Northeast

When European settlers arrived in the land that is now the northeastern United States, they found a vast forest with rich living resources. Stretching from the Coastal Plains to the Mississippi River was an environment shaped by trees. The climate, soils, and glacial history produced a forest that was unique in the world. In the 300 years since the arrival of Europeans, however, human activities have drastically changed this landscape. Still, as immense as the changes have been, they largely altered the appearance, but not the processes, of the ecosystems of the Northeast.

A comparison of pictures of the Northeast from the 1700's with the 1900's would reveal striking differences. Early Europeans encountered great forests of American beeches, maples, birches, eastern hemlocks, and spruces from New England to northern Pennsylvania, and oaks, hickories, American chestnuts, and pines from Maryland through Ohio. Inhabiting these great forests were many wildlife populations: white-tailed deer, beaver, wild turkey, passenger pigeon, common raven, elk, moose, black bear, gray wolf, mountain lion, lynx, and bobcat.

These hypothetical snapshots of the Northeast would show forests which had occupied 90% of the landscape in 1700 occupied less than 30% in 1900. The forests had been cleared for farmland and to feed a growing industrial base. What had been an uninterrupted forest became a mosaic of fields and woodlots. Many wildlife species, such as deer, beaver, and turkey, were nearly or completely destroyed by unregulated hunting for food, and species such as wolves and timber rattlesnake were heavily persecuted. As species that depended on the old-growth forests declined, species common to forest edges became more numerous. In addition, the Industrial Revolution had produced the first wave of urbanization and the introduction of many nonindigenous plants and animals, which exposed native species to a host of new influences (Whitney 1994).

Although these early effects of humans caused irreversible changes to the snapshot, they hardly changed the processes that shaped environments in the Northeast. Native species such as the passenger pigeon are extinct, and the American chestnut is nearly extinct. Nonindigenous species such as the European starling and the gypsy moth are well established. Although we may never know the full ecological significance of these changes, we do know that the landscape that was so greatly changed by the removal of the forest and by extensive creation of agricultural fields is today more than 60% forested. The essential elements of the physical environment persist: the water, soil, and climate. Only small portions of the original forest exist today, but regrown forests may eventually acquire many of the characteristics of the original forest. Vegetation changes and conservation have brought about the return of many wildlife species such as white-tailed deer, wild turkey, beaver, bald eagle, Canada goose, and wood duck.

In the past 30 years, the appearance of the northeastern landscape has continued to change. Today, the northeastern United States contains nearly half of the country's human inhabitants, although the large human population of the Northeast is still changing; it experienced only a 1% increase between 1970 and 1980 and will probably continue to grow at

that rate in the near future (McCorkle and Halver 1982). Movement from the country into urban centers is now reversed—the human population is moving into the country. This movement has three significant effects: the loss of agricultural land to low-intensity human development, which creates a new type of patchwork of forest and open land; continued introduction and expansion of nonindigenous species, which change the character of natural environments; and increased conflict between humans and wildlife that may significantly shift society's values of wildlife and ecological processes.

Knowledge of the major components of the environments of the Northeast is extensive, but much remains to be learned. Knowledge of the species and ecological processes of natural environments has grown enormously since the birth of the science of ecology in the late 1800's, although the basic biology of organisms contains many mysteries, and understanding systems that are composed of thousands of species is exceedingly difficult. As a result, people face the great challenge of promoting the development of the region's economic base while protecting the ecological systems on which their lives depend. To paraphrase Frank Egler (1986), a prominent ecologist, the question is not whether the combination of economic and ecological systems is more complicated than conceived, but whether it is more complex than can be conceived.

Forests

Forest Types

Historically, the Northeast was a forested region unlike any other in the country. Indeed, the combination of mountains, lakes, and mixed hardwood forests is unique in the world (Fig. 1). If the land had not been disturbed and if there were no humans in the Northeast, the natural vegetation of this region would consist of 14 different types of forests, all named for their most common tree species (Küchler 1964). The ancient types are clearly evident in the second-growth forests of the present. Bailey (1978) described two dominant natural community types (also called provinces) in the northeastern United States: the Laurentian mixed forest and the eastern deciduous forest.

Laurentian Mixed Forest

The Laurentian mixed forest type occurs from northern Pennsylvania to Maine (excluding coastal areas) and in Connecticut, Rhode Island, and New York. In this region, glacial features are common, precipitation is moderate (600–1,150 millimeters per year), and the average annual temperature is 2°C–10°C; snow cover usually persists throughout winter. The vegetation consists of a mixture of American beech, maple, yellow birch, spruces, balsam fir, eastern white pine, and tamarack (Bailey 1978).

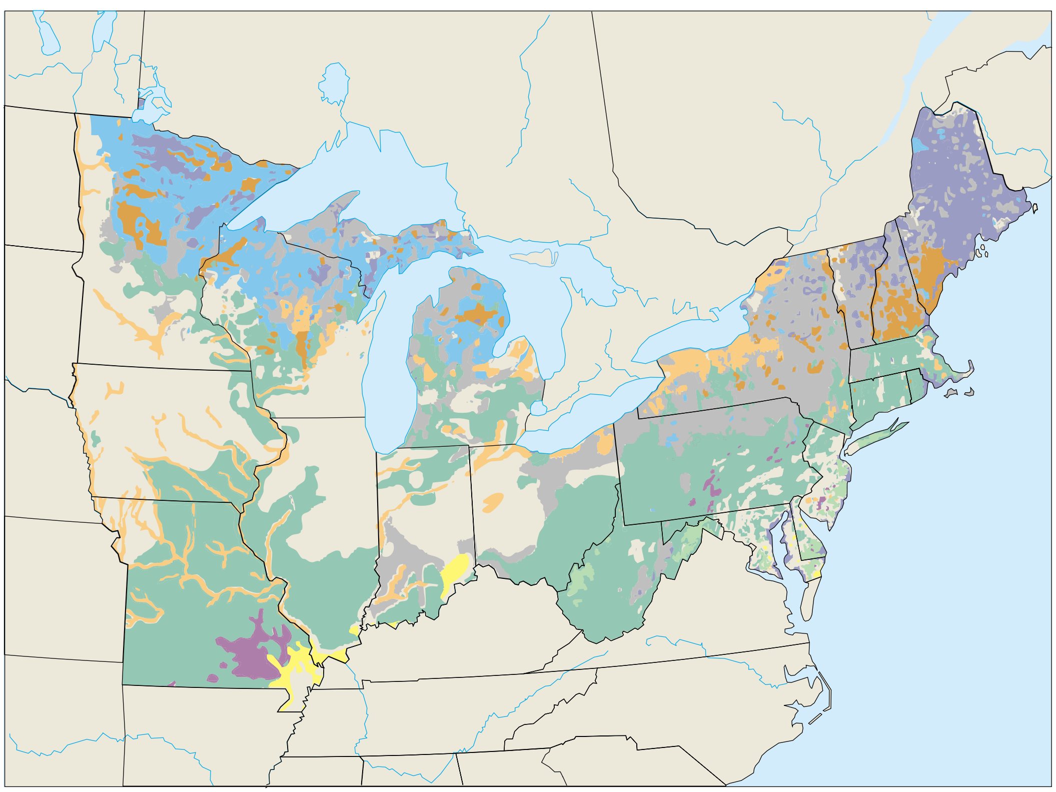


Fig. 1. Forest types in the northeastern United States, Ohio and eastward (Twardus et al. 1993).

Eastern Deciduous Forest

The eastern deciduous forest type occurs throughout most of Pennsylvania, West Virginia, Ohio, northern New Jersey, and coastal New England except in Maine. It is characterized by rolling hills, a precipitation regime that is equally distributed throughout the year and which averages 900–1,500 millimeters per year, and an average annual temperature of 4°C–15°C. The vegetation is primarily broad-leaved trees, such as American beech, oaks, hickories, and yellow-poplar (Bailey 1978).

Southeastern Mixed Forest

In addition to the two dominant forest types, southern New Jersey, Delaware, and most of Maryland also have characteristics of the southeastern mixed forest type. The southeastern mixed forest type consists of pines or a mix of broadleaf and needleleaf trees on uplands, and sweet gum and baldcypress swamps in lowlands and coastal marshes. Shrubs include dogwoods, viburnums, and haws (Bailey 1978).

Forest Changes

Although the Northeast contains some of the largest metropolitan areas in the country, the region is still dominated by forest (Table 1). Forests cover approximately 60% of the total land area, and in New England alone, the coverage is 80% (DeGraaf et al. 1989). Forest is least common in Ohio (30%) and most common in Maine (80%). New York has the greatest area of forested land with approximately 7.2 million hectares.

On average, forested area increased slightly (less than 5%) or remained stable during 1965–1990 and is expected to decrease approximately 3% in the Northeast (west to the Mississippi River) in the next 50 years. Losses of forested land in the 1980's were attributed to cropland conversions, but losses after 1990 are mainly due to urban expansion and reservoir construction (Flather and Hoekstra 1989).

Table 1. Land-use statistics (in thousands of hectares) by state in the northeastern United States (U.S. Forest Service, 1980–1981 unpublished data).

State	Forestland	Crop/pastureland	Total[a]
Maine	6,875.0	284.8	7,748.8
Vermont	1,775.0	346.5	2,318.2
New Hampshire	1,948.0	68.6	2,248.2
Massachusetts	1,259.8	103.9	1,956.1
Connecticut	713.3	87.9	1,217.9
Rhode Island	158.2	11.0	263.7
New York	7,227.0	2,627.0	11,810.5
New Jersey	784.0	340.2	1,867.0
Delaware	152.3	234.6	483.1
Pennsylvania	6,640.6	2,296.9	11,222.0
Maryland	1,055.9	846.9	2,459.2
Ohio	3,071.9	4,939.8	10,238.2
West Virginia	4,726.6	895.3	6,029.7
Total	36,387.6	13,083.4	59,862.6

[a]Numbers do not sum because these categories represent only two of many land-use categories.

Forest Composition

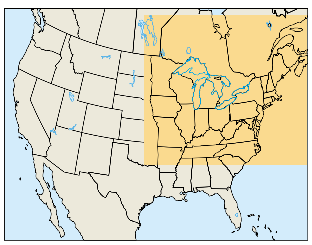
Forest composition is a product of the soils, climate, topography, and periodic natural and human disturbances. Soils and climate promote a natural sequence of tree species that occupy a given site for varying periods. The replacement of one set of species by another (called succession) generally follows a predictable sequence after a major disturbance (see chapter on Natural Processes). In northeastern forests, aspen, birch, ash, and pin cherry grow back first after a disturbance, but they are eventually replaced by sugar maple, eastern hemlock, and American beech. Today, most forests from New York northward consist of these latter species. South of New York, the species that grow back first are replaced primarily by oaks. Northern red oaks and yellow-poplars are especially prominent in the southern part of the region, and pitch pines and loblolly pines dominate the coastal regions of Delaware and New Jersey. Topography plays an indirect role in the revegetation of disturbed areas. More rugged areas were first abandoned by early farmers and now support the oldest regrown forests. The rolling, less-rocky ground to the west continues to be farmed.

Disease and Insect Effects

Introduced diseases and insects are shaping a forest that is very different from that encountered by the colonists. The American chestnut (see box on American Chestnut Blight in Nonindigenous Species chapter) once made up as much as 25% of the trees in some areas and was economically the most important hardwood in the eastern forests, but chestnut blight has almost completely wiped out the American chestnut. The blight, which is caused by a fungus, was introduced into the United States from the Far East around the turn of the century and killed as many as a billion trees in just a few decades. Although the forest lives on, the absence of the American chestnut may have caused the disappearance of at least five species of insects (Opler 1978) and eliminated a major food source for species such as chipmunk, deer, bear, and turkey. Research into the reestablishment of the American chestnut is pursuing three approaches: development of a virus that attacks the fungus (Chen et al. 1994), breeding hybrid chestnuts that resist the fungus (Burnham 1988), and genetic engineering to make chestnuts resistant to the fungus (Maynard 1994).

American beeches and American elms are other trees that dominate the forest overstory and are declining because of introduced non-indigenous species. The beech scale insect, which was introduced from Europe, allows a fungus to invade and kill beech trees. As the insect moved through the region, the fungus killed 85% of the trees that were greater than 35 centimeters in diameter and reduced beechnut production by 43%. The insect is now attacking smaller trees—the fungus has infected 97% of the trees with trunks that are more than 15 centimeters in diameter (R. Sage, State University of New York, Syracuse, personal communication). Elms are attacked by a combination of Dutch elm disease and elm phloem necrosis. Scientists successfully curbed Dutch elm disease by controlling the elm bark beetles that transmit the disease to the trees. Little is known about elm phloem necrosis, however, and researchers predict that it will eliminate elm trees from the Northeast (S. Teale, State University of New York, Syracuse, personal communication).

Many tree species have been affected by the gypsy moth, one of the most widespread and damaging pests in the Northeast (Fig. 2). The gypsy moth caterpillar, accidentally introduced from Europe around 1870, now occurs in every northeastern state and can completely defoliate forests (U.S. Congress, Office of Technology Assessment 1993). In 1971, it caused from 25% to 100% defoliation of more than 608,000 hectares of forest (Metcalf and Metcalf 1993). The cost of research, control, and lost trees probably makes the gypsy moth the most expensive pest in the Northeast. In 1981, when the loss was greatest, the U.S. Department of Agriculture estimated that $764 million worth of timber was destroyed (U.S. Congress, Office of Technology Assessment 1993). The most promising control is a combination of viruses, bacteria, and chemicals (Metcalf and Metcalf 1993; Fig. 3).



