LIVING RESOURCES

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 Appalachian Mountains into the drowned Delaware River Valley, recently flooded by a rising ocean. This river valley broadened into Delaware Bay, the center of a vast estuary, bordered with productive coastal marshes, abundant with shellfish and waterfowl.

Today, following nearly 400 years of natural resource consumption and the conversion of habitats for agricultural purposes, Delaware's remnant natural areas — woodlands, rivers, swamps, and marshes — still provide a biological history of Delaware. Yet, these natural remnants are under continually increasing 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.

Characterization

In many ways, our living resources reveal more about the state of our environment than any other factor. Our native species, which have evolved to depend upon, as well as play their role in, the intricate web of life are generally the first indicators of change or disruption. They experience firsthand 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 generally 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 thus are notoriously sensitive to the effects of sedimentation and pollutants. Furthermore, many mussel species require the presence of particular fish species, to which their larvae must attach to complete their life cycle. When native fish species decline due to loss of habitat, damming of streams, or introduction of non-native fish, the 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 indicate the loss and fragmentation of mature forests in our area. Increased numbers of American robins are in some ways comforting after the scare of Rachel Carson's *Silent Spring* in the early 1960s, but are also reminders that mowed lawns have replaced most of what used to be pastureland and forest. Similarly, the presence of daunting numbers of non-migratory Canada geese is largely a result of land managers' recent habit of maintaining turf adjacent to human-made ponds. Ironically, these large numbers of urban 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 Piedmont Basin's flora and fauna. Fish and waterfowl are probably the two best-studied groups of species, largely because of federal funds available to support the work. Annual waterfowl counts date back to 1955, with more than 20 years of species-specific counts (Whittendale 1996). Fish species were inventoried for all of Delaware's major Piedmont tributaries in 1988 and summarized in two reports funded by the Federal Aid in Fisheries Restoration Act (Shirey, 1988, 1991).

Ongoing studies of some of the basin's rare and declining species have been conducted by the Delaware Division of Fish and Wildlife. The Delmarva fox squirrel, once found in the forests of Delaware, was extirpated from the entire state. Re-introductions have been moderately successful in Sussex County, but have not been attempted in the Piedmont Basin in part because of a federal moratorium on new releases. The division receives annual federal funding for mark, release, and recapture studies of bog turtles. This species is notoriously difficult to study because of its elusive habits; its rarity only compounds the challenge. Annual reports indicate that very few individuals of this species have been captured in Delaware and that, despite concerted effort, findings are declining (Gelvin-Innvaer and Stetzar, 1992; Gelvin-Innvaer and Greenwood, 1995).

The Delaware Natural Heritage Program, (formerly the Delaware Natural Heritage Inventory), also part of the Division of Fish and Wildlife, conducts ongoing 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 data base, both electronic and manual, of its findings throughout the state. The program has never conducted a comprehensive review of the status of biodiversity in the Piedmont physiographic province or any of its drainages, but from data that have been collected, it is known that an alarming number of species that were once common in the Piedmont are now known from only one or two locations, or have been extirpated entirely.

For instance, the regal fritillary is a butterfly that was abundant in many old fields just 30 years ago. Now, for unknown reasons, it is thought to be entirely gone from the region even in the isolated areas where one finds appropriate habitat and food plants. It is also known that of all 50 states, Delaware has lost the highest proportion of its native flora (Kutner and Morse, 1996). Although not confirmed, it is thought that a large portion of this decline is due to habitat loss and degradation in the Piedmont Basin.

Historic Biotic Communities

The land surface of North America has been divided into more than 20 physiographic provinces, each with its own unique history of formation and erosion (Lobeck, 1948). The physiographic provinces in Delaware are the Atlantic Coastal Plain and the Piedmont. These provinces intersect in Delaware within the Piedmont Basin along the "Fall Line," a zone from 2 to 4 miles wide stretching east to west across the state, roughly paralleling the Christina River. The entire Piedmont Basin, 80% of which lies within the Commonwealth of Pennsylvania, ultimately empties into the Delaware River and is considered to be part of the Delaware Estuary (Dove et al., 1995).

