2.7 LIVING RESOURCES

2.7.1 INTRODUCTION

By the beginning of the 16th century, the land that would become the political entity known as the State of Delaware encompassed a region of outstanding natural diversity. Clear freshwater rivulets tumbled down rocky streams and rivers from the hills of the Appalachian Piedmont Plateau into the drowned Susquehanna and Delaware River valleys. These river valleys broadened into two magnificent bays, the centers of two vast estuaries, bordered with productive coastal marshes, abundant with shellfish and waterfowl that isolated the intervening coastal plain lands into an elongated peninsula. The larger of the two estuaries, Chesapeake Bay, formed the western boundary of the Delmarva Peninsula. The headwaters of many rivers and streams that enter Chesapeake Bay originate in what is now Delaware.

Today, following nearly 400 years of natural resource consumption and the conversion of habitats by an ever-increasing number of immigrants for agricultural, residential, and industrial purposes, Delaware's remnant natural areas (woodlands, rivers, swamps, and marshes) still provide a biological history of Delaware. Yet, these natural remnants are under continual, increasing, and unprecedented new pressures from humans. This portion of the document will assess the current status of these living resources, measure their spatial change and trends, outline protection and restoration efforts, and suggest possible solutions to retaining a dynamic natural resource base for Delaware's future.

2.7.2 CHARACTERIZATION

In many ways, our living resources reveal more about the state of our environment than any other factor. Our native species are generally the first indicators of change or disruption. They experience first-hand the direct impact of habitat loss, degraded air and water quality, and competition from exotic species. In particular, studies of rare and declining species can play special roles as environmental indicators. These are often the species most sensitive to environmental change and habitat degradation, and hence can bring the first hints of environmental impact. The trick is in knowing how to observe and understand nature's messages.

For instance, a stream's invertebrate fauna tells volumes about the water quality in a tributary. Although not usually included as a standard water quality indicator, the diversity of freshwater mussels is an excellent tool for understanding the health of a waterway. Mussels are filter feeders and hence are especially sensitive to the effects of sedimentation and pollutants. Furthermore, many mussel species require the presence of particular fish species onto which their larvae must attach to complete their life cycle. When native fish species decline because of loss of habitat, damming of streams, or introduction of non-native fish, mussels are often the first to feel the impact.

Changes in an area's avifauna can also illustrate the accumulated environmental changes that often proceed unnoticed. Steep declines in insectivorous forest birds may

CONTENTS

LIVING RESOURCES

indicate the loss or fragmentation of mature forests in our area. Increased numbers of American robins are in some ways comforting after the scare of *Silent Spring* in the early 1960s, but are also, unfortunately, reminders that fields, pastures, roads, and mowed lawns have replaced most of what used to be forest. Similarly, the presence of increasing numbers of non-migratory Canada geese is largely a result of human changes to the landscape, and the intentional introduction of goslings, which had no motive or inclination to migrate. Ironically, these large numbers of "transplanted" geese can lull the uninformed into complacency about their environment when, in fact, *migratory* Canada geese are experiencing region-wide declines.

There have been a number of studies, both ongoing and short-term, of the Chesapeake Basin's flora and fauna. Fish and waterfowl are probably the two best-studied groups of species. Annual waterfowl counts date back to 1955, with more than twenty years of species-specific counts (Whittendale, 1996). Fish species were inventoried for all of Delaware's major streams in 1988, and summarized in two reports funded by the Federal Aid in Fisheries Restoration Act (Shirey, 1988; 1991).

The Delaware Division of Fish and Wildlife's Nongame and Endangered Species Program has conducted ongoing studies of some of the Basin's rare and declining species. The federally endangered Delmarva Fox Squirrel, once found in the forests of Delaware, was extirpated from the entire state. Reintroductions have been moderately successful in eastern Sussex County, but have not been attempted in the Chesapeake Basin, in part because of a federal moratorium on new releases.

The Delaware Natural Heritage Program (DNHP), part of the Division of Fish and Wildlife, conducts on-going inventories of natural communities as well as rare and declining species, (e.g., state and globally rare plants, birds, insects, mussels, reptiles, and amphibians). It maintains a database, both electronic and manual, of its findings throughout the state. The DNHP has never conducted a comprehensive review of the status of biodiversity in the Chesapeake or any of Delaware's basins. But from data that have been collected, it is commonly accepted that an alarming number of species which were once common are now found at only one or two locations, or are extirpated entirely. Of the 50 states, Delaware has been estimated to have lost the highest proportion of its native flora (Kutner and Morse, 1996).

2.7.2.1 Emergence of Delmarva Habitats

The modern habitats of the Chesapeake Basin have their origins in the relatively recent past. Delaware's Coastal Plain Province is young by comparison to the Piedmont's 500-million to billion-year-old rocks. Built by depositions of ancient sediments over the last 150 to 200 million of years, the coastal plain has been repeatedly inundated and exposed by rising and dropping sea levels. These sediments were eroded from Piedmont and Appalachian highlands and deposited along the margin of the continent by the Delaware and Susquehanna rivers when the ocean covered the peninsula. The last time this happened was during the Sangamon interglacial event when the ocean was 30 feet higher than today. Since the Sangamon ended, approximately 80,000 years ago, the peninsula has remained above sea level. In fact, when the Wisconsin Glacier advanced southward around the globe from the Arctic 25,000 years ago, it trapped so much of the world's water that the ocean dropped 300 feet below modern levels, perhaps doubling the modern dimensions of the peninsula. This sheet of ice approached as far south as mid-New Jersey and greatly influenced the types of plants and animals that inhabited Delaware's coastal plain (Scott, 1991).

The cold air mass associated with the huge ice sheet covering the globe produced very cold, cloudy, wet weather over the peninsula. This pattern persisted until about 12,000 years ago when a dramatic warming trend and a melting ice sheet increased the levels of precipitation and caused a rise in the ocean level that continues today. During this period, a shift in the peninsula's vegetation occurred. Tundra-like grassland with scattered boreal species such as spruce had occupied the peninsula during the height of the glacial period. As the weather warmed, northern boreal forest with intermittent remnant grass openings covered the landscape. About 10,000 years ago, pine replaced spruce as the dominant species in this coniferous forest. Over the next 2,000 years, hemlock became a major component on the peninsula, while oaks first began to appear in these moist, mesic (well-drained) forests. During this period, the extinction of the mammoth, mastodon, giant beaver, and other megafauna left a largely modern group of animals on the peninsula. The warm moist weather pattern continued for over 5,000 years until the peninsula supported dense mesic forest, with numerous areas of swamps.

A drying trend began around 5,000 years ago in the Mid-Atlantic, and peaked from 4,700 to 2,200 years ago (Custer, 1984). This xerothermic period had dramatic effects on the flora of the peninsula, bringing about an increase in drought tolerant oak-hickory forest, an eastward extension of prairie grasslands, and a reduction or loss of many mesic species, including hemlock. Also about this time, sea-level rise slowed enough to allow the formation of the estuarine marshes in Chesapeake and Delaware bays (Kraft, 1977). Once the dry trend was replaced by moister and cooler weather, a landscape that approximates modern Delaware emerged.

The Chesapeake Basin's modern flora and fauna associations have existed in similar form on the peninsula for the last 2,000 years. The ocean is still rising, slowly shrink-

ing the size of the peninsula, and demonstrating that weather patterns are constantly and inextricably linked to the future of the Delmarva Peninsula. But perhaps the quickest changes to the living resources in the Chesapeake Basin, and to the entire peninsula, have occurred over the last four centuries since the period of European contact with Native Americans.

2.7.2.2 Prehistoric Human Impacts

It was during the post-glacial period, possibly as far back as 15,000 years ago, when man first ventured onto the peninsula. These were a stone-age people that criss-crossed the landscape in search of food. All they left behind was their stone tools, although some attribute the extinction of the megafauna to these skilled hunters (Martin, 1984). But these people brought another tool with them, fire, which they frequently applied to the landscape to drive game, maintain wildlife pastures, and for other uses (Pyne, 1982). The introduction of anthropogenic fire, added to the much more infrequent natural fire regime, was a major factor in shaping the modern Chesapeake Basin ecosystem. The introduction of fire favored fire-resistant species, such as oak and pine, over hemlock and other fire-vulnerable species.

The descendants of these Native Americans followed similar lifestyle patterns until approximately 1,000 years ago, when they developed a more sedentary life-style based, in part, upon domesticated plants. Growing of plants such as corn, beans, squash, and melons began to supplement the hunting and wild food gathering traditions. However, seasonal burning of the landscape continued until the first Europeans landed in Delaware.

2.7.2.3 Historic Human Impacts

By the 17th century, initial European settlement of the Chesapeake Basin had begun, not by the Dutch or Swedes, but by the English. Lord Baltimore believed that the Eastern Shore was part of his proprietorship, so he granted warrants for land along both the Nanticoke River and Marshyhope Creek that included parts of modern Delaware. These early settlers were subsistence farmers at first, growing rye, barley, tobacco, and sugar cane, and planting apple and peach orchards. Later in the century, they abandoned tobacco and sugar cane and began to grow wheat and corn as cash crops. They introduced hogs, horses, sheep, and cattle to the peninsula and released them into the woods. They adopted the Native American method of burning the landscape, partially out of defense, but also to clear the forest. They girdled the larger trees and planted under them, cutting the smaller trees and shrubs. Their homesteads were usually located within 300 feet of the stream on which they fronted. Transportation was by water, but sedimentation, dead logs, and ship ballast blocked many previously navigable waterways. By the beginning of the 18th century, most of the remaining Native Americans, that had not been ravaged by disease, had left the peninsula or had adapted to the predominant Euro-American society.

During the 18th century, the colonial settlement pattern began to extend away from stream banks into remote upland sites within a half-day of travel (maximum eight miles) from the local grist and sawmills. Beginning in the 1760s, several iron furnaces were established along the Nanticoke, Gravelly Branch, Deep Branch, and other locations in the Chesapeake Basin. These furnaces processed bog iron deposits dug from the surrounding wetlands (Heite, 1974). The forges required prodigious amounts of charcoal and wood to operate, and these were acquired from the surrounding forests. Most of these furnaces were out of production by the American Revolution. By 1770, the boundary dispute between Maryland and Pennsylvania was settled, and the Chesapeake Basin became part of the Lower Three Counties of Pennsylvania. The rapid growth of Delaware's population during this period, especially in "New Sussex," as the previously disputed territory was called, forced many new farmers to clear and farm land of poor quality. Streams and creeks were dammed to provide power for saw and gristmills. The milldams became focal points as well as crossing points for the surrounding population, with taverns, shops, stores, and cart paths developed near these dams. The lumbering of the peninsula increased rapidly and continued unabated. Not only were the forests an impediment to agriculture, but wood was needed for many purposes, including new construction, energy, furniture, shipbuilding, bridges, and charcoal. Even the ancient submerged giant cypress logs that had fallen into the swamp long before the colonies existed were pulled from the Great Cypress Swamp and made into shingles (Scharf, 1888).

In the early 19th century, agricultural production had fallen. Many farms were abandoned in the 1820s and '30s when farmers left for better lands to the west of the mountains (De Cunzo and Catts, 1990). Although these abandoned, played-out farms could no longer support 19th-century farming practices, they quickly developed young healthy secondary forests of loblolly pine. Still, by 1880, between 75 and 90 percent of each county was farmland. Virtually every upland habitat had been cleared. This practice had been driven in part by the arrival of the railroad, which, after reaching Seaford in 1858, provided a fast route to market for farmers in the western part of Delaware. By 1890, Sussex County produced peaches, corn, and enormous amounts of strawberries (by 1900, Sussex County led the nation in strawberry production).

The successful introduction of European agricultural practices meant not only a conversion of a significant per-

centage of forest to agriculture and pasture, but the extermination of predators, and the over-harvesting of game and furbearing animals. Beaver had been trapped out with the first fur traders in the 17th century. Great flocks of passenger pigeons had once returned annually to a "pigeon-roost," or breeding place, in the great oak groves of the *Moyamensing*, the Native American descriptive word for an unclean place or dung-heap (Scharf, 1888). The huge flocks of pigeons quickly disappeared from Delaware with the cutting of the trees, long before the species became extinct in 1914. Numerous species were exterminated from Delaware near the end of the 19th century, including eastern gray wolves, eastern cougar, and black bear. Wild turkey fell to logging practices and market hunting by 1880, but were later reestablished. White-tailed deer were essentially gone from Delaware by 1900. In fact, deer hunting was illegal in Delaware for over 150 years, until the 1950s.

The holly wreath industry flourished from the 1880s through 1960s in Sussex County. Most of the large marketable holly was cut for wood products, while smaller boughs went into making large quantities of holly wreaths. Although largely centered in eastern Sussex, Bridgeville was the major shipping point for holly wreaths collected in the Chesapeake Basin during November and December of each year. Collecting wreaths supplemented farm incomes during this time of year, especially during the Depression (Hancock, 1976).

Despite the almost constant lumbering of Delaware's forests beginning with the earliest settlements in the 17th century, a record amount of timber was harvested in 1909 (records were not kept prior to the Civil War). Fifty-five million board feet of lumber was shipped from Sussex County, mostly secondary growth loblolly pine that had naturally reestablished on abandoned farms and other clearings 100 years previous. Charcoal production was also an important industry and still persisted in the Redden area as late as the 1950s (Passmore, 1978).

2.7.2.4 Biotic Communities

The following DNHP descriptions summarize the natural communities found within Delaware's Chesapeake Basin. Because the Basin ranges over 81 miles from north to south, it includes a significant transition zone where a number of northern plant species reach their southern limits of natural distribution, while an even greater number of southern species reach their northern distribution limit. Despite the low elevations and generally simple topography throughout the Basin, a wide assortment of habitat types harbor a diverse flora and fauna.

