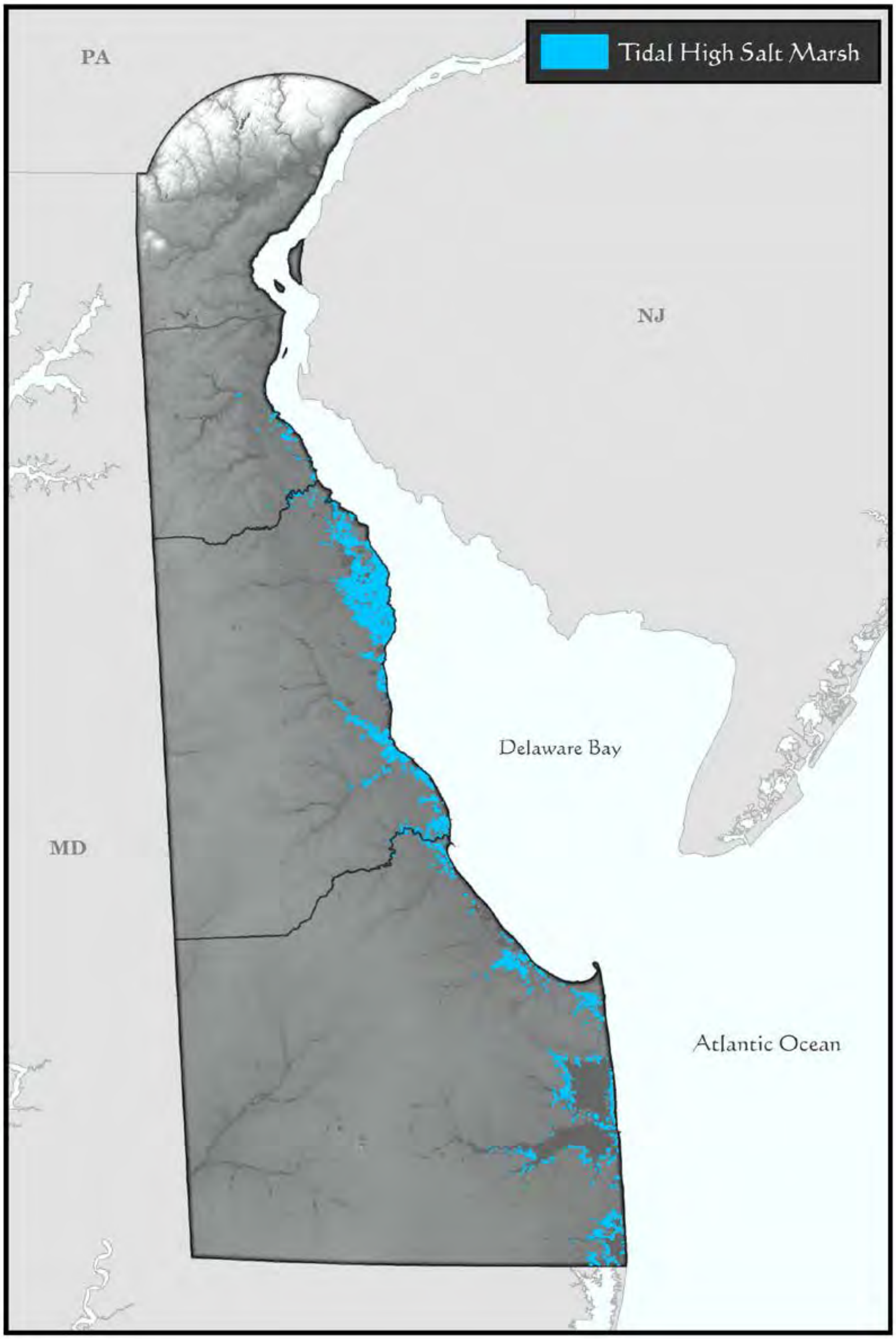
Tidal Low Salt Marsh

The more seaward of the coastal salt marshes, these habitats are flooded for longer periods of time during daily tidal cycles (Figure 2.44). Ribbed mussels (*Geukensia demissa*) are an intertidal species found primarily in association with tidal salt marsh plants. Smooth cordgrass (*Spartina alterniflora*) provides a surface for mussel attachment, and the mussels fertilize the plants. Ribbed mussels form dense beds on the edges of salt marshes and help increase marsh elevation and resistance of the marsh shoreline to erosion, assisting in stabilizing the habitat for SGCN such as the American black duck, clapper rail, Nelson's sparrow, Northern diamond-backed terrapin, saltmarsh sparrow, snowy egret, and willet.

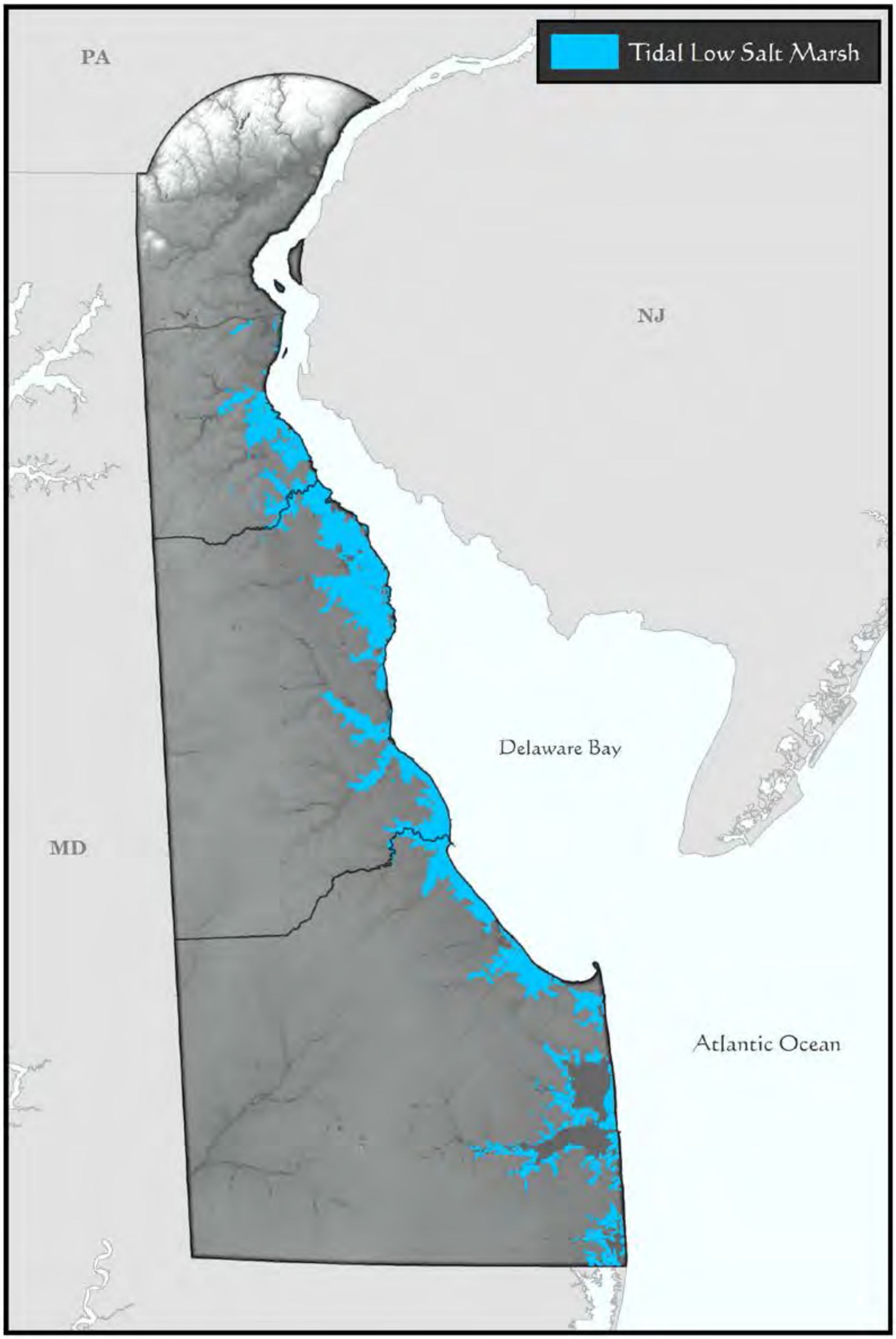
Much of the vast acreage of Tidal Low Salt Marsh is in conservation ownership, and that which is not has substantial protection from state regulation of tidal wetlands. Nonetheless, this habitat was significantly altered through ditching, draining, dredging, and filling until just a few decades ago. "Eat outs" from burgeoning snow goose populations have substantially degraded some low marshes in the last 30 years (Young 1985). Low marsh should be capable of migrating landward in response to sea level rise – in part at the expense of Tidal High Marshes – although many marshes lack sufficient buffers to accommodate this shift.

Ecological System: *Northern Atlantic Coastal Plain Tidal Salt Marsh (CES203.519)* **Estimated Extent:** 47,263 acres (DNREC DFW 2015) **Habitat of Conservation Concern**

Figure 2. 44 Tidal Low Salt Marsh in Delaware's Inland Bays**.** Photo: William A. McAvoy