The Piedmont flora in Delaware is almost identical to that of the adjoining parts of Pennsylvania. The rich bottomland soil in the valleys and rocky terrain on the steep hillsides "support a flora of great variety and richness, including many species rare or non-existent on the Coastal Plain" (Tatnall, 1946). Most of the soil, rocks, and boulders on the surface of the Piedmont province originate from ancient metamorphic rock that produces predominantly acid soils. However, a surficial exposure of alkaline serpentine rock occurs in Delaware in a single outcrop east and northeast of Mount Cuba. In addition, the Cockeysville Marble Formation, an important aquifer recharge area, is a limestone formation that emerges as an outcrop on the surface along Pike Creek east of Pleasant Hill at a site known as the Eastburn Complex.

The following descriptions summarize the natural communities found within Delaware's Piedmont Basin, including adjacent areas along the Fall Line and within the Christina River watershed. This list should not be construed as representing the entire array of natural communities found in this part of Delaware; additional data are needed. Many of these communities support a plethora of animal and plant species of special concern.

Forest Communities

Delaware's Piedmont Basin is home to a variety of important forest communities, most of which occur as repeating units on the landscape. These forests would fall within the broadly classified *Mixed Mesophytic Forest Region* of Braun (1950). In general, the forests are composed of a mixture of hardwoods, dominated by oaks, beech, tulip poplar, hickories, and sweet birch on the steep slopes and dry ridge tops, and by box elder, sycamore, sweet gum, slippery elm, red maple, tulip poplar, and sometimes river birch and black willow along narrow stream-side forests. American chestnut and, to a lesser degree, American elm were formerly important components of the mixed mesophytic forest.

There is tremendous variability in the ages and quality of these forests. It is safe to say that all the woodlands in the Piedmont Basin are second- or third-growth forest, most with trees less than 50 to 100 years old. Yet, some of the oldest trees in the state are found in the Piedmont Basin, where several forests contain specimens nearing 200 years of age. Even though the age of these magnificent trees is unusual in the Delaware Piedmont, and indeed in the entire watershed, many of these huge plants are just past 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 Piedmont Basin. However, several of these mature forest patches are developing some of the typical characteristics of an old-growth forest.

Areas adjacent to these older forests may support young successional woods, or maturing forests that are composed of a high proportion of exotic species. However, nearly 75% of the Piedmont Basin's terrestrial forests are no longer in existence, having been cleared long ago for pastureland and early settlements, or more recently for urban sprawl. Additionally, forests that are present on the drier ridge tops are typically of very poor quality, often consisting of young second- and third-growth thickets with a smothering blanket of exotic vines, shrubs, and herbs.

Tables 38 – 41 provide brief descriptions of the forest types that one is likely to encounter in the Piedmont region and adjacent Fall Line area of Delaware.

Trends

An undeniable fact within the Piedmont Basin is that the species composition of the remaining natural areas is changing at an unnaturally rapid pace. Direct habitat conversion has altered a functioning natural landscape into a sprinkling of isolated islands and ribbons of natural areas. Add to this the further insults 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 (Harris, 1984). In

Table 38
PIEDMONT REGION FOREST TYPES

COMMUNITY TYPE	COMMUNITY CHARACTERISTICS
FOREST COMMUNITIES	
Scientific Designation: *Quercus spp. – Liriodendron tulipifera – Fagus grandifolia* Forest Community Common Designation: oak – tulip poplar – beech forest	◆ This community usually occupies the relatively steep, rocky slopes associated with stream valleys. ◆ The oak – tulip poplar – beech forest may be extremely diverse and of good to excellent quality. ◆ Oaks usually present include red oak *(Q. rubra)*, black oak *(Q. velutina)*, scarlet oak *(Q. coccinea)*, white oak *(Q. alba)*, and chestnut oak *(Q. prinus)*. 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, Thelypteris hexagonoptera, Podophyllum peltatum, Asarum canadense, Claytonia virginica, Dentaria laciniata, Aster divaricatus, Prenanthes altissima, Cimicifuga racemosa, Erythronium americanum, Aralia nudicaulis,* among a host of other species.
Scientific Designation: *Liriodendron tulipifera* Forest Community Common Designation: tulip poplar forest	◆ 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). ◆ This community is found on the lower slopes more often, but may also be on the mid- to upper portions of steep slopes. ◆ The understory may be comprised of many of the same species as in the previous community.
Scientific Designation: *Quercus prinus – Betula lenta/Kalmia latifolia* Forest Community Common Designation: Chestnut oak – sweet birch/mountain laurel forest	◆ Occurs as small isolated stands on steep, dry rock outcrops on upper slopes. ◆ It is characterized by having a canopy co-dominated by chestnut oak and sweet birch, and a dense shrub layer of mountain laurel. ◆ The herbaceous layer is generally less diverse than other Piedmont forest communities. A rare natural community in Delaware.
Scientific Designation: *Platanus occidentalis – Acer negundo/Lindera benzoin* Wetland Forest Community Common Designation: sycamore – box elder/spice bush wetland forest	◆ Found as narrow occurrences along Piedmont streams. ◆ Associates include *Acer rubrum, Juglans nigra, J. cinerea, Quercus palustris, Ulmus rubra, Fraxinus pennsylvanica, Carpinus caroliniana, Staphylea trifolia, Prunus serotina, Cornus florida*. Included among the woody species and herbs are *Onoclea sensibilis, Rudbeckia laciniata, Laportea canadensis, Geum canadense, Woodwardia areolata,* and *Impatiens capensis.* ◆ These communities, especially when adjacent to roads, often have an infestation of exotic species.