Forest Communities

The Chesapeake Basin is home to a variety of important forest communities that are found as repeating units on the landscape. These forests would fall within the broadly classified Mixed Mesophytic Forest Region in the northern portion of the Basin and gradually transitioning in the south to the Oak-Pine Forest Region (Braun, 1950), or the Oak-Pine-Hickory Forest Sub-Region, according to Greller (1988). In general, the northernmost forests in the Chesapeake Basin are comprised of a mixture of hardwoods, dominated primarily by oaks, beech, tulip poplar, and hickories on the drier sites. The predominate tree species in a wide variety of wetland habitats include box elder, sycamore, sweet gum, slippery elm, red maple, tulip poplar, ash, pin oak, and sometimes river birch and black willow. The farther south one travels in the Basin, a transition in forest species begins, but nowhere is this more dramatic than as one enters Sussex County. Here, the deciduous hardwood-dominated forest gives way to an evergreen forest with a distinctive southern feel. This is the Oak-Pine Forest Region.

Two major components have been virtually eliminated from both of these forest types. American chestnut (*Castanea dentata*) and, to a lesser degree, American elm (*Ulmus americana*) were formerly important components of both of these forest regions, but have been virtually eliminated by the introduction of chestnut blight and "Dutch" elm disease. A new threat, anthracnose fungus (*Discula destructiva*), which attacks flowering dogwood (*Cornus florida*), is predicted by some to wipe out this significant understory tree from Delaware forests in the near future.

At one time, the Chesapeake Basin was virtually entirely forested. Native American fire practices opened park-like gaps within the forest and altered the upland composition of the forest. Consequently, over the thousands of years of use, burning favored fire-tolerant species such as oak and pine over maple, beech, and hemlock. When European colonists arrived, they cleared the land with incredible speed relative to their numbers. They permanently fragmented and isolated the forest into small, scattered woodlots. The first areas to be cleared were upland forest habitats. These areas provided the best-drained farmland and easy accessibility. As a result, intact, old growth, upland coastal plain forest probably no longer exists in Delaware. At first, the colonists avoided swamps and other wet forestlands. These forests were protected by their waters, which had also generally insulated them from Native American fires for millennia. But even these forests could not avoid the ax. In a trend that continues today, forests too wet to farm are regularly used for wood supply, livestock, hunting, and timber products. Many have had their hydrology altered by successful (and even unsuccessful) attempts at drainage. All of the forested stream corridors in the Chesapeake Basin have been dammed, dredged, or have been used for irrigation. Still, somewhat amazingly, after the consistent and resourceful efforts to utilize these forests, a variety of wetland forest types remain.

However, because of their heavy utilization for over 200 years, there is tremendous variability in the quality of these forests. In all probability, the woodlands throughout the Chesapeake Basin are second-, third-, or even fourth- growth forest, most with trees less than 50 to 100 years old. Because of these repeated disturbances, many forest-dependent plant and animal species in Delaware are threatened with extirpation. The greatest loss of species throughout the state has occurred in forested habitats. Yet, the oldest trees in the state are to be found in this Basin, where one forested wetland contains specimens estimated at 500 years of age. Although the age of these magnificent trees is unusual in Delaware, and indeed in the entire Chesapeake watershed, many of these huge plants are just reaching middle age. Although the term "old growth" is frequently used to describe patches of forest containing these large specimens, a true, virgin, old growth forest is not likely to remain in the Chesapeake Basin. However, some of these mature forest patches are developing some of the typical characteristics of an old growth forest.

Nearly 75 percent of the Chesapeake Basin's terrestrial forests are no longer extant, having been cleared long ago for farmland and early settlements, or more recently for urban sprawl. Most of the remaining forests throughout the Basin are young successional woods or maturing forests that are comprised of a high proportion of pioneer tree species that quickly reforest abandoned farmland or timber clear-cuts. A significant transition from loblolly pine forest to red maple and sweet-gum forests occurred during the 1960s and '70s as a result of clear-cutting second- and third-growth loblolly pine forest (Ferguson and Mayer, 1974). Twentieth-century forest practices that encouraged planting loblolly pine seedlings and suppressing hardwood competition with herbicide and mechanical means has lead to an increase in timber plantations and a further reduction in structural and functional forest diversity.

The following are brief descriptions of the forest types that one is likely to encounter in the Chesapeake Basin along its entire length in Delaware:

Quercus spp.-Liriodendron tulipifera-Fagus grandifolia Forest Community (oak – tulip poplar – beech forest)

This community is usually found in scattered small stands or "rich woods" in the coastal plain. The oak–tulip poplar–beech forest may be extremely diverse and of good to excellent quality. Oaks usually present include red oak (*Q. rubra*), southern red oak (*Q. falcata*), scarlet oak (*Q. coccinea*), and white oak (*Q. alba*). Common associates include *Fraxinus americana*, *Carya ovata*, *C. glabra*, *C. tomentosa*, *Lindera benzoin*, *Kalmia latifolia*, *Hamamelis virginiana*, *Carpinus caroliniana*, *Rhododendron periclymenoides*, *Viburnum prunifolium*, and *Cornus florida,* among other woody taxa. Herbs are typified by such species as *Arisaema triphyllum*, *Podophyllum peltatum*, *Asarum canadense*, *Claytonia virginica*, and *Aralia nudicaulis*, among a host of other species.

Liriodendron tulipifera Forest Community (tulip poplar forest)

This is a forest community where the majority of the canopy is comprised of tulip poplar. This is similar to the preceding community but without the oaks and beech (though certainly these may be present but in low numbers). The understory may be comprised of many of the same species as in the previous community.

Acer rubrum Wetland Forest (red maple wetland forest)

This forest can be found on narrow or broad floodplains. While red maple *(Acer rubrum)* may be the dominant canopy tree, several additional canopy associates may include sweet gum (*Liquidambar styraciflua)*, black gum *(Nyssa sylvatica)*, green ash *(Fraxinus pennsylvanica)*, pin oak *(Quercus palustris)*, and sycamore *(Platanus occidentalis)*. The subcanopy woody layer is comprised of *Cornus amomum, Clethra alnifolia, Itea virginica, Lindera benzoin, Vaccinium corymbosum, Leucothoe racemosa, Viburnum nudum*, and *V. dentatum*, among others. Herbs may include various sedges (*Carex* spp.), *Symplocarpus foetidus, Juncus effusus, Impatiens capensis, Scirpus cyperinus, Phalaris arundinacea, Solidago rugosa, Cinna arundinacea, Polygonum hydropiperoides, Aster puniceus, Lycopus* sp., *Arisaema triphyllum, Onoclea sensibilis, Acorus calamus, Chelone glabra, Thelypteris palustris, Woodwardia areolata*, and *Boehmeria cylindrical.*

Acer rubrum-Liquidambar styraciflua Forest Community (red maple-sweet gum forest)

This community may be found on dry as well as wet sites. It is often indicative of second- or third-growth forest stands, and often may be characterized as disturbed or degraded. On dry sites, associates include *Lindera benzoin, Viburnum dentatum, V. prunifolium, Toxicodendron radicans, Smilax rotundifolia, Lonicera japonica, Rosa multiflora, Prunus serotina, Podophyllum peltatum, Smilacina racemosa, Bartonia virginica, Cypripedium acaule*, and *Maianthemum canadense.* Wet sites may consist of *Lindera benzoin, Sambucus canadensis, Vitis labrusca, Smilax rotundifolia, Symplocarpus foetidus, Apios americana, Boehmeria cylindrica, Carex prasina, Cryptotaenia canadensis, Dioscorea villosa, Glyceria striata*, and *Impatiens capensis.*

Quercus spp.-Pinus virginiana Forest Community (oak-scrub pine forest)

Occurs in non-xeric sand dune ridges (see below), a successional forest comprised of scrub pine, which may be dominant with high canopy cover. Several oaks may be co-dominant including white oak *(Quercus alba)*, southern red oak *(Q. falcata)*, and water oak *(Q. nigra)*. Less abundant canopy associates include post oak *(Q. stellata),* sassafras *(Sassafras albidum)*, black gum *(Nyssa sylvatica)*, and loblolly pine *(Pinus taeda)*. Sub-canopy and shrub associates include *Prunus serotina, Sassafras albidum, Ilex opaca,*

Q. marilandica, Vaccinium stamineum, Gaylussacia baccata, G. frondosa, Magnolia virginiana, Cornus florida, and *Myrica pensylvanica.* Herbs are sparse with *Panicum* spp., *Carex* spp., *Chimaphila maculata, Cypripedium acaule,* and *Melampyrum lineare,* typical. Vines include *Smilax rotundifolia, S. glauca, Parthenocissus quinquefolia, Toxicodendron radicans, Vitis aestivalis, V. rotundifolia,* and *Ipomea pandurata.* Lichens and mosses may or may not be prevalent. This community type occurs in sandy, well-drained substrate.

Quercus spp.-Carya spp. Forest Community (oak-hickory forest)

This community can be found in drier habitats where there has been little disturbance, usually at the highest elevations on the more level uplands. It is characterized by an abundance of oaks (*Q. alba, Q. rubra, Q. coccinea, Q. falcata*) and hickories (*C. cordiformis, C. ovata, C. glabra, C. tomentosa*). Associates may include *Liriodendron tulipifera, Acer rubrum, Betula lenta, Fraxinus americana*, *Hamamelis virginiana, Kalmia latifolia, V. dentatum, Cornus florida, Lindera benzoin, Euonymus americanus, Lonicera japonica, Prunus serotina, Ariseama triphyllum, Aralia nudicaulis, Chimaphila maculata, Galium* spp., *Circaea lutetiana, Sanguinaria canadensis, Epifagus grandifolia, Podophyllum peltatum, Smilacina racemosa,* and *Thelypteris noveboracensis* (Clancy, pers. comm.).

Scrub-Shrub Communities

Scrub-shrub communities can be quite variable, are generally small, and may represent an early serial stage of a forested community. Many of the scrub-shrub communities are more accurately described as impenetrable thickets, with a dense understory of brambles and greenbrier. The more persistent scrub-shrub communities are usually found along stream sides and seepage wetlands, and are often situated between marsh and forest habitats. Shrub communities recur within the Nanticoke watershed. Examples include (1) Alder Shrub Community dominated by *Alnus serrulata* and *A. maritima*; (2) Red Maple-Green Ash-Swamp Rose Shrub Community, a low statured and stunted shrub assemblage due to flooding; and (3) Mixed Shrub-Mixed Herb Community representing a diverse assemblage of shrubs, herbs, and stunted trees (Clancy, pers. comm.).

Herbaceous Communities

Examples of the herbaceous communities within the Chesapeake Basin include the following: Tussock Sedge Herb Community *(Carex stricta)*; Reed Canary Grass Herb Community *(Phalaris arundinacea)*; Cat-tail Herb Community *(Typha latifolia, T. angustfolia)*; Indian Rice Herb Community *(Zizania aquatica)*; Pickerel-Weed - Arrow Arum Herb Community *(Pontederia cordata, Peltandra virginica)* abundant on the Nanticoke River; Mixed Forbs Tidal Herb Community; Spatterdock Herb Community *(Nuphar lutea)*; Water Lily Herb Community *(Nymphaea odorata)*; Quillwort Herb Community *(Isoetes riparia)*; Sweet Flag Herb Community *(Acorus calamus)*; Tape Grass Submerged Herb Community *(Vallisneria americana, Potamogeton spp.)* (Clancy, pers. comm.).

Rare Community Types

The DNHP, in an ongoing process of describing and classifying natural communities within Delaware, located and mapped several unique and significant community types in the Chesapeake Basin (McAvoy and Clancy, 1993). *Map 2.7-1 Living Resources* shows these locations along with other natural areas.

Bald Cypress Communities

The DNHP considers naturally occurring bald cypress (*Taxodium distichum*) to be a rare species in the State of Delaware, including the Chesapeake Basin. This tree species has a relatively limited distribution and is found in only four watersheds in the state, two of which are in the Chesapeake Basin (e.g., Nanticoke and Pocomoke). The tree has a low number of natural occurrences within Delaware, where it reaches the northernmost limit of its North American range.

Bald cypress wetland communities are principally found on the forested floodplains of rivers and creeks that are temporarily and seasonally flooded. These wetland communities are considered to be climax communities in Delaware because of their extensive canopy coverage, large size, and potential life span. On floodplains, bald cypress is rarely found growing in pure, mono-specific stands. It is typically associated with a mix of hardwood species, such as red maple (*Acer rubrum*), black gum (*Nyssa sylvatica*), sweet gum (*Liquidambar styraciflua*), and green ash (*Fraxinus pennsylvanica*). The James Branch and its tributaries contain the most extensive and finest examples of bald cypress wetlands in the state (McAvoy and Clancy, 1993). The cypress-hardwood association may be indicative of a short hydroperiod because most other tree species can not have their roots submerged for extended periods of time. This is clearly demonstrated where floodplains have been dammed, creating ponds. The only trees still surviving in these ponds are bald cypress. Bald cypress trees are adapted to prolonged flooding that would exclude other tree species. Some conifers such as Atlantic white cedar (*Chamaecyparis thyoides*) and loblolly pine (*Pinus taeda*) may also be associated with bald cypress wetlands.

The shrub and herbaceous layers of these floodplain wetlands are very diverse. However, the species found in these wetlands are often also common to hardwood floodplain wetlands as well. According to McAvoy and Clancy (1993), the bald cypress floodplains were not found to contain rare species outside of the bald cypress itself.