Map 2. 33 Tidal High Salt Marsh and Shrubland

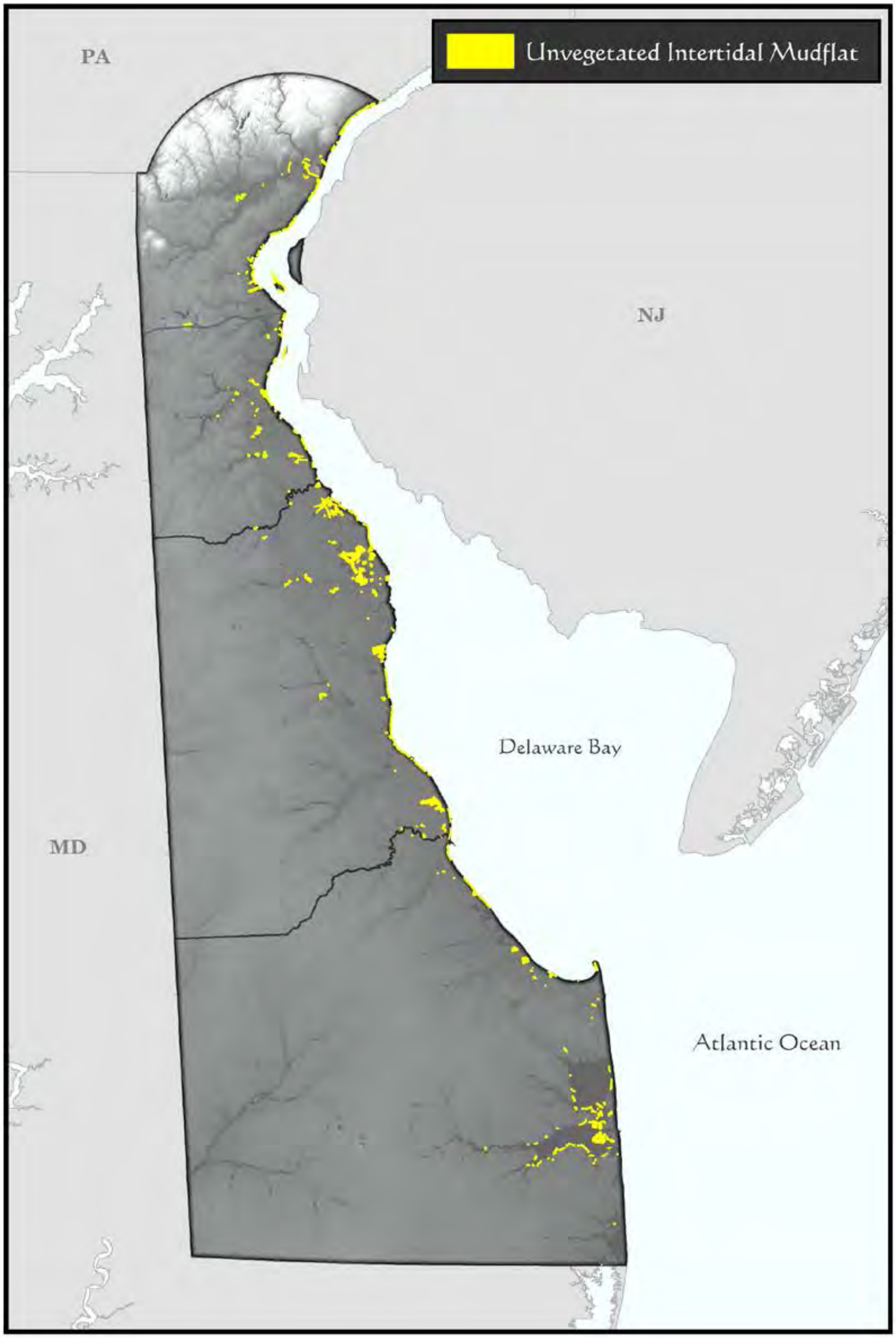


Map 2. 34 Tidal Low Salt Marsh

Intertidal Mud Flat

These intertidal flats are best developed in shallow protected estuarine bays, pools, and along small tidal creeks and guts. The depth and frequency of tidal flooding is variable depending on the landscape setting, but most flats are exposed twice daily during low tide cycles. Intertidal mud flats are critically important feeding areas for many SGCN waterbird species, especially migratory shorebirds. Some SGCN using this habitat include: American black duck, black skimmer, common tern, horseshoe crab, least tern, piping plover, red knot, sanderling, and semipalmated sandpiper. Intertidal flats face threats from sea level rise, rip-rapping, bulkheading, and associated development issues.

Ecological System: *Northern Atlantic Intertidal Mudflat (CES201.050)* **Coastal and Marine Ecological Classification Standard (CMECS):** Geoform: Tidal Flat **Estimated Extent:** 1,324 acres (DNREC DFW 2011)



Map 2. 35 Intertidal Mudflat

Intertidal Sand Flat

These sandy flats along the Delaware Bay and Atlantic Ocean beaches are inundated at high tide and exposed at low tide (Figure 2.45). They support a diverse assemblage of infaunal invertebrates, thus providing critical foraging areas for beach-nesting birds and migratory shorebirds such as American black duck, black skimmer, common tern, least tern, piping plover, red knot, sanderling, and semipalmated sandpiper. The major threats to this habitat are compaction from vehicular traffic and impacts on invertebrate communities from beach nourishment.

Ecological System: *Northern Atlantic Tidal Sand Flat (CES201.049)* **Coastal and Marine Ecological Classification Standard (CMECS):** Geoform: Tidal Flat **Estimated Extent:** Unavailable **Habitat of Conservation Concern**

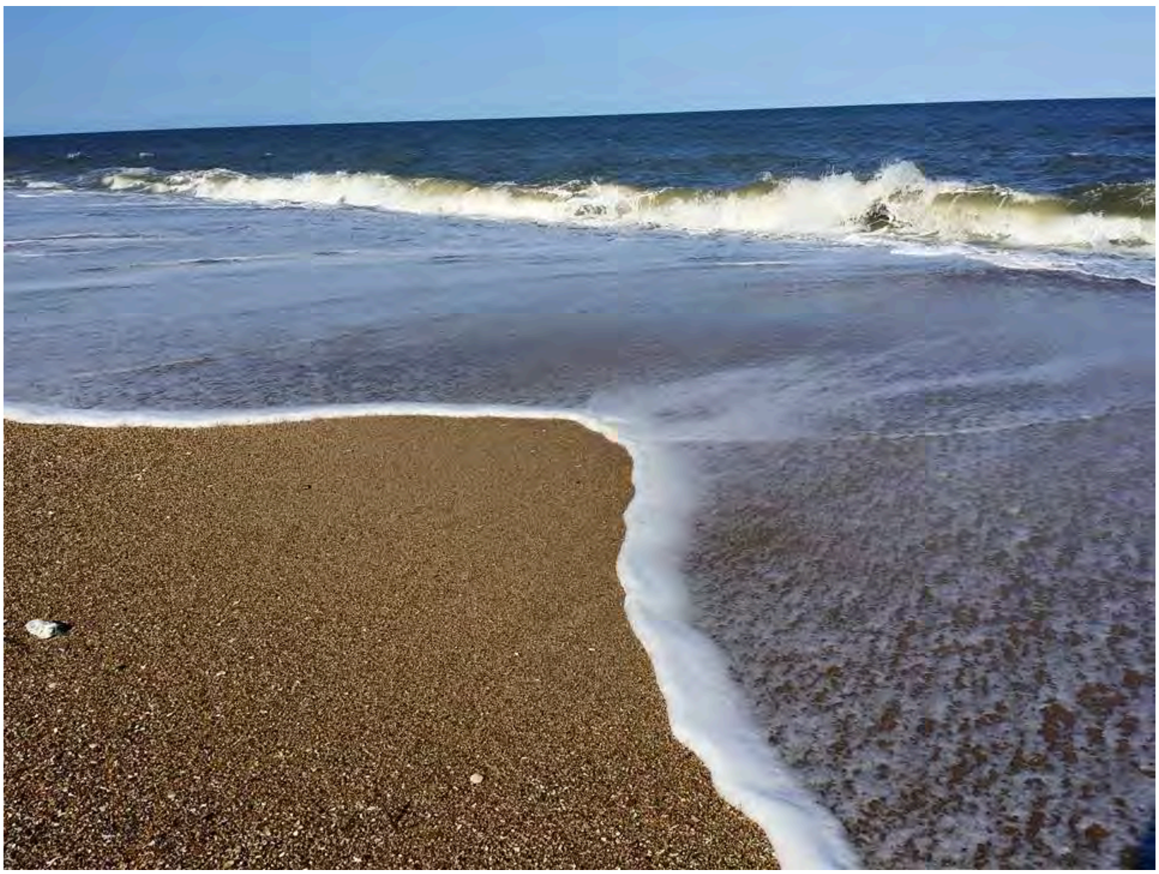


Figure 2. 45 Intertidal Sand Flat along Delaware's Atlantic Coast. Photo: Chris Bennett

Riverine Aquatic Habitats

The Delaware River is the longest un-dammed river in the United States east of the Mississippi, extending 330 miles from the confluence of its East and West branches at Hancock, N.Y. to the mouth of the Delaware Bay where it meets the Atlantic Ocean. The river is fed by 216 tributaries, the largest being the Schuylkill and Lehigh Rivers in Pennsylvania. The tidal reach extends from where the river enters Delaware Bay near Wilmington, Delaware upstream to near Trenton, NJ. The salt line, where brackish waters meet fresh waters, usually ranges across approximately the lower third of this reach (DRBC 2008). As of September 10, 2015, the salt line was located 76 river miles upstream from the mouth of the Delaware Bay, seven miles upstream of the Delaware Memorial Bridge (DRBC 2015)

It is important to note that sea level rise may inundate between 39% and 78% of the Delaware's dams, dikes, and levees by the turn of the century. As these structures protect wildlife areas, people, property, and even contaminated sites, the resulting flooding would affect large areas (Love et al. 2012) and certainly the water quality of the riverine habitats themselves.

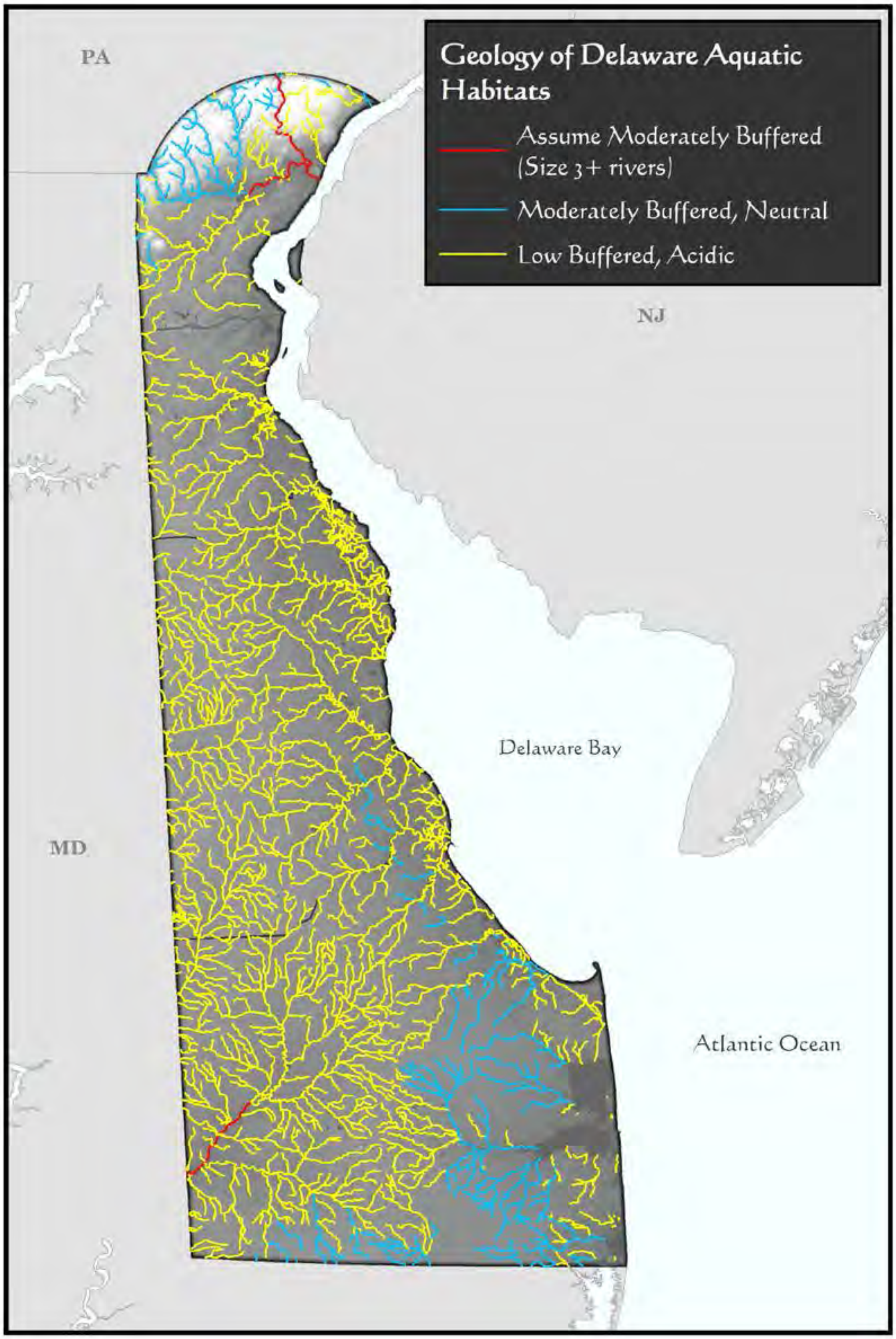
Non-tidal stream and river habitats in Delaware range from small headwaters and creeks to medium rivers. DNREC has found that 94% of Delaware's rivers and streams do not fully support the fish and wildlife designated use as defined by criteria such as dissolved oxygen. Most of these waters do not meet the standards because of nonpoint source pollution impacts (DNREC 2013).