Table 39
PIEDMONT REGION FOREST TYPES — CONT'D.

COMMUNITY TYPE	COMMUNITY CHARACTERISTICS
FOREST COMMUNITIES	
Scientific Designation: *Acer rubrum* Wetland Forest Common Designation: red maple wetland forest	◆ Found in seepage wetlands along lower slopes that empty into Piedmont streams, as well as on narrow or broad floodplains. ◆ While *Acer rubrum* may be the dominant canopy tree, several additional canopy associates may include *Fraxinus pennsylvanica, Quercus palustris, Acer negundo,* and *Platanus occidentalis.* ◆ The subcanopy woody layer is comprised of *Cornus amomum, Cephalanthus occidentalis, Prunus spp., Lindera benzoin,* and *Viburnum 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 spp., Arisaema triphyllum, Onoclea sensibilis, Acorus calamus, Chelone glabra, Thelypteris palustris, Woodwardia areolata,* and *Boehmeria cylindrica.*
Scientific Designation *Acer rubrum – Liquidambar styraciflua* Forest Community Common Designation 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.*
Scientific Designation *Quercus spp. – Carya spp.* Forest Community Common Designation oak – hickory forest	◆ Found in drier habitats where there has been little disturbance, usually at the highest elevations on the more level uplands. ◆ Characterized by an abundance of oaks *(Q. alba, Q. prinus, Q. rubra, Q. coccinea, Q. velutina)* and hickories *(C. cordiformis, C. ovata, C. glabra, C. tomentosa).* ◆ Associates may include *Liriodendron tulipifera, Acer rubrum, Betula lenta, Fraxinus americana, Carpinus caroliniana, Hamamelis virginiana, Kalmia latifolia, Staphylea trifolia, Viburnum acerifolium, V. dentatum, V. prunifolium, Cornus florida, Lindera benzoin, Euonymus americanus, Lonicera japonica, Prunus serotina, Ariseama triphyllum, Aster divaricatus, Aralia nudicaulis, Chimaphila maculata, Cimicifuga racemosa, Dentaria laciniata, Galium spp., Circaea lutetiana, Sanguinaria canadensis, Epifagus grandifolia, Podophyllum peltatum, Smilacina racemosa, Thelypteris noveboracensis,* and *Aster divaricatus.*

Table 40
PIEDMONT REGION FOREST TYPES — CONT'D.