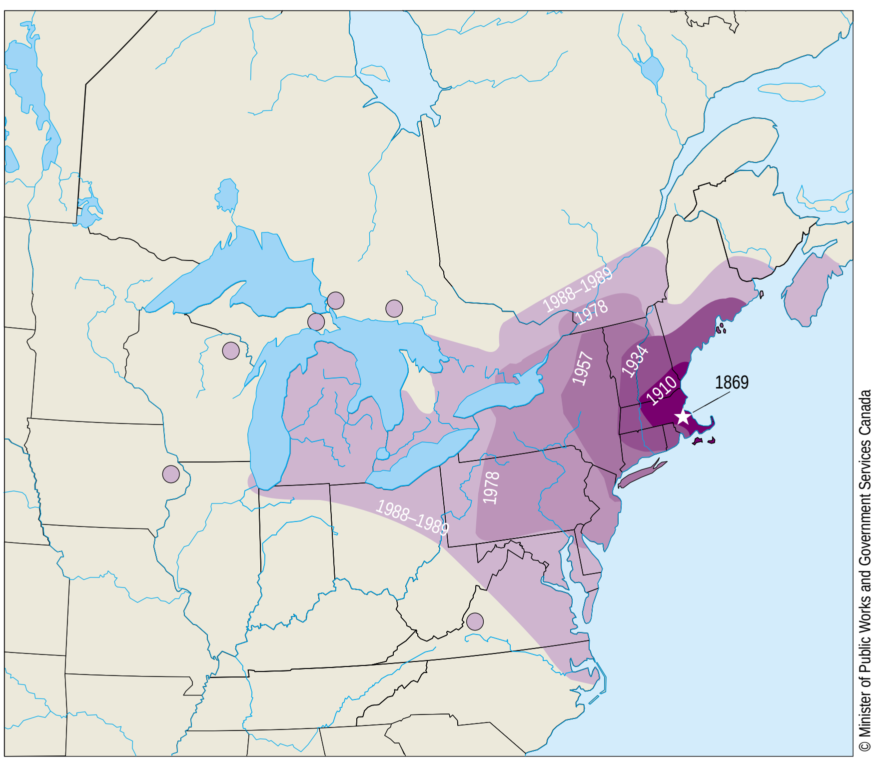


Fig. 2. Historical spread of the introduced gypsy moth in the United States, 1990 (Nealis and Erb 1993).

Dogwood anthracnose is a disease that causes a severe decline in populations of the flowering dogwood throughout the eastern United States (see chapter on Southeast).

Acid Precipitation

Acid precipitation may change forests throughout the Northeast, especially at high elevations. More acid pollutants are deposited at high-elevation sites in the Northeast than anywhere else in North America. The most common pollutants, sulfur dioxide and nitrogen oxides, damage the leaves of trees and can also leach important nutrients like calcium and magnesium from the soils. Acid rain may be the cause for the decline of red spruce at high elevations in the Northeast, although the specific mechanisms through which damage occurs are not known. Studies revealed that pollutants in cloud water and rain can lower the tolerance of the trees to midwinter cold by 4°C–10°C. The lowered tolerance increases the trees' susceptibility to harsh winter conditions that are common in the mountainous Northeast. In addition, large deposits of nitrogen increase the leaching of nutrients from the soil and may make surface water acidic. Trends based on conditions in 1985 show that the proportion of acidic lakes in the Adirondacks could increase from 14% to 22% by 2034. A 40%–50% reduction of sulfur deposits would be needed to reduce the number of acidic lakes to 5% by 2034 (National Acid Precipitation Assessment Program 1993).

The Acid Deposition Control Program, which is Title IV of the Federal Clean Air Act, calls for reducing sulfur dioxide emissions by 40% from 1980 levels and nitrogen oxide emissions by 10% by 2010. Programs such as the Forest Health Monitoring Program and the North American Maple Project, a joint United States–Canadian effort, are monitoring long-term responses of forests to changing levels of ozone, acid rain, and other stressors. Data from the 1980's show that sulfate levels are decreasing at 49 of 53 sites in the Northeast, although nitrate levels are increasing at 27 of 53 sites (National Acid Precipitation Assessment Program 1993).

Old-Growth Forests

The changing composition of the dominant tree species is only one of the major trends in northeastern forests; changing age structure is another. The old-growth forests that were common before European settlement consisted of trees that could live as long as 300 years. Large stands of such trees are rare today and are becoming increasingly fragmented (Flather and Hoekstra 1989). No old-growth forests are left in Rhode Island, and only 40–80 hectares remain in Connecticut. Massachusetts, New Hampshire, and Vermont have a few hundred to a few thousand hectares, and Pennsylvania has 2,400–3,200 hectares in many sites of varying size. By far the largest area of old-growth forest is in New York; more than 81,000 hectares remain in the Adirondack Mountains and more than 24,000 hectares in the Catskill Mountains. Although a variety of old-growth forest types exist, these communities are typically dominated by eastern hemlock, American beech, sugar maple, eastern white pine, and yellow birch. Not all of these areas are untouched by humans; they are considered old-growth forests because their ages and species compositions reflect those of an undisturbed community.

Second-Growth Forests

Today's second-growth forests are not old enough to include trees of advanced age and the associated mix of trees of other ages that characterizes old-growth forests. Most trees in the Northeast are less than 100 years old. Stands often consist of trees that are of the same age because all the trees began growing in the same year, for example, after a fire, after a farm field was abandoned, or after a forest stand was logged. These stands can regain the qualities of old-growth forests if they are given enough time and the proper conditions (Dunwiddie et al. 1996). Concern over old-growth forests, however, persists because a variety of factors prevents most communities from acquiring the characteristics of their original state. Areas that were cut by humans probably have fewer eastern hemlocks, American beeches, and sugar maples and more black cherries, yellow birches, red maples, and black birches than undisturbed sites. Furthermore, clear-cutting and repeated logging probably favor short-lived species such as pin cherries, quaking aspens, and red maples. Eventually, the time span between successful reproduction of longer-lived species may be so great that the source of seeds for some species may be lost from the environment.

Loss of Forest Understory Plants

When most people think of forests, they think only of trees. Yet other species of plants are important components of many forest environments. The forest understory has been significantly affected by human activities, and hundreds of plant species are now rare, threatened, or endangered in the northeastern states. In fact, loss of plant species is higher in the Northeast than in any other part of the United States except Hawaii. Many states in the region are losing more than 5% of their native plants; the loss in Delaware is proportionally the highest at a rate of 15% (Guntenspergen 1995; Fig. 4; Table 2).

Two species, small-whorled pogonia and Robbins' cinquefoil, illustrate the variety of habitats and the modern causes of declines of species. The small-whorled pogonia is one of many endangered orchids; it occurs in second-growth forests in the Northeast, South, and Midwest. Reasons for its decline are not understood, but collection by people is believed an important factor (Mathews and Moseley 1990). The U.S. Fish and Wildlife Service drafted a recovery plan in 1992. Robbins' cinquefoil is an alpine plant, occurring above the treeline on shallow, sandy mountain soils. It now occurs in a single location in New Hampshire and in several places in Vermont. Hikers are a major problem for the plant because they climb to admire the views from mountain peaks and in the process disturb the fragile soils and trample plants (Mathews and Moseley 1990). Two methods by which this unique plant and its habitats are being protected are signs requesting that hikers stay on the trail and forest rangers stationed at the summits of mountains.

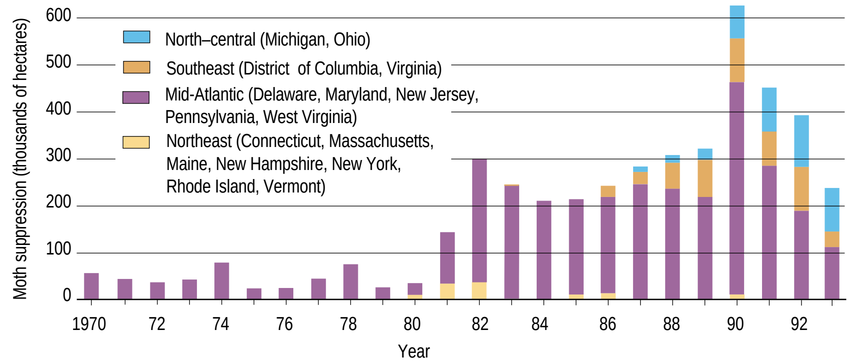


Fig. 3. History of gypsy moth suppression by federal or state cooperative suppression projects, 1970–1993 (Twardus 1994).

Table 2. Vascular plants that occur in the northeastern United States and are on the federal list of endangered species as of 20 August 1994 (U.S. Fish and Wildlife Service 1994).

Northern wild monkshood
Sensitive joint-vetch
Sandplain gerardia
Seabeach amaranth
Mead's milkweed
Jesup's milkvetch
Pitcher's thistle
Smooth coneflower
Swamp pink
Lakeside daisy
Small-whorled pogonia
Canby's dropwort
Furbish lousewort
Eastern prairie fringed orchid
Robbins' cinquefoil
Knieskern's beaked-rush
American chaffseed
Northeastern bulrush
Leedy's roseroot
Virginia spirea
Running buffalo clover
American hart's-tongue fern

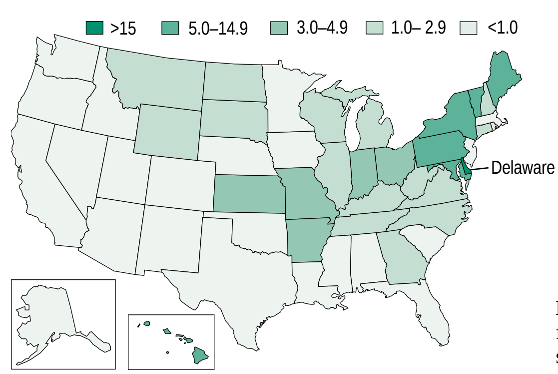


Fig. 4. The percentage of native flora potentially lost from each state (Morse et al. 1995).

The mosses may be among the smallest plants, but they also may be among the most politically potent plants. The famous surveyor VerPlanck Colvin used mosses to defend the need for a forest preserve in New York. He maintained that these species served as natural sponges that soak up moisture and release it slowly, thus keeping the canal system in New York state operating throughout the summer (Graham 1978). Although Colvin surely stretched the facts, his argument was sustained. In New York alone are 465 species of mosses, and new species are occasionally still discovered. The oldest list of rare nonflowering plants in the Northeast is probably from New York. In general, however, basic information on the occurrence and distribution of mosses is lacking in all states in the Northeast. This lack is troubling because many of these species are rare and some are already endangered. The principal threats to mosses in the Northeast are habitat destruction from suburban development, wetland alteration by humans and beavers, and fire suppression where fire formerly occurred naturally (Slack 1992).

Forest Vertebrate Animals

The forests of the Northeast are among the most important environments for the diversity of vertebrate species in North America. Nationwide estimates indicate that at least 90% of the total bird, amphibian, and fish species in the country and 80% of the mammal and reptile species rely on forests for at least part of their life requirements (Flather and Hoekstra 1989). Forests provide a three-dimensional structure that gives much more than simple shelter from weather and cover from predators. This structure also moderates temperature extremes, increases humidity and water retention in the community, and provides energy in the form of edible leaves, fruits, and nuts.

Forest Birds

Contaminant Effects on Forest Birds

Chemical contaminants, especially pesticides, have had substantial effects on birds. A good example is the pesticide that was used for the control of the eastern spruce budworm, an insect that is a favored food of many songbird species. Budworm populations follow a cycle of outbreak and dieback, and songbird densities increase and decrease according to the increasing or decreasing abundance of the budworm (Hill and Hagan 1991). The use of pesticides disrupted the cycles of the budworm populations and reduced the abundances of many bird species (see chapter on Contaminants).

Abundance Changes in Bird Populations

Many people are under the impression that the abundances of birds have substantially declined in the past 50 years, yet the abundance levels of a few species have shown extraordinary increases (Table 3), whereas many others are threatened (Table 4). A one-time candidate for the national symbol and a valued game species—the wild turkey—has thrived in the Northeast in the last few decades. From small populations in Pennsylvania in the 1950's, wild turkeys have spread to all northeastern states and number more than 280,000 (Kennamer and Kennamer 1990). The fragmented forest–agricultural environment provides the best habitat for these birds. Turkey populations were restored by transplanting birds to areas of their former range and by strengthening law enforcement against illegal hunting (Dickson 1992, 1995).

Human activities also provide new food sources for some species. The mourning dove, for example, has responded favorably to the modern landscape by increasing in numbers and by expanding its range, probably because of increased food from farming and residential feeders (Applegate 1993). Feeding in residential areas has also sustained species such as the house finch. Formerly western breeders, these small birds were released in western Long Island, New York, in 1940. The population growth of this species was exponential until about 1971 and has since been increasing more slowly. Concern has been expressed that the purple finch may be adversely affected by the invasion of the house finch, but recent findings suggest that the two species prefer different habitats and that competition between the purple finch and the house finch is probably minimal. The house finch does, however, compete directly with the house sparrow, and the outcome of this competition is unclear (Bosakowski 1986).

Forest Mammals

After birds, mammals are the most comprehensively studied taxonomic group. Two of the large predators, the gray wolf and the mountain lion, were extirpated from the Northeast. Interest continues in reintroducing the gray wolf to the Adirondack Mountains, where large tracts of wilderness still exist. Such a plan depends on public opinion, and restoration will be influenced by the current experience with the reintroduction of wolves in Idaho, Montana, and Wyoming. The eastern cougar, an endangered subspecies of the mountain lion, was also extirpated, and although individuals are periodically reported, self-sustaining populations probably do not exist (Cumberland and Dempsey 1994). The reintroduction of the eastern cougar to the Northeast is not believed feasible because human and road densities are too high, even in

Birds and Landscape Changes in Northeastern Forests

The past four centuries have brought to the landscape of the Northeast a series of changes of a magnitude and rapidity that has few precedents on Earth. Before European settlement, this region was a mosaic of open old-growth forests, shifting agriculture, and fire-maintained grasslands and savannahs. Following European contact, disease decimated Native American populations, and much of the unsettled interior became wooded. By the mid-1800's agriculture, the demand for wooden fencing, charcoal, tanning, and fuel for households, and iron and lime industries created a landscape that was devoid of all but scattered trees. This century has seen the return of forests throughout much of the region.