DEN spatial analysis identified "core" streams that included at least 1 km of stream reach with the following characteristics:

- Natural morphology (e.g., not ditched, channelized, impounded, or entrenched)
- Perennial flow
- <10% impervious surface in catchment
- At least 30 m riparian forest or marsh on both sides of the bank
- No dams, road crossings (except for bridges), or other stream blockages
- Unchannelized streams containing freshwater mussel Element Occurences

DEN core streams totaled 2276 km, 26% of all streams, rivers, and ditches in the state (as measured by National Hydrography Dataset (NHD) flowlines, which missed most farm ditches and many small tidal creeks). The majority (74%) of core streams were tidal (Weber 2013).

Most current problems stem from non-point source pollution such as nutrients from agricultural fields and septic systems; hydrocarbon pollutants from streets and parking lots; and sediment from land that has been cleared for development. The hydrology of many streams has also been impacted by the increase in impervious surfaces that accompanies residential and commercial development, such that base flows have decreased and storm flows have increased. Recent surveys of fish and mussel communities in non-tidal streams provide further indication of the condition of these habitats – species abundance was skewed toward types that are more tolerant of degraded habitat. Although water quality issues are being actively addressed, the rate of land development in Delaware will make long term improvements in stream habitat condition difficult to obtain.



Map 2. 36 Geology of Delaware's Riverine Aquatic Habitats.

Freshwater Tidal Open Water

This system includes the freshwater tidal reach of the Delaware River and the freshwater tidal portions of tidal rivers and large tidal creeks offshore of the 4 m depth contour (Figure 2.46). The deep, freshwater tidal habitats of this system are critical for the federally endangered shortnose sturgeon and Atlantic sturgeon, as well as other deepwater species. Threats to this habitat include upstream migration of the salt front, pollution and disturbance from industrial and shipping activities, thermal pollution, and impingement from cooling water withdrawals, and changes in water temperature and chemistry resulting from climate change.

Coastal and Marine Ecological Classification Standard (CMECS): Subsystem: Estuarine Tidal Riverine Open Water **Northeast Aquatic Habitat Classification:** Tidal Headwaters and Creeks (in part), Tidal Small and Medium River (in part), Tidal Large River (in part) **Estimated Extent:** Included in various riverine classifications and not separately mapped

Freshwater Tidal Coastal

This system includes shallow habitats landward of the 4 meter depth contour, including most small tidal freshwater creeks and the shallow margins of larger freshwater tidal creeks. These habitats are important for numerous SGCN, from birds to estuarine and diadromous fishes, to freshwater mussels. Threats are similar to those for freshwater tidal open water, but temperature and nutrient-related threats may be more severe in these shallower habitats, leading to hypoxic and anoxic conditions.

Coastal and Marine Ecological Classification Standard (CMECS): Subsystem: Estuarine Tidal Riverine Coastal **Northeast Aquatic Habitat Classification:** Tidal Headwaters and Creeks (in part), Tidal Small and Medium River (in part), Tidal Large River (in part) **Estimated Extent:** Included in various riverine classifications and not separately mapped

Figure 2. 46 Freshwater Tidal Aquatic Habitat on Christina Creek. Photo: William A. McAvoy

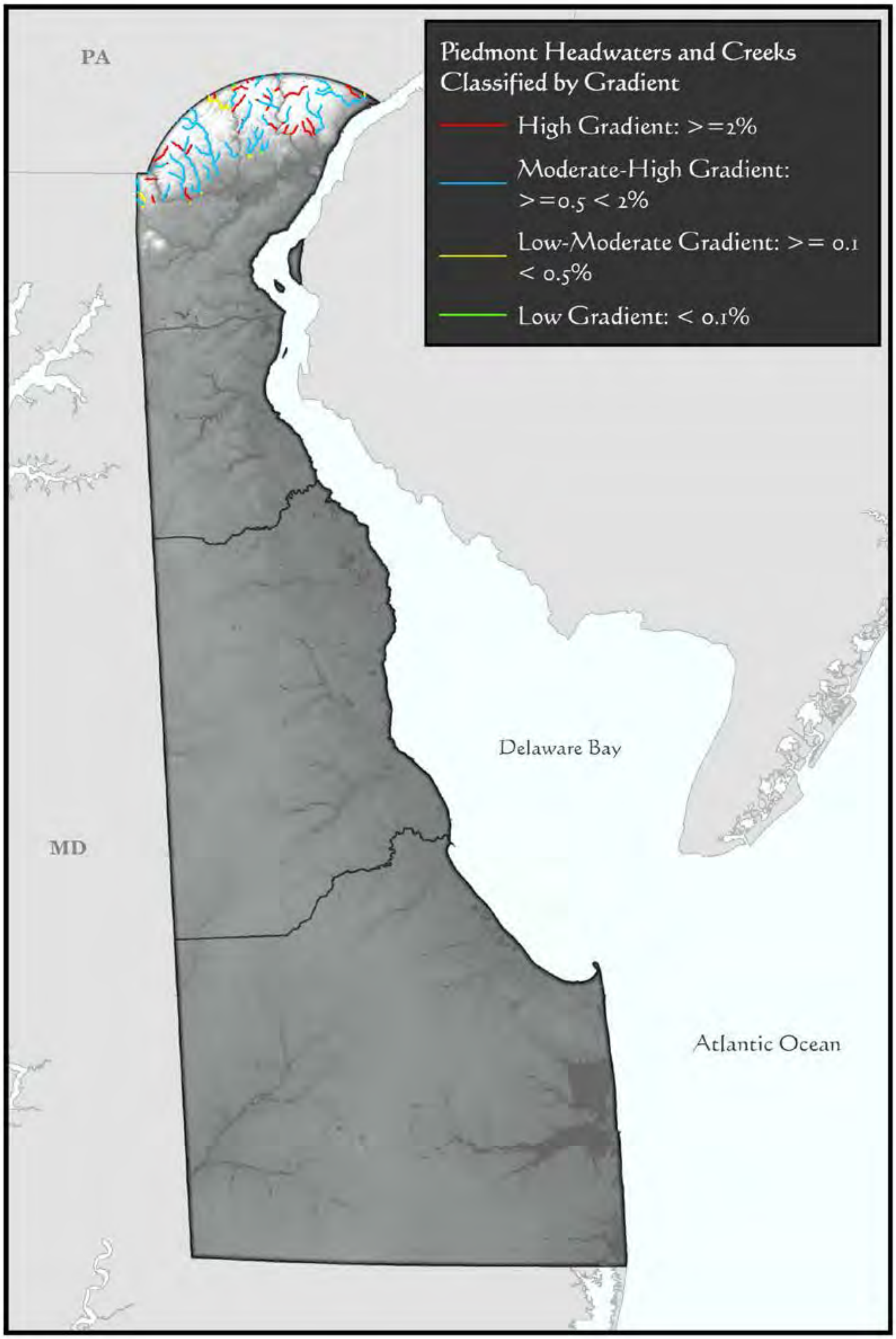
Piedmont Headwaters and Creeks

Figure 2. 47 Rocky Run, a tributary of Brandywine Creek, is an example of a high gradient Piedmont creek. Photo: William A. McAvoy

In the Delaware Piedmont, stream channel gradient is generally moderate to high and the resulting habitats for fish and other aquatic species vary in relation to gradient (Jenkins and Burkhead 1993). These water bodies (Figure 2.47) are classified as primarily cool according to the system of Olivero and Anderson (2008). Due to the presence of metamorphic rock high in base mineral content, the headwaters and creeks in most of the Piedmont exhibit buffered pH. The moderately fast-moving waters are well-oxygenated by riffles and pools. Stream bed substrates are dominated by cobble, gravel, and sand with occasional patches of boulders. These habitats are critical for many SGCN stream-breeding odonates, freshwater fishes, diadromous fishes, salamanders, and caddisflies.

Threats to these habitats include pollution from road salt, industrial contaminants, and sediment and nutrient loading, development of adjacent forested buffers, and in-stream barriers created by dams and other obstructions.

Northeast Aquatic Habitat Classification: Cold to Cool, High to Moderate Gradient, Buffered, Headwaters and Creeks **Estimated Extent:** 95 miles (Olivero and Anderson 2008)