COMMUNITY TYPE	COMMUNITY CHARACTERISTICS
SCRUB-SCRUB COMMUNITIES	
Scrub-shrub communities can be quite variable and are generally small in areal extent, and some may only represent an early seral 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 in seepage wetlands and along stream sides, and are often situated between marsh and forest habitats. Only a brief mention of this community type will be made; more data for scrub-shrub habitats are needed.	
HERBACEOUS COMMUNITIES	
Herbaceous communities described in this section include small seepage wetlands surrounded by forested habitats and flood-plain marshes. These communities can be extremely diverse, or conversely, be relatively depauperate in species composition.	
Scientific Designation: *Impatiens capensis – Sagittaria latifolia – Peltandra virginica* 'Herbaceous Wetland Common Designation: Jewelweed – arrowhead – arrow arum herbaceous wetland	◆ Fresh/tidal marsh with the above species as co-dominants, but also with an assemblage of other species. ◆ Associates may include *Amaranthus cannabinus, Acorus calamus, Polygonum arifolium, P. punctatum, P. sagittatum, Cuscuta spp., Nuphar lutea, Bidens laevis, Leersia oryzoides, Phalaris arundinacea,* and *Zizania aquatica,* in addition to others.
Emergent Herbaceous Wetlands	◆ Extremely diverse herbaceous wetlands of freshwater marshes (tidal and nontidal). ◆ Some of the species found in these wetlands include *Acorus calamus, Bidens spp., Carex spp., Asters spp., Cinna arundinacea, Cyperus spp., Eupatorium spp., Hibiscus moscheutos, Impatiens capensis, Iris spp., Juncus spp., Leersia oryzoides, Lilium superbum, Nuphar lutea, Onoclea sensibilis, Peltandra virginica, Phragmites australis, Polygonum spp., Rumex spp., Sagittaria latifolia, Sium suave, Solidago spp., Thalictrum pubescens, Typha,* and *Zizania aquatica.* ◆ This community is found along the Christina River.
Piedmont Stream Valley Seepage Wetlands	◆ Primarily open herbaceous graminoid and forb dominated wetlands with scattered shrubs and small trees, usually located at the base of a steep slope. ◆ Plant diversity is usually high and includes such species as *Symplocarpus foetidus, Arisaema triphyllum, Osmunda cinnamomea, O. regalis, Carex spp., Juncus effusus, Glyceria striata, Athyrium thelypteroides, Cardamine spp., A. filix-femini, Impatiens capensis, Chelone glabra, Sambucus canadensis,* and *Onoclea sensibilis.* ◆ Scattered shrubs and trees include *Acer rubrum, A. negundo, Liriodendron tulipifera, Platanus occidentalis, Juglans nigra, Fagus grandifolia, Lindera benzoin,* and *Sassafras albidum.* ◆ These wetlands are hydrologically influenced by groundwater seepage flowing from the base of the slope. ◆ A significant natural community assemblage in Delaware. ◆ More data are needed to adequately distinguish seepage wetland community types.

Table 41
PIEDMONT REGION FOREST TYPES — CONT'D.

COMMUNITY TYPE	COMMUNITY CHARACTERISTICS
HERBACEOUS COMMUNITIES	
Scientific Designation: *Spartina alterniflora* Salt Marsh Common Designation: smooth cordgrass marsh	◆ In northern New Castle County, this community may be found as small colonies in the intertidal zone along the Delaware River. ◆ Intermingled with the cordgrass may be *Sagittaria calycina, Scirpus pungens,* and *Lythrum salicaria,* as well as others.
MODERN ANTHROPOGENIC OR EARLY SUCCESSIONAL COMMUNITIES	
Cultivated Fields, Pastures, Wastelands	◆ These are common habitats throughout the state, as well as in the Piedmont Basin. ◆ Disturbed, anthropogenic habitats that contain a diversity of plant species; many of these species are exotics.
Old Fields	◆ Fields that have remained fallow for several years and are dominated by tall grasses and other forbs (many of the same species occurring in the previous habitat types occur in old fields; however, fewer aliens are present). ◆ Common old-field herbaceous species include bluestem, panic and other grasses, asters, milkweeds, thistles, clovers, goldenrods, as well as many others. ◆ Scattered young trees and other woody plants are also present, including red cedar, privet, red maple, sweet gum, grapes, honeysuckle, multiflora rose, sumacs, sweet gum, poison ivy, Virginia creeper, and several blackberries.
Xeric Old Fields	◆ Old fields where soils are drier and succession rates are extremely slow (has also been referred to as *Dry Upland Glades* (Newbold et al., 1988). ◆ Typical species here include sweet vernal grass *(Anthoxanthum odoratum),* little bluestem *(Andropogon virginicus),* short husk-grass *(Brachyelytrum erectum),* tumblegrass *(Eragrostis spectabilis),* Indian grass *(Sorghastrum nutans),* and purpletop *(Tridens flava),* among numerous other species.

sum, direct loss and degradation of habitat, as well as the loss of connectivity between habitats, have resulted in a significant loss of species diversity from our natural areas.