The headwaters and tributaries of the Pocomoke River encompass a portion of the area known as the Great Cypress Swamp. Much of the Pocomoke River and its tributaries have

been greatly altered by wide and deeply cut dredge channels. As a result, the riparian floodplain community has been severely affected, with the wetland herbaceous habitat of the floodplain swamp forests reduced to a remnant of its former self. Weedy species such as Japanese honeysuckle (*Lonicera japonica*), poison ivy (*Toxicodendron radicans*), pokeweed (*Phytolaca americana*), multiflora rose (*Rosa multiflora*), hercules club (*Aralia spinosa*), wild grape (*Vitus* sp.), greenbrier (*Smilax rotundifolia*), and paw paw (*Asimina triloba*) have invaded the altered habitat and are now well established and abundant. Red maple, sweet gum, and black gum have replaced the formerly dominant bald cypress tree canopy. Sweetleaf is abundant throughout the Pocomoke River watershed. However, bald cypress remains only in sporadic stands in this watershed following the extensive 18th- and 19th-century logging, drainage, and subsequent wildfires that have greatly altered the hydrology and, consequently, available habitat.

Atlantic White Cedar Communities

Atlantic white cedar (*Chamaecyparis thyoides*) is a wide ranging, but uncommon tree species found in a narrow, interrupted belt scattered along the Atlantic coast from Maine to Florida, then west along the Gulf coast to Mississippi. The historical distribution of Atlantic white cedar on the Delmarva Peninsula is reported to be either very sketchy or limited. According to Dill and others (1987), Atlantic white cedar exists today on the Delmarva Peninsula in remnant stands that represent only a fraction of the species' former geographic and ecologic importance.

The many uses of Atlantic white cedar and its commercial exploitation are well documented in the literature (e.g., Little, 1950; Frost, 1987; Zampella, 1987; Laderman, 1987). Since colonial times, this tree has been logged repeatedly. Because the wood was lightweight, easily worked, and resistant to decay, it had many uses during the colonial period. Many Atlantic white cedar stands have been logged two, three, or more times in the past, not surprisingly making the tree a minor element in the landscape today.

Significant remaining populations of Atlantic white cedar are in Delaware's portion of the Chesapeake Basin, in the Nanticoke River watershed and its associated tributaries. Several small remnant populations exist in the Great Cypress Swamp in the Pocomoke drainage. A past estimate (Anonymous, 1797) claimed that one-fifteenth of the 50,000-acre Great Cypress tract contained green "cypress" (Atlantic white cedar). This anonymous author further states, "Beautiful green cypress, or rather cedar, whose regular and majestic height cast such a venerable shade that it kept every other tree of the forest at an awful distance and impressed the beholder with a religious solemnity." If this estimate is true, approximately 3,333 acres of the Great Cypress Swamp consisted of this tree species. Today, only 10,000 acres of the great swamp remain, and virtually none of these acres is hydrologically intact or vegetated with bald cypress or Atlantic white cedar.

In its natural range, Atlantic white cedar is typically found along creeks and rivers (Laderman, 1987). In Delaware, it formed dense stands at the headwaters of colonial period millponds in portions of Kent and Sussex counties. Atlantic white cedar wetlands occur on very poorly drained, highly organic acid soils. These soils are described as muck-peat and range in thickness from a few inches to many feet. The cedars occur on hummocks of organic matter, leaf litter, and developing soils, surrounded by hollows that are flooded for lengthy periods of time (McAvoy and Clancy, 1993).

Where Atlantic white cedar forms pure stands, typical associated understory species include Collin's sedge (*Carex collinsii*), sweet pepperbush (*Clethra alnifolia*), inkberry (*Ilex glabra*), Virginia willow (*Itea virginica*), spicebush (*Lindera benizoin*), sweet bay (*Magnolia virginiana*), partridge berry (*Mitchella repens*), golden club (*Orontium aquaticum*), swamp azalea (*Rhododendron viscosum*), greenbriers (*Smilax laurifolia* and *S. walteri*), sphagnum moss (*Sphagnum* spp.), highbush blueberry (*Vaccinium corybosum*), arrowood (*Viburnum dentatum* var. *lucida*), and possumhaw (*V. nudum*). Generally, except where openings occur in the cedar canopy, the overall floral diversity is lower in these swamps than in mixed white cedar/hardwood swamps. However, these openings often harbor a plethora of rare species (McAvoy and Clancy, 1993).

Where Atlantic white cedar is not the dominant canopy species and co-occurs with other tree species (most notably, red maple, green ash, and black gum), there tends to be greater diversity of shrubs and herbs in the understory. In addition to the species mentioned above that are found in a pure Atlantic white cedar community, these woody species are commonly found in a mixed cedar-hardwood swamp: seaside alder (*Alnus maritima*), red chokeberry (*Aronia arbutifolia)*, persimmon (*Diospryros virginiana*), strawberry bush (*Euonymus americanus*), American holly (*Ilex opaca*), winterberry (*Ilex verticillata*), fetterbush (*Leucothoe reacemosa*), sweet gum, tulip poplar, wax myrtle (*Myrica cerifera*), mistletoe (*Phoradendron flavescens*), loblolly pine, Virginia pine (*Pinus virginiana*), and greenbrier (*Smilax rotundifolia*) (McAvoy and Clancy, 1993).

Atlantic white cedar wetlands in Delaware and throughout their range are considered refugia for both state and globally rare species.

Coastal Plain Pond Communities

Coastal plain ponds (also known as Carolina or Delmarva bays, whale wallows, etc.) are characterized as shallow elliptical or ovate variable-sized depressions oriented in a southeast-northwest direction. However, in Delaware, coastal plain ponds are usually less than an acre in size, and may or

may not have the southeast-northwest orientation. Frequently, a pronounced sand ridge may be on the southeast side of the pond. A prominent rim circumscribing the pond is also a common characteristic, although not always present. Most of the ponds are located in Delaware's portion of the Chesapeake Basin, and are primarily in northwest Kent and southwest New Castle counties.

The origin of coastal plain ponds is a mystery. The ponds occur in the sandy soils of the Atlantic Coastal Plain, from New Jersey to Florida, and are positioned on several different geologic formations (Prouty, 1952; Gamble et al., 1977). On the Delmarva Peninsula, the coastal plain ponds occur on the Wicomico, Talbot, and Pamilico terraces, between sea-level and 90-feet elevations, in the Pennsauken and Calvert formations (Rasmussen, 1958; Pickett and Spoljaric, 1971; Benson and Pickett 1986; Stolt 1986; and Stolt and Rabenshorst, 1987). At the present time, there is no accepted explanation of coastal plain pond formation.

Soil studies of coastal plain ponds in Maryland indicate the soils have low pH values (from 3.6 to 4.6); are poor to very poorly drained; and range from silt loam to silty clay loam at one extreme, to loamy sand at the other (Stolt and Rabenshorst, 1987). Coastal plain ponds in Delaware have similar textural characteristics as the Maryland coastal plain ponds. Most coastal plain ponds are characterized by fluctuating water tables and are mainly derived from groundwater recharge in the winter. As a result of ongoing biological surveys by DNHP staff, it is surmised that these fluctuating water tables contribute to the establishment of much of the unique herbaceous flora, while often precluding establishment of most woody species, such as shrubs and trees. Moreover, DNHP estimates that as a result of anthropogenic activities (subdivisions, channelization, etc.), more than half of the known coastal plain ponds have been destroyed or have severely disrupted hydrology.

According to a 1993 DNHP survey, the majority of the coastal plain ponds (which occur in the west-central portion of the state within the Chesapeake Basin) are degraded. Impacts to the ponds resulted from perturbations of the local ground-water supply due to clear-cutting of adjacent forest habitat, channelization of natural streams, and ditching to drain nearby agricultural lands. These activities are thought to have altered the environmental character of these systems by disrupting the surficial and subterranean water supply and affecting water quality of the ponds.

Coastal plain ponds are important to preserve and protect. They are critical refugia for a variety of endangered species of animals and plants and are geologically unique entities with no definitive origin. They provide a unique and local habitat for the Delmarva Peninsula complex of flora and fauna. They are important for local ground-water recharge to maintain adequate drinking water and baseflow for streams. Efforts to protect these wetlands via acquisition, public outreach programs, or regulatory protection will be necessary if we are to preserve this unique resource.

Xeric Sand Dune Ridges

These dry sand dune ridges are a unique natural community type to Delaware and the Delmarva Peninsula. They are most prominent within the Nanticoke River Watershed, where the best development of xeric sand-ridges is found along the east side of the river. Thought to have originated from Parsonburg Sand deposited between 13,000 and 30,000 years ago (Denny and Owens, 1979), the distribution of this community is irregular. Some are found in groups, while others are isolated. Forested with a mix of oak and pine, the ridges are long, narrow, and irregular in shape, and of low relief with gentle sloping sides. Dominated by Virginia pine (*Pinus virginiana*) with a variety of oaks, this "barren" type of community, with its low canopy (6 to 40 feet), supports an understory of low heaths, and a sparse herbaceous layer characterized by sedges, grasses, lichens, and mosses (Clancy, pers. comm.). This community appears to be fire-dependent and has been somewhat altered by modern fire suppression.

2.7.2.5 Wildlife

Game Populations

There are 58 species currently classified as "Delaware game animals" and managed by the Division of Fish and Wildlife (F&W). Among these species are 44 birds, 11 mammals, 2 reptiles, and 1 amphibian. All of the mammals, reptiles, and amphibians, as well as 6 bird species, are year-round residents. The remaining 38 bird species are classified exclusively as migratory and fall under the jurisdiction of the U.S. Department of the Interior.

The white-tailed deer (*Odocoileus virginianus*) is native to the Chesapeake Basin and has adapted and thrived in the human-altered habitat. Deer damage to agricultural crops has become a serious concern within Delaware. The Basin includes most of the top deer management zones in terms of the number of crop damage complaints and severity of damage. Since 1992, the deer harvest within the Basin has increased approximately 53 percent, far exceeding the overall statewide increase of 36 percent. Crop damage complaints and deer harvest levels indicate that the white-tailed deer population is at high levels within the Chesapeake Basin.

Beaver (*Castor canadensis*) was apparently extirpated from Delaware by the mid-1800s. They were reintroduced to the state in 1935 with the release of one pair in each county. Since then, additional animals have moved in from Maryland. In 1943, the population was estimated at 24 animals. By the mid-1980s, the beaver was beginning

Table 2.7-1

TURKEY RESTORATION WITHIN THE CHESAPEAKE BASIN

AREA	YEAR(S)	NO. OF BIRDS
Redden State Forest	1989	16
Norman G. Wilder WMA	1990, 1991	27
Chesapeake Corp.	1992	15
Tabor State Forest	1993	17
Nanticoke WMA	1993, 1997	19
Blackiston WMA	1997	13

to come into conflict with humans, primarily because of road and field flooding and destruction of trees. In 1990, Fish & Wildlife captured and relocated 28 problem animals in Sussex and southern Kent counties. A 1991 survey of beaver colonies found 126 statewide, with approximately 90 of those in the Chesapeake Basin. In 1997, there were an estimated 300 colonies within the Delaware portion of the Basin, with a population in excess of 1,500 animals. Approximately 150 animals were captured and moved from sites in the Chesapeake Basin alone. Beaver populations are increasing within the Basin.

Like the beaver, the wild turkey (*Meleagris gallopavo*) was extirpated from Delaware by the mid-1800s. In 1984, 34 wild birds were brought to Delaware from New Jersey, Vermont, and Pennsylvania. Between 1989 and 1997, 107 turkeys were captured within the state and transferred to 6 release sites in the Chesapeake Basin. *Table 2.7-1* shows these release sites, the years of release, and the number of birds stocked.

Since 1990, selected turkey management zones have been surveyed for wild turkeys. Several zones have most or all of their area within the Chesapeake Basin. Due to budgetary limitations, not all zones are surveyed each year. The data collected, however, indicate increasing turkey populations in the Basin *(Table 2.7-2)*. What appears to be a dramatic decline in Zone 16 is likely a survey anomaly since turkey-hunting data do not suggest a significant decline.

Wild turkeys are very adaptable and will use a variety of habitats from mature forests to open agricultural fields. The current mix of these habitats in the Chesapeake Basin makes the area good turkey habitat. Agricultural land provides an important winter food source in the form of waste grain. Forestland (especially forests with a significant oak component) provides food as well as nesting and roosting cover.

When Delaware residents think of Canada Geese (*Branta canadensis*), they generally think of the migratory flocks that come here from Canada in the fall. More and more, however, resident flocks that stay all year are becoming common. Resident flocks first became established in northern New Castle County, likely the result from releases of captive birds. Resident flocks are flourishing throughout the state, with approximately 500 geese using small ponds scattered throughout the Chesapeake Basin. Birds in the Basin represent approximately 15 percent of the state population.

Resident geese are becoming a problem in Delaware. In this Basin, geese have caused damage to lawns on residential and commercial properties. They litter areas with feathers and are sometimes aggressive toward humans. Trap Pond State Park has had problems with resident birds because of large amounts of droppings deposited on the public beach. There have also been complaints concerning water quality in ponds used by large numbers of birds, as well as complaints concerning crop damage to young corn and soybean plants. Because of the abundance of agriculture and small ponds, resident goose numbers are expected to increase in the Basin. To date, methods for controlling resident geese have been largely ineffective. As the human population continues to build in the Basin, goose/human conflicts will likely increase as well.