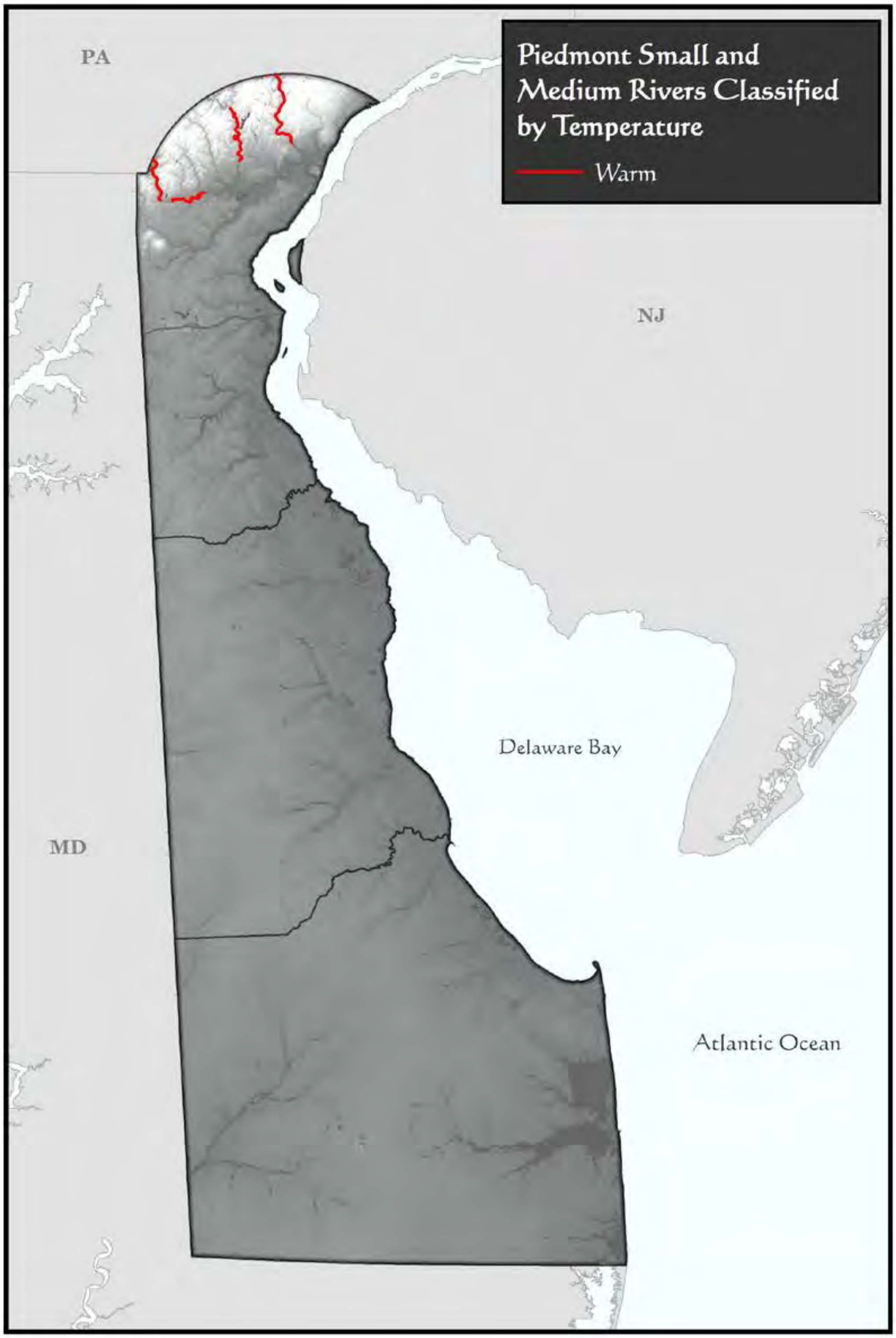


Map 2. 37 Piedmont Headwaters and Creeks

Piedmont Small and Medium River

These riverine habitats are important to a wide variety of SGCN, particularly diadromous fish, odonates, and freshwater mussels. Dams are a major issue for riverine aquatic habitats statewide, since they present a barrier to movement of many aquatic SGCN. This issue is discussed in detail Chapter 3. In addition, these rivers are potentially threatened by saltwater intrusion, particularly in their lower reaches, as well as impacts from changes in temperature and flow regimes.

Northeast Aquatic Habitat Classification: Cool to Warm, Small and Medium River **Estimated Extent:** 21 miles (Olivero and Anderson 2008)



Map 2. 38 Piedmont Small and Medium Rivers

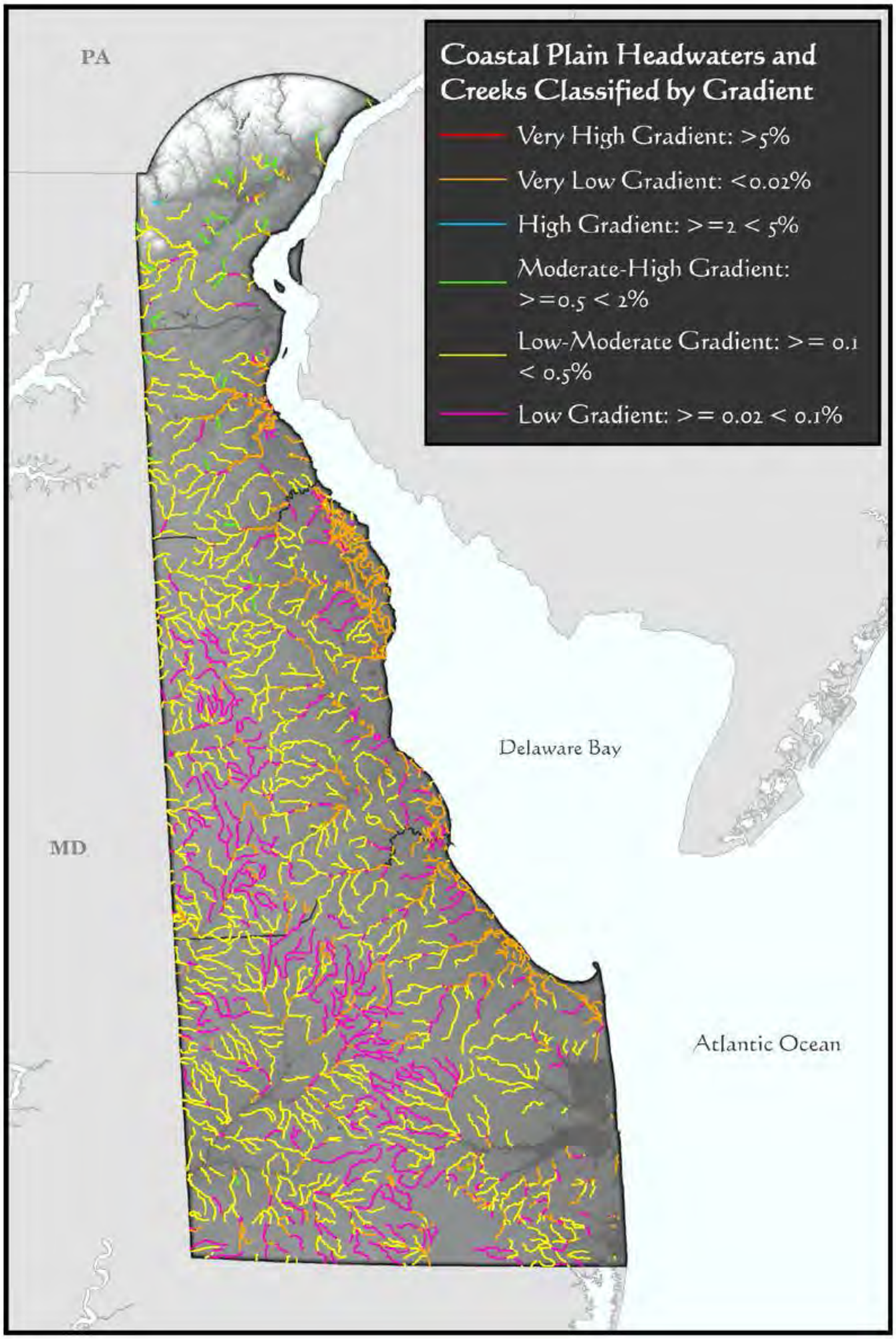
Coastal Plain Headwaters and Creeks

Headwaters and creeks are some of the most important aquatic habitats for SGCN. In the Coastal Plain of Delaware, all of these water bodies are classified as warm and acidic according to the system of Olivero and Anderson (2008). Stream gradients are low and bed materials are primarily sands and silts (Figure 2.48). These habitats are important to several SGCN fish species, including black-banded sunfish, ironcolor shiner, American brook lamprey, and glassy darter.

Threats to Coastal Plain Headwaters and Creeks are similar to those for Piedmont Headwaters and Creeks. Sea level rise impacts may be greater in these more low-lying watersheds.

Figure 2. 48. Beaverdam Creek, an example of an acidic Coastal Plain creek. Photo: William A. McAvoy

Northeast Aquatic Habitat Classification: Warm, Low to Moderate Gradient, Acidic Headwaters and Creeks **Estimated Extent:** 2,204 miles, including tidal (Olivero and Anderson 2008) **Habitat of Conservation Concern**

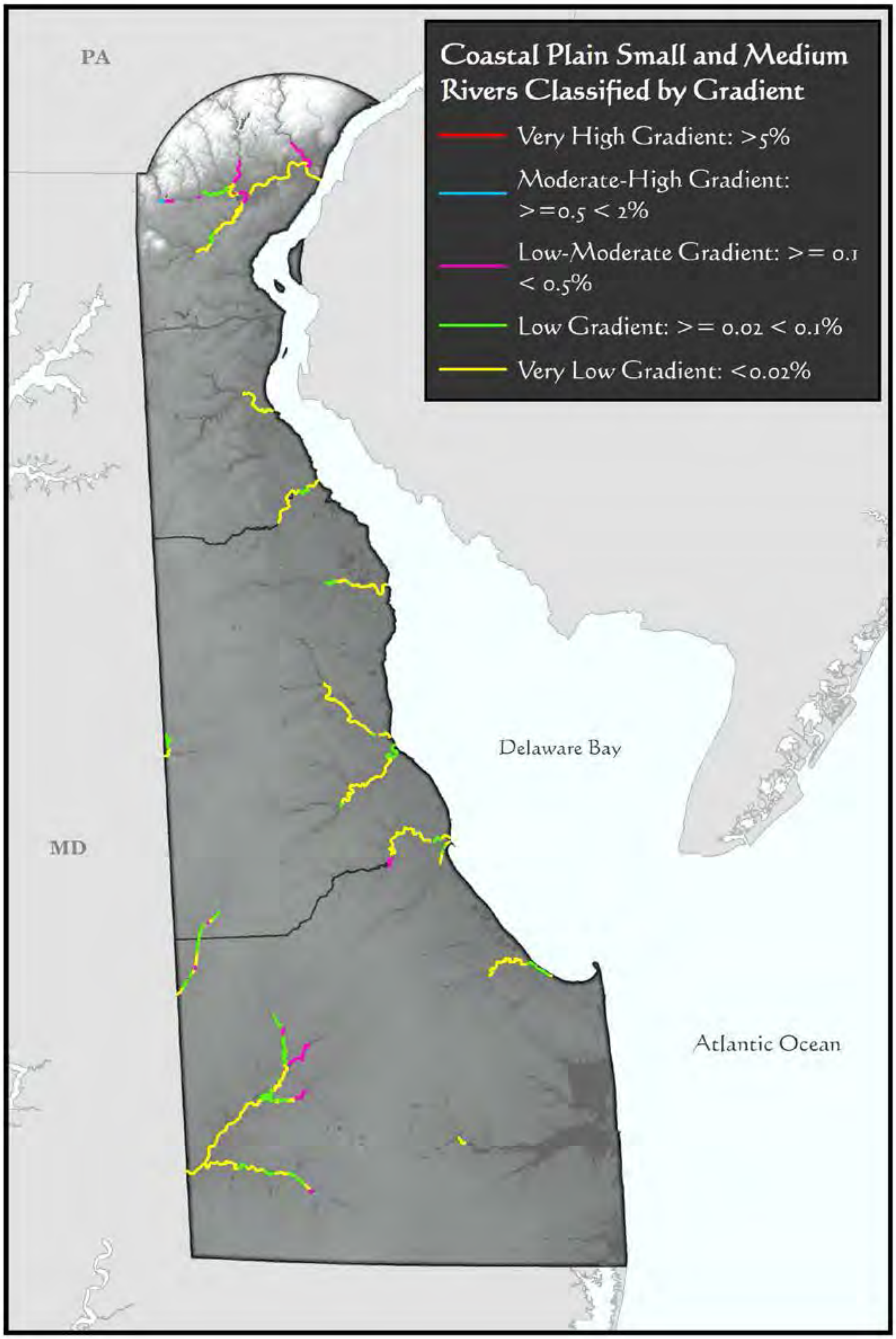


Map 2. 39 Coastal Plain Headwaters and Creeks

Coastal Plain Small and Medium River

These riverine habitats are important to a wide variety of SGCN, particularly diadromous fish and freshwater mussels. Dams are a major issue for riverine aquatic habitats statewide, since they present a barrier to movement of many aquatic SGCN. On the Coastal Plain, millpond dams are also creating a barrier to the upstream movement of freshwater tidal systems, as salinity and sea level increases downstream. The freshwater tidal stream reaches are shortening, as they are "pinched" between increasing salinity and millpond dams.