Such sweeping changes bring with them changes in bird communities. Clear preferences by many bird species for forested environments should mean that their populations wax and wane with changes in the composition, age, and distribution of forested lands. Given these predilections, it should be possible to use information on changes in bird populations as one gauge of the effects humans have had on the landscape.

Birds are connected to their environment in a direct and uncompromising manner. They have no buffer against regional changes in food, cover, predators, or landscapes. Marketing factors and government social welfare programs cannot compensate them if their environment deteriorates. If a site changes in such a way that the locale lacks what it takes to support their needs, they must leave or die. Consequently, the distribution, abundance, and changes in bird populations are a direct statement of the quality and suitability of a region to support birds.

Two large data sets are available for investigating changes in bird populations in the Northeast: the Christmas Bird Count, begun in 1900 (Butcher 1990), and the U.S. Geological Survey's North American Breeding Bird Survey, begun in 1966 (Peterjohn 1994; Price et al. 1995). Data from the early years of the Christmas Bird Count have not yet been converted to electronic format, but Christmas Bird Count data from 1959 to 1988 and Breeding Bird Survey data from 1966 to 1994 are available. Trends in bird populations from these data provide the means to examine the relative welfare of guilds of forest birds (Robbins et al. 1989).

The table presents a state-by-state breakdown of the numbers of bird species increasing and decreasing, organized by several categories or guilds (Droege and Sauer 1989). Results for birds inhabiting mature forests show different patterns. Summer patterns present a mix of regions where increases and decreases predominate in different conditions, whereas winter populations show a pattern of uniform increases (Fig. 1a, b). Bird species composition shifts in forests with the seasons—some birds fly to the tropics, others shift farther south in the United States, and some are permanent residents.

Table. Summary, by season, state, and guild, of increasing and decreasing numbers of species of birds based on data from the North American Breeding Bird Survey (1966–1994) and Christmas Bird Counts (1959–1988).

Breeding season										
State	Mature forest		Scrub		Neotropical migrant		Permanent resident		Short-distance migrant	
	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase
Maine	11	19	9	6	6	12	1	2	4	5
New Hampshire	11	17	8	3	10	7	0	2	1	8
Vermont	11	8	9	3	6	4	2	1	3	3
Massachusetts	10	10	9	2	8	5	1	1	1	4
Connecticut	12	5	10	4	9	3	1	1	2	4
New York	14	20	7	6	11	7	0	3	3	0
Pennsylvania	14	17	11	4	7	10	3	2	4	9
New Jersey	9	4	13	2	7	2	1	0	1	4
Maryland	8	18	8	2	8	9	0	4	0	1
West Virginia	12	7	9	4	11	3	1	2	0	4
Virginia	12	13	9	1	9	7	1	4	1	3

Wintering season								
State	Mature forest		Scrub		Permanent resident		Short-distance migrant	
	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase
Maine	6	14	6	3	1	4	2	8
New Hampshire	5	10	3	2	1	3	2	6
Vermont	1	9	0	4	0	3	0	6
Massachusetts	10	15	7	8	2	3	5	9
Connecticut	10	13	6	6	2	3	7	7
New York	10	18	8	5	2	4	5	10
Pennsylvania	6	20	7	7	1	5	2	13
New Jersey	10	16	10	5	2	3	4	11
Maryland	7	13	9	3	0	3	6	9
West Virginia	0	15	9	3	3	2	3	12
Virginia	5	21	10	4	2	5	2	14

If the overall results are broken down along lines of residency status, Neotropical migrants (Fig. 1c) are declining in more states than they are increasing. Short-distance migrants and permanent residents show the opposite pattern (Fig. 1d,e,f,g). Winter patterns for short-distance migrants and permanent residents both show increasing numbers of species in all states. Clearly the difference between the initial summer and winter results comes from the greater number of declines in Neotropical migrants.

The patterns and causes of changes in Neotropical migrants are a matter of much recent concern and speculation (James et al. 1996). The complexity of their migration, the diversity in their winter and summer life histories, and their great range in geographic and habitat locations in the winter make it difficult to separate out many competing hypotheses as to the causes of these patterns. Data (Table) indicate, though, that populations of Neotropical migrants, as a guild, are experiencing greater negative changes than their less-traveled, forest-dwelling neighbors.

Excluding the complex case of forest-dwelling Neotropical migrants, a clear pattern is evident of increases in forest-dwelling birds during the past 30 years. These patterns coincide with patterns of forest change revealed in the U.S. Forest Service Forest Inventory Program. Forest acreage, particularly of mature forests, has increased throughout the Northeast during this time, though increases in acreage have recently plateaued or declined slightly in some regions (Powell et al. 1994). There has also been a shift from pioneer plant species and those encouraged by regular fires, such as Virginia pine, black locust, and oaks, toward species that regenerate quickly following forest cutting, such as red maple, sugar maple, and yellow-poplar (U.S. Forest Service 1995).

Such patterns of forest change are the indirect result of the exploitation of rich prairie agricultural lands, the loss of local markets for agricultural goods through decreased transportation costs, and subsequent declines in farming of the rocky uplands of much of the Northeast. Over the past 125 years these lands have slowly returned to forest cover. The fact that this process may have stabilized and that the rate of such change has declined is illustrated by the decline of bird species inhabiting early successional forests (scrub; see Table).

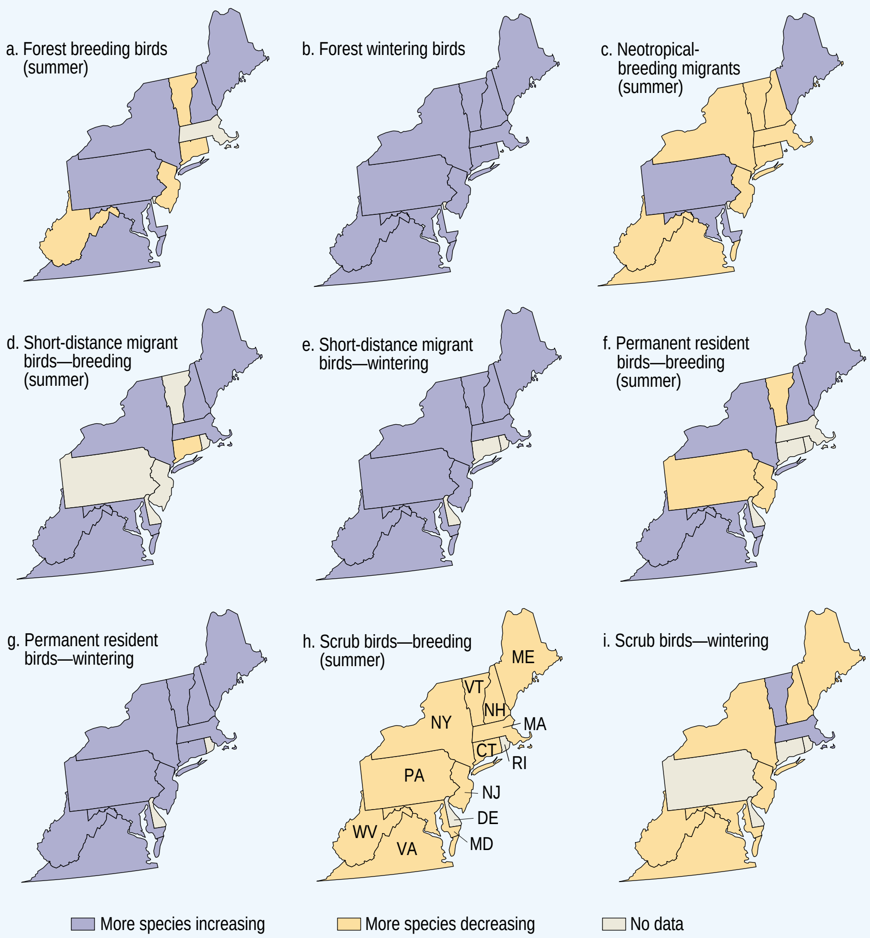


Fig. 1a–i. Regions of overall increase or decrease for wintering and breeding birds (by state). States colored yellow have more species declining. States colored blue have more species increasing. Breakdowns are given for a, b) the collective sum of all forest birds, c) Neotropical migrants (there are no wintering estimates), d, e) short-distance migrants, f, g) permanent residents, and h, i) scrub-inhabiting birds.

Both summer and winter data sets reveal that far greater numbers of scrub-nesting species are decreasing rather than increasing (Fig. 1h,i). Furthermore, the species showing most of the increases are species widely adapted to mechanized agriculture and suburban habitats, such as the mourning dove and the northern cardinal. Land-use patterns in the Northeast are likely to further decrease the number of successional habitats present. Already, Bewick's wren, Bachman's sparrow, and the lark sparrow, all inhabitants of sparsely wooded scrub areas and widely distributed until the middle of this century, have declined to the point that they are locally extirpated or that only a handful of individuals remain. Other species may soon follow.

Changing bird populations reflect the Northeast's changing landscape. Species differ in their responses to landscape change, each having unique preferences for the habitat architecture of their surroundings. By tracking changes in bird populations and other species, we can make statements and develop hypotheses regarding the health and future of our environment. Such measures cannot be found through inspection of our gross national product or consumer price indices. We must listen to what these changes tell us about our effects on the lands we share. By distancing ourselves from such information, we risk making the present round of changes irreversible.

See end of chapter for references

Author

Sam Droege
U.S. Geological Survey
Biological Resources Division
Patuxent Wildlife Research Center
12100 Beech Forest Road
Laurel, Maryland 20708-4038

sparsely settled areas. A low rate of reproduction, mortality on roads, and losses from illegal hunting would keep the eastern cougar from increasing its population (Brocke 1994).

Although most of the larger forest mammals have disappeared, several are showing stable or increasing population levels. Elk are confined to a small population in northern Pennsylvania. In spite of threats from habitat alteration and poaching, black bear populations are stable or increasing in all states in the Northeast. In fact, there are more than 40,000 bears in the northeastern forests; most are in Maine (20,000) and Pennsylvania (7,500), but populations that number from 150 to 5,000 are reported in every state except Connecticut, Ohio, and Rhode Island (Vaughan and Pelton 1995). The area's largest animal, the moose, was extirpated from the region in the mid-nineteenth century. Now, however, the moose is common in northern New England as a result of protection from unregulated hunting, expansion of the forest, and subsequent intensive tree harvest and regeneration. Some moose are even venturing into Connecticut, Massachusetts, and New York.

The two smaller cat species, bobcat and lynx, still occur in the Northeast. Bobcat and lynx prefer unbroken forests and are at risk from continuing human intrusion on forestlands. Bobcats are protected in Connecticut, Delaware, Maryland, New Jersey, Ohio, Pennsylvania, and Rhode Island. Bobcat populations seem to have declined since settlement; estimated densities are 2 to 6 cats per 100 square kilometers (Fox 1990). The bobcat will probably persist because of its high rate of reproduction and its ability to adapt to varying landscapes (Koehler 1987). An effort to restore the lynx to Adirondack Park was made in 1985; the outcome of this project is still unclear (Brocke and Gustafson 1992).

Misunderstood Forest Wildlife

Because public pressure plays a major role in wildlife conservation, unpopular or feared animals are at a distinct disadvantage when their populations or habitats are threatened. This category of misunderstood wildlife includes bats and snakes. At least 10 species of bats occur in the Northeast. The Indiana bat is on the federal list of endangered animals; the small-footed myotis is on the state list of endangered animals in New Hampshire, on the state list of threatened animals in Vermont and Pennsylvania, and is of special concern in New York (Genoways 1985; New York, New Hampshire, Vermont, and Pennsylvania Natural Heritage Programs, unpublished data).

The status of an even more feared animal, the timber rattlesnake, is similarly precarious. The timber rattlesnake is extirpated in Maine and Rhode Island, endangered in Connecticut, Massachusetts, New Hampshire, New Jersey, and Vermont, and threatened in New York and Ohio. These snakes are still hunted in Pennsylvania, where populations are large but not necessarily secure (Breisch 1992). Populations of this snake are declining in all northeastern states, and a survey of den sites in northern New Jersey and New York revealed that den sites had decreased by an average of 60% since 1968 (Stechert 1992). The snake populations and their habitats are declining because of human development, various disturbances, and willful destruction (New York Natural Heritage Program, Latham, unpublished material).

Many different species that inhabit the forest floor are often overlooked because of their small sizes. These species include rodents, other small mammals, salamanders, insects, other arthropods, and many creatures that are too small to be seen with the naked eye. Animals that lack public appeal often get less attention from the scientific community and are therefore the least well known. The consequences of such a lack of knowledge are illustrated in the case of the American burying beetle, a forest insect that was widespread in the eastern forests before 1960. By 1970, though, the beetle was thought extinct but was then rediscovered in Rhode Island. No conservation measures were under way until 1983 (Wells et al. 1983); the beetle was placed on the federal list of endangered species in 1989 (U.S. Fish and Wildlife Service 1994).

Table 3. Number of species of Neotropical breeding birds in the Northeast with significant population trends and the number of these species that are short- and long-distance migrants[a] (Smith et al. 1993).

Wintering habitat	Upward	Downward	No trend
Short-distance	6	15	10
Long-distance	10	14	22
Total	16	29	32
Breeding habitat	**Upward**	**Downward**	**No trend**
Mature forest	7	7	16
Successional	9	22	3
Total	16	29	19
Breeding habitat	**Short-distance**	**Long-distance**	**Total**
Mature forest	11	41	52
Successional	32	42	74
Total	43	83	126

[a] Values are partitioned by habitat and migratory behavior.

Table 4. The status of birds that are endangered or extirpated in at least one of seven northeastern states in the United States (Vickery 1991). X = extirpated, E = endangered, T = threatened, S = special concern, • = occurs but not listed, N = does not occur.