Table 2.7-2

TURKEY POPULATION SURVEYS WITHIN THE CHESAPEAKE BASIN

ZONE	1990	1991	1992	1993	1994	1995	1996
6	—	63	50	—	—	27	115
7	—	—	6	—	—	125	—
10	34	—	69	—	—	—	121
11	3	62	59	167	183	—	—
13	2	—	7	—	—	80	53
14	25	29	39	41	68	—	—
16	146	100	—	22	—	—	—

The previous four game species are very adaptable and are, for now, doing relatively well in the face of human impacts on the land. The northern bobwhite quail (*Colinus virginianus*) is, however, another story. This species is tied closely to, and dependent upon, early successional/grassland habitats. This type of habitat was common on the small family farms that once dotted Delaware's landscape. However, farm hedgerows that once provided escape cover for quail have been eliminated to accommodate more crops and the large equipment used for planting and harvesting. As a rule, crops are now planted to the wood's edge, leaving no buffer strips of grasses or weeds. In addition, today's crop-harvesting techniques are much more efficient than they used to be. As a result, the amount of waste grain left for quail has been reduced. Finally, the use of chemical pesticides and herbicides has increased over the years. All of these factors combined have caused a drastic decline in bobwhite quail numbers.

Due to the decline in bobwhite quail populations, Fish & Wildlife implemented random statewide quail roadside survey routes in 1995. Observers count the number of quail heard whistling along a standardized route. Data are then broken down to the number of quail heard per mile driven, and comparisons are made between years. Survey data demonstrate a drop in quail numbers since 1995 *(Table 2.7-3)*.

The decline in Chesapeake Basin quail populations appears to follow the state trend as indicated by the 1997 survey results. It is important to note however, that this Basin represents about one-third of the land area of Delaware, and includes some of the most undeveloped and unpopulated habitat. As a result, this Basin has a great potential for providing quail habitat protection and restoration. The 1996 U.S. Farm Bill presents resource managers with perhaps the last best chance to stabilize or reverse the quail decline. Congress has earmarked $2.5 billion annually for the next 10 years to fund programs that will enhance wildlife habitat and water quality, as well as reduce soil erosion. The most significant program under this bill is the Conservation Reserve Program under which farmers and other landowners can take land out of production and receive annual payments for a 10- to 15-year period. In addition, the program will cost-share up to 50 percent of the funding required to create and maintain wildlife habitat. Another program is the Wildlife Habitat Incentives Program that provides a one-time cost-share of 75 percent to landowners who would like to implement projects for wildlife.

Non-Game Populations

The only information people generally receive about non-game wildlife populations is about the listed (rare) species. Many animal species are not threatened with extinction. In fact, some species have even benefited from the anthropomorphic changes to the landscape over the past 300 years (e.g., red fox, gray squirrels, and woodchucks have probably never been this common). Broad-spectrum habitat users such as American robins, blue jays, and ring-billed gulls have far more available habitat now than they had before the major land-clearing efforts began. Brown-headed cowbirds, killdeer, and other open-country animals have taken quite well to the man-made expansion of the agricultural "prairies" and successional forest margins. Finally, due to its ability to thrive in a variety of habitats, the coyote may quite possibly be the latest animal to be commonly observed in the Basin.

In contrast to the above "successes," too many non-game species of animals have had their habitats reduced significantly. These animals usually have narrow habitat requirements. The critical factor to the success or failure of a species could be available breeding or nesting habitat, foraging habitat, or direct competition for habitat with exotic or native invasive species. In many cases, these vital habitats have become isolated, small, or of degraded quality. Even the best habitats are vulnerable or threatened. One example of this is a breeding colony of great blue herons (*Ardea herodias*) that has occupied an isolated portion of Blackbird State Forest for the past several years. This is one of two breeding locations discovered within the Chesapeake Basin (other rookeries have been located in Maryland). Great blue herons are intolerant of human activity near their nest location. Lack of available nesting habitat is a potential limiting factor for this species in Delaware. All but two of the Great Blue Heron colonies in Delaware are located within protected conservation lands. This is not accidental, but represents the only available nesting habitat left for this species. The Delaware Department of Agriculture, Forest Service Section (DDA, Forest Service) protects this small colony, but what must be done to ensure that the great blue heron continues to be part of Delaware's avian fauna?

Most forest species populations are in decline in Delaware. This should not be surprising when one understands

Table 2.7-3

RESULTS OF THE WHISTLING BOBWHITE QUAIL SURVEY IN DELAWARE

	1995	1996	1997
Miles surveyed	472.5	465.5	869.0
Total whistling quail	785	464	468 (223)*
Whistling quail/ mile surveyed	1.66	1.00	0.54 (0.52)*

( ) * results of routes within the Chesapeake Basin

that most of Delaware's forests have been reduced in both area, connectivity, and overall forest quality for over 300 years. Many bird species that once commonly bred in Delaware are now found infrequently or are briefly seen passing through in migration. The situation is even more troubling for the less mobile animals, fish, reptiles, amphibians, and invertebrates. The survival of these animals is critical because they represent a measure of the living resources of the state. The imperative identification and protection of natural areas that preserve this faunal diversity, which will also protect the floral diversity, is critical to keeping a healthy living resource base in the Chesapeake Basin, Delaware, and throughout the neighboring Eastern Shore.

For example, a DNHP inventory of the fauna found within the Choptank River's floodplain and surrounding upland forests revealed many species of concern for preservation. Bird species such as the Kentucky warbler (*Oporornis formosus*), Louisiana water thrush (*Seirus motacilla*), and yellow-throated vireo (*Vireo flavifrons*), are migratory neo-tropical passerine species that breed in the palustrine forests of the watershed, but are rare elsewhere in the state. The cerulean warbler (*Dendroica cerulea*) is also dependent on mature deciduous floodplain forests and surrounding upland forests for reproductive success. Formerly present along the Choptank River, this species was not sighted during the DNHP's latest survey. Habitat reduction may have eliminated this species from the Choptank River environs. It is now known to be breeding in fewer than six sites throughout Delaware and is faring poorly throughout its global range.

Other bird species such as the barred owl (*Strix varia*), red-shouldered hawk (*Buteo lineatus*), and pileated woodpecker (*Dryocopus pileatus*), are important forest predators that have disappeared from most of Delaware's woodlands. These species require extensive tracts of mature floodplain forests to ensure successful reproduction (Clancy et al., 1995). The populations of these birds, and many others, are also in decline in Delaware because of fragmentation and elimination of the surrounding upland forests.

The high diversity of insect species, particularly odonates (dragonflies and damselflies) was found to be reflective of the variety of wetland habitats found within the study area. The most notable species found were the blue-faced meadowfly (*Sympetrum ambiguum*), blackwater bluet (*Enallagma weewa*), and the blue corporal (*Libellula deplanata*) (Clancy et al., 1995).

In all of the Chesapeake Basin areas that have been inventoried, there are 19 aquatic animal species that have been ranked S1 (extremely rare with 5 or fewer occurrences), S2 (very rare with 6 – 20 occurrences), or SH (historically known, but not found for 15 years or more) (Delaware Natural Heritage Program Database, 1998). The list is comprised of 11 fish, 3 freshwater mussels, and 5 aquatic insects. These species, with depressed population numbers, are especially vulnerable to water-quality degradation and alterations in established food chains caused by the introduction and establishment of non-native species. Also, damming of rivers and their tributaries for millponds impedes the movement of some fish species which, in turn, impedes mussel larvae, which are dispersed by those fish.

There is a need for an inventory to determine abundance and presence of species in areas that have never been surveyed or in areas that have not been surveyed for 10+ years. Current data are incomplete regarding native minnows and freshwater mussels. Once identified, the locations of these populations need to be protected.

Although highly visible non-game species such as the bald eagle (*Haliaeetus leucocephalus*) have received a lot of attention, it was the protection of the bald eagle's habitat (and the elimination of DDT use) that protected both it and perhaps thousands of other species that share the eagle's foraging territory. Ultimately, it is the protection of vital identified habitat that will preserve Delaware's living resources and protect our biological history.

2.7.2.6 Fisheries Resources

Commercial Fisheries

The streams and rivers that drain into the Chesapeake Bay support many species of fish that are harvested for both food and profit. The majority of commercial fishing efforts take place in the Nanticoke River, with American shad (*Alosa sapidissima*), blueback herring (*A. aestivalis*), alewife (*A. pseudoharengus*), white catfish (*Ameiurus catus*), channel catfish (*Ictalurus punctatus*), striped bass (*Morone saxatilis*), and white perch (*Morone americana*) representing the highest percentage of the catch (Whitmore, 1997). Fishing efforts are regulated via limited entry, landing quotas, seasons, size limits, gear restrictions, and area closures. Despite these restrictions, some species have declined, are at low population levels, or at depressed historic levels. A combination of habitat loss, water-quality degradation, and overfishing has contributed to this decline (Chesapeake Bay Foundation, 1996).

Historically, the Nanticoke River was the third most productive tributary for American shad in the Chesapeake drainage (Craig Shirey, pers. comm.). Near the turn of the century, commercial landings in the Delaware portion of the Nanticoke exceeded 200,000 lbs. In the past 100 years, spawning stocks have suffered a general decline. A baywide moratorium on commercial fishing for American shad was adopted in 1980 for Maryland waters and in 1993 for Virginia waters (Dale Weinrich, Maryland DNR, pers. comm.). Harvest is still permitted in Delaware waters with no seasonal closure, size limits, or limit on the number landed.

The alewife and blueback herring, which use this drainage for spawning and nursery habitat, have also

suffered a population decline. In the Delaware portion of this drainage, there are no restoration efforts or fishing restrictions in place.

Several rivers in this Basin have been dammed to create ponds, which in turn impede anadromous species (such as alewife, blueback herring, and American shad), from reaching historic spawning areas. Below is a list of tributaries that drain into the Chesapeake Bay, and Delaware ponds that potentially impede migration through these tributaries (secondary and tertiary impediments are in parenthesis):

Nanticoke River:
Collins, Concord (Fleetwood), Craigs, Williams (Hearns)

Broad Creek:
Records (Trap, Raccoon, Trussum, Chipmans), Horseys, Portsville (Tussock)

Choptank River:
Mud Mill Pond

The Department is currently evaluating the impact of fish ladders installed in 1996 on several Delaware Bay tributaries. Once evaluations are completed, an anadromous species management plan will be drafted. At that time, recommendations will be made regarding tributaries of the Chesapeake Bay that impede migration of anadromous species.

Yellow perch (*Perca flavescens*) populations have had a steady system-wide increase in reproduction since 1993, and the lifting of current restrictions on commercial and recreational harvest in Maryland waters is being evaluated (Paul Piovis, Maryland DNR, pers. comm.). In the Delaware portion of this drainage, there are no special restrictions and no commercial fishery for yellow perch. Minimal data exist regarding current yellow perch populations and structure.

The American eel (*Anguilla rostrata*) is a species of special concern. This species utilizes the Chesapeake Bay drainage as a nursery and feeding area. Harvested eels never have an opportunity to spawn. There is a "black market" for elvers (i.e., eels less than 6 inches), which are illegally collected and sold in foreign markets for over $300/lb. The 6 – 12 inch juveniles are sold legally as bait and live food in U.S. and foreign markets. Currently, Delaware has no limit on the number of commercial licenses, no limit on the number of pots allowable per fisher, and no reporting requirements. An American eel management plan is being prepared, but minimal data exist regarding fishing effort, landings, or stock size (John Clark, F&W, pers. comm.).

Recreational Fisheries

Due to heavy fishing pressure on the freshwater ponds in the Basin, active fisheries management is necessary to sustain the resource and maintain recreational value. In addition, the Nanticoke River system supports the heaviest fishing pressure of all tidal streams in Delaware (Martin, 1996). The most-sought-after resident freshwater gamefish is the largemouth bass (*Micropterus salmoides*). Many fishing tournaments and man-days of fishing are directed strictly toward this species. Catch-and-release fishing by anglers is a major factor in preserving the quality of this fishery (Martin, 1997). Identifying and protecting spawning habitat is crucial, especially in tidal waters. Due to low recruitment into the fishery, supplemental stocking of fingerlings into the Nanticoke River has been conducted annually since 1995.

According to a 1994 angler mail survey (Martin, 1996), there was a substantial increase in projected fishing effort from 1990 – 94. The highest projected catch and effort was for the following species: largemouth bass, bluegill (*Lepomis macrochirus*), pumpkinseed (*L. gibbosus*), black crappie (*Pomoxis nigromaculatus*), white perch, yellow perch, chain pickerel (*Esox niger*), and catfish (*Ictalurus sp.*). The size and structure of gamefish populations in state-owned ponds are intensely monitored. The increase in fishing effort has continued, resulting in a need for more public freshwater fishing opportunities. A project to construct new ponds (less than 5 acres in size) on public lands was initiated, with construction funding available beginning in 1998.

There is a recreational gill-net fishery in this drainage, with tidal stream catch data available for each county (Whitmore, 1997). However, other than the Nanticoke River, the data are not separated by individual stream/creek. Major species targeted in these tidal areas are river herring (alewife and blueback), catfish (white and channel), white perch, striped bass, and American shad.

Spawning/Nursery/Rearing/Feeding Habitat

Yellow perch and golden shiners (*Notemigonus crysoleucas*) utilize submerged aquatic vegetation (SAV) for spawning and nursery areas. Other species, especially sunfish, may nest adjacent to SAV, using it as cover and as a nursery area for their offspring. It is critical that these habitats be identified and protected from degradation. Deep Creek and Gravelly Run, tributaries of the Nanticoke River, support extensive SAV beds. Siltation caused by shoreline development and destruction of shoreline buffers is a major destructive factor, killing SAV and smothering egg masses that are within the beds. Dredging and channelization projects have been proposed for some areas of the Nanticoke watershed. This type of alteration would severely affect shellfish, plant, and fish species by direct take, and by alteration of spawning, nursery, and feeding habitat.

Due to impediments that prevent upstream migration, river herring (blueback and alewife) utilize spill pools below ponds for spawning. Large spawning aggregations have been observed below Williams, Records, Craigs, and Portsville Ponds (Seagraves et al., 1990). The protection of

critical spawning habitats is important for the reproductive success of these anadromous species.