Northeast Aquatic Habitat Classification: Warm, Small and Medium River **Estimated Extent:** 142 miles, including tidal (Olivero and Anderson 2008)



Map 2. 40 Coastal Plain Small and Medium River

Freshwater Riverine Biotic Habitat Types

Freshwater Submerged Aquatic Vegetation

Submerged aquatic vegetation (SAV) is found in varying degrees in streams and rivers throughout the state in portions of the channel that are permanently inundated during the growing season. SAV is a key primary producer, providing substrate for epiphytic algae and physical structure, cover, and low-velocity refuge for aquatic organisms. Presence of SAV has been linked to increased macroinvertebrate abundance, and it provides critical habitat for fish (Hutchens et al. 2004).

The most extensive beds of SAV are found in the Brandywine Creek of New Castle Co., and in the upper reaches of the Nanticoke River and Deep Creek in Sussex County. The most common SAV in these systems is tape-grass (*Vallisneria americana*). Historically, this species was also found in mill ponds including Lum's Pond, where in the 1950s it was "found throughout the pond in water up to 3 and 4 feet in depth" (Delaware Board of Game and Fish Commissioners 1952).

Freshwater SAV within the Nanticoke River system was surveyed by McAvoy (2006), who found 15 native species and 2 non-native, invasive species, Carolina fanwort (*Cabomba caroliniana*) and hydrilla (*Hydrilla verticillata*).

Several SGCN are associated with freshwater non-tidal SAV, including bridle shiner, swamp darter, and banded and blackbanded sunfish.

Coastal and Marine Ecological Classification Standard (CMECS): Biotic Group: Freshwater and Brackish Tidal Aquatic Vegetation **Estimated Extent:** Unavailable **Habitat of Conservation Concern**

Non-tidal Freshwater Mussel Bed

Freshwater mussel beds may provide important structural habitat for other aquatic species. A discussion of the status of freshwater mussel species and beds in Delaware is found in Chapter 1.

Atlantic Coastal Fish Habitat Partnership: Non-tidal Freshwater Mussel Bed **Estimated Extent:** Unavailable

Estuarine and Marine Aquatic Habitats

Estuarine and Marine aquatic habitat classification in this plan generally follows the CMECS (FGDC 2012), which provides a comprehensive national framework for organizing information about coasts and oceans and their living systems. This system was developed by NOAA's National Ocean Service, NOAA's National Marine Fisheries Service, NatureServe, U.S. Environmental Protection Agency, U.S. Geological Survey, University of Rhode Island, and other partners.

CMECS classifies the environment into biogeographic and aquatic settings that are differentiated by features influencing the distribution of organisms, and by salinity, tidal zone, and proximity to the coast. Within these systems are four underlying components that describe different aspects of the seascape. These components provide a structured way to organize information and a standard terminology. The components can be mapped independently or combined as needed.

The Northwest Atlantic Marine Ecoregional Assessment (NAMERA) (Greene et al. 2010) was developed by TNC to classify marine aquatic environments from Cape Hatteras to the Gulf of Maine. Weaver et al. (2013) developed a crosswalk from the NAMERA aquatic habitat classification developed by TNC to the CMECS system.

Delaware falls within the NAMERA Mid-Atlantic Bight Ecoregion and the CMECS Virginian Ecoregion. The National Marine Fisheries Service (NMFS) developed a habitat assessment improvement plan to assist in gathering better data on marine fish habitats (NMFS 2010).

The condition of marine and estuarine habitats is poorly studied, due to lack of historical baseline data and limited funding, constraints identified in the NOAA NMFS Marine Fisheries Habitat Assessment Improvement Plan (NMFS 2010). Improvements in standardization of coast-wide habitat classification and survey methods (including CMECS) will allow improved assessment of the condition of these habitats.

Marine and Estuarine Species Movements

Assessing spatiotemporal patterns of species distribution for marine and estuarine species is very difficult due to widely differing habitat needs of various life stages and seasonal changes in distributions related to temperature, currents, and life cycle.

Movements of many species are complex and it is not just pelagic species that move great distances in and out of our region. The Atlantic menhaden, a fish of coastal and estuarine waters that serves as a critical prey base for other fish and seabirds, shows large seasonal movements between juvenile nursery areas in Delaware and Chesapeake Bay salt marshes and spawning areas in shelf waters along the Atlantic coast, with one study indicating that as many as 92% of juveniles in samples from local nursery habitats were the result of winter spawns south of Cape Hatteras (Light and Able 2003). Cross-shelf migrants like summer flounder and black sea bass, north-south migrants like striped bass and menhaden, and large whales all use Delaware's marine habitats as they move from southern and near shore locations in winter to offshore or northern locations in summer.

These examples illustrate the importance of improving our understanding and conservation of Delaware’s estuarine and marine habitats in order to ensure region-wide and coast-wide conservation of species.

Estuarine Habitats

The Delaware Bay covers nearly one quarter the surface area of the state of Delaware. The Bay's benthic habitats are highly diverse in their physical characteristics. They include shallow submerged mudflats, rippled sand flats, rocky hard-bottom habitats, silty and sandy shoals, shellfish beds, and tube worm reefs.

Generally, nearshore habitat in the Delaware Estuary has experienced an improvement since the 1930s and 1940s when pollution blocks degraded habitat, particularly in the upper estuary.

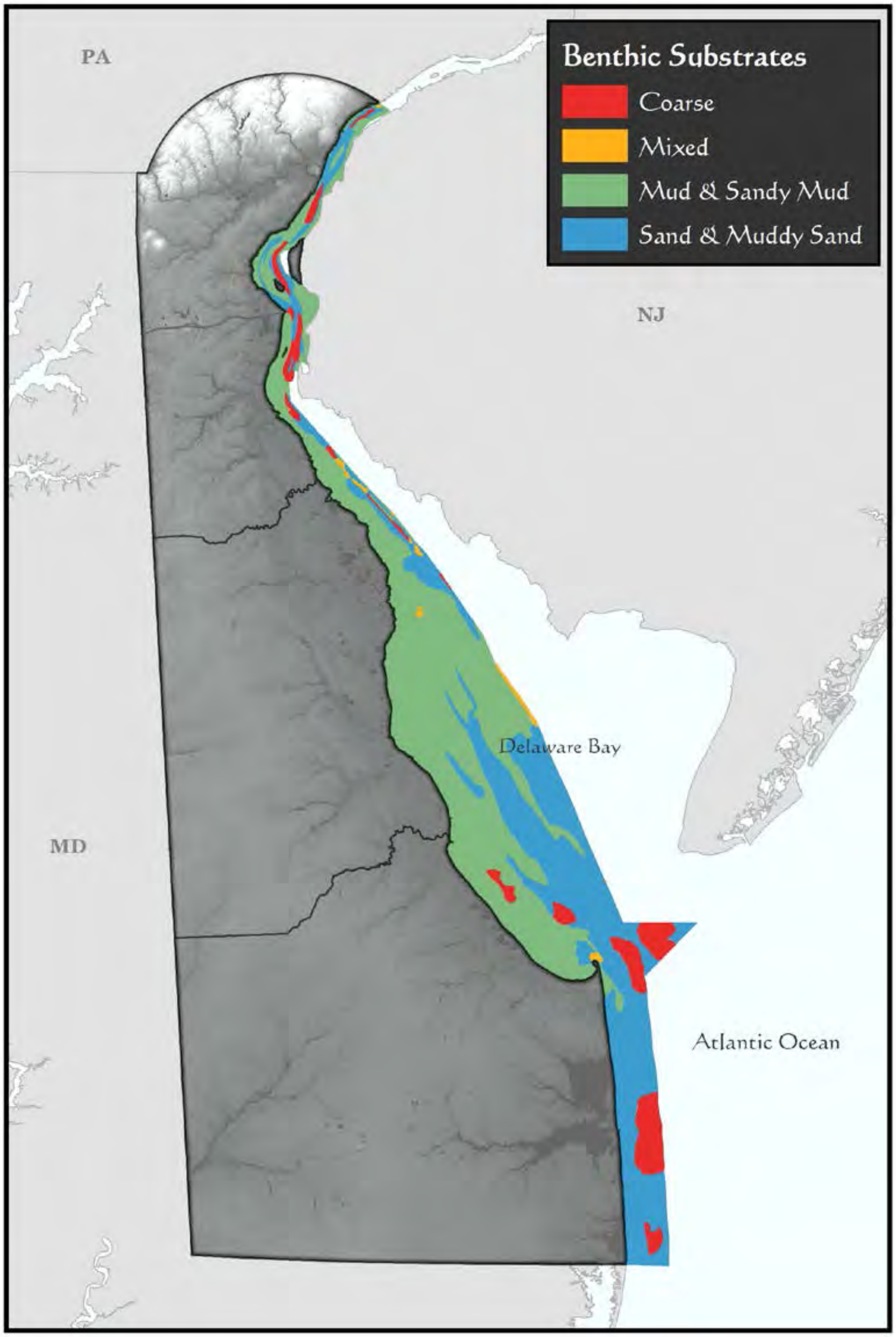
Estuarine Benthic Habitats

Sediment grain size in the Delaware Estuary varies across a wide range, from gravel to clay. The grain size of sediments is an important ecological indicator and one of the primary factors influencing the distribution of various benthic organisms and ecological communities.

In 2014, DNREC's Delaware Coastal Programs completed work on an acoustic mapping project of the benthic sediments in the Delaware portion of the Bay and the nearshore Atlantic marine areas. This project classified substrates into one of four categories: Sand and Muddy Sand, Mud and Sandy Mud, Coarse Sediments, and Mixed Sediments (Delaware Coastal Programs 2014), see Map 2.41.

There is significant heterogeneity of sediment types and patchy distribution at many locations within the estuary, particularly in the reach from Wilmington to Liston Point. In this segment of the estuary, the dominant bottom sediment type is mud, whereas downstream of Liston Point the bottom is dominated by mixtures of sand and gravel with lesser amounts of mud. The zone of dominant muddy bottom corresponds to the estuary turbidity maximum (ETM), which results from the complex interaction of freshwater inflows from upstream sources with denser, more saline water from the Atlantic Ocean (Partnership for the Delaware Estuary 2012).