Species	State status						
	Maine	New Hampshire	Massachusetts	Vermont	Rhode Island	Connecticut	New York
Common loon	•	T	S	E	N	S	S
Pied-billed grebe	•	S	T	S	X	E	•
Black-crowned night-heron	S	X	•	•	S	S	•
American bittern	•	•	S	•	E	E	•
Osprey	•	T	•	E	S	S	T
Bald eagle	E	E	E	E	E	E	E
Northern harrier	•	T	T	S	E	E	T
Sharp-shinned hawk	•	•	S	•	X	T	•
Peregrine falcon	E	E	E	E	E	E	E
Spruce grouse	•	•	N	E	N	N	T
Long-eared owl	•	S	S	S	S	E	•
Short-eared owl	N	S	E	S	N	T	S
Red-headed woodpecker	•	N	N	•	S	S	E
Sedge wren	E	S	E	T	N	E	T
Loggerhead shrike	X	X	E	E	N	N	E
Golden-winged warbler	•	N	S	E	•	X	S
Northern parula	•	•	T	•	X	•	•
Black-throated blue warbler	•	•	•	•	X	•	•
Yellow-breasted chat	N	N	N	N	E	E	•
Vesper sparrow	S	S	•	•	E	E	S
Grasshopper sparrow	E	S	S	S	T	E	S
Henslow's sparrow	N	S	E	E	N	X	S

Unique Forest Environments

Two forest systems in the Northeast deserve special mention because of their unique species and relative integrity—the Adirondack Park of New York and the Pine Barrens of New Jersey. Although these environments have experienced many disturbances by humans, both still include large parcels of land that are somewhat protected from development and disturbance and are functioning, largely intact, natural environments.

Adirondack Park

The Adirondack Park covers 2.3 million hectares in northern New York and is the largest park in the contiguous United States. Politically, the region is unique because it is a mosaic of public (45%) and private (55%) land that is under the stringent regulation of the Adirondack Park Agency. As part of the Lake

Champlain–Adirondack Biosphere Reserve, this region is involved in an experiment in the simultaneous development of human economy and protection of wilderness character. Although the park was historically exploited for timber and mineral resources, today it is dominated by second-growth forest. More than one million hectares of the park are designated as Adirondack Forest Preserve and held forever wild by an amendment to the New York State Constitution. Mining was a major portion of the economy as recently as the 1970's, and logging and tourism continue, but most of the species and environmental diversities of 300 years ago still exist (Davis 1988).

One inhabitant of the Adirondacks is the spruce grouse, a species that illustrates how subtle changes in the forest can isolate and ultimately eliminate species. The spruce grouse is slightly smaller than the more widespread ruffed grouse and inhabits spruce–fir forests throughout the Northeast and Canada and west into the Rocky Mountains. Populations in the Adirondacks have been declining since the late 1800's, primarily because logging changed the species composition of forests. Spruce and fir trees are critical habitat for spruce grouse, and these trees once composed 45% of the Adirondack forest. After logging, spruce and fir are replaced by other tree species. Today, only 10% to 25% of the Adirondack forest is spruce and fir, and these stands occur in isolated patches. The entire breeding population of spruce grouse in the Adirondack Park now consists of an estimated 175–315 individuals (Bouta 1991). Because of the small size and fragmented nature of this spruce grouse population and because of its need for mature spruce–fir forest, the long-term prognosis for the species is not favorable (R. Chambers, State University of New York, College of Environmental Science and Forestry, Syracuse, personal communication).

The mountainous terrain of the Adirondack Park includes hundreds of lakes. Unfortunately, because the park is downwind from metropolitan and industrial centers to the west, the Adirondack region has the highest percentage of acid waters in the United States. Nearly 20% of the Adirondack lakes have lost one or more fish populations to acidification. Brook trout and acid-sensitive minnow species suffer the most; however, no species seem in danger of extinction at present (Baker et al. 1993).

The decline of fish populations in acidified lakes also affects nesting common loons. Although common loons occur throughout North America, they have become a symbol of the northern wilderness in New England, New York, and the Great Lakes states. Loons show strong fidelity to specific nesting areas and continue to nest even on lakes that are acidic. Such acid lakes support few fishes, which are the primary food for the quickly growing young (Parker 1988). Loons are also at risk from a variety of human disturbances. Throughout New England, adult birds die from PCB and mercury poisoning and are easily disturbed by recreation and development. In fact, the leading cause of death for the species may be lead poisoning from anglers' lead sinkers (Pokras et al. 1991).

Pine Barrens

Although the Pine Barrens of New Jersey are not as large as the Adirondack Park, they are equally unusual. The Pine Barrens consist of 500,000 hectares of sandy soils in central New Jersey and are dominated by pitch pines and scrub oaks that are adapted to frequent fire. Pine barrens occur in all the coastal northeastern states, but nowhere in the world is the type as extensive and undisturbed as in New Jersey. Although the Pine Barrens are only a 2-hour drive from New York City and Philadelphia, they continue to have remarkable ecological integrity. Roads are relatively uncommon and large areas remain free from human disturbance (Kerlinger and Doremus 1981); some areas are farmed, mainly for blueberries and cranberries. Approximately 365,000 hectares of the Pine Barrens are preserved and managed under the New Jersey Pinelands Commission (Boyd 1991).

The New Jersey Pine Barrens provide habitat for 54 species of plants and 33 species of animals on the state list of threatened or endangered species. Two plants, the sand-myrtle and Pickering's morning-glory, occur nowhere else; Knieskern's beaked-rush and blazing star occur only in the barrens and in similar sites in Delaware. In addition, the environment's many bogs support more than 20 species of sphagnum moss. The low plant diversity and low nutrient conditions of the Pine Barrens support few birds, earthworms, or snails, but do support many butterflies, skippers, and moths, and some amphibians and reptiles (Table 5). The pine snake is a common inhabitant of the Pine Barrens but is threatened in New Jersey at large (Boyd 1991). Likewise, the Pine Barrens treefrog once was on the federal list of endangered species but is abundant in this region (U.S. Fish and Wildlife Service 1994).

Historically, the pine barrens habitat extended farther north and east, but today only portions persist. The portion near Albany, New York, is most notable. Commonly called the Pine Bush, this area is only 1,200 hectares (originally 104 square kilometers) and is so disturbed that continuous patches rarely exceed 300 hectares (Kerlinger and Doremus 1981). Heavy deer browsing, traffic, windbreaks made

Northeastern Spruce–Fir Forests

Forests dominated by red spruce and balsam fir cover 4.1 million hectares in the Northeast, principally in northern New England and eastern New York (Figure). Pollen records of past forests suggest that today's spruce–fir forests became prominent only around 1,000 years ago, corresponding to a decline in eastern hemlock and American beech abundance (Jacobson et al. 1987). Spruce–fir forests predominate on somewhat poorly drained, acidic soils of glacial origin. The region's cold climate and infertile soils have largely prevented the widespread conversion of natural spruce–fir forests to agriculture, as is common in more southerly regions.

The highly variable glaciated landscape creates many interesting habitat types. *Spruce flats* occur at low elevations on shallow glacial tills with impeded drainage. Red spruce and balsam fir mixtures dominate these sites, with minor components of paper birch and red maple. *Spruce swamps* support nearly pure stands of black spruce mixed with tamarack and Atlantic white-cedar on organic or poorly drained mineral soils. *Spruce slopes* occur on mountainsides above approximately 800 meters elevation on shallow, very rocky soils. Balsam fir and paper birch represented a minor component of the spruce slope type before human disturbance. On more fertile midslopes with well-drained soils, deciduous species—yellow birch, red maple, American beech, and sugar maple—mix with spruce and fir. Eastern hemlock and eastern white pine are also common associates (Westveld 1953).

Human Influences on Forests

Human disturbances have profoundly affected the current condition of the spruce–fir forest resource. Throughout the 1800's, virgin forests were logged repeatedly, first for scattered white pines, then for spruce, and finally for northern hardwoods. Since 1900 landownership has changed from the early lumber barons to pulp and paper companies. The largely unpopulated spruce–fir region of northern Maine comprises the largest contiguous industrial ownership in the United States, and commercial forestry continues to be the dominant land use.

Natural Disturbances

Natural disturbances, mainly wind storms and insect outbreaks, although frequent, have rarely killed stands over extensive areas before human exploitation. Large, stand-replacing wildfires were especially rare, averaging nearly 2,000 years between events. This presettlement regime of small spatial-scale disturbances maintained a landscape of multiaged stands dominated by long-lived trees as much as 300 years old (Lorimer 1977). The most prominent natural disturbance agent of spruce–fir forests is the eastern spruce budworm, a native insect that has reached outbreak status three times during the twentieth century (Irland et al. 1988). Balsam fir, a much shorter-lived species than red spruce, is the budworm's primary host, although spruce can also be killed in severe outbreaks. Widespread insecticide application during the 1972–1984 outbreak prevented the extensive mortality experienced during the very severe 1913–1919 outbreak. The spruce beetle was once a common cause of death of old, large-diameter red spruce (Hopkins 1901). The introduced insect, the balsam woolly adelgid, affects balsam fir in coastal regions but appears to be climatically limited and does not cause serious damage inland.

Although the current spruce–fir forest is, in many respects, quite natural in appearance, more than 150 years of human exploitation and forest management have significantly altered its age structure and species composition. Logging has always concentrated on the older, more valuable conifers, so late successional forests with old-growth structures have become quite rare, limited mainly to small stands in public and conservation ownerships. The second- and third-growth forests under management have much less age diversity than the presettlement forests. Although red spruce remains abundant, balsam fir has no doubt expanded greatly. Selective logging of conifers has also reduced tree species richness of formerly mixed stands that are now composed of pure northern hardwoods (Seymour 1992).

Future of Northeastern Spruce–Fir Forests

The future condition and sustainability of the spruce–fir forest will depend on how management practices of large landowners evolve to meet increasing demands for commodities while conserving biodiversity. One paradigm currently under wide discussion is a landscape *triad*, combining areas devoted to commodity production, unmanaged ecological reserves, and modified forestry practices (Seymour and Hunter 1992).

© R. S. Seymour, University of Maine

Figure. One of the finest remaining examples of an old-growth, low-elevation red spruce forest, a type of forest that once covered millions of hectares in northern Maine.

See end of chapter for references

Author

Robert S. Seymour
Department of Forest Ecosystem Science
University of Maine
Orono, Maine 04469

Table 5. Number of species that occur in the New Jersey Pine Barrens, United States (Boyd 1991).

Taxon	Number of species
Algae	360
Fungi	>1,000
Lichens	275
Liverworts	78
Mosses	274
Horsetails and club-mosses	8
Ferns	21
Flowering plants	288
Insects	10,385
Fishes	36
Amphibians	24
Reptiles	19
Birds	73–144
Mammals	34
Total	13,000

by roads and buildings, development of open dunes, nonindigenous species, and fires at the wrong intervals have altered the environment. In the last century, 28 species of moths and butterflies have been lost from the Albany Pine Bush; the greatest decline occurred in the last two decades. Pine barrens regions are often home to insects that are not restricted to the environment but are on the edges of their ranges, which makes them more susceptible to local extinction. One species that depends heavily on pine barrens and the blue lupine plants that grow there is the Karner blue butterfly, which is on the federal list of endangered species. Its populations in the Albany Pine Bush have declined drastically since 1980, and its continued existence is doubtful (McCabe 1995).

The high human populations of the Northeast do not permit a complete restoration of pine barrens. The Nature Conservancy owns a large portion of what pine barrens remain in New York and together with state agencies is attempting to preserve them. A section of pine barrens on Long Island, New York, is 100,000 hectares but is much dissected by roads and development, and fire suppression has reduced the environment to less than 50% of its original size. The New Jersey barrens are somewhat more secure but are not isolated from development and pollution; fertilizers, pesticides, herbicides, and organic wastes have changed the water quality and have led to changes in the flora. This, in turn, crowds out species like the threatened Knieskern's beaked-rush, which inhabits areas of early regrowth (Moseley 1992).

Agricultural Lands

Although unforested lands occur naturally in the Northeast, the majority of open land in the region was created by humans for agriculture. Today, agricultural lands make up 22% of the total land area, or about 13.1 million hectares. This includes farmed land, fallow fields, and pastures. Agricultural land is most common in Delaware (49%) and in Ohio (48.3%); the greatest total area of farmland, 4.9 million hectares, is in Ohio (U.S. Forest Service, forest statistics for states, 1980–1991, unpublished data).

Cropland Trends

Total cropland in the Northeast and in the country has been declining since the 1930's. Exclusive of Ohio, the Northeast showed a net shift of 1.3 million hectares from cropland to other uses between 1967 and 1975. This trend was reversed somewhat in the 1980's because of an expanding export market but quickly tapered off. Further increase in cropland in the Northeast is not probable (McCorkle and Halver 1982). Continuing expansion of rural communities is converting significant amounts of agricultural land to housing and commercial developments. The consequences of this trend include a rise in agricultural land prices and more intensive farming of remaining land (McCorkle and Halver 1982). Economic forces continue to encourage the removal of hedgerows, field-border strips, wetlands, and woodlots, all of which are prime wildlife habitats (Flather and Hoekstra 1989).

Sustainable Use of Croplands

Agricultural land and its products are of such economic importance that legislation designed to encourage sustainable use continues to be developed. In the past decade, the Conservation Reserve Program, part of the Food Security Act of 1985, encouraged the removal of erosion-prone and marginal-soil lands from production for at least 10 years. As of 1989, 2 million hectares were under contract in the Northeast (west to the Mississippi; Flather and Hoekstra 1989). National legislation with so-called swampbuster clauses discouraged the conversion of 625,000 hectares of unprotected wetlands (6.1% of the nation's total) into croplands. In addition to protecting wetlands and reducing erosion, these programs produce prime habitat for a wide range of species that live in open land, as well as species that use both fields and forests. The preservation of agricultural land is beneficial to small game, nesting waterfowl, nongame animals, and fishes. If programs such as the Conservation Reserve Program are discontinued, many native species are expected to decline.