Tidal wetlands, which become inundated during high-tide conditions, are important feeding areas for predatory fish such as largemouth bass. This factor should be considered when drafting tidal wetland protection plans. The potential for bulkheading and private piers to impact or destroy the ecological integrity of these areas should also be considered before issuing permits. Some privately owned piers on the Nanticoke River transect wetlands and extend well out into the river, creating possible environmental and navigational hazards.

In areas with limited cover, dead falls and other natural debris provide protection for prey species. Mass removal of this critical 'habitat' could be detrimental to the populations of such species. Where possible, natural debris should be left intact.

Water quality conducive to growth, survival, and reproduction of aquatic species must be maintained or improved. Runoff of pesticides and herbicides, excess nutrients, toxic chemicals, ditching, dredging, siltation, clear-cutting for development, and loss of woodland buffers adversely affect water quality. Depending on the causative factor, aquatic species can be adversely affected during any life stage.

Water-quality degradation and subsequent eutrophication also have been linked with *Pfiesteria piscicida,* a toxic marine microorganism that can cause sudden large fish kills. This organism can persist in the environment in a dormant state, but become active when conditions are conducive to its growth and survival. It appears to thrive in nutrient-rich waters, which derive excess nutrients from various sources including runoff from lawns, golf courses, septic systems, farms, and discharge from wastewater treatment plants (DNREC and DHSS, 1997). The potential for this toxic organism to invade Delaware waters should be taken seriously. Preventive measures and efforts to curb excess nutrients should be undertaken immediately, before the organism becomes a human health risk and/or affects local fish populations.

Lakes and Ponds

Most ponds within the Chesapeake Basin have problems with nuisance aquatic plant growth, which in some cases is so severe that access to the pond for water-related activities is limited or even eliminated *(see Table 2.7-4)*. The presence and spread of exotic aquatic vegetation has been documented from 1966 (Lesser, 1966) to the present (Miller, 1988). Exotic vegetation out-competes beneficial native vegetation, clogs waterways, and impedes fishing. Nutrient enrichment and subsequent water-quality degradation give exotic vegetation a competitive edge over native vegetation. The types of plants that create the most problems include several species of filamentous algae and two introduced species of submerged aquatic vegetation: hydrilla *(Hydrilla verticillata)* and cabomba *(Cabomba caroliniana)*.

The Division of Fish and Wildlife (F&W) uses aquatic herbicides and an aquatic weed harvester to mitigate these problems in the public ponds. This task is carried out as requested and as resources are available. The control of excess aquatic vegetation can be expensive, costing Delaware an annual average of $40,000 – $50,000 (Miller, pers. comm.). For most years, requests for aquatic plant control overwhelm the resources available for F&W to respond. Finally, it has recently been observed that the treatment of hydrilla with herbicides is usually followed by infestations of filamentous algae — an even worse problem. This pattern needs to be further verified, but, until then, herbicide control of hydrilla should be done with extreme caution and only when absolutely necessary.

Filamentous Algae

Extensive floating mats of these algae are observed during the summer months on the surface of ponds throughout the state. At moderate and slight levels of infestation, filamentous algae cause little trouble for people and provide beneficial habitat for aquatic life. In extreme abundance, thick floating mats of filamentous algae have inhibited and even temporarily eliminated recreational use of Craigs Pond, Hearns Pond, and others. Other lakes that have less intense problems with this type of algae include Chipmans Pond, Horseys Pond, Records Pond, Trap Pond, and Williams Pond. Effects of heavy infestations on fish populations are unclear. For example, Hearns Pond has such a severe infestation of filamentous algae every year that residents complain for much of the summer, yet bass and bluegill fishing remains very good. On the other hand, during the month of May in most years since 1990, Hearns Pond has had a fish kill involving primarily large bluegills. Although the causes of this kill have not been positively verified, it usually coincides with the first appearance of floating filamentous algae mats and has been attributed to a combination of factors, including stress brought on by severe eutrophic conditions.

A handful of species are responsible for filamentous algae infestations in Delaware ponds including, *Pithophora*, *Rhizoclonium*, *Hydrodictyon,* and *Lyngbya*. Aquatic herbicides and mechanical harvesting are the control methods of choice. Harvesting is the only viable way to remove *Lyngbya* mats, and has the added benefit of removing nutrients from the system. All but *Lyngbya* respond well to herbicides, but there can be detrimental water-quality effects caused by the release of nutrients and oxygen-demanding substances from decaying algae. In Hearns Pond, a dense bloom of phytoplankton (blue-green algae) almost always follows herbicide treatment of algae mats. This bloom is characterized by poor water quality, including pH levels rising above 9.5, biological oxygen demand concentrations over 10.0 mg/l (acceptable concentrations are < 5 mg/l) and increased murkiness of water.

Table 2.7-4
IMPACTED LAKES AND PONDS

POND	ACRES	SUB-BASIN	TYPE(S) OF NUISANCE PLANTS	MAGNITUDE OF THE PROBLEM
Chipman Pond	52	Broad Creek	hydrilla, filamentous algae	Moderate to Severe
Concord Pond	68	Nanticoke River	hydrilla	Moderate
Collins Pond	110 +	Nanticoke River	hydrilla	Moderate
Craigs Pond	12	Nanticoke River	filamentous algae	Very Severe
Fleetwood Pond	30 +	Nanticoke River	unknown	Unknown
Hearns Pond	53	Nanticoke River	filamentous algae	Very Severe
Horseys Pond	46	Broad Creek	filamentous algae, hydrilla	Moderate to Severe
Mud Mill Pond	60	Choptank River	none	None
Portsville Pond	14.5	Broad Creek	bladderwort	Slight to None
Raccoon Pond	13.5	Broad Creek	hydrilla, cabomba	Moderate to Severe
Records Pond	92	Broad Creek	filamentous algae, hydrilla	Moderate to Severe
Trap Pond	88	Broad Creek	hydrilla, filamentous algae	Moderate to Severe
Trussum Pond	59	Broad Creek	cabomba, duckweed	Very Severe
Tussock Pond	8.6	Broad Creek	hydrilla	Moderate
Williams Pond	60 +	Nanticoke River	filamentous algae	Severe to Moderate

Hydrilla and Cabomba

Incidental or deliberate introduction of non-native aquatics can cause major problems to existing native species, fishing, other forms of water-based recreation, and water quality. Although there are numerous examples of exotic species in this drainage, several species have more potential to cause negative impacts.

Hydrilla and cabomba are introduced species of submerged aquatic vegetation (SAV). Although SAV is desirable in moderate-to-high abundance (occupying about 40 to 60 percent of the bottom and water column of a pond), these two species can cover up to 75 to 95 percent of the bottom and water column. Such extensive growth inhibits boating access and fishing effort, and can also upset predator-prey relationships that support normal growth rates and numbers of warmwater gamefish (Swingle, 1950; Cooper and Crowder, 1979; Colle, 1980; Savino and Stein, 1982; Werner et al., 1982). Ponds that have experienced problems with these plants include Chipmans Pond, Collins Pond, Concord Pond, Horseys Pond, Records Pond, Raccoon Pond, Trap Pond, Trussum Pond, and Tussock Pond.

Hydrilla and cabomba can be controlled using approved types of aquatic herbicides. Lowering the pond water level during the winter, and thereby freezing the root system, can also control cabomba. Hydrilla does not respond well to water-level drawdowns because it produces tubers, which are not as susceptible to freezing. The control of both these plant species must be done very carefully, for there is an apparent pattern of herbicide treatments being followed by even more problematic infestations of filamentous algae and phytoplankton (blue-green algae). Despite the access problems caused by hydrilla and cabomba, water quality associated with these and other SAV species is better than that associated with filamentous algae and phytoplankton blue-green algae.

Trussum Pond, located in the eastern Broad Creek watershed, is an exception to the general rule of better water quality for ponds with SAV. An extremely dense population of cabomba has taken over this pond, as it becomes covered over with duckweed during the summer. This covering exceeds 90 percent of the entire pond's surface from mid-June through mid-September and results in the complete exhaustion of dissolved oxygen throughout the water column. The results of fishery surveys indicate that most of the pond's fish population has succumbed to this harsh condition. Management alternatives are contingent on replacement of the spillway because the present structure does not allow for any water-level manipulation. The pond has too many stumps and snags to allow the use of herbicides. In any event, there would be concern that the herbicides could harm the stand of bald cypress trees — the unique distinguishing characteristic of this pond. Some progress has been made toward correcting this situation, although funding sources to replace the spillway need to be identified.

Carp and Gizzard Shad

Common carp *(Cyprinus carpio),* a 19th-century introduction to North America from Eurasia, and the native gizzard shad (*Dorosoma cepedianum*) are non-game fish species. When extremely abundant, these species can upset the ecological balance in ponds. Mud Mill Pond is the only pond in the Chesapeake Basin with carp occurring in large enough numbers to potentially impact other fish species. There are no ponds in the Basin where gizzard shad are dominant, although the species is abundant in the Nanticoke River and Broad Creek. A population of carp is also known to exist in Williams Pond, but they do not appear to affect other species. There is no evidence that either of these species is a problem or represents a threat to the gamefish populations.

Grass Carp

One species that is considered an exotic, but is used as a tool for aquatic vegetation control, is the grass carp *(Ctenopharyngodon idella)*. In Delaware, only controlled stocking of sterile triploid grass carp is permitted. The State of Maryland is concerned that this herbivorous fish may escape from Delaware ponds into the Chesapeake Bay, where they could potentially destroy beneficial aquatic vegetation. Because of this concern, a moratorium was imposed in October 1995 on the stocking of grass carp in waters that empty directly into Chesapeake tributaries.

Asiatic Clam

The Asiatic clam *(Corbicula fluminea)* is an exotic species that has a widespread distribution in the Chesapeake Bay drainage. It has altered ecosystem food chains, decreased diversity, and out-competed or displaced native mussel species, some of which are rare. Its tolerance of water-quality degradation gives the Asiatic clam a competitive edge over more environmentally sensitive native mussel species. Ironically, as a filter feeder, the Asiatic clam may have some beneficial effect on water quality. The significance of any such potential benefit is not known.

Zebra Mussel

The potential for zebra mussel *(Dreissena polymorpha)* invasion exists for some areas in the Chesapeake drainage. Environmental conditions conducive to zebra mussel survival exist in northern and central Delaware waterways, and regions along the eastern side of Chesapeake Bay (Bochenek, 1995). Zebra mussel veligers are found in the upper Susquehanna River, a major tributary to Chesapeake Bay. This discovery was one factor that led to the development of a regional policy for prevention and control of non-indigenous aquatic species found in the Chesapeake Basin (Terlizzi et al., 1995). Zebra mussels can impact water-dependent industries by clogging systems and decreasing diversity through competition with native species for food and habitat. Once established, zebra mussel populations prove difficult to control, so preventive measures need to be considered.

2.7.2.7 Living Resource Based Recreation

Delaware's natural resources provide a variety of recreational opportunities for the state's residents and visitors. In a 1995 statewide telephone survey conducted as a part of the state's outdoor recreation planning process, Delawareans identified hiking and walking trails as well as historic and nature education as priority recreational needs. These needs, along with the need for boating and fishing areas and campgrounds, were desired most strongly in the Chesapeake Basin area.

Many of Delaware's residents and visitors depend on water for their recreation enjoyment. Fishing, swimming, and boating are popular activities throughout Delaware. All of Delaware's state parks and many local parks feature lakes, ponds, bays, rivers, or the ocean, and depend on these water bodies to draw visitors year-round. Delaware's portion of the Chesapeake Basin includes more than a dozen publicly owned ponds and lakes, comprising nearly 700 acres, that serve recreational needs. Trap Pond State Park is a popular place for swimming, fishing, and boating, while other ponds, operated by the Division of Fish and Wildlife, are popular places for fishing and boating. Many of these ponds include boat ramps and fishing piers. The health of Delaware's surface waters will affect the recreation potential of these lakes and streams.

Delaware's wildlife represents a vital recreational resource base. Both consumptive recreation such as hunting, and non-consumptive recreation, such as birding, depend on the health of the state's natural resources. The Chesapeake Basin includes three wildlife areas — Blackiston, Nanticoke, and portions of Norman G. Wilder Wildlife Areas; three nature preserves — Barnes Woods, Blackbird Delmarva Bays and James Branch Nature Preserve; and one state park — Trap Pond State Park; as well as private conservation land. In addition, the DDA Forest Service also manages important public land in the Basin, including Blackbird and Tabor State Forests, as well as the portion of Ellendale-Redden State Forest in the Nanticoke watershed. These areas include places to hunt, hike, bird-watch, camp, and enjoy nature.

Greenways

Greenways are corridors of open space that serve a variety of purposes. While the recreation and transportation components of paved greenway trails receive the bulk of public attention, undeveloped conservation greenways are important for preserving increasingly fragmented habitat, protecting stream corridors, and filtering nutrients before they reach our surface waters. Staff from Delaware's Greenway and Trails Program work with Open Space Program staff, conservation groups, local governments, and other state agencies to promote the protection of open-space conservation corridors throughout the state. Within the Chesapeake Basin, the Broad Creek Greenway, James Branch Greenway, and Nanticoke Greenway include

significant stream-corridor protection efforts as well as recreational opportunities.