As part of TNC's NAMERA, a detailed map of benthic habitat types was created for the Delaware Bay and Atlantic Ocean (Map 2.41). These habitat types, called Ecological Marine Units (EMUs), are the three-way combination of physical variables: depth, sediment grain size, and seabed forms. The breaks in bathymetry and substrate grain size are based on ecological thresholds revealed by the benthic organism relationships.



Map 2. 41 Benthic Substrate Types of the Delaware Bay and Atlantic Ocean. Delaware Coastal Programs.

Benthic Species

Benthic invertebrates tend to live longer than most planktonic organisms and can therefore be useful as indicators of changing environmental conditions over time. The Delaware Estuary Benthic Inventory (DEBI), a cooperative project led by the Partnership for the Delaware Estuary, resulted in a significant body of information on the condition and extent of benthic habitats of Delaware Bay. Overall, the DEBI identified 233 benthic species in 112 families and 9 phyla. Five stations had 40 or more species and the mean species richness (number of species) was 13. The most diverse groups were: polychaetes (27 families, 79 species), amphipods (15 families, 35 species), bivalves (17 families, 27 species), and gastropods (15 families, 25 species). The mean benthic invertebrate abundance was 8,800 individuals per square meter. The dominance by polychaetes, bivalves, and amphipods was expected for the estuary's mixed sand/silt sediment as well as from previously published studies, although the abundances found at some sites were greater than previous reports. (Kreeger et al. 2010, Cole and Kreeger 2012)

Other preliminary assessments of the benthic invertebrate diversity of the Delaware Bay have enumerated over 300 species in 8 phyla (see Table 2.11) (Anderson et al. 2013). With improved mapping of natural hard bottom areas in Delaware Bay, epifaunal associations are being characterized more accurately.

Table 2. 11 Delaware Bay Benthic Invertebrate Diversity based on 246 samples. Modified from Anderson et al. (2011)

Phylum	Organisms	Species Diversity
Annelids	Sea worms	130
Arthropods	Crabs, lobsters, shrimp, barnacles	106
Mollusks	Clams, scallops, squid, limpets, sea slugs, snails	75
Echinoderms	Sea stars, sea urchins, sea cucumbers, sand dollars	8
Nemerteans	Ribbon worms	6
Cnidarians	Corals, anemones, jellyfish	5
Chordates	Sea squirts	4

Poriferans	Sponges	1

Estuarine/Marine Substrate Types

The substrate types used in this plan are adapted from those used by the Atlantic Coastal Fish Habitat Partnership (ACFHP); these also correspond to the CMECS Substrate Component. Data on percent sand in Delaware Estuary sediments are shown in Figure 2.49.

Silt/Mud Substrate

Fine-grained sediment derived from watershed runoff/stream bank erosion, and transported in suspension, is the chief source of new inorganic (mineral) sediment in the estuary. The combined sediment load of the piedmont river tributaries is quantitatively the most important source term in the sediment budget. The Delaware River Estuary acts to trap and store these sediments within the system. The efficiency of this trapping is incredible; radionuclide dating of river sediments indicates that much of the sediment retained in the system can be attributed to erosion from 19th century agriculture (Delaware Estuary Regional Sediment Management Workgroup 2013).

These fine sediments support a wide variety of benthic invertebrates as described above. SGCN associated with this substrate type are listed in full in Appendix 2.C.

Coastal and Marine Ecological Classification Standard (CMECS): Substrate Groups: Mud, Sandy Mud. **Estimated Extent:** Unavailable

Sand Substrate

Sand substrates are those that contain greater than 50% sand particles <2 millimeters in diameter (CMECS). The Bureau of Ocean Energy Management (BOEM) and the State of Delaware recently signed a two-year cooperative agreement to identify sand resources for coastal resilience and restoration planning. The agreement will help BOEM and Delaware conduct research to increase knowledge of sand resources offshore, and contribute to long-term coastal resilience planning efforts. Under this agreement, the Delaware Geological Survey (DGS) will evaluate and consolidate Delaware's existing geologic and geophysical data. The data will be used to identify new sand resources to meet future needs. SGCN associated with this substrate type are listed in full in Appendix 2.C.

Coastal and Marine Ecological Classification Standard (CMECS): Substrate Groups: Sand and Muddy Sand. **Estimated Extent:** Unavailable

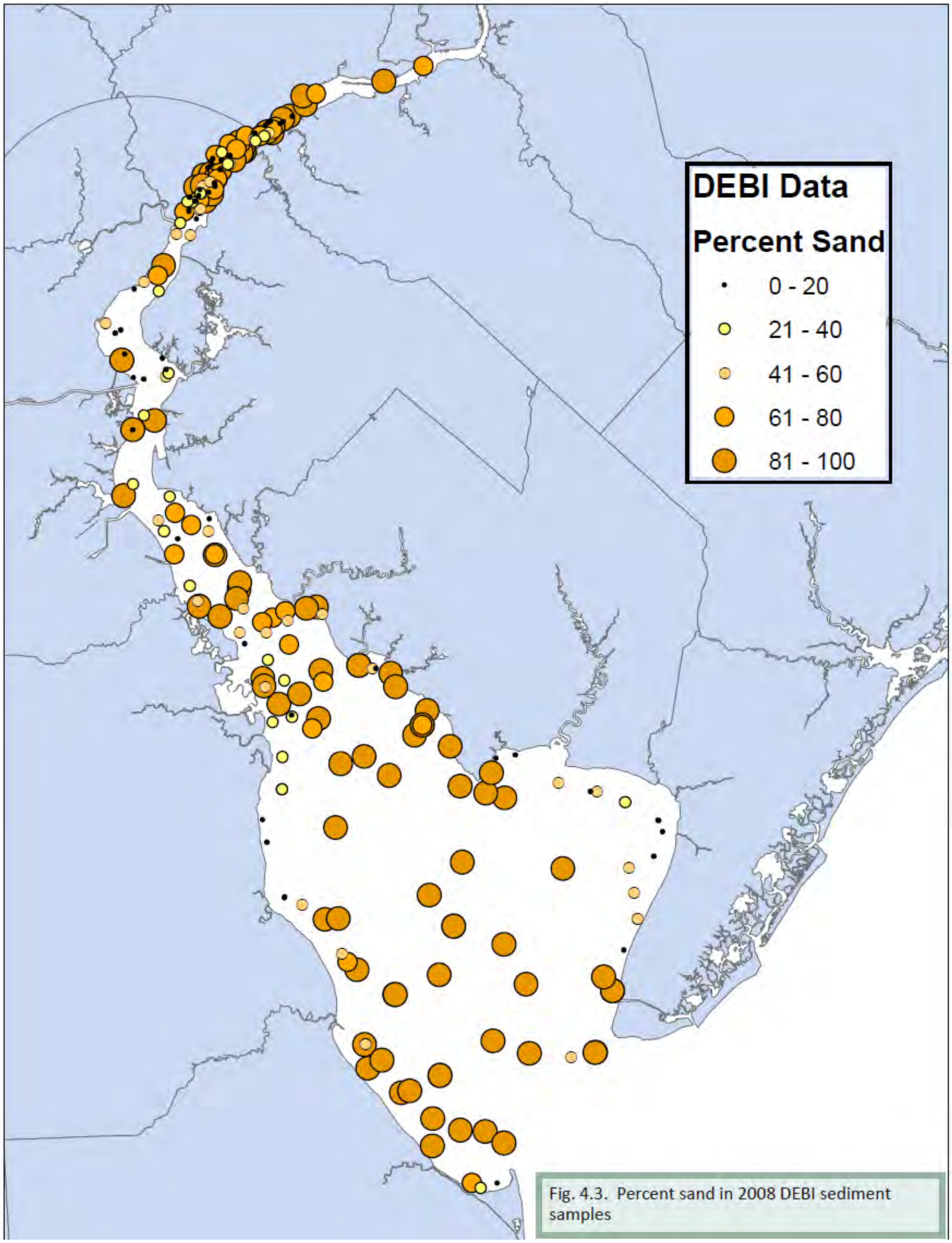


Figure 2. 49 Percent sand in 2008 DEBI sediment samples. Partnership for the Delaware Estuary

Gravel Substrate

Gravel substrates are important to a variety of species, including many SGCN fish, as well as American oyster. A firm gravel substrate is highly favorable to the establishment and persistence of submerged aquatic vegetation, which is critical to many SGCN.

The distribution of gravel and cobble substrates is highly affected by currents and shear stress along the benthic/water column interface. In order to insure the long term stability of the benthic habitat, the proper energetic conditions must be present. SGCN associated with this substrate type are listed in full in Appendix 2.C.

Coastal and Marine Ecological Classification Standard (CMECS): Substrate Subclass: Coarse Unconsolidated Substrate. **Estimated Extent:** Unavailable

Embedded Rock

Embedded rock hard bottom substrate is rare in the soft-bottom environments of Delaware Bay. SGCN associated with this substrate type are listed in full in Appendix 2.C.

Coastal and Marine Ecological Classification Standard (CMECS): Substrate Class: Rock Substrate **Estimated Extent:** Unavailable

Structured Sand Habitat

This substrate feature includes sand shoals and offshore sand bars. SGCN fishes associated with this habitat include: sandbar shark, striped bass, black sea bass, scup, Spanish mackerel, winter flounder, red drum, Atlantic croaker, and others.

These shoals may be disturbed by scallop and toothbar dredge activity associated with the commercial fisheries. The extent of the impact is not well known, but it has been suggested that disturbance is spatially patchy.

Coastal and Marine Ecological Classification Standard (CMECS): Geoform: Shoal **Estimated Extent:** Unavailable **Habitat of Conservation Concern**

Estuarine Biotic Habitat Types

These habitats are equivalent to the Biotic Component of CMECS.

Tubeworm Reefs

These are intertidal and subtidal areas dominated by relatively stable, ridge- or mound-like aggregations of living and non-living material formed by the colonization and growth of tubeworms of the genus *Sabellaria*. These tubeworms are important foundation species in Delaware Bay.

Though several areas in the estuary have been identified as important for *Sabellaria* and associated wildlife, only minimal protection has been offered (e.g., limiting suction dredging for beach nourishment projects) and little information is available on long-term abundance and distribution of tubeworms in the Bay.

Brown (2009) documented a preference for coarse substrate (>0.5 mm) in *Sabellaria* larval colonization, and also found 56 other species associated with areas of *Sabellaria* colonization.

Coastal and Marine Ecological Classification Standard (CMECS): Biotic Group: Sabelariid Reef **Estimated Extent:** Unavailable **Habitat of Conservation Concern**

Oyster Beds

The Eastern oyster is a keystone species that has a large effect on its environment relative to its abundance. Oyster reefs increase habitat complexity, diversity, and abundance of other organisms, as well as provide ecosystem services such as water quality enhancement (Coen and Grizzle, 2007) and buffering of coastal flooding.