Wildlife Trends

Many wildlife species that inhabit open lands in the Northeast have declined in the past 20 years. Species such as the eastern and New England cottontails were plentiful in the 1960's but now seem to be declining across their ranges (DeGraaf et al. 1989). Grassland birds declined drastically in the Northeast during the last 100 years. Open habitats support many threatened and endangered bird species; nine species from grasslands are listed as threatened or endangered by five or more northeastern states (Vickery 1991). The populations of the long-eared owl declined between 1956 and 1986. Likewise, the northern bobwhite experienced a 40-year decline across its primary range, and although the rate of decline is less now than in recent history, populations are not expected to return to even the 1985 levels (Flather and Hoekstra 1989). Even

American Woodcock

The American woodcock is a shorebird that inhabits forested areas from Manitoba east to Newfoundland and Labrador and south to the Gulf of Mexico. It is known by a variety of colorful local names including timberdoodle, Labrador twister, brush snipe, woods snipe, and bog sucker. The woodcock is a popular game bird throughout eastern North America and is the object of an estimated 3.4 million days of recreational hunting annually (U.S. Department of the Interior 1990). Hunters in the United States harvest an estimated 1.1 million woodcock annually (Straw et al. 1994), making woodcock among the top ten species of migratory game birds harvested in the Atlantic and Mississippi flyways.

The most distinctive features of the woodcock are its long bill (60–75 millimeters), which is specialized for feeding on earthworms, and its large eyes, which are set far back for 360° vision (Keppie and Whiting 1994). Woodcock are cryptically colored and more compact than other shorebirds. Females are larger than males, with female weights ranging from 151 grams to 279 grams, and males from 116 grams to 219 grams (Mendall and Aldous 1943; Owen and Krohn 1973). Their plumage consists of a mottled pattern of browns, black, buff, and gray. Short powerful wings allow them excellent maneuverability when flying through the thickets and tangled brush where they live (Fig. 1).

The northeastern states are a major breeding area for woodcock. Most woodcock winter south of the region except for a small population along coastal Virginia. Cape May, New Jersey, and Cape Charles, Virginia, are major staging areas for woodcock during migration, especially in the fall. Birds arrive in the Northeast from wintering areas as early as February in some states, but the peak of the breeding season is in April and May. These birds are probably the earliest nesters among ground-nesting species in North America. Around dawn and dusk during the breeding season, males of this secretive species come out of hiding to perform a spectacular display. Courtship begins with a ground display during which the male turns and utters a nasal "peent" for about a minute. This is followed by a 45- to 60-second aerial display in which the male spirals 30 to 90 meters above the ground while creating a distinctive twittering sound with the outer three wing primaries. The display ends with a melodic warbling call during the descent. After the bird alights at the takeoff point, the sequence is repeated (Mendall and Aldous 1943; Straw et al. 1994). Courtship bouts last 25–45 minutes, depending on duration of twilight, but may continue throughout the night during periods of bright moonlight.

Habitat requirements of woodcock vary with activity, time of day, and season. Woodcock spend the daylight hours using their long bills to probe for earthworms, which make up nearly 80% of their diet (Sperry 1940; Keppie and Whiting 1994). They rely on their cryptic coloration and the dense vegetation to hide them from predators. At dawn and dusk they fly from the protection of their daytime cover to fields and openings to roost, feed, or mate. They are not restricted to specific plant assemblages (Keppie and Whiting 1994) as long as the habitat provides the necessary stem density and structure (Straw et al. 1994). The birds prefer early-successional habitats created by periodic disturbance of the forest; optimal habitat is provided by dense hardwood cover on good soils with an abundance of earthworms (Straw et al. 1994). Thus, young forests and abandoned farmland mixed with forested land are ideal woodcock habitat (Keppie and Whiting 1994).

Woodcock use forest openings, clearcuts, fields, roads, pastures, and abandoned farmland as display areas (singing grounds) for courtship (Mendall and Aldous 1943; Liscinsky 1972). Vegetative composition of the singing ground varies locally and throughout the range and is probably unimportant as a determinant of use (Dwyer et al. 1988; Sepik et al. 1993). More likely the quality of the adjacent habitat for nesting and brood-rearing determines use by males. Young aspen, birch, hawthorn, alder, and dogwood provide appropriate cover in the Northeast (Keppie and Whiting 1994; Straw et al. 1994). Nests and broods are found in young to mixed-age forests, but young, open, second-growth stands are preferred (Mendall and Aldous 1943). In areas where habitat is managed, woodcock select stands of young hardwood regeneration (Gregg and Hale 1977; McAuley et al. 1996). During summer, young hardwoods and mixed woods with shrubs, particularly alders less than 20 years old, provide daytime cover for feeding (Morgenweck 1977; Rabe 1977; Hudgins et al. 1985).

Woodcock are sometimes found in stands of mature forest, but only if there is a dense understory (Sheldon 1967; Rabe 1977). In the Northeast, woodcock rarely use conifer stands, except during drought when they may be critical for survival (Sepik et al. 1983). On summer nights, many birds roost in clearings, such as blueberry barrens, pastures, recently harvested woodlands, and plantations (Dunford and Owen 1973; Sepik et al. 1981; Sepik and Derleth 1993). Woodcock use many of these same fields as singing grounds in the spring. In the fall and during migration, woodcock spend the days in young, moist hardwoods with shrub understories (Keppie and Whiting 1994), whereas in winter they use a variety of habitats during the day, especially bottomland hardwoods, upland mixed

Courtesy D. McAuley, USGS

Fig. 1. A female American woodcock in typical habitat.

pine–hardwoods, and recently burned stands of longleaf pine (Glasgow 1958; Britt 1971; Dyer and Hamilton 1977).

Woodcock are managed on the basis of two regional populations, the eastern and the central (Owen et al. 1977); northeastern states are part of the eastern management unit. Analysis of band recovery data indicates that little crossover of birds occurs between the regions (Martin et al. 1969; Krohn et al. 1974). Furthermore, regional boundaries conform with the boundary between the Atlantic and Mississippi waterfowl flyways.

Reliable indices of population size, productivity, harvest size, and distribution of woodcock are difficult to obtain (Bruggink and Kendall 1995). Because of their small size, cryptic color, and preference for dense vegetation, woodcock cannot be censused. The status of the woodcock population is now monitored with a wing-collection survey and the singing-ground survey.

The wing-collection survey was developed in the 1960's to monitor productivity. Cooperating woodcock hunters and some waterfowl hunters who hunt woodcock provide wings from birds that they shoot (Bruggink and Kendall 1995). Hunters are also asked to record the effort and success of their hunts. Age and sex of the birds can be determined from plumage characteristics (Martin 1964), and the ratio of immature birds to adult females in the survey sample provides an index of recruitment. The recruitment index for woodcock in the eastern region for 1995 (1.4 immatures per adult female) was higher than in 1994 but was 17.6% less than the long-term average of 1.7 immatures per adult female (Bruggink and Kendall 1995; Fig. 2), indicating poor production of young in recent years, although these numbers should be interpreted with caution (see Owen et al. 1977 and Straw et al. 1994). A major problem of the wing-collection survey is that it is not random, because no comprehensive sampling frame exists for woodcock hunters. When the U.S. Fish and Wildlife Service's Harvest Information Program is implemented, this framework will be provided. Under this program, states will provide the U.S. Fish and Wildlife Service with a computerized address list of everyone who purchases a hunting license, allowing for a true random selection of hunters for the survey.

Researchers developed the singing-ground survey to count displaying males during the breeding season. Since 1968 randomly chosen roadside routes have been surveyed for "singing" male woodcock to provide an index of the population size. Routes were established along lightly traveled secondary roads in the central and northern portion of the breeding range. The survey consists of approximately 1,500 routes, each 5.8 kilometers long and consisting of 10 listening points. Recent (1985–1995) and long-term (1968–1994) trends in the singing-ground survey suggest that woodcock populations have declined at an annual rate of 2.0% recently and 2.4% long term in the eastern region (Fig. 3). Populations in the central region declined an average of 2.8% annually from 1985 to 1995 and an average of 1.4% per year from 1968 to 1994 (Bruggink and Kendall 1995). In every state in the Northeast except New Hampshire, the number of males heard on the singing-ground survey has declined (Bruggink and Kendall 1995).

The major causes of the long-term decline in woodcock populations are not known but probably result from degradation and loss of suitable habitat on both the breeding and the wintering grounds (Owen et al. 1977; Dwyer et al. 1983; Straw et al. 1994). Researchers have associated habitat loss with urbanization and forest succession on the northern breeding areas and with drainage and land-use conversion on the wintering grounds (Straw et al. 1994). Although forests cover 60%–90% of New England (Brooks and Birch 1988; Waddell et al. 1989) and northern New England is at least 75% forested (DeGraaf et al.1993), the forests of the Northeast are aging. New England forests are currently dominated by saw timber-sized trees, whereas the early successional seedling–sapling stands that woodcock require are becoming regionally scarce. As of 1988, young stands made up only 8% of the timberland in New England (Brooks and Birch 1988), a trend consistent throughout the Northeast (Fig. 4). The decline in young forest is the result of changing management objectives and techniques, changing attitudes of landowners, a decline in farm abandonment, increased fire suppression, and increased urbanization (Brooks and Birch 1988; U.S. Fish and Wildlife Service 1996). Thus, most changes in the timberland resources of this region have resulted from changes in forest structure and not from gains or losses in acreage. Most woodcock habitat in the Northeast is privately owned; timber companies control the next largest portion of this resource, and state and federal agencies control the smallest portion (U.S. Department of the Interior 1990). State and federal governments and private agencies need to determine ways to stimulate creation of woodcock habitat on private lands.

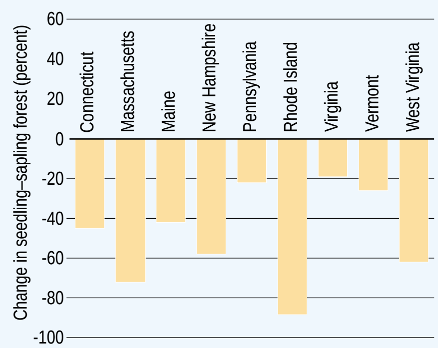


Fig. 4. Changes in the area of seedling–sapling forest in selected states in the Northeast, 1978–1996 (U.S. Fish and Wildlife Service 1996).

To increase the woodcock population, the U.S. Fish and Wildlife Service has developed an American Woodcock Management Plan (U.S. Department of the Interior 1990). In the Northeast, the management goal (U.S. Fish and Wildlife Service 1996) is to restore woodcock populations to 1985 levels by the year 2005. Conservation and management of woodcock habitat are critical to achieving these population objectives. Habitat management that promotes early successional forest types increases local breeding populations of woodcock and other wildlife. Crucial to this effort is encouraging commercial timber companies to incorporate woodcock habitat management into their timber-management activities and to inform private landowners of potential habitat-management opportunities on their lands. In addition, identification and management of woodcock wintering habitat are also necessary. Most importantly,

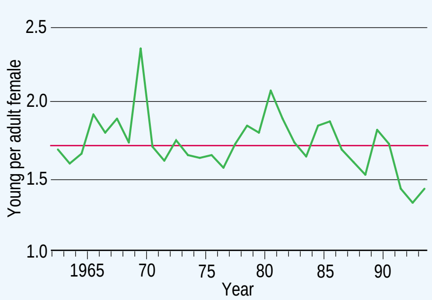


Fig. 2. Adjusted annual indices of recruitment, 1963–1994, determined from wings sent in to the annual woodcock wing-collection survey from states in the eastern region. Red line is the 1963–1993 average (Bruggink and Kendall 1995).

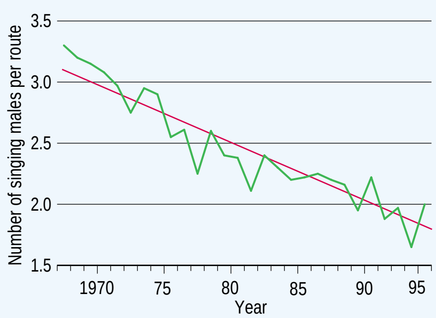


Fig. 3. Long-term trend and annual indices of the number of woodcock heard on the woodcock singing-ground survey in the eastern region, 1968–1995 (Bruggink and Kendall 1995).

cooperation in habitat management among state, federal and nongovernment organizations, and private citizens will be necessary to reverse the downward trends of the woodcock population.

Although available data do not indicate that hunting has played a major role in woodcock population declines, proper management requires that we understand the relationship among hunting regulations, harvest, and woodcock populations, especially at the local level (Straw et al. 1994). Implementation of the Harvest Information Program will be the first step in determining this relationship. Research into the effects of hunting on local and regional populations is also necessary, but few studies are under way on woodcock in the Northeast. Likewise, research is needed to address the potential effects of new pesticides on woodcock, their habitat, and earthworms; such research has not been done for 15 years.

See end of chapter for references

Authors

Daniel McAuley
David A. Clugston
U.S. Geological Survey
Biological Resources Division
Patuxent Wildlife Research Center
Northeast Research Group
5768 South Annex A
Orono, Maine 04469-5768

nonindigenous species such as the ring-necked pheasant have had drastic population-level declines.

Many losses of wildlife populations are attributed to changes in habitat as a result of current farming practices. During the past 20 years, use of row cropping and reduced field edges, use of herbicides and pesticides, widespread plowing under of crop residues in the fall, and abandonment of marginal fields to forest have increased. Many fields abandoned during the 1940's and 1950's were dominated by shrubs during the 1960's and early 1970's and were then taken over by trees. The combination of intensive cropping and maturing forest leaves little land in shrub and small sapling stages, reducing the habitat for many species that depend on these plant communities (Crawford 1987).

Some species have benefited from recent agricultural practices. Birds that find suitable habitat in row crops include the horned lark and the killdeer (Whitney 1994). The abundances of wild turkeys and Canada geese increased because of crop residues that are available throughout fall and winter. The practice of spreading liquid manure on fields in the winter also provides food in the form of undigested grain for turkeys, American crows, and many songbirds.