2.7.3 CURRENT SOURCES OF IMPACT UPON LIVING RESOURCES

2.7.3.1 Loss of Available Habitat

Baseline data for the original historic habitat in the Chesapeake Basin are not available. However, we do know that Chesapeake Basin forest acreage was lowest in the late 19th century, as the demands for pastureland, wood for construction and energy, and farmland reached its zenith. Abandonment of unproductive farms during the Depression, followed by the industrialization and urbanization of the workforce, led to a decline in the number of people working on farms. This phenomenon, coupled with the invention of the automobile and tractor, and the decreased need for wood for fuel, led to an overall increase in total forest acreage in the early 20th century. In many areas of Delaware, the suburban development and economic prosperity, which began in the middle of this century, caused these young forests to be replaced with homes, roads, retail shopping centers, and commercial areas. However, such development has largely been avoided in the Chesapeake Basin. A series of aerial photographs taken approximately every decade from 1926 until the present provide a glimpse of changes in available habitat in the Basin. The permanent loss of upland habitat, although continuing, has not increased appreciably over the past 70 years in this Basin. Changes in the quality of these remaining forests is harder to measure.

Assessments of forest cover have been conducted by the United States Department of Agriculture three times over the last 40 years, most recently in 1986. The document, *Forest Statistics for Delaware – 1972 and 1986* (Frieswyk et al., 1988), compares the last two forest inventories for each county in Delaware. Although total forest cover over this time decreased by 38,000 acres statewide, this loss was for the most part related to the urbanization of New Castle County. Sussex County lost an estimated 4,000 acres of forest during this period.

Most losses of wetland habitats in Delaware have also occurred following European settlement. Over the last 300 years, the landscape gradually has became drier due to the construction of canals, drainage ditches, and stream channelization projects to promote agriculture, shipping, and mosquito control. Dams to build millponds for waterpower altered natural freshwater and tidal fluctuations, creating new anthropogenic habitats that replaced the existing natural ones. Thousands of acres of wetlands were drained throughout the state.

In the 1980s, the Department was concerned about the destruction of unique and significant exceptional wetlands in Delaware's portion of the Chesapeake Basin. The DNHP located, mapped, and developed community classifications for these wetlands based on the community's assemblage of rare species, geologic origins, and their distinctive physiognomic characteristics (McAvoy and Clancy, 1993). In order to convey the location, distribution, and importance of these exceptional wetlands, they were mapped and identified as Type I wetlands (e.g., bald cypress, Atlantic white cedar, coastal plain ponds).

Although Type I wetlands are considered the most unique and significant/exceptional wetlands, other wetland habitats, designated Type II wetlands, (e.g., riparian mixed hardwood wetland communities, mixed emergent communities, etc.) are also important refugia for many rare and not-so-rare native plant and animal species. An intensive biotic survey of palustrine and terrestrial habitats of Type II wetlands bordering the Choptank River confirmed the value of such wetlands. According to the DNHP, the riparian habitats associated with the Choptank include some of the finest and most diverse habitats in Kent County and are home to many species of rare plants and rare animals. The Choptank River and its associated wetlands are just one example of a high-quality riparian wetland habitat within Delaware's portion of the Chesapeake watershed.

Wetland habitats not classified as either Type I or Type II are nonetheless also very important to biotic integrity.

2.7.3.2 Fragmentation of Habitat

In addition to the loss of available habitat, the remaining habitat in the Chesapeake Basin has become increasingly splintered and isolated. Fragmentation of forest was already significant by the beginning of the 19th century, largely due to land clearing for agriculture. Today, most of the remaining forest in the Basin is found along stream bottoms and floodplains that have remained unavailable to agricultural production.

The clearing of the Chesapeake Basin forest was accomplished nearly 200 years ago and has had several effects. Some non-game animal species, which require extensive mature forests to persist, have become significantly reduced in numbers or extirpated. The remaining fragmented forest habitats contain a high ratio of "edge" as opposed to interior forests. Detrimental edge effects on the forest include increased sunlight, wind exposure, drying of soils, higher temperatures, loss of interior species, and increased vulnerability to exotic species invasion. Fragmentation favors species that prefer an open patchwork of woodlots, edges, and meadows. Examples of such species include red fox, brown-headed cowbird, raccoon *(Procyon lotor),* and white-tailed deer. These animals have become more numerous and live in closer proximity to humans than they ever have.

As the Basin's human population increases, long-range management considerations become vital as human/pet/wild animal conflicts increase. Already, the increased

threat from zoonotic diseases (Lyme disease, hanta virus, and rabies) has caused public health concerns as animal and human populations increasingly interact.

2.7.3.3 Sedimentation

Accumulation of sediment in Chesapeake Basin streams has had terrible consequences for aquatic systems. Centuries of forest clearing, livestock grazing, and agriculture contributed enormous amounts of soil and gravel to both tidal and non-tidal rivers, creeks, and streams. The worst problems occurred before the 1950s. Modern soil conservation practices have greatly reduced the damage. However, there are still problems with sediment entering streams. As a result of this sediment load, fish spawning areas, which require clean sand, are destroyed. Sediment has contributed greatly to the demise of numerous species of mollusks and other filter feeders. Some historic species no longer survive in Delaware. Others have been driven close to extinction in all but the highest quality streams. Many species exist only in the protected portions of the watershed (mainly, small tributaries).

Fortunately, once sediment loads are sufficiently reduced, it is possible to achieve a higher level of stream quality, and, thereby, gradually improve stream habitat over succeeding decades. At that point, refuge populations of currently stressed aquatic species can be re-introduced. Therefore, it is crucial that we save all of the aquatic components possible. Aquatic fauna and flora must be allowed to survive in the remnants of good quality habitat that are left, so they are available for spreading diversity throughout the watershed when better conditions are established.

2.7.3.4 Modern Forestry

The application of silvicultural techniques has improved greatly over the last 100 years. Modern foresters develop forest management plans that effectively deal with a wide variety of conservation issues, including sediment control, game management and hunting, and passive recreational opportunities in addition to providing lumber and fiber products. Each forest management plan is tailored to the request of the landowner. These can range from maximized production of forest products by eliminating competing "non-productive" elements in the forest, to timber stand improvement and forest legacy programs. In Delaware, one result of this planning was the development of loblolly pine plantations in the southern portion of the Chesapeake Basin. These trees are actively managed by mechanical and chemical means to achieve superior forest products within a projected 40-to-50-year harvest rotation (Brown, pers. comm.). This practice has also reduced biological diversity by changing the structural and functional forest diversity. It "homogenized" the oak-pine forest.

An effort to develop "working forests" that promote biotic diversity while maintaining economic viability of forest products is currently under way (Brown, pers. comm.). However, the vast majority of forestland in the state is in private ownership and not under the management of state foresters. The DDA Forest Service directly manages less than 10,000 acres of forest. By comparison, forests owned by private forest industry total 30,000 acres. In 1986, the U.S. Forest Service estimated that private individuals owned 88 percent of Delaware's forestland. Much of the timber on these lands is being managed without a forest management plan, essentially as it has been for 300 years. Although the total privately owned forest habitat does not appear to be decreasing significantly in the Chesapeake Basin, it typically:

- has trees less than 50 years old;
- is smaller than 100 acres in size;
- does not have a forest management plan;
- is owned by several different people;
- is too wet to clear for farmland;
- may be used as supplemental grazing for livestock;
- has been further fragmented by tax ditches; and
- provides supplemental income to the owner through hunting leases, firewood sale, or through a once-in-a-lifetime timber harvest.

Often, following the private contracted harvest of timber on these private lands, the DDA Forest Service receives complaints from landowners about how badly their forest was treated. A "working forest" management plan could avoid many of these problems if the landowner would contact the Forest Service prior to signing a contract (Brown, pers. comm.).

2.7.3.5 Exotic Species

A major threat to fragmented natural areas in both public and private holdings has been the introduction of numerous invasive exotic or alien species of plants and animals. Unlike most introduced exotic plant species which are benign additions to the landscape, invasive exotic plant species are overrunning forests, wetlands, open habitat, and aquatic communities. Native plant communities are in direct competition with introduced exotics. Exotic species, combined with habitat disturbance/fragmentation and an increasing population of white-tailed deer, has placed the remaining natural habitat in the Chesapeake Basin under an additional threat. At present, fewer exotic species currently threaten the Chesapeake Basin's natural areas than in Piedmont habitats. But this is likely to change over the next few decades.

Over one-third of the species in Delaware's flora are exotic. Several dozen species have the capability of

permanently altering habitat. To date, only the largest, oldest, most intact, or most isolated forest tracts have been able to resist exotic invasion, but even these forests are ultimately vulnerable to shade-tolerant exotic species such as Norway maple *(Acer platanoides)*. Many sites are in grave need of exotic species control and habitat restoration.

Although the presence of exotic species is well known, very little data (other than "present/absent" designation) have been collected that documents the extent of the exotic infestation in Delaware. Invasive exotic-species issues have not been a priority with land managers, planners, or heritage databases. Meanwhile, new species of plants are being introduced into natural areas, sometimes intentionally. As the exotic plant species compete with native species for the already reduced available habitat, they do so without the threat of disease or insect herbivores that affect natives. Even deer, which eat almost anything, seem to favor the native plants over the new, unfamiliar, and/or unpalatable imported exotics.

A common event (such as the blow-down of a large tree during a thunderstorm) creates available habitat for exotic invasion, especially by vines [i.e., Asiatic bittersweet *(Celastrus orbiculatus)*]. Once established in sunny gaps created by the death of a mature tree, the vines smother the normal successional replacement of the fallen tree by native saplings. Clambering over the young trees, covering them with their leaves, denying them sunlight, the vines maintain an exotic tangle that native species cannot penetrate. These vine thickets are permanent. In the normal successional process, this canopy gap would return to forest eventually. Today, once the exotic vines become established, the forest cannot recover without human intervention. Instead, the vines slowly kill surrounding trees, gradually expanding the gap in an ever-widening circle.

Under these circumstances, a catastrophic storm would create the same scenario, but instantaneously and over a larger area. For decades, in most Piedmont forests, an incredible number of exotic seeds have been raining on the forest floor every year. Seedling vines have sprouted to become a significant understory component. Once an ice storm, northeaster, tornado, or hurricane strip or kill the forest canopy, these seedling vines will be able to utilize the increased nutrient load released from the dead leaves and branches left by the storm. The combination of the nutrient boost and the increased sunlight from the reduced canopy will allow the vines to permanently alter and dominate entire forests. At this point, the cost of restoration management of these forests would be enormous. An effort to protect the best natural forests must begin in the immediate future, before a catastrophic event. It is only a matter of time until this scenario becomes reality.

Major climatic storm events occur on a regular, if not predictable basis. These events are part of the abiotic processes to which all plants and animals in the region are subjected. Human alteration of habitat over the past 300 years has made some parts of the ecosystem more vulnerable and less likely to recover from future storms. Any similar event, whether natural or man-made, can potentially open the canopy to promote the spread of exotic plant species, and thereby, further degrade the remaining forests.

2.7.3.6 Insufficiently Protected Habitat

Protection of land in Delaware has been attempted from three different approaches: private ownership, public ownership, and regulatory protection. Of these approaches, protection via regulatory processes has been the most difficult and least successful. New Castle County protects lands to varying degrees by ordinance for lands comprising steep slopes, floodplains, and riparian buffers, water recharge areas, and land identified as Critical Natural Areas. The level of protection that is accomplished by these laws is significant, especially when compared to Kent and Sussex counties. However, the limited protection for sites not included in the state's Natural Areas Inventory have all contributed to a continuing pattern of fragmentation and degradation of remaining habitat. Upland areas that do not fit into one of the ordinances are particularly vulnerable. Kent County has recently improved their protection efforts, particularly along riparian buffers. Opportunities to improve protection of habitat exist in all three counties, especially regarding upland forest protection.

Delaware's lack of a Freshwater Wetlands Law has contributed to a continuing attrition of these wetlands. Ditching has also significantly altered habitat.

2.7.3.7 Other

Historic industrial and nonpoint pollution, including heavy metal and pesticide residues, have contributed to the degradation of Chesapeake Basin habitats, especially aquatic ecosystems. Historic spraying for mosquitoes and gypsy moths has certainly had negative effects upon the insect and avian fauna of Delaware in localized areas. Improved pest management techniques have reduced this impact. In-depth discussions of these issues are contained elsewhere within this document.

2.7.4 POSITIVE INITIATIVES

2.7.4.1 Protection of Habitat

In 1973, the Delaware Nature Education Center, Inc., (now Delaware Nature Society) brought together 25 experts in their respective fields to identify the most important natural areas in Delaware. Led by the project director Norman G. Wilder and principal author Lorraine M. Fleming, the culmination of this effort was the 1978 publication of *Delaware's Outstanding Natural Areas and Their Preservation*.

The State of Delaware enacted Title 7, *Delaware Code,* Chapter 73: Natural Areas Preservation System, on February 10, 1978. This legislation and the subsequent regulations that were passed provided the State of Delaware, through the Department, the ability to dedicate public and private nature preserves, identify and maintain a statewide Natural Areas Inventory, and establish a Natural Areas Advisory Council to review and make recommendations to the Department Secretary. One of the first nature preserves, Barnes Woods, was established in 1984 in the Nanticoke River watershed.

The definition of a *natural area* is an area "of land or water or both land and water, whether in public or private ownership, which either retains or has re-established its natural character (although it need not be undisturbed), or has unusual flora or fauna, or has biotic, geological, scenic or archaeological features of scientific or educational value" (Natural Areas Preservation System, Title 7, *Delaware Code,* Chapter 73). Natural character refers to the native plant and animal species and associations that occupied Delaware under the influence of Native North Americans at the time of European occupation.

The following are examples of the major programs conducted by the Lands Preservation Office of the Division of Parks and Recreation.