A number of bird species are experiencing local, regional, and, for some, global declines. The taxa most affected are those that depend on pristine, forest-interior habitats, as well as insectivorous and ground-nesting species (Davis, 1996). There are a number of local and regional factors in addition to direct habitat loss that are thought to contribute to their decline. One likely factor is the loss of structural diversity within forests. This, in turn, is thought to be due in part to over-grazing by white-tailed deer, as well as a desire for "clean" forests in areas directly managed by people. An additional factor is the explosion in domestic cat populations, both feral cats and pets. 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 and freshwater macroinvertebrate species (Shirey, 1991; Maxted, 1994) little is known of the current status of animal populations and their distribution in the Piedmont Basin. Several other animal groups including birds, reptiles, amphibians, and some insects (butterflies) have been sporadically sampled throughout the

region. Of the animals that are listed by the Delaware Natural Heritage Program (1995) as species of concern, many are found exclusively in Piedmont habitats. Generally, the more secretive the animal, the less is known about it. The bottom line is if more habitat 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 into and beyond the next century.

While many native species have been lost, or severely diminished, others are increasing. To our knowledge, while no one has taken on the task of systematically summarizing these trends, if they did, they would no doubt have raccoons, opossums, American robins, Canada geese, rock doves, and brown-headed cowbirds on their list. These are adaptable, "broad-niche" species that can tolerate or even thrive living in a human-dominated, suburbanized landscape. While they may be as close to "wildlife" as many people ever come, their ubiquity is in many ways an indication of just how unbalanced our natural systems are becoming.

Additional sources of impact include the following:

- Fragmentation due to increased road capacity.
- No nontidal wetlands legislation in the state.
- No upland forest protection provisions.
- Many natural areas not included in the state Natural Areas Inventory.
- Sedimentation.
- Inadequate or inappropriate management practices within natural areas (due to funding constraints, conflicting resource needs, lack of knowledge).
- Stormwater management design.
- Gravity sewer lines.

Sources of Impact

Loss of Available Habitat

The alteration of habitat by humans has been occurring in Delaware's Piedmont Basin since the arrival of the first Paleo-Indians. Along with the climatic and vegetational changes that accompanied the retreat of the continental ice sheets to the north, humans have played a significant role in the extinction of large herbivores (Martin, 1986). With the adoption of agricultural techniques in the Mid-Atlantic region approximately 3,000 years ago, the woodland culture became more dependent on crops and on the use of fire to clear the forest. Their slash and burn type of agriculture opened park-like gaps in the woodlands. The introduction of European agricultural practices meant a conversion of a significant percentage of forest to agriculture and pasture, extermination of predators, and the over-harvesting of game and furbearing animals. Numerous species were exterminated from Delaware, including elk (1855), eastern gray wolves, eastern cougar (1899), and black bear (1900). Wild turkey fell to logging practices and market hunting by 1880, later to be re-established from Pennsylvania populations in the 1970s. White-tailed deer were essentially gone from Delaware by 1900 for the same reasons. In fact, it was illegal to hunt white-tailed deer in Delaware for over 150 years, until the 1950s. The majority of forest clearing for agriculture and wood products occurred prior to the 20th century in the Piedmont Basin.

Dependence upon the horse and other livestock directly influenced the intentional creation of meadows or "old field habitat," dominated by Eurasian plant species. These areas have become part of the American landscape and are valued recreationally and aesthetically. They were neither natural, nor native, but with the transition from the horse to engines, much of this man-made habitat has been converted to other land uses or reverted to forest.

Baseline data of the original historic habitat in the Piedmont Basin are not available. However, a series of aerial photographs taken approximately every decade from 1926 until the present provide a glimpse of the changes in available habitat in the basin over the last 70 years. The Piedmont Basin forest acreage reached a low point in the late 19th century as the demands for pasture for horses, wood for construction and energy, and farmland reached its zenith. Abandonment of unproductive farms, invention of the automobile and tractor, and the increased use of coal and oil for heat led to an overall increase in total forest acreage in the early 20th century. Suburban development and economic prosperity, beginning in the middle of this century began replacing these second-growth forests with homes, roads, retail shopping centers, and commercial areas. This permanent loss of upland habitat is continuing today.

Assessments of the change in forest cover have been conducted by the U.S. 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 Delaware with a breakdown for each county. Broad indications of the reduction in forest cover over this period in the Piedmont Basin can be found in this document.

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 mill ponds for water power, and dikes, to create freshwater impoundments along the coast, 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, but largely south of the

Piedmont Basin. Most of the affected areas in the Piedmont Basin were along the lower elevations of the Christina and Delaware rivers. More detailed information regarding the loss of wetland habitats in the Piedmont Basin can be found in the Land Use section of this report.