Oyster harvesting reached its pinnacle in Delaware Bay in the 1880s with 2.4 million bushels harvested by more than 500 oyster vessels on the bay (PDE 2012). Oyster beds suffered a drastic decline in the 1950s due to overfishing and disease (MSX). The current status of the oyster population in Delaware Bay is low but relatively stable and is sufficient to support a limited commercial fishery. Beck et al. (2009) classified the oyster stock in Delaware Bay as poor, having suffered 90-99% losses compared to historic populations.

The oyster population abundance in Delaware Bay is currently controlled by a balance between recruitment and disease related mortality. Both of these processes respond to environmental factors such as the annual temperature cycle and salinity (freshwater input) and thus cannot be predicted. This unpredictability makes annual surveys a key to sustainably managing the resource. Recent good settlement of young indicates that the adult population will increase in the next few years. Shell planting to enhance recruitment is a mechanism for increasing population abundance (PDE 2012). The extent of oyster beds has been partially mapped (see Wilson et al. 2006). SGCN associated with oyster reefs include: American oystercatcher, oyster toadfish, black sea bass, red drum, and many others.

Coastal and Marine Ecological Classification Standard (CMECS): Biotic Group: Oyster Reef *and* Biotic Group: Oyster Bed **Estimated Extent:** Unavailable **Habitat of Conservation Concern**

Shell Accumulations

Shells of dead mollusks sometimes accumulate in sufficient quantities to provide important habitat. Accumulations of Eastern oyster shells are a common feature in the intertidal zone of many southern estuaries. Shell accumulations are often important areas for juvenile fish. SGCN using this habitat include black sea bass, tautog, scup, weakfish, Atlantic croaker, blue crab, and others.

Coastal and Marine Ecological Classification Standard (CMECS): Substrate Class: Shell Substrate
Estimated Extent: Unavailable

Sulfur Sponge

Hard bottom habitat in the Bay is sometimes extensively colonized by the boring sponge *Cliona celata* (Miller and Kreeger 2009). Large areas of sulfur sponge in the lower bay provide an important habitat for numerous species. Whereas areas of heavy *Sabellaria* concentrations tend to be avoided by the commercial dredge fisheries, sulfur sponge beds are sometimes targeted by the commercial blue crab dredge fishery, which may pose a threat to this habitat.

Coastal and Marine Ecological Classification Standard (CMECS): Biotic Group: Attached Sponges and Biotic Group: Mineral Boring Fauna **Estimated Extent:** Unavailable

Estuarine Submerged Aquatic Vegetation

SAV refers to plants that live and grow entirely underwater, or just at the water's surface (Figure 2.50). These species are critical wildlife resources, providing food and cover for a wide variety of SGCN, from waterfowl to sea turtles. Most of the SAV flora of Delaware is found in fresh water systems (35 species), with only 6 species found in brackish to salt water systems. These mesohaline and polyhaline SAV species are often collectively referred to as "seagrasses" (Fonseca et al. 1998).

Figure 2. 50 Submerged Aquatic Vegetation - Wigeon Grass Estuarine (*Ruppia maritimus)*, Muddy Neck Pond, Assawoman Wildlife Refuge. Photo: Rob Gano

Delaware Bay does not have the large expanses of SAV that were historically present in the Chesapeake Bay. Causes for the limited amount of estuarine SAV in Delaware Bay might be inappropriate bathymetry or unsuitable subtidal substrates. The turbid waters of the Delaware River and Bay do not favor SAV growth. In the lower Delaware Estuary, the SAV species most frequently observed is widgeongrass (*Ruppia maritima*), primarily confined to small salt marsh ponds that have permanent water, or to larger man-made coastal impoundments (Delaware DNREC and DNERR 1999). Eelgrass (*Vallisneria americana*) is a characteristic species of higher salinity tidal areas, although this species is not commonly found in the Bay, and its historic distribution there is unclear.

Estuarine SAV is critical as nursery cover for juvenile and adult SGCN fish, juvenile sea turtles, and estuarine waterfowl. SGCN associated with this substrate type are listed in full in Appendix 2.C.

Coastal and Marine Ecological Classification Standard (CMECS): Biotic Group: Seagrass Bed
Estimated Extent: Unavailable **Habitat of Conservation Concern**

Mussel Reef

Areas dominated by the ridge- or mound-like structures formed by the colonization and growth of mussels that are attached to a substrate of live and dead conspecifics. Blue mussel (*Mytilus edulis*) beds provide valuable nearshore habitat, though they tend to be ephemeral in the estuary and are probably limited by high summer water temperatures. SGCN associated with this habitat include: tautog, greater and lesser scaup, surf scoter, and long-tailed duck.

Coastal and Marine Ecological Classification Standard (CMECS): Biotic Group: Mussel Reef
Estimated Extent: Unavailable **Habitat of Conservation Concern**

Macroalgae

This habitat consists of aggregations or floating particles of macroalgae including *Fucus* spp., *Laminaria* spp., and *Ulva lactuca*. SGCN associated with this habitat include several species of fish, as well as brant and American lobster.

Coastal and Marine Ecological Classification Standard (CMECS): Biotic Group: Algal Rafts and Biotic Group: Algal Particles **Estimated Extent:** Unavailable

Hard Clam Beds

This habitat consists of dense aggregations of the hard clam (*Mercenaria mercenaria*) that are found in the subtidal regions of bays and estuaries to approximately 15 meters in depth. Clams are generally found in mud flats and firm bottom areas consisting of sand or shell fragments (Atlantic Coastal Fish Habitat Partnership 2009), although local studies suggest that oyster shell and sandy substrates host much higher densities than mud or gravel substrates (Bott and Wong n.d.) Hard clam density was mapped for Indian River Bay and Rehoboth based on field surveys conducted in 2010 and 2011 and compared to previous surveys in the late 1970s. No statistically significant difference in clam density between the 1976 (Cole and Spence 1976) and 2010-2011 surveys was found (Bott and Wong n.d.). SGCN associated with this habitat include: Atlantic sturgeon, scup, black sea bass, Atlantic croaker, red drum, and knobbed whelk.

Coastal and Marine Ecological Classification Standard (CMECS): Biotic Group: Clam Bed
Estimated Extent: Unavailable **Habitat of Conservation Concern**

Artificial Substrate Habitats

Artificial Reefs

Delaware has 14 permitted artificial reef sites, 9 in the Delaware Bay and 4 along the Atlantic Coast. Development of these sites began in 1995 and has continued to the present. The Delaware Reef Program is designed to enhance fisheries habitat, benefit structure-oriented fish, and provide fishing opportunities for anglers. Reef materials can develop an invertebrate community which is much richer than adjacent bottom, providing food and physical protection for reef fish such as tautog, sea bass, scup, spadefish and triggerfish. In addition, game fish such as bluefish, striped bass, and weakfish are attracted to baitfish that congregate around reef structures (Delaware Division of Fish and Wildlife 2014).

Recycled materials have supported Delaware's reef development efforts, with donated concrete culvert pipe and other concrete products comprising the primary material used at the eight Delaware Bay sites. Ballasted tire units have been deployed at the ocean sites. Through the year 2000, 24,500 tons of concrete products, 8,000 tons of ballasted tire units and 86 decommissioned military vehicles had been deployed on Delaware sites. Subsequently, hundreds of New York City subway cars and several retired vessels from 40-565 feet in length have bolstered and expanded Delaware's artificial reefs. The reefs range in size from 0.28-1.3 square nautical miles, and in depth from 16 feet at mean low water for the smaller bay sites to 131 feet for the Del-Jersey-Land site located 26 nm from Indian River Inlet (Delaware Division of Fish and Wildlife 2014).

Coastal and Marine Ecological Classification Standard (CMECS): Geoform: Artificial Reef
Estimated Extent: Unavailable

Other Artificial Habitats

Additional artificial habitats may provide structure used by aquatic organisms. Examples include: breakwaters and jetties, bulkheads, riprap shorelines, docks, piers and pilings, and dredged or excavated channels and submerged dredge deposits. SGCN associated with each of these artificial habitat types are listed in Appendix 2.C

Coastal and Marine Ecological Classification Standard (CMECS): Various (See Appendix 2.A)
Estimated Extent: Unavailable

Estuarine Open Water Habitats

Estuarine Open Water

This system includes all estuarine waters offshore of the 4 m depth contour, with salinity greater than 0.5 ppt, including much of the Delaware Bay. Some representative SGCN using this habitat include: black scoter, bufflehead, canvasback, common eider, common loon, common tern, loggerhead sea turtle, long-tailed duck, Northern diamond-backed terrapin, red-breasted merganser, surf scoter, white-winged scoter, and many others. For a complete list, see Appendix 2.C. These estuarine habitats are impacted by changes in water temperature and chemistry associated with climate change, as well as by impacts associated with vessel traffic and shipping in the deeper areas of the Delaware Bay.

Coastal and Marine Ecological Classification Standard (CMECS): Subsystem: Estuarine Open Water **Estimated Extent:** Unavailable

Estuarine Coastal

This system extends from the supratidal zone at the land margin to the 4 meter depth contour in waters that have salinity greater than 0.5 ppt. Because of their shallow depth, the Delaware Inland Bays aquatic habitats fall entirely within this system. Due the presence of extensive shallow flats, a large portion of the Delaware Bay on both the Delaware and New Jersey sides also falls into this system. Some representative SGCN using this habitat include: black scoter, bufflehead, canvasback, common eider, common loon, common tern, loggerhead sea turtle, long-tailed duck, Northern diamond-backed terrapin, red-breasted merganser, surf scoter, and white-winged scoter. For a complete list, see Appendix 2.C. Threats to these habitats include changes in temperature and nutrient loading that may create hypoxic conditions, invasive estuarine species, and impacts from pollution.

Coastal and Marine Ecological Classification Standard (CMECS): Subsystem: Estuarine Coastal **Estimated Extent:** Unavailable

Marine Habitats

Delaware is located in the Middle Atlantic Bight (MAB) of the U.S. East Coast region bounded by Cape Hatteras to the south and by Cape Cod and Nantucket Shoals to the northeast. The MAB is a relatively shallow region of the continental shelf, with high primary productivity induced by strong vertical mixing in fall and winter, followed by stratification in spring and summer. Currents in these shelf waters generally follow a southwestward flow parallel with depth contours (Beardsley and Boicourt 1981). The high productivity supports important fisheries including Atlantic sea scallop (*Placopecten magellanicus*), Atlantic surf clam (*Spisula solidissima*), and the ocean quahog (*Arctica islandica*) (Zhang et al. 2015). The Mid-Atlantic Bight shelf waters are eventually exported eastward to the open ocean and Gulf Stream at Cape Hatteras, at the southern terminus of the bight (Savidge and Savidge 2014).

Along the shelf break, numerous features, including cold water corals and submarine canyons, provide spawning, nursery, and forage habitats that support diverse resident and migratory marine life including invertebrates, seabirds, fishes, and marine mammals. Baltimore and Wilmington Canyons are the largest shelf break canyon features off Delaware Bay.