The Natural Areas Inventory

The Natural Areas Inventory has identified 12 natural areas (out of the 67 identified in the state) within, or partially within, the Chesapeake Basin *(see Map 2.7-1 Living Resources)*. A previously digitized GIS layer for the inventory is currently being compared with DNHP element occurrences. The finished maps will form the basis of a Natural Areas Directory, which will be used as a planning document to help protect Delaware's dwindling natural areas. Once the directory is completed and distributed to interested parties, the task will shift toward updating the inventory by identifying and adding qualified new areas previously excluded, and deleting areas recently destroyed. The Natural Areas Advisory Council must vote to amend the inventory before any changes can be made. Updates of the directory will be sent to the recipients of the first edition. It is hoped that the directory will facilitate the protection of some of Delaware's most important natural areas. Currently, protection of natural areas is voluntary, except in New Castle County. There, the owner, prior to the county's acceptance of any development plan, must produce a Critical Natural Areas Report. Even in this case, the ultimate decision on whether to protect a natural area or not is New Castle County's and not the state's.

In selecting a state-recognized natural area, the Office of Nature Preserves, in conjunction with the Natural Areas Advisory Council, evaluates a site based on the following non-prioritized criteria: representativeness; biological rarity; uniqueness; diversity; size; viability; defensibility; research, education, or scenic value; and outstanding geological, archaeological, or aquatic features. Sites can be added or deleted from the inventory.

The Natural Areas Inventory was not intended to include every natural area remaining in Delaware. The intent was to include only the areas that were of statewide significance. As a result, many areas that meet the criteria were not included in the inventory. During the 19 intervening years since the inventory was established, a tremendous amount of suburban expansion has taken place in Delaware. Lands formerly considered marginal for housing purposes are being developed today. Areas not currently included on the inventory are being reconsidered for inclusion. Among the concerns and priorities of this review is providing adequate upland buffer to wetlands and stream and river corridors, and protecting the larger isolated upland forest patches and rare habitats scattered throughout the region.

New Castle County's new Unified Development Code (UDC) provides protection for lands within New Castle County that have been listed on the state's Natural Areas Inventory. The UDC refers to lands on the inventory as "Critical Natural Areas." County planners work closely with the Office of Nature Preserves and private landowners to coordinate protection of these identified natural areas. The UDC also offers varying amounts of protection for steep slopes, riparian buffers, and floodplains, and provides the only non-voluntary state or local protection of privately held natural areas within the Chesapeake Drainage Basin.

State Nature Preserves

Three of the 19 dedicated State Nature Preserves are within the Chesapeake Basin: Blackbird Delmarva Bays, Barnes Woods, and the James Branch. These locations are depicted on *Map 2.7-1 Living Resources*. Natural Area Protection Plans are being developed to maintain the natural conditions that merited the original dedication of these preserves. Numerous other possible additions to the preserve program exist within the Basin. Nature preserve dedication is the highest legal protection available within the state, requiring the concurrence of the governor and the legislature to remove or "deactivate" a nature preserve.

State Resource Areas

Lands purchased by local and state government is the latest and perhaps the most important step in providing protection for areas that contain significant habitat. Thousands of acres scattered across the watershed are now owned by public agencies *(see Map 2.7-1 Living Resources)*. Significant habitat remains on these properties.

The State of Delaware has acquired land through various programs for recreational benefit and natural resource

protection. The State of Delaware enacted Title 7, *Delaware Code,* Chapter 75: Delaware Land Protection Act, on July 13, 1990. Perhaps better known as the "Open Space Program," the initial funding for this program was provided by the sale of bonds. In 1990, the Open Space Program, administered by the Division of Parks and Recreation's Land Preservation Office, continued a systematic approach to land acquisition that had begun with the Governor's Land Acquisition Program established in 1987.

Twenty regions in the state identified as State Resource Areas (SRAs) encompass a total of 250,000 acres. These SRAs include protected state, federal, local, and private conservation lands and inholdings, as well as potential additions to these areas (approximately 125,000 acres). These lands are protected through a variety of means, including purchase, donation, and conservation easements. Forty-seven-million dollars of open-space funding (plus $9 million from other sources) had been spent for land acquisition in these SRAs as of May 1, 1996. These monies acquired 13,175.4 acres valued at $84 million dollars. SRAs within the Chesapeake Basin include Nanticoke River, James Branch, parts of Chesapeake and Delaware Canal, the Blackbird and the Great Cypress Swamp SRAs, as well as most of Ellendale/Redden and Central Kent County SRAs (which includes Norman G. Wilder Wildlife Area). It also includes the Tabor State Forest, which is considered a stand-alone area not located within an identified SRA.

From 1990–1997, the acquisition of 4,272 acres of land within the Chesapeake Basin, for a total net cost of $4,859,900 (including $385,600 in federal match grants via F&W), reflects the relatively low cost of land acquisition in this Basin. The average per acre cost was $1,047. However, this does not reflect the cost of maintaining these properties for the managing agencies.

Farmland Preservation

The Department of Agriculture has been leading the effort to preserve farmland by establishing Agricultural Districts and purchasing development rights to critical farmland throughout Delaware. Because many farms contain some natural areas, the purchase of development rights offers protection for these areas as part of the overall "working farm." *Map 2.2-4 Agricultural Preservation Districts* shows the lands currently covered under this program.

Private Conservation Organizations

Significant habitats within the Chesapeake Basin have been acquired by two important non-profit organizations: Delaware Wild Lands, Inc., and The Nature Conservancy. Delaware Wild Lands' record of land conservation in Delaware began in Chesapeake Basin with the acquisition of Trussum Pond. Later acquisitions preserved a major portion of the forested riparian habitat along the James Branch. Delaware Wild Lands acquired perhaps the most important natural habitat in Delaware, the Great Cypress Swamp, in the 1970s when a major portion of the property was threatened with development. This 10,000-acre property has been responsibly managed by this organization for over 20 years. The Pocomoke River drains the western portion of the Great Cypress Swamp to Chesapeake Bay.

The Delaware Chapter of The Nature Conservancy has been very active in recent years working with landowners and acquiring significant natural areas in the Middleford North area along the upper drainage of the Nanticoke River north of Seaford.

2.7.5 TRENDS

An undeniable fact within the Chesapeake Basin is that the species composition of the remaining natural areas has permanently changed. The 18th-century direct habitat conversion of natural areas to agricultural use has altered a functioning natural landscape into a sprinkling of isolated islands and ribbons of natural areas in a sea of agricultural fields. Add to this the introduction of alien species, pollution, excessive sedimentation, altering of natural waterways, etc., and each natural area is further eroded. In addition to species loss from these direct impacts, the theories of island biogeography have shown that, in general, as landscape patches become smaller and more isolated, they can each sustain a diminished number of species over time (Harris, 1984). In sum, direct loss and degradation of habitat, as well as the loss of connectivity between habitats, has resulted in a significant loss of species diversity within our natural areas.

A number of bird species are experiencing local, regional, and, for some, global declines. The taxa most affected are those which depend upon pristine, forest-interior habitats, as well as insectivorous species and ground-nesting species (Davis, 1996). There are a number of local and regional factors, in addition to direct habitat loss, which are thought to contribute to their decline. One likely factor is the loss of structural diversity within forests. This loss, in turn, is due in part to over-grazing by white-tailed deer and livestock, modern forest management practices, and the desire for "clean" forests in areas directly managed by people. An additional factor is the explosion in feral cat populations. In many areas, these "super hunters" are present at densities far beyond natural predator densities, and are taking a disproportionate toll on songbird populations (Frink, 1996).

With the exception of fish, freshwater macroinvertebrate species, and game species, little is known of the current status of animal populations and their distribution in the Chesapeake Basin. Several other animal groups, including birds, reptiles, amphibians, and some insects (butterflies) have been sporadically sampled throughout the region. Of the animals and plants that are listed by the Delaware Natural Heritage Program (1998) as species of concern,

many are found exclusively in Chesapeake Basin habitats. Generally, the more secretive the animal, the less is known about it. Basically, if more habitats can be protected, both in diversity, connectivity, and size, then the greatest number of species of plants and animals will be able to survive in Delaware.

While many native species have been lost, or severely reduced, others are increasing in number. Species increasing in number include raccoons, opossums, American Robins, resident Canada geese, rock doves, and brown-headed cowbirds. These are adaptable, "broad-niche" species, which can tolerate or even thrive on living in a human-dominated, suburbanized landscape. While they may represent "wildlife" to many people, their ubiquity is in many ways an indication of just how unbalanced our natural systems are becoming.

2.7.6 INFORMATION NEEDS

In compiling the information for this assessment, one is overwhelmed with how little is known and how little effort has been made to pull together diverse sources of information. Some of the state's most valuable natural lands are located in this Basin. Many of these are still intact because most growth has occurred in other areas of the state. Although, the Department and other non-profit organizations may try to protect these natural lands, the scarcity of data and the lack of a coordinated analysis prohibit any comprehensive protective approaches. The following recommendations highlight some of the major data gaps and information needs.

2.7.7 DATA GAPS AND RECOMMENDATIONS

1. Upland forests have been almost eliminated from the majority of the landscape, limited to floodplain borders, or isolated patches in palustrine forest. What remains continues to decline and degrade because of repeated disturbance. *Recommendation:* A survey of the Chesapeake Basin should be conducted as soon as possible to identify remaining upland forests and to evaluate the quality of these areas using such factors as biodiversity, size, age, and exotic infestation. Appropriate actions should then follow such as landowner contact, natural area designation for qualifying tracts, legal protection, and/or restoration. "Reference forests" should be established on public or private conservation lands to provide management baselines.
2. Some rare habitat types may be in danger of disappearing completely from the Delaware portion of the Chesapeake Basin. *Recommendation:* A survey of such habitats should be conducted and summarized. Appropriate actions should be taken to protect these areas, including natural area designation for qualifying tracts, landowner contact, legal protection, and/or restoration.
3. Establish guidelines for protection of these resources in each county Comprehensive Plan. *Recommendation:* To varying degrees, each Comprehensive Plan has already incorporated some of the ideas put forward in this document. A dedicated effort to improve and enforce the plans must be made in the future to prevent further degradation of natural resources.
4. Identify and educate private forest owners regarding wildlife habitat, biodiversity maintenance, and the establishment of long-range goals to achieve acceptance of multiple-use land management objectives.
5. The majority of our most critical living resources are dependent upon good quality aquatic habitats as well as a natural flooding regime. *Recommendation:* Promote activities which eliminate unnaturally high sedimentation and erosion rates, and unnaturally high nutrient inputs. Assess the effect of direct stream irrigation on aquatic and riparian systems.
6. One of the most significant impacts on our environment comes from the direct and indirect effects of new construction in areas more and more peripheral to existing urban areas, schools, and employment centers. *Recommendation:* When and where construction is needed, encourage infill to existing developed areas rather than development of "green" spaces. Encourage the placement of trails and other recreation amenities away from sensitive natural areas not suitable for recreation. Continue to work with communities to encourage the protection of stream corridors.
7. Resident geese are becoming a nuisance. Their numbers have been increasing annually in the Basin, and are problematic due to their feces and feather residues, eutrophication of the lakes and streams where they reside, and aggression toward some humans. *Recommendation:* Encourage stream and pond management that incorporates wide buffers of natural vegetation, including stands of woody species when possible.
8. Develop a uniform approach toward the management of aquatic weeds that does not allow for the degradation of our ponds into dead-end filamentous algae pools. *Recommendation:* Examine current management approaches and develop a more effective, broad-based management approach. Educate pond managers and concerned public with the issues regarding the eutrophication problem in ponds.
9. Recognition of the threat of invasive plant and animal species to the Chesapeake Basin drainage. *Recommendation:* Discourage planting invasive plants in Delaware. Discourage introduction of invasive animals to Delaware. Encourage the use of native and non-aggressive exotic plant species. Train management personnel to recognize invasive species and to develop management strategies. Make this information available to local citizens.

10. The lack of fire during the 20th century in the Delaware upland landscape has had a negative effect on the fire-dependent plant and animal species across the state. *Recommendation:* A test-scale controlled burn should be conducted on fire-dependent plant communities to re-establish the link between fire and the natural diversity and adaptability of the extant species in Delaware's modern forests and marshes. This should be done under the lead auspices of the DDA Forestry Service. The tests could be attempted upon DNREC and/or DDA lands.
11. There is a lack of data regarding the status of the American eel (*Anguilla rostrata*) population. While the harvest of elvers (less than 6 inches) is illegal in Delaware, there is a legal commercial fishery for subadults (6–12 inches). Currently, there is no limit on the number of commercial licenses that can be issued, no limit on the number of pots allowable per fisher, and no reporting requirements. *Recommendation:* Mandatory reporting requirements are needed to determine the status of the fishery.
12. The American shad is an anadromous fish that breeds in Delaware rivers and streams. The numbers of shad remaining are low compared to historic populations. *Recommendation:* Implement American shad restoration and protection projects including the construction of fish-passage facilities, development of a hatchery program, and limiting existing harvests to allow for the population to reach sustainable harvest levels.
13. Recreational fisheries need to be protected from water quality and habitat degradation resulting from accelerated development. *Recommendation:* Maintain or establish "no wake" zones where needed. Boat wakes can cause siltation and wave action detrimental to submerged aquatic vegetation (SAV). The use of non-structural alternatives for erosion control or a combination of rip-rap with natural vegetation should be emphasized where shoreline erosion is a problem for property owners.
14. Prohibit dredging in the Nanticoke upstream of Rte. 13 in Seaford. Siltation and mechanical removal of benthic sediments would disrupt SAV beds, freshwater fish, wetland plants, shoreline vegetation, and benthic invertebrates. Secondary impacts associated with a resulting increase in boat traffic could have a detrimental effect on overall water quality. Dredging would also eliminate much in-stream structure so attractive to largemouth bass. Critical spawning habitat in the Nanticoke River should be identified through subaqueous mapping and available fish-sampling data. Once identified, these areas should be afforded protection from excess siltation, dredging, and water-quality degradation.
15. Freshwater mussel surveys designed to determine distribution, age structure, and density of the populations is ongoing. However, there is currently no protection afforded those areas with high quality mussel populations. *Recommendation:* Once high-quality freshwater mussel sites have been identified, they should be afforded protection from habitat degradation.
16. If it has not been initiated already, a plan needs to be developed regarding how to prevent zebra mussels from becoming established in Delaware (educating anglers, boaters, etc.). Veligers have been found in the upper Susquehanna, and it is probably a matter of time before they arrive closer to Delaware.
17. Facilitate the Department's Conservation Reserve Program and Conservation Reserve Enhancement Program efforts to provide matching funding to landowners to restore habitat.
18. Incorporate Delaware Natural Heritage Program databases with other planning databases, including those in Maryland, so that rare species are identified prior to development.
19. Identify restoration possibilities to increase connectivity between available habitats (include cooperative opportunities with Maryland).
20. Little information is known about the status of many native fishes (mostly non-game species). More data need to be collected on the presence and population levels of these native species.
21. There is a need for data collection pertaining to yellow perch. There are no data available on spawning locations, spawning success, population structure, and population levels.