Some mammals benefited as well. Small seed-eating mammals thrive on the abundant grain waste on farms. Two species with increasing population levels because of row crops are the deer mouse and the house mouse (Whitney 1994). The predators of small mammals, such as birds of prey, snakes, foxes, and weasels, are also common. White-tailed deer, raccoons, coyotes, skunks, and Virginia opossums take advantage of residual corn and other crops, and their populations have grown more than tenfold across the region in the past 20 years.

Wetlands

Loss of Wetlands

Marshes, swamps, bogs, fens, ponds, lakes, and rivers are wetlands, a landscape class that is saturated with water at least part of the year. Wetlands are abundant in the Northeast and are rich in plant and animal life. Continuing human development, pollution, and use of water resources, however, threaten these environments, and loss of wetlands ranges from 9% in New Hampshire to 90% in Ohio (Table 6). Currently, small shallow pools and ponds are exempt from many permit requirements under the Clean Water Act unless the impact exceeds 0.4 hectares. Pollution and filling often threaten these important habitat islands, causing serious declines in many species of plants and animals (Table 7). Seasonally wet areas, known as vernal ponds, are important to amphibians and have been particularly affected in this region.

Table 6. Wetland loss by state in the Northeast between pre-Columbian settlement and the 1980's (Whitney 1994).

State	Percentage lost
Connecticut	74
Maine	20
Massachusetts	28
New Hampshire	9
Rhode Island	37
Vermont	35
Delaware	54
Maryland	73
New Jersey	39
New York	60
Pennsylvania	56
Ohio	90

Declining Wetland Wildlife

Human alteration of the water regime of wetlands has caused serious repercussions for many species. Among the freshwater mollusks (snails, mussels, and clams), 13 northeastern species are on the federal list of endangered species (Table 8). Damming and channeling of rivers cause destruction of mussel and clam habitat because siltation and low oxygen levels are created above the dam, and fluctuating water temperatures and levels are created below the dam. Pollution of waterways, a common problem in this most densely populated part of the country, is also very detrimental to freshwater mollusks (Moseley 1992). Other invertebrates are also at risk; for example, three species of butterflies, moths, and dragonflies that occur in wetlands are extirpated from the Northeast (Opler 1993).

Table 7. Percentage of hydrological basins in the northeastern United States affected by pollutants (McCorkle and Halver 1982).[a]

Type of pollutant	Percentage affected
Nutrients	63
Suspended solids	65
Dissolved solids	10
pH	18
Oil and grease	15
Toxics	33
Pesticides	18

[a] $N = 40$.

Table 8. Freshwater mollusk species in the northeastern United States that are on the federal list of endangered species (U.S. Fish and Wildlife Service 1994).

Dwarf wedgemussel
Ring pink
Winged mapleleaf
Orange-foot pimpleback
Pink mucket
Purple cat's-paw
White cat's-paw
Fat pocketbook
Northern riffleshell
Appalachian ambersnail
Cheat three-toothed snail
Clubshell
Fanshell

Invasion by Nonindigenous Species

Purple Loosestrife

Invasions by nonindigenous species also disrupt these environments, and purple loosestrife is one of the most rapidly expanding pest species in the country (Fig. 5). Introduced from Europe in the early 1800's, purple loosestrife spread throughout the Northeast, mostly because of the development of canal systems for transportation and the use of the plant by beekeepers and gardeners. Once purple loosestrife invades a wetland, it quickly crowds out cattails and other native plants and forms a one-plant habitat. Thus, the habitat suitability for songbirds, waterfowl, muskrats, and many other species declines (Thompson et al. 1987). The bog turtle, an endangered species in the Northeast, is also affected because purple loosestrife invades and covers its preferred habitat (Groombridge 1982; New York Natural Heritage Program, unpublished material). A variety of controls have been tested, including the herbicide glyphosphate (Rodeo™), water-level manipulation, and replacement with other species, but results have been mixed at best. At present, biological control by introducing European insects that destroy the plant shows the most promise (Thompson et al. 1987; Malecki 1995).

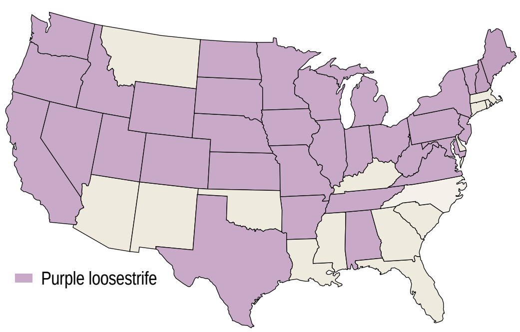


Fig. 5. Distribution of purple loosestrife in the United States, 1985 (U.S. Congress, Office of Technology Assessment 1993).

Invasion of Lakes by Nonindigenous Species

Introduction of nonindigenous species also affects lake environments. Lake Champlain and the Finger Lakes of New York illustrate important trends. Lake Champlain occupies a large shallow basin and drains to the St. Lawrence River. Plant and animal life include interior North American species and, because of the lake's proximity to the ocean, those of the North Atlantic. Landlocked Atlantic salmon and lake trout are abundant and economically important. As a result of the construction of a canal system the sea lamprey invaded Lake Champlain from the south and caused a major reduction in fish population levels throughout the 1970's and 1980's. Experimental management of sea lamprey was initiated in 1990 and has significantly reduced lamprey population levels (see box on Sea Lampreys in Great Lakes chapter). Consequently, abundance of fish populations has increased dramatically. The need for stocking of hatchery-produced Atlantic salmon, lake trout, brown trout, and steelhead has been reduced from 650,000 to 4,000 fish per year (C. Baron, U.S. Fish and Wildlife Service, Essex Junction, Vermont, personal communication).

Two nonindigenous plants, Eurasian watermilfoil and water chestnut, also invaded Lake Champlain from the south. Eurasian watermilfoil is a submersed plant with upper leaves that reach the surface. This species entered the lake in 1962, and because it spreads from plant fragments, mechanical removal is not effective; control with an herbicide is under consideration (Pullman 1994). Mechanical harvest, however, is effective for controlling water chestnut, and management has been aggressive until recently. Federal budget reductions preclude continued control, and water chestnut is expected to increase (H. Crossan, Vermont Department of Conservation, Waterbury, personal communication).

The most recent invader is the zebra mussel, first observed in the south end of the lake in 1993. Monitoring is under way, but no management is contemplated at present (Baron, personal communication).

The Finger Lakes are among the best-known lakes in the Northeast. These 11 lakes in central and western New York were formed as outlets to glacial Lake Iroquois and developed as deep canyons draining south. As glaciers receded to the north, these canyons were blocked by sediment at their southern ends and today drain north into Lake Ontario. Fish communities are primarily those associated with cold, clear waters such as trout and landlocked Atlantic salmon, but some lakes support warmwater fishes such as bass and sunfish.

Invasion by nonindigenous species began in the early 1800's when the Erie Canal was linked to many of the Finger Lakes (Schaffner and Oglesby 1978). Recent invasions include the alewife and the zebra mussel; both species are affecting the food chain (see chapter on Great Lakes). The alewife increases the forage base for larger fishes and thus supports species of economic importance. Because the zebra mussel is so prolific, however, it significantly reduces the amount of plankton, which are the foundation of the food chain in these lakes; thus, fish populations may eventually decline. As of July 1994, zebra mussels were in Canandaigua, Cayuga, Keuka, and Seneca lakes (New York Sea Grant 1994a,b).

Imperiled Fish Species

In the Northeast, 4.3% of the native freshwater fish species are imperiled (Johnson 1995). The number of different species in a state usually is related to the size of the state; the greatest number of species occurs in Pennsylvania (166), and the fewest number of species occurs in Rhode Island (43). Of New York's 155 species, 10 are endangered, threatened, or of special concern; at least 2 species of concern are in every state (Warren and Burr 1994; Table 9). In Pennsylvania alone, 27 species have been extirpated because of pollution and loss of marsh habitat; overfishing is often a contributing factor (Cooper 1985).

Table 9. Numbers of native freshwater fishes in the northeastern United States considered endangered, threatened, or of special concern by fisheries professionals (Warren and Burr 1994).

State	Number of species endangered, threatened, of special concern	Number of native fish species
Maine	4	49
New Hampshire	3	55
Vermont	2	88
Massachusetts	2	62
Rhode Island	2	43
Connecticut	2	55
New Jersey	2	77
Pennsylvania	8	166
Delaware	2	70
Maryland	4	99
West Virginia	9	148
Ohio	8	153

One of the most endangered fishes in the country is the Maryland darter. This species most likely occurs in only one stream in Maryland and has not been reported since 1988. The Maryland darter faces a host of threats, including silt, impoundments, pesticide and herbicide use, reduction of stream flow for consumption, and waste from sewage treatment plants (Ono et al. 1983).

Amphibian Declines

Amphibian population levels in the Northeast may be decreasing, although no documented evidence for a regionwide decline exists. A decline is predicted because of the acid precipitation problems in the Northeast; acid levels only slightly greater than normal can kill amphibian eggs and cause deformities in tadpoles. In addition, acidity can slow the development of tadpoles; consequently, the water in the temporary ponds where they are hatched dries up before they transform into adults (Milstein 1990). Although no amphibians from the region are on the federal list of endangered species, the eastern tiger salamander is listed as endangered in New York and New Jersey and is extirpated in Pennsylvania. Tiger salamander population levels and habitat sizes are listed as declining in New York. The reasons for the declines are pollution, introduction of predatory game fishes, illegal collection, and automobile-related mortality. With proper protection and management, the outlook for recovery is good (New York Natural Heritage Program, unpublished material).

Threats to Wetland Reptiles

Reptiles are also common wetland inhabitants and face many of the same threats as amphibians. Some reptiles that are generally considered too dangerous to be pets are often killed because of their perceived threat to human safety. Because of persecution, overcollection, and habitat destruction, the massasauga, a small rattlesnake, is of special concern in Ohio and is endangered in Pennsylvania and New York (Beltz 1993). Open wetlands—its preferred habitat—exist in relatively small isolated patches, which makes each population more vulnerable to extirpation because of local chance events. Only 2 confirmed populations still exist in New York (Johnson and Breisch 1993) and 8 populations exist in Pennsylvania, down from 19 (Reinert and Bushar 1993; G. Johnson, State University of New York, Syracuse, personal communication). Damming, highway construction, and forest succession harm the remaining habitat (Reinert and Bushar 1993).

Perhaps the rarest reptile in the Northeast is the Plymouth red-bellied turtle. This subspecies of the more common red-bellied turtle is restricted to a small portion of southeastern Massachusetts. The estimated total population size is 200, which makes the survival of the population vulnerable to chance events such as hurricanes. Added to this risk is the species' low rate of reproduction and its sensitivity to human disturbance. Management strategies, such as artificial incubation of eggs, may increase the population size from its critically low level (Groombridge 1982).

Hybridization and Decline of the American Black Duck

Introductions of nonindigenous species and habitat degradation are not always the main causes of a species' decline. For example, population levels of the American black duck have decreased by half in the past 40 years. Although habitat loss is partially responsible for the decline, acid rain, overharvest, and competition with the mallard are important contributing factors (Heusman 1991; Dwyer and Baldassarre

American Black Duck

The American black duck, with its brownish-black plumage and iridescent violet speculum, is one of the wariest of all the large dabbling ducks (Kortright 1942; Fig. 1). The black duck's distribution is confined to eastern North America but extends into Manitoba. The black duck breeds in a variety of habitat types, from the brackish coastal marshes of North Carolina to the open boreal forests of northern Quebec and Labrador (Bellrose 1976). In acidic bogs, beaver streams, and sluggish riverine and floodplain habitats of the boreal forest, the black duck's dark plumage (males and females have similar plumage) blends with the dark organic-stained waters of forested wetlands (Fig. 2).

After an intense courtship period in late March to May, depending on latitude, the female chooses a nest site, lays from 7 to 12 eggs, and incubates them for an average of 26 days (Fig. 3). She cares for her brood for about 60 days, after which time an average of 4 to 5 young fledge. Females then become flightless while molting to renew their worn primary wing feathers. Males, which leave after females have been incubating 2 weeks, fly north to isolated, traditionally used areas to molt (Bowman and Brown 1992).

In late summer and early fall, black ducks congregate on large freshwater river systems and coastal marshlands in the northern breeding areas. Depending on latitude, black ducks leave these staging areas in mid-November and migrate to the coastal marshes of the mid-Atlantic states (Maine to North Carolina), where more than 90% of the birds overwinter.

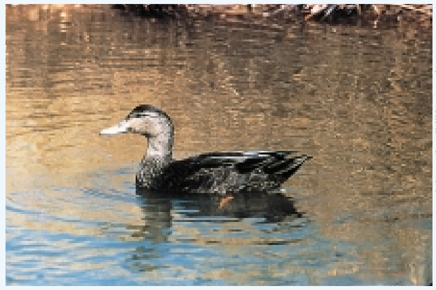
Determining the population status of the black duck has been difficult. The prehunting season black duck population in the 1950's was calculated as 3,738,000 (Geis et al. 1971) and averaged 804,000 during 1959-1961 (Bellrose 1976). Annual black duck status has been based mainly on the Midwinter Survey, which began in 1955 and is a survey by federal, state, and private agencies and individuals who attempt to count all waterfowl on the wintering areas during the first week of January. In 1955, in the Atlantic Flyway, 582,500 black ducks were counted (Serie 1994), whereas the preliminary count of black ducks in 1996 was 313,000 (Serie 1996).