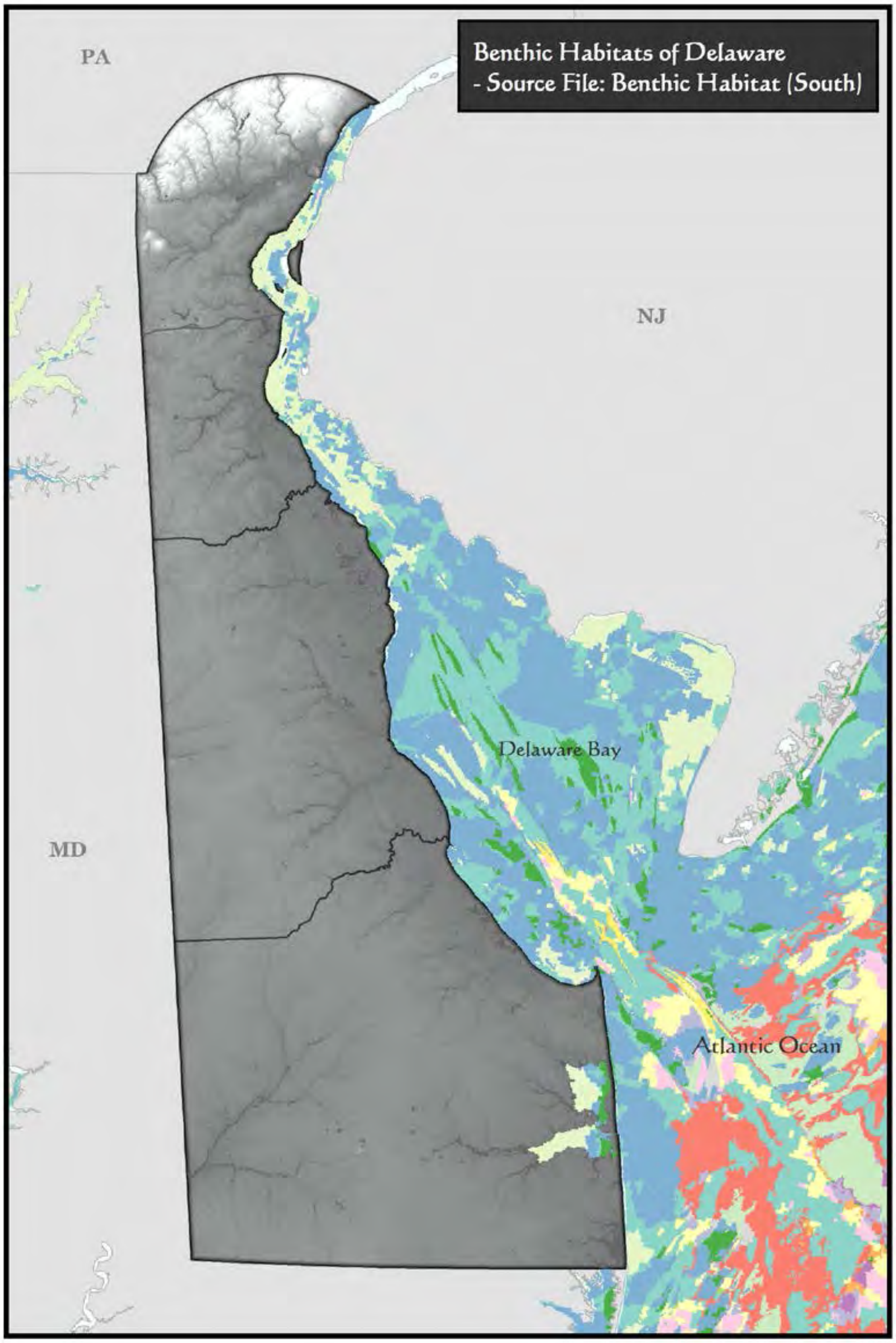
A habitat condition assessment for NAMERA was completed by Greene et al. (2010).

Marine Benthic Habitats

Benthic habitats of the MAB contain over 2000 species of invertebrates, including marine worms, sponges, shrimp, crab, clams, scallops, snails, sea stars, and anemones (Mid-Atlantic Regional Council on the Ocean [MARCO]).

The 2014 DNREC Delaware Coastal Programs mapping project for benthic sediments (Delaware Coastal Programs 2014) collected acoustic chirp transect data at 2200 m spacing for Atlantic nearshore areas to 2.2 km from shore. These data indicate that the predominant bottom type in nearshore areas is sand, interspersed with several large areas of coarse substrate.

Benthic substrate habitat types for marine habitats are classified according to the same substrate types for estuarine habitats above.



Map 2. 42 Benthic Habitat Types of the Delaware Bay and Atlantic Ocean (Ecological Marine Units). The Nature Conservancy.

Marine Biotic Habitat Types

These are specific biotic habitat types that do not also occur in the estuarine system. Those biotic and artificial habitats that occur in both estuarine and nearshore marine systems are treated under estuarine habitats above.

Coldwater Corals

Coldwater hard corals (Order Scleractinia) or stony corals are found in scattered locations on the shelf, and are most abundant near the shelf break (MARCO Data Portal, Figure 2.51). Numerous records of a diverse fauna of hard corals have been reported from Baltimore Canyon. The Mid-Atlantic Fishery Management Council has recently proposed a Deep Sea Corals Amendment to the Mackerel, Squid, and Butterfish Fishery Management Plan (FMP) that considers management measures to protect areas that are known or highly likely to contain deep sea corals. The draft amendment includes a range of alternatives that aim to protect corals by restricting fishing in select areas where fishing effort and prime coral habitats overlap, as well as by restricting expansion of effort into less heavily fished areas where corals are known or are highly likely to be present.

Coastal and Marine Ecological Classification Standard (CMECS): Biotic Subclass: Deepwater/Coldwater Coral Reef Biota *and* Biotic Group: Attached Corals **Estimated Extent:** Unavailable

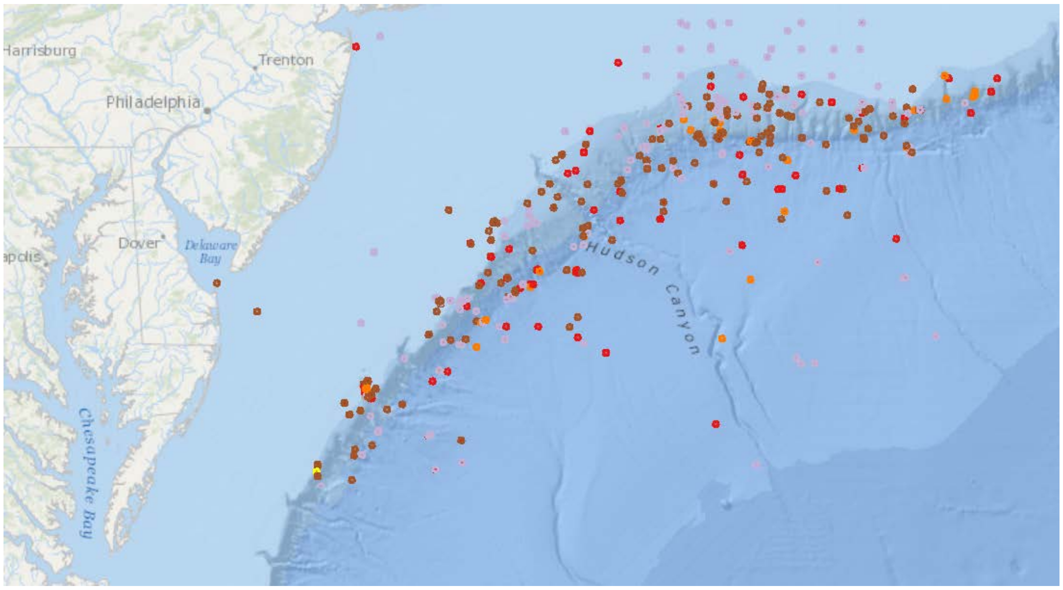


Figure 2. 51. Coldwater Coral Observations off Delaware. Source: NOAA Deep Sea Coral Research and Technology Program, mapped by MARCO Data Portal. http://portal.midatlanticocean.org/static/data_manager/metadata/html/corals.html

Scallop Beds

Areas of dense aggregations of scallops on the ocean floor. Common Atlantic coast species include: (1) the large Atlantic sea scallop (*Placopecten magellanicus*), which ranges from Newfoundland to North Carolina; (2) the medium-sized Atlantic calico scallop (*Argopecten gibbus*), which is found in waters south of Delaware; and (3) the bay scallop (*Argopecten irradians*), which occurs from Cape Cod to Florida as well as in the Gulf of Mexico (ACFHP 2009). Rotational dredging restrictions placed on Atlantic sea scallop fisheries starting in the mid-1990s have helped populations recover from record lows to near record highs. For a complete list of SGCN using scallop beds, see Appendix 2.C.

Coastal and Marine Ecological Classification Standard (CMECS): Biotic Group: Scallop Bed **Estimated Extent:** Unavailable

Marine Open Water Habitats

Marine Oceanic

These habitats occur from the shelf break to the deep ocean. Oceanic waters typically have salinity levels of ≥ 36 ppt. Water depths typically range from 100-200 meters at their shallowest at the shelf break to over 11,000 meters at the deepest point in the ocean. Especially important for Delaware are the oceanic waters near the continental shelf break, where nutrient exchange and upwelling supports a rich diversity of marine species. For a complete list of SGCN using this habitat, see Appendix 2.C. Threats to marine habitats in general from climate change are discussed in Chapter 3.

Coastal and Marine Ecological Classification Standard (CMECS): Subsystem: Marine Oceanic **Estimated Extent:** Unavailable

Marine Offshore

These habitats are found from the 30 m depth contour to the continental shelf break, which is generally 100-200 m depth. These shelf habitats are important for many nektonic species. For a complete list of SGCN using this habitat, see Appendix 2.C.

Coastal and Marine Ecological Classification Standard (CMECS): Subsystem: Marine Offshore **Estimated Extent:** Unavailable

Marine Nearshore

Marine nearshore habitats occur at less than 30 m depth. This depth "is intended to represent an ecologically significant depth to which water column and benthic processes are strongly coupled in the Nearshore Subsystem" (FGDC 2012). Marine nearshore habitats can supplement estuarine habitats for some species, such as larval crabs retained in areas of low subtidal current near the mouth of Delaware Bay (Steppe and Epifanio 2006). Some representative SGCN using this habitat include: black scoter, bufflehead, canvasback, common eider, common loon, common tern, loggerhead sea turtle, long-tailed duck, Northern diamond-backed terrapin, red-breasted merganser, surf scoter, and white-winged scoter. For a complete list of SGCN using this habitat, see Appendix 2.C.

Coastal and Marine Ecological Classification Standard (CMECS): Subsystem: Marine Nearshore **Estimated Extent:** Unavailable

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