Fragmentation of Habitat

In addition to the loss of available habitat, the remaining habitat in the Piedmont Basin has become increasingly splintered and isolated. Fragmentation of the Piedmont forest has been increasing at a steady rate over the last half of the 20th century, largely for the development of new suburban housing, supporting infrastructure (roads and utilities), and commercial businesses. Privately owned forest tracts over 50 acres in size are becoming increasingly rare and isolated. Most of the remaining forest in the Piedmont Basin is found along steep slopes that are too difficult to farm or develop, along narrow stream bottoms and floodplains, and within the boundaries of large 19th-century family landholdings. The latter example is property that essentially established private preserves for these families, which later in the 20th century have become the best remaining examples of Delaware's natural heritage in the Piedmont Basin. Some of these properties have been donated to, or purchased by public entities, for state and local parks and open space protection.

The clearing of the Piedmont forest over the last 50 years 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 habitats contain a high ratio of "edge" as opposed to interior forests. Edge effects on the forest include increased sunlight, wind exposure, drying of soils, higher temperatures, loss of interior species, and vulnerability to exotic species invasion. Fragmentation favors species that prefer an open patchwork of woodlots, edges, and meadows such as the red fox, brown-headed cowbird, raccoon, white-tailed deer, and the newly invading coyote. These animals have become more numerous than ever in close proximity to humans. This may have long-range management implications as human/pet/wild animal conflicts increase. Already, the increased threat from zoonotic diseases — lyme disease, hanta virus, rabies — has caused some public health concerns where animal and human populations interact.

Sedimentation

Sediment accumulation in streams has had terrible consequences for the aquatic systems in the Piedmont Basin. Centuries of forest clearing, livestock grazing, agriculture, and now, the steady stream of development construction projects, has contributed enormous amounts of soil and rock to Piedmont Basin rivers, creeks, and streams, both in nontidal and tidal waters. The addition of impervious surfaces, such as roads, roofs, and parking lots in the 20th century, has contributed to the decline of stream habitat by increasing runoff volume, thereby increasing the erosion potential of stream banks. Modern stormwater management practices have reduced the sediment load, but there is desperate need for improvement. The historic practice of using stream corridors for gravity sewer systems, which is still in use today, has contributed to major disruptions of many of the basin's streams.

As a result of this sediment load, fish spawning areas, which require clean sand, have been 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 to extinction in all but the highest quality streams. Many species exist only in the protected portions of the watershed, mainly small tributaries. The small Thompson Station tributary of White Clay Creek, currently under consideration as a possible location for a drinking water reservoir for New Castle County, has the greatest macroinvertebrate diversity left in Delaware's entire Piedmont Basin.

From an optimistic view, once sediment loads are sufficiently reduced, it would be possible to achieve a higher level of stream quality in the basin. Stream habitat would gradually improve over succeeding decades. At some point in time, aquatic habitat would become available to be repopulated by the refuge populations of stressed aquatic species. But first, we must save all the aquatic components possible. Aquatic fauna and flora must be allowed to survive in the remnants of quality habitat that are left, or there will not be much diversity to spread throughout the watershed when better days arrive.

Exotic Species

A major threat to the fragmented natural areas in public (which are assumed by many to be protected) and private holdings has been the introduction of numerous exotic or alien species of plants and animals that have successfully invaded all types of natural areas. Unlike most introduced plant species which are benign additions to the landscape, invasive exotic species are overrunning forests, wetlands, open habitat, and aquatic communities at all levels: submersed, emergent, herbaceous, shrub, mid-canopy, and canopy layers. Native plant communities are in direct competition with introduced exotics. The threat of exotic species, combined with habitat destruction and fragmentation along with an overpopulation of white-tailed deer, has placed the remaining natural habitat in the Piedmont Basin under severe pressure. Over one-third of the species in Delaware's flora are exotic. Of this number, several dozen

species have the capability of permanently altering habitat. To date, only the largest, oldest, most intact forest tracts have been able to resist the exotic invasion, but even these forests are ultimately vulnerable to shade-tolerant exotic species such as Norway maple. 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 has been collected that documents the extent of the exotic infestation in the Piedmont Basin. Clearly, the problem is large and growing. The only data that exist are presence/absence data. Invasive exotic species issues have not been a priority with land managers, planners, or heritage data bases. 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 that they have been eating for eons, over the new, unfamiliar, and/or unpalatable imported exotics.