Researchers began an experimental helicopter survey in 1990 for counting breeding black ducks and other waterfowl species in eastern Canada and Maine. During 1990–1994, the mean number of black ducks on 25 100-square kilometer plots in Maine ranged from 24.4 in 1994 to 36.9 in 1991. Similar aerial surveys were conducted in the Canadian provinces, where numbers of breeding black ducks seemed stable or increasing in the Maritime provinces (Prince Edward Island, Nova Scotia, New Brunswick), decreasing in Newfoundland, stable in Ontario, and decreasing in Quebec (Dickson 1995).

For waterfowlers in the Northeast, the black duck has historically been the "bread-and-butter duck," accounting for 40% to 60% of the annual harvest in many states (Martinson et al. 1968). Because it is such a prized game duck, more than 200,000 to 300,000 were harvested annually through 1981 in the Atlantic Flyway states alone (Serie 1994). As early as the mid-1930's, however, Wright (1947) recognized that black ducks were declining even before the dieback of eelgrass had occurred on the wintering grounds during the same decade (Cottam et al. 1944; Lincoln 1950). Gabrielson (1947:8), realizing the role of habitat loss, urged that marsh restoration programs be initiated and that they "be accompanied by restrictions on shooting limits sufficient to limit the kill to less than the annual number of ducks put on the wing."

Hunting seasons in the Atlantic Flyway ranged from 55 to 93 days throughout the 1950's and mid-1960's, and black duck bag limits varied from 5 to 8 in Canada and from 2 to 4 in the United States (Martinson et al. 1968). Munro (1968:81) noted the high recovery rate of bands from black ducks (mostly adult females and immatures) banded in southern Canada, and stated that this "strongly suggests that Canadians are equally responsible [as hunters in the United States] for the decrease in black ducks."

In 1968 waterfowl biologists and administrators reviewed the population status of the black duck (Barske 1968) and concluded that the population had declined to a critically low level and that restrictive regulations were required (Addy and Martinson 1968). By using methods and data available then, researchers agreed that to increase the black duck breeding population in the Atlantic Flyway by only 10%, the black duck kill would need to be reduced by about 40% from that of 1966. Because the Atlantic Flyway states could not meet their objective without substantial cooperation from



Courtesy U.S. Fish and Wildlife Service

Fig. 1. A male American black duck.

Courtesy J. R. Longcore, USGS

Fig. 2. Ginn Brook, Maine: typical brood habitat of American black ducks.

Courtesy J. R. Longcore, USGS

Fig. 3. A black duck nest on an upland site.

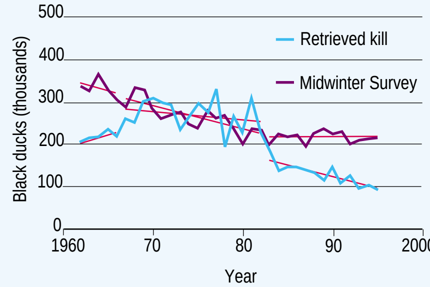


Fig. 5. Retrieved kill and Midwinter Survey counts of American black ducks for the Atlantic Flyway, 1962–1995. Three regression lines each, for black duck retrieved kill and the Midwinter Survey data, represent the periods 1962–1966, when hunting regulations were most liberal; 1967–1982; and 1983–1995, when hunting regulations were most restrictive.

Canada, the recommended action was to negotiate with Canada to develop a unified management program.

Unfortunately, during the mid-1960's and 1970's, the black duck population continued to decline at an average rate of about 4% annually (Ringelman and Longcore 1980). The decline might have been prolonged by the adoption of "stabilized" regulations for black ducks, wherein the hunting regulations were the same from 1974 to 1977 (Grandy 1983) despite a declining population. At the same time, the development of modern band-recovery models allowed biologists to address the question of whether hunting resulted in an additive or compensatory effect relative to population size (Anderson and Burnham 1976; also see chapter on Harvest).

Mortality from hunting that merely replaces mortality from nonhunting causes is defined as compensatory. After levels of mortality reach some threshold, mortality from hunting that reaches or exceeds the threshold directly reduces the next year's breeding population and is considered additive. This threshold has never been determined and probably varies annually and geographically. The initial analysis of black duck band recovery data seemed to support the idea that hunting mortalities were mostly compensatory with other nonhunting kinds of death (Nichols et al. 1984).

From 1976 through 1981, the black duck population continued to decline, and Blandin (1982), after a thorough analysis of all the band recovery data for black ducks, recommended greater hunting restrictions on black ducks. Based on Grandy's (1983) review of the U.S. Fish and Wildlife Service's management of the black duck, the Humane Society of the United States brought a lawsuit against the U.S. Fish and Wildlife Service in 1982 requesting an injunction to keep the hunting season for black ducks closed. The result of this action was a compromise in which the 1982 season was allowed, but more restrictive regulations were started in 1983 to reduce the harvest of black ducks by 25% in each Atlantic Flyway state. Although effective restrictions were finally achieved in Canada sometime after 1986 (Boyd 1988), and retrieved kill in Canada started to decline in 1990, recovery rates of banded black ducks remain substantially higher in Quebec than anywhere else (Serie et al. 1997). Retrieved kill for black ducks declined considerably during 1983–1995 (Figs. 4 and 5).

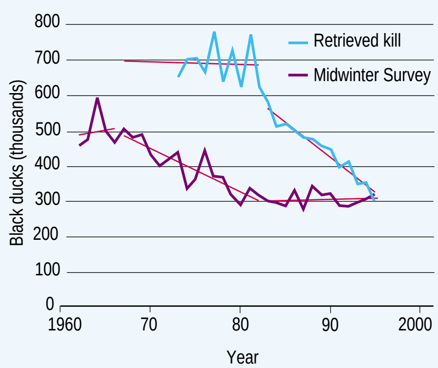


Fig. 4. Retrieved kill and Midwinter Survey counts of American black ducks for North America, 1962–1995. Two regression lines for black duck retrieved kill and three regression lines for the Midwinter Survey data represent the periods 1962–1966, when hunting regulations were most liberal; 1967–1982; and 1983–1995, when hunting regulations were most restrictive.

Recently, the question of additive versus compensatory mortality for black ducks has been revisited. With larger data sets and improved statistical models for band recoveries, later analysis suggested more instances of additivity (Nichols 1993). Between the periods 1950–1966 and 1967–1982, mean survival rates of black ducks increased consistently with the model for total additivity of hunting mortality (C. M. Francis, Long Point Bird Observatory, Port Rowan, Ontario, Canada, unpublished manuscript). Between the periods 1967–1982 and 1983–1995, hunting mortality was additive for immature male black ducks, indicating that the long-term decline of the black duck population was related to excessive harvest.

Recent more stringent hunting regulations in the United States and Canada seem to have caused a decline in the retrieved harvest, and perhaps not coincidentally, the Midwinter Survey for black ducks in North America and for the Atlantic Flyway has stabilized (Figs. 4 and 5). Furthermore, in recent years the loss of intertidal and estuarine wetlands (Frayer 1991) has abated, at least in much of the mid-Atlantic region. Thus, some optimism seems justified that managers can achieve the goal of approximately 260,000 wintering black ducks for the Atlantic Flyway by the year 2000. The goal of attaining 385,000 wintering black ducks in the Midwinter Survey for North America will rely on increases in breeding populations in Mississippi Flyway states and Canadian provinces, where such increases might be a greater challenge because of the loss and conversion of habitat in southern Ontario (Snell 1987). Even achieving the population goal of 260,000 in the Atlantic Flyway will require discipline to reduce the continuing high harvest of young and adult females in Quebec, because most (Blandin 1982) of Quebec's black ducks winter in the Atlantic Flyway. Overall, with continued vigilance on protecting and enhancing the numbers of breeding pairs on the vast breeding grounds of North America, we can expect the black duck population to increase.

Acknowledgments

We thank P. O. Corr, G. M. Haramis, H. W. Heusmann, J. R. Sauer, and J. R. Serie for reviewing and improving this manuscript. C. T. Moore performed the regression analysis and prepared the figures.

See end of chapter for references

Authors

Jerry R. Longcore
David A. Clugston
U.S. Geological Survey
Biological Resources Division
Patuxent Wildlife Research Center
Northeast Research Group
5768 South Annex A
Orono, Maine 04469–5768

1994). Restrictions on black duck harvest started in the early 1980's but have had no effect (Merendino et al. 1993). Black ducks and mallards are closely related species, having diverged from a common ancestor about 40,000 years ago. Both species are native to the Northeast, inhabit the same areas, exhibit similar behavior, and hybridize (Baldassarre and Bolen 1994). In the Atlantic Flyway, hybridization is common and is exacerbated by state and private releases of mallards in winter when pair bonding occurs. Even when mallards and black ducks do not interbreed, mallards displace black ducks from high-quality wetlands. The mallard also causes problems when it breeds with the rouen barn duck, an imported domestic breed from Europe. The results of these crosses are nonmigratory mallards, which occupy prime nesting sites before wild black ducks, green-winged teal, and blue-winged teal return from winter habitat. Both teal species were once common and are now rare (Lazell 1989).

Recovery of the Wood Duck

In contrast, the wood duck has recovered from low abundances in the last century. Although no actual census figures at the turn of the century are known, the wood duck seemed endangered by overharvest. Closed seasons from 1918 to 1941 (under provisions of the Migratory Bird Treaty Act) and widespread establishment of nest boxes allowed numbers to rebound. Census figures during the past three decades indicated a steady increase in the number of wood ducks from 1959 to 1985 and a relatively constant population size since the mid-1980's (Bellrose and Heister 1987).

Creation of New Wetlands by Beavers

An important trend in the Northeast is the rapid creation of new wetlands by beavers. These mammals have been prized for their thick, luxurious pelts and were heavily trapped by Europeans throughout much of the past three centuries. Because of overtrapping, beavers were extirpated in much of the Northeast by the beginning of this century. The economic importance of the species led to its prompt reintroduction in the early 1900's, and populations were reestablished in most of the major watersheds by the 1950's.

Ponds and wet meadows created by beavers support more than 100 bird and more than 20 other mammal species (Grover 1993). In the past two decades, the demand for pelts has declined, and beaver populations have increased substantially. If trends continue, the beaver will probably become a widespread pest, flooding roads and blocking water-control structures (Distefano 1987). Beavers are now expanding into urban areas and will probably exacerbate conflicts between wildlife and humans in the future.

Urban Areas

Trends in Urban Landscapes

Urban landscapes are those in which human development and activities (except agriculture) have appreciably changed the character of the environment. The Northeast is the most densely populated part of the country, with an extensive megalopolis extending from Boston to Washington, D.C. The total area of urban land in the Northeast was 4.9 million hectares in 1987, a 53% increase from 1960 (Daugherty 1991). The pace of the shift in environment from rural to urban development in the Northeast was much slower than predicted: 859,000 hectares from 1960 to 1980 and slightly more than that from 1980 to 2000 (George 1982). Regardless of the precise numbers, urban land makes up a significant portion of the Northeast and is increasing.

Trends in the Chesapeake Bay Watershed Wetlands

The Chesapeake Bay watershed is a 163,170-square-kilometer drainage basin that encompasses portions of six northeastern states (Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia; Fig. 1). Chesapeake Bay is the receiving body for surface water runoff from this basin. The watershed also includes parts of six major physiographic provinces (Lower Coastal Plain, Upper Coastal Plain, Piedmont, Blue Ridge, Valley and Ridge, and Appalachian Plateau). This diverse landscape, with its varied topography and surface geology, has profound effects on the abundance and types of wetlands throughout the watershed. Annual precipitation ranges from 89 to 114 centimeters across the region.

An estimated 2.1 million hectares of wetlands and deepwater habitats existed in the Chesapeake watershed in 1989 (Tiner et al. 1994). Wetlands accounted for roughly 690,000 hectares, covering about 4% of the watershed. This amounts to an area about 1.4 times the size of Delaware or about one-quarter the size of Maryland. Freshwater (palustrine) wetlands are the predominant type, occupying nearly 608,000 hectares, with forested wetlands alone representing 60% of the watershed's wetlands (Fig. 2). Estuarine marshes, palustrine shrub swamps, and palustrine nontidal marshes each make up about 10% of the watershed's wetland resources. Approximately two-thirds of the watershed's wetlands (Fig. 3) occur in Virginia (40%) and Maryland (27%).

Between 1982 and 1989, palustrine vegetated wetlands (freshwater marshes, wet meadows, swamps, and bogs) declined by 2%. A total of 14,580 hectares was converted to drylands and water bodies: 5,954 hectares of forested wetlands, about 4,293 hectares of emergent wetlands, and about 4,334 hectares of scrub–shrub wetlands. These collective losses equal an area about the size of the District of Columbia. In addition, about 7,290 hectares of palustrine forests were harvested for timber. This is not considered a loss, however, since these areas are still wetlands that in time will likely revert to forested wetlands.