2.7.8 REFERENCES

Benson, R. N., and T. E. Pickett. 1986. *Geology of South-Central Kent County, Delaware.* Geologic Map Series #7. Newark, DE: Delaware Geological Survey.

Bochenek, E. A. 1995. "Using GIS to Predict Areas at Risk of Zebra Mussel Invasion in the Mid-Atlantic Region (NJ to NC)." *Proceedings NE Conference Non-Indigenous Aquatic Nuisance Species,* pp. 27 – 28. Cromwell, CT.

Braun, E. L. 1950. *Deciduous Forests of Eastern North America.* NY: Hafner Publishing.

Chesapeake Bay Foundation. 1996. *Nanticoke River Watershed: Natural and Cultural Resource Atlas.* Annapolis, MD: Chesapeake Bay Foundation.

Clancy, K. 1993. "Selected Rare and Historical Vascular Plants of Delaware." *Bartonia* 57: Supplement 75 – 92.

Clancy, K. 1995. *Vegetation Structure and Composition: Guidelines for Wetlands Mitigation Project Plans.* Submitted to Delaware Dept. of Natural Resources and Environmental Control, Div. of Water Resources, Wetlands and Subaqueous Lands Section.

Clancy, K. E., C. M. Heckscher, W. A. McAvoy, and A. Dalton. 1995. "Biological and Natural Community Analyses of Riparian Communities within the coastal Zone of Kent County, Delaware (Task No. 94-9)." Unpublished report submitted to DE Coastal Management Program.

Colle, D. E. 1980. "Coefficients of Condition for Largemouth Bass, Bluegill and Red-Ear Sunfish in Hydrilla-Infested Lakes." *Trans. Amer. Fish. Soc.* 109:521 – 531.

Cooper, W. E., and L. B. Crowder. 1979. "Patterns of Predation in Simple and Complex Environments." *Predator-Prey Systems in Fisheries Management,* eds. R. H. Stroud and H. Clepper, pp. 237 – 267. Washington, DC: Sport Fishing Institute.

Custer, J. F. 1984. *Delaware Prehistoric Archaeology: An Ecological Approach.* Newark, DE: Univ. of Delaware Press.

Davis, M. B., ed. 1996. *Eastern Old Growth Forests.* Washington, DC: Island Press. 383 pp.

De Cunzo, L. A., and W. P. Catts. 1990. *Management Plan for Delaware's Historical Archaeological Resources.* Newark, DE: Univ. of Delaware Dept. of Anthropology.

Delaware Dept. of Health and Social Services and Delaware Dept. of Natural Resources and Environmental Control. 1997. Informational brochure "First State Facts, *Pfiesteria* Facts and Fallacies." Doc No. 40-01/97/08/04.

Delaware Natural Heritage Inventory. 1994. "Preliminary Natural Community Studies of Potential Category I Wetland Types in Delaware: Sea-level Fens and Piedmont Stream Valley Wetlands." Submitted to Dept. of Natural Resources and Environmental Control, Div. of Water Resources, Wetlands and Aquatic Protection Branch.

Delaware Natural Heritage Program. 1995. *Delaware's Animals of Conservation Concern.* Dover: Delaware Dept. of Natural Resources and Environmental Control, Div. of Fish and Wildlife.

Delaware Natural Heritage Program. 1996a. *Rare Native Plants of Delaware.* Dover: Delaware Dept. of Natural Resources and Environmental Control, Div. of Fish and Wildlife.

Delaware Natural Heritage Program. 1996b. *Zoological, Botanical, and Natural Community Analyses of Selected Riparian Communities of New Castle County, Delaware: Red Clay Creek and Christina River.* Dover: Dept. of Natural Resources and Environmental Control, Div. of Fish and Wildlife.

Delaware Natural Heritage Program. 1998. *Biological and Conservation Database.* Dover: Delaware Dept. of Natural Resources and Environmental Control, Div. of Fish and Wildlife.

Denny, C. S., and J. P. Owens. 1979. "Sand Dunes on the Central Delmarva Peninsula, Maryland, and Delaware." U.S. Geological Survey Professional Paper 1067-C. 15 pp.

Dill, N. H., A. O. Tucker, N. E. Seyfried, and R. F. C. Naczi. 1987. "Atlantic White Cedar on the Delmarva Peninsula." Atlantic White Cedar Wetlands, pp. 41 – 55. Boulder, CO: Westview Press.

Ferguson, R. H., and C. E. Mayer. 1974. "The Timber Resources of Delaware." Northeastern Forest Experimental Station Resource Bulletin NE-32. Upper Darby, PA: U.S. Dept. of Agriculture, Forest Service. 43 pp.

Fleming, L. M. 1978. *Delaware's Outstanding Natural Areas and Their Preservation.* Hockessin, DE: Delaware Nature Education Society. 422 pp.

Frieswyk, T. S., and D. M. DiGiovanni. Feb. 1989. "Forest Statistics for Delaware — 1972 and 1986." Northeastern Forest Experiment Station, Resource Bulletin NE-109, U.S. Dept. of Agriculture, Forest Service. 86 pp.

Frink, L. 1996. "Super Hunters." *Outdoor Delaware* 5(1): 15 – 17.

Frost, C. C. 1987. *Historical Overview of Atlantic White Cedar in the Carolinas,* pp. 257 – 264. Boulder, CO: Westview Press.

Gamble, E. E., R. B. Daniels, and W. H. Wheeler. 1977. "Primary and Secondary Rims of Carolina Bays." *Southeastern Geol.* 18:199 – 212.

Greller, A. M. 1988. *Deciduous Forest, North American Terrestrial Vegetation,* eds. M. G. Barbour and W. D. Billings, pp. 287 – 316. Cambridge, England: Cambridge Univ. Press.

Hancock, H. B. 1976. *The History of Sussex County, Delaware.* Privately Published.

Harris, L. D. 1984. *The Fragmented Forest.* Chicago, IL: Univ. of Chicago Press. 211 pp.

Heite, E. F. 1974. "The Delmarva Bogiron Industry." *Northeast Historical Archaeology* 3(2):18 – 34.

Kraft, J. C. 1977. "Late Quaternary Paleogeographic Changes in the Coastal Environments of Delaware, Middle Atlantic Bight, Related to Archeological Settings." *Annuals of the New York Academy of Sciences* 288:35 – 69.

Kutner, L. S., and L. E. Morse. 1996. "Where Have All the Flowers Gone." *Nature Conservancy* 46(3):7.

Laderman, A. D., F. C. Golet, B. A. Sorrie, and H. L. Woolsey. 1987. *Atlantic White Cedar Wetlands,* pp. 19 – 34. Boulder, CO: Westview Press.

Lesser, C. 1966. *Aquatic Vegetation Survey.* Federal Aid Fish Restoration Project No. F-21-R. Dover: Delaware Dept. of Natural Resources and Environmental Control, Div. of Fish and Wildlife.

Little, S. 1950. "Ecology and Silviculture of White Cedar and Associated Hardwoods of Southern New Jersey." Yale University, School of Forestry. Bulletin No. 56.

McAvoy, W., and K. Clancy. 1993. *Characterization of Category I Non-tidal Wetland Communities in Delaware: Bald Cypress* Taxodium distichum (L.) *Richard and Atlantic White Cedar* Chamaecyparis thyoides (L.) BSP. Dover: Delaware Natural Heritage Program and Dept. of Natural Resources and Environmental Control, Div. of Fish and Wildlife.

Martin, C. C. 1996. "Freshwater Fishing Statistical Survey." *Annual Report, Federal Aid Fisheries Restoration Project F-41-R-7.* Dover: Delaware Dept. of Natural Resources and Environmental Control, Div. of Fish and Wildlife.

Martin, C. C. 1997. "Enhancement of Nanticoke River Largemouth Bass Population." *Annual Report, Federal Aid Fisheries Restoration Project F-41-R-8.* Dover: Delaware Dept. of Natural Resources and Environmental Control, Div. of Fish and Wildlife.

Martin, P. S., and R. G. Klein, eds. 1984. *Quaternary Extinctions: A Prehistoric Revolution.* Tucson: Univ of Arizona Press.

Maxted, J. R., E. L. Dickey, and G. M. Mitchell. 1994. *Habitat Quality of Delaware Non-tidal Streams.* Appendix D, 305(b) Report. Dover: Delaware Dept. of Natural Resources and Environmental Control, Div. of Water Resources. 21 pp.

Miller, R. 1988. "The First State's Experience Controlling the Northern Monoecious Form of Hydrilla." *Aquatics* 10(2): 16 – 23.

Passmore, J. O. 1978. *Three Centuries of Delaware Agriculture.* Dover: The Delaware State Grange and the Delaware American Revolution Bicentennial Committee.

Pickett T. E., and N. Spoljaric. 1971. *Geology of the Middletown-Odessa Area.* Geologic Map Series #2. Newark, DE: Delaware Geological Survey.

Prouty, W. F. 1952. "Carolina Bays and Their Origin." *Geol. Soc. Bulletin* 63:167 – 224

Pyne, S. J. 1982. *Fire in America, A Cultural History of Wild-land and Rural Fire.* Princeton, NJ: Princeton Univ. Press.

Rasmussen, W. C. 1958. Geology and Hydrology of the "Bays" and Basins in Delaware. Ph.D. Dissertation, Bryn Mawr College, Bryn Mawr, PA.

Savino, J. F., and R. A. Stein. 1982. "Predator-Prey Interaction Between Largemouth Bass and Bluegills as Influenced by Simulated Submersed Vegetation. *Trans. Amer. Fish. Soc.* 111:255 – 266.

Scharf, J. T. 1888. *History of Delaware, 1609 – 1888. Vols. I and II.* Philadelphia, PA: L. J. Richards and Co.

Scott, J. 1991. *Between Ocean and Bay, A Natural History of Delmarva.* Centreville, MD: Tidewater Publishers.

Seagraves, R. J., R. W. Cole, and C. A. Shirey. 1990. *Stream and Inland Bays Fish Survey.* Annual Report, Federal Aid Fish Restoration Project F-37-R-4. Dover: Delaware Dept. of Natural Resources and Environmental Control, Div. of Fish and Wildlife.

Shirey, C. 1988. *Stream and Inland Bays Fish Survey, Project F-37-R-3.* Dover: Delaware Dept. of Natural Resources and Environmental Control, Div. of Fish and Wildlife. 36 pp.

Shirey, C. 1991. *An Inventory of Fishes and Macroinvertebrates in Delaware's Streams.* Dover: Delaware Dept. of Natural Resources and Environmental Control, Div. of Fish and Wildlife.

Stolt, M. H. 1986. Distribution, Characterization, and Origin of Delmarva Bays on Maryland's Eastern Shore. Master of Science Thesis, University of Maryland.

Stolt, M. H., and M. C. Rabenhorst. 1987. "Carolina Bays on the Eastern Shore of Maryland: II. Distribution and Origin." *Soil Sci. Soc. Am. J.* 51: 399–405.

Swingle, H. S. 1950. "Relationships and Dynamics of Balanced and Unbalanced Fish Populations." Bulletin #274. Auburn, Alabama: Agricultural Experiment Station of the Alabama Polytechnic Institute. 74 pp.

Terlizzi, D. E., R. J. Klauda, and F. P. Cresswell. 1995. "Development and Implementation of a Regional Policy on Non-Indigenous Aquatic Species for the Chesapeake Basin." *Proceedings NE Conference Non-Indigenous Aquatic Nuisance Species,* pp. 72 – 78. Cromwell, CT.

Tiner, R. 1985. *Wetlands of Delaware.* Dover: U.S. Fish and Wildlife Service, National Wetlands Inventory, Newton Corner, MA, and Delaware Dept. of Natural Resources and Environmental Control, Wetlands Section. 77 pp.

Werner, E. E., et. al. 1983. "An Experimental Test of the Effects of Predation Risk on Habitat Use in Fish." *Ecology* 64:1540 – 1548.

Whitmore, W. H., and R. W. Cole. 1997. *Commercial Fishing in Delaware 1996.* Dover: Delaware Dept. of Natural Resources and Environmental Control, Div. of Fish and Wildlife.

Whitmore, W. H. 1997. *Recreational Gill Netting in Delaware 1996.* Dover: Delaware Dept. of Natural Resources and Environmental Control, Div. of Fish and Wildlife.

Whittendale, T. 1996. *Waterfowl Incidence.* Unpublished report. Dover: Delaware Dept. of Natural Resources and Environmental Control, Div. of Fish and Wildlife. 6 pp.

Zampela, R. A. 1987. *Atlantic White Cedar Management in the New Jersey Pinelands,* pp. 295 – 311. Boulder, CO: Westview Press.