A common event, such as the blowing down of a large tree during a thunderstorm, creates available habitat for exotic invasion, especially from 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 replacements of the fallen tree: native saplings. Clambering over the young trees, covering them with their leaves, denying them sunlight, the vines maintain an exotic tangle that native species can not penetrate. These vine thickets are permanent. In the normal successional process, this canopy gap would eventually become forest once more. Today, once the exotic vines become established, the forest will not recover without 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 simultaneously over a large area. For decades in most Piedmont Basin 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 strips or kills 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 forests must begin in the immediate future, before a catastrophic event. It is only a matter of time until this scenario becomes a 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 200 years has made some parts of the ecosystem more vulnerable and less likely to recover from future storms. Any event that can open up the canopy will promote the spread of exotic plant species, thereby further degrading the remaining forests.

Insufficiently Protected Habitat

Protection of land in Delaware has been accomplished through 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 by ordinance if they are on steep slopes, floodplains, water recharge areas, or 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, variances granted to developers; lack of buffer protection along tributaries, streams, and rivers; and the lack of 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 under one of the ordinances are particularly vulnerable.

Other

Historic industrial and nonpoint pollution, including heavy metal and pesticide residues, have contributed to the degradation of Piedmont Basin habitats; especially aquatic ecosystems. The current 1996 fish consumption warnings on most of the major streams in the basin are indicative of the bioaccumulation of chemicals and heavy metals in the food chain. In-depth discussions of these issues are contained in the *Possible Contaminant Sources* and *Surface Water* sections in this document.

Positive Initiatives

Protection of Habitat

Large family estates in the Piedmont Basin that were gradually acquired over the previous 150 years ultimately have led to the preservation of large tracts of natural areas in the basin. Protection efforts in the basin began as early as 1906, when William Bancroft began orchestrating the acquisition of lands along the Brandywine. His efforts were mirrored by various members of the duPont family, mainly in the valleys of the Brandywine, Red Clay, and White Clay creeks. These private holdings were the first efforts to conserve open space. Clearly, without the foresight and financial investment of these people early in the 20th century,

the quality of the remaining natural areas in the Piedmont Basin would have been greatly reduced.

However, the large family holdings have been breaking apart during the later part of the 20th century. Some parcels have been developed. Private nonprofit organizations, such as the Woodlawn Trustees, Brandywine Conservancy, and the Delaware Nature Society have long worked with the area's major landowners to continue to preserve the natural resource values of the basin. The Brandywine Conservancy has purchased many acres in this watershed in Pennsylvania and also holds conservation easements granted by the landowners to protect thousands of more acres in the Piedmont Basin — primarily in Pennsylvania, but also in Delaware. The Woodlawn Trustees are the owners and land stewards of a significant portion of Brandywine Creek Valley.

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

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 DNREC Office of Nature Preserves in the Division of Parks and Recreation — 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 DNREC Secretary regarding the identification, protection and acquisition of natural areas throughout the state. Delaware's first nature preserves, Freshwater Marsh and Tulip Tree Woods, were established in the Piedmont Basin in Brandywine Creek State Park in 1982.

The definition of a natural area in the State of Delaware enabling legislation (Natural Areas Preservation System, Title 7, *Delaware Code,* Chapter 73) 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 character refers to the native plant and animal species and associations that occupied Delaware under the influence of Native Americans at the time of European occupation.

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 18 intervening years since the inventory was established, a tremendous amount of suburban expansion has taken place in the Piedmont Basin. Lands formerly considered marginal for housing purposes are, today, being developed. 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 Ordinance No. 91-028 provides protection for lands within New Castle County that have been listed on the state's Natural Areas Inventory. The county ordinance 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. This ordinance, along with other county codes protecting steep slopes and floodplains, provides the only non-voluntary state or local protection of privately held natural areas within the Piedmont Basin.

Land purchased by local and state governments with monies derived from the 21st Century Fund is the latest and perhaps the most important step in accomplishing protection for areas that contain significant habitat. Thousands of acres scattered across the watershed are now owned by public agencies. Significant habitat remains on these properties. Much of this land was also purchased from large landholding estates throughout the Piedmont Basin. The New Castle County Parks and Recreation Department has concentrated upon acquisitions in the floodplain of the Christina River and in the Middle Run Natural Area. State acquisitions have centered primarily around White Clay Creek, Brandywine Creek, and Bellevue State parks.

The State of Delaware has acquired land through various programs for the recreational benefit and natural resource protection on behalf of its citizenry for many years. This has been especially true in the Piedmont Basin. The State of Delaware enacted Title 7, *Delaware Code,* Chapter 75 — The Delaware Land Protection Act, on July 13, 1990. Perhaps better known as the O*pen Space Program,* the initial funding for this program was provided by the sale of bonds. Lands identified throughout the state as State

Resource Areas are the priority lands for acquisition. State Resource Areas in the Piedmont Basin include lands along Brandywine Creek, Red Clay Creek, White Clay Creek, the Christina River, and the upper Delaware River. (See Map 22.) At present, the program is funded as part of the 21st Century Fund. From 1990 through 1996, the acquisition of 1,752 acres of land within the Piedmont Basin for a total net cost of $30,360,450 reflects the increasing cost of land acquisition for this voluntary program. It does not reflect the cost of maintaining these properties. An additional $14 million dollars of funding has been released by the legislature to continue the purchase of additional open space statewide through July 1997, with a similar amount projected for the following year.

The Delaware Division of Fish and Wildlife, in conjunction with the U.S. Fish and Wildlife Service, provides wildlife habitat restoration planning and funding to private landowners through a program called Partners for Wildlife. The division also has spearheaded the Northern Delaware Wetlands Rehabilitation and Restoration Program, which ultimately will restore the degraded marshes along the lower Christina River. For more detailed information about this and other wetland-related projects, refer to the Wetlands section in this document.

Restoration Actions

Several restoration initiatives have begun in the Piedmont Basin. The Delaware Nature Society has several staff members and many volunteers working on the Middle Run Restoration Project, a reforestation effort. Approximately 35 acres of former pasture and agricultural fields have been planted with thousands of native seeds and seedlings. Delaware Nature Society is also mounting a reforestation effort at their Burrows Run Nature Preserve. Both projects include exotic plant species control efforts. In addition, Delaware Nature Society sponsors stream cleanup days throughout the region on several of the watersheds.

The Division of Parks and Recreation, Office of Nature Preserves, is conducting two natural area management projects. The first project, at Tulip Tree Woods Nature Preserve in Brandywine Creek State Park, is establishing a baseline of the native and exotic vegetation cover at all levels in the forest. Some of the study areas will be maintained as control plots. Ultimately, this information will provide a measure of the success or failure of the long-term management goals for the preserve. The second project, in Flint Woods Nature Preserve, is testing the efficacy of various exotic-plant control techniques on different exotic plant species. This project will also develop a per-unit-cost analysis to provide managers with a realistic budget estimate for exotic plant control at similar sites throughout the Piedmont Basin.

Local involvement is critical to the successful management of natural areas. The Village of Arden is committed to managing its forests. Arden has been actively involved in the preservation of the municipal forestlands of the community. The village's Conservation Committee has been learning all they can about the value of their natural resources and how to protect them. They have begun an exotic species control program, are establishing a baseline data set about their forest, and are working on a forest management plan. A forest fire management plan has been completed by the village in consultation with a DNREC forester. Arden has recruited the neighboring villages of Ardencroft and Ardentown and the neighboring developments of Indian Field and Buckingham Greene into a partnership concerned about the issues along Perkins Run and the South Branch of Naamans Creek. Arden has applied for a Partners for Wildlife grant to purchase adjacent forestland, and has contacted the National Park Service for assistance in developing a management plan for the village's public areas.

A private nonprofit organization, Friends of Brandywine Creek, has sponsored stream restoration activities on Brandywine Creek near the zoo. These efforts involved the installation of coconut fiber logs into the eroded banks of the creek and replanting them to restore the bank.

Target Needs

In pulling together this information, we have been overwhelmed with how little we know and how little effort has been made to pull together diverse sources of information. We have identified the following major needs:

- Freshwater mussel surveys (Red Clay Creek has had an initial survey, but other creeks are unsurveyed).
- A more thorough synthesis of available information.
- Collection of additional information from academic, nonprofit, and governmental institutions.
- Incorporation of Delaware Natural Heritage Program data base with other planning data bases.
- A survey of habitat types remaining in the Piedmont Basin, overlaid with rare species data bases.
- Identification of restoration possibilities to increase connectivity between available habitats.