Virginia had the greatest palustrine vegetated wetland losses of any state in the watershed, losing approximately 9,315 total hectares: about 1,620 hectares of emergent wetlands, more than 3,240 hectares of scrub–shrub wetlands, and nearly 4,455 hectares of forested wetlands during the study period. Maryland lost about 2,025 total hectares of the palustrine vegetated

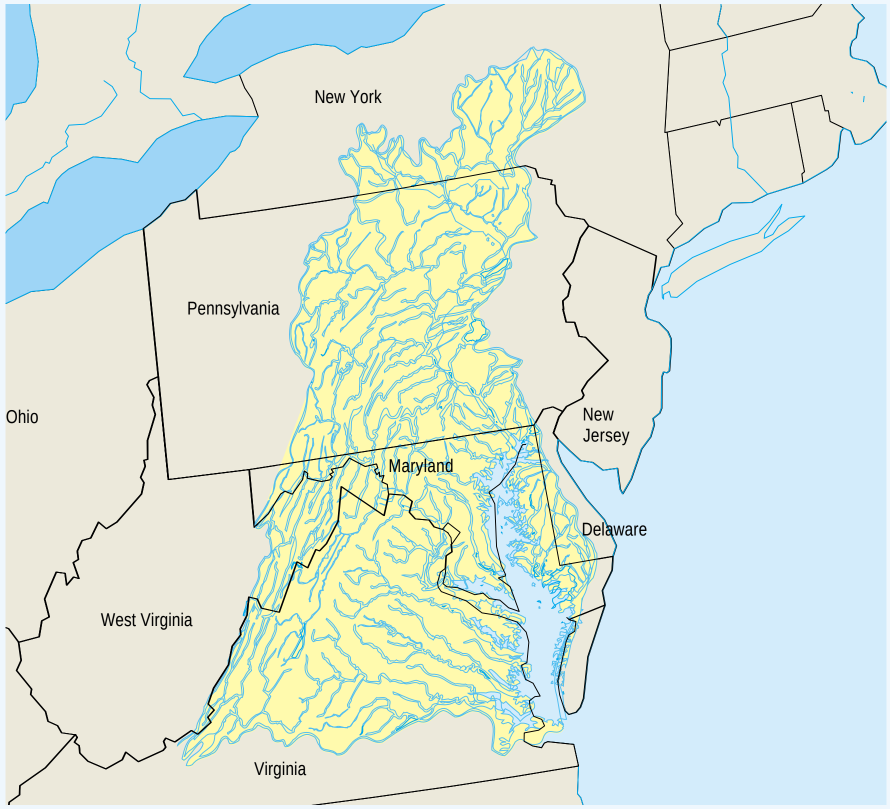


Fig. 1. The Chesapeake Bay watershed.

Table. Changes in specific types of vegetated wetlands in the Chesapeake Bay watershed (1982–1989).

Vegetated wetland type	1982 hectares	1989 hectares	Hectares changed to other vegetated wetlands	Hectares gained from vegetated wetlands	Hectares destroyed	Hectares gained from other areas	Net change (hectares)
Palustrine forested wetlands[a]	406,517 *	400,682 *	10,390 *	9,054 **	5,954 **	1,456	-5,834 **
Palustrine scrub–shrub wetlands[b]	72,262 *	71,870 *	10,803 *	14,253 *	4,331	489 **	-391
Palustrine emergent wetlands[c]	69,457 *	67,722 *	7,788 *	5,667 *	4,310 *	4,696 **	-1,735
Estuarine intertidal emergent wetlands[d]	68,976 *	68,775 *	114 **	300	439 **	52 **	-201
Estuarine scrub–shrub wetlands[e]	1,309 *	1,496 *	79 **	239 **	0	28	+188 **
Estuarine forested wetlands[f]	9,633 **	9,280 **	529	190 **	25	11	-353

[a] Mostly nontidal freshwater wetlands dominated by woody plants 6 meters or taller, commonly called wooded swamps, river swamps, or bottomland swamps.

[b] Mostly nontidal freshwater wetlands dominated by woody plants less than 6 meters tall; includes shrub swamps and bogs.

[c] Mostly nontidal freshwater wetlands dominated by herbaceous species, commonly called marshes, wet meadows, and Carolina bays.

[d] Tidally influenced wetlands dominated by herbaceous plants, including areas commonly known as salt and brackish tidal marshes.

[e] Tidal wetlands dominated by woody plants less than 6 meters tall, including hightide bush and other halophytic shrubs.

[f] Low-lying hardwood, pine, or mixed Coastal Plain wooded swamps, originally nontidal, but now flooded by saltwater tides due to a combination of rising sea level and coastal subsidence.

* Reliable estimate (standard error is equal to or less than 20% of the estimated area).

**Less reliable estimate (standard error is less than 50% of the estimate, but greater than 20% of the estimated area). Estimates without an asterisk have higher standard errors and are not reliable, although they are the best available statistics.

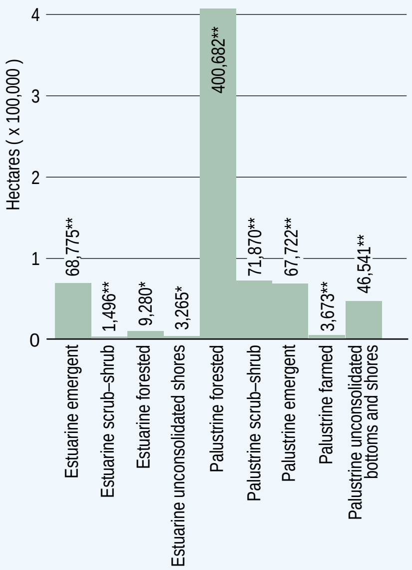


Fig. 2. Estimated 1989 wetland hectares for the Chesapeake Bay watershed. * = standard error is between 20% and 50% of the estimate and ** = standard error is 20% or less of the estimate.

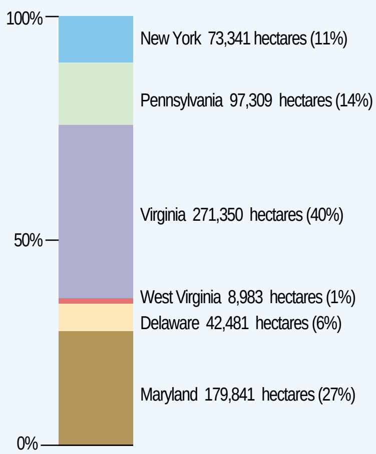


Fig. 3. Distribution of wetlands in the Chesapeake Bay watershed by state. Estimated hectares are also shown.

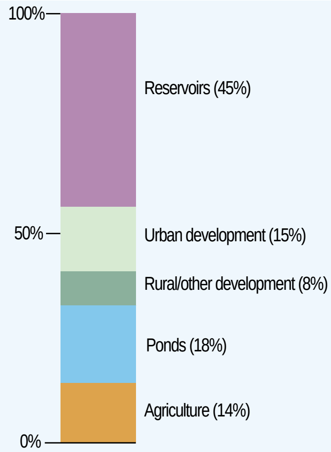


Fig. 4. Causes of palustrine forest destruction in the Chesapeake Bay watershed. (Note: excludes about 7,290 hectares that were harvested between 1982 and 1989.)

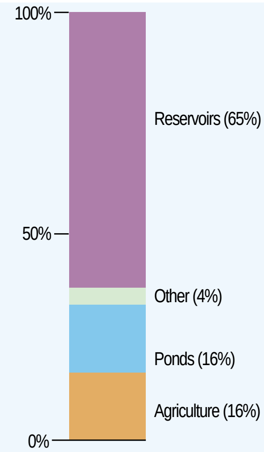


Fig. 5. Causes of palustrine scrub–shrub wetland destruction in the Chesapeake Bay watershed.

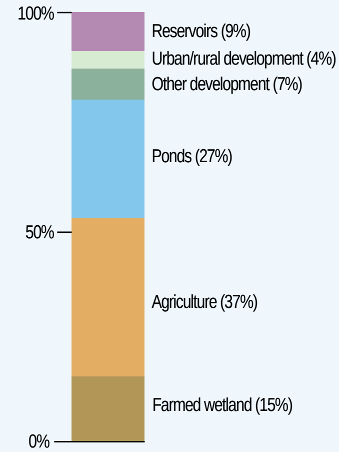


Fig. 6. Causes of palustrine emergent wetland destruction in the Chesapeake Bay watershed.

wetlands during this time, including about 972 hectares of emergent wetlands, about 203 hectares of scrub–shrub wetlands, and more than 1,013 hectares of palustrine forests. Pennsylvania lost almost 1,600 total hectares, mostly emergent wetlands (more than 810 hectares) and scrub–shrub wetlands (almost 689 hectares). The Table summarizes vegetated wetland trends for the watershed based on wetland type. Causes of palustrine vegetated wetland losses are presented in Figures 4, 5, and 6.

Overall, the status of estuarine wetlands (salt and brackish tidal marshes) has improved. Before the enactment of state coastal or tidal wetland laws and strengthened federal regulation under the Clean Water Act, these wetlands were dredged or filled at high rates. From the 1950's to 1980, for example, almost 203 hectares of estuarine marshes were lost annually, compared with an estimated 29-hectare annual loss from 1982 to 1989. Increased state and federal wetland regulations since the 1970's have improved the condition of these wetlands, which are no longer being wantonly destroyed. There is still pressure to convert these wetlands to alternative uses, but most landowners, developers, and the general public realize the values of these wet areas and are aware of government programs to protect them.

The situation for palustrine vegetated wetlands is quite different (Fig. 7). These wetlands continue to be destroyed at

Courtesy R. Tiner, U.S. Fish and Wildlife Service

Fig. 7. Pa1ustrine forested wetlands have been subjected to many changes, including conversion to farmland and filling for development and roads. Although forested wetlands are generally better protected today, some types are still threatened.

alarming rates. Despite the existence of federal regulations, nontidal freshwater wetlands continued to experience heavy losses from 1982 to 1989. Almost 6,075 hectares of palustrine forests were destroyed through conversion to drylands and to open waters such as reservoirs and ponds. In addition, another 8,505 hectares of vegetated wetland losses involved emergent and scrub–shrub wetlands. It is evident that wetland regulations must be improved if we are to protect our remaining freshwater wetlands. Many forested wetlands continue to be converted to alternative uses, particularly the wet flatwoods dominated by loblolly pine, which are currently unregulated because they fail to meet requirements of the 1987 delineation manual.

Seven areas were identified as hot spots where tremendous losses of certain wetland types occurred from 1982 to 1989: southeastern Virginia, the Piedmont region of Virginia, the Eastern Shore of Maryland, western Delaware, the upper Coastal Plain of Virginia, western Virginia (Blue Ridge and Appalachians), and northeastern Pennsylvania (Susquehanna, Bradford, and Tioga counties). These areas accounted for about 85% of the palustrine vegetated wetlands that were converted to drylands and open waters during the 7-year study period. Wetland protection efforts need to be strengthened in these regions.

See end of chapter for reference

Author

Ralph W. Tiner
U.S. Fish and Wildlife Service
Ecological Services
300 Westgate Center Drive
Hadley, Massachusetts 01035

Structure of Urban Landscapes

Urban environments, from the concrete core of large cities to the lawns and gardens of suburbs, represent an extreme on the gradient of natural habitat conditions. Fragmentation reaches its maximum in urban landscapes because landownerships are relatively small and legal jurisdictions are divided (Zipperer et al. 1989). Soils are highly disturbed and ground vegetation and shrub layers reach minimum development in terms of abundance and species diversity. Furthermore, the structural form of ground cover, shrubs, and trees is often highly altered (for example, mowed lawns, trimmed hedges, and pruned trees). The spatial arrangement of shrubs and trees is often linear because their locations are determined by roads and property lines. Parks and green spaces occur in the heart of many urban areas, but these are isolated islands in the midst of a largely artificial environment. Even so, abandoned lots, parks, human structures, and even sewer systems provide a rich array of habitat conditions in the urban environment.

Urban Wildlife

Although wildlife diversity is lower in urban areas than in forests and wetlands, certain species thrive in these human-dominated habitats. Many of these species are not native, and not all were city dwellers in their native lands. Examples include the house mouse, Norway rat, German cockroach, house sparrow, European starling, and rock dove (Whitney 1994). In addition, native species like the house finch and raccoon increased because of an abundance of human structures and garbage that provide cover and food. Of native mammals, squirrels and raccoons are among the most successful, feeding on the fruits of native and ornamental trees, human handouts, and garbage. Urban raccoons have become a health threat in the past few years because they are unusually susceptible to a variant of the rabies virus. The high densities of urban raccoons and their proximity to humans have meant that the disease is quickly spread and that the potential exposure of humans or pets to this disease is high (Jenkins 1983). Although pets may be vaccinated and techniques for distributing the vaccine in the wild are in experimental phases, the feasibility of widespread vaccination of raccoons is low. Rabies was expected to reduce the population substantially in 1994, perhaps as much as 90% in many areas (L. VanDruff, State University of New York, Syracuse, personal communication). Raccoon rabies was spread from Florida to Virginia through translocation of animals to restock populations (Dein 1995).

Gray Squirrel

Gray squirrels are among the most visible mammals in urban areas, and although some people enjoy seeing and feeding these animals, others consider them pests that steal from bird feeders, damage ornamental plants, and den in attics. No widespread population surveys of squirrels are available in the Northeast, but the abundance of squirrels is influenced by vegetation (for example, broad-leafed trees with a diameter of more than 38 centimeters; Allen 1987) and by the amount of area that is covered by pavement and buildings. Densities range from 0.15 squirrels per hectare in highly urbanized areas to 1.08 squirrels per hectare in parks, college campuses, and cemeteries (Williamson 1983); more than 51.5 squirrels per hectare have been observed in Washington, D.C. Supplemental feeding is the primary cause of exceptionally high squirrel densities (Manski et al. 1981).

Peregrine Falcon

One of the most unusual success stories is that of the peregrine falcon, an endangered

Status of Living Resources in Chesapeake Bay

Chesapeake Bay is the largest estuary in the United States, covering 165,760 square kilometers and including parts of six states. Salinity gradations from fresh water, where the Susquehanna River empties into the bay, to near-ocean salinity at the bay's mouth contribute to high biological diversity. Around 2,700 plant and animal species inhabit the bay (White 1989); each year, 29 species of waterfowl rest or overwinter in the Chesapeake Bay watershed (Chesapeake Bay Program 1990). Wildlife, fish, and plant life compete for land and water resources with more than 14.7 million people (Chesapeake Bay Program Office 1995, Annapolis, Maryland, unpublished data).

Three centuries of human population growth have significantly affected the bay's water quality and its living resources. Toxic contaminants, excess nutrients, and suspended sediments compromise Chesapeake Bay water quality and threaten plants and animals. Recent evidence indicates that air pollution also adds contaminants to the bay (Appleton 1995). In addition, loss of forests and wetlands to suburban sprawl, agriculture, and commercial development jeopardizes the survival of many species.

Chesapeake Bay was the first estuary in the United States targeted for an integrated approach to watershed and ecosystem protection and restoration. The 1983 Chesapeake Bay Agreement initiated the Chesapeake Bay Program, which fosters cooperation among states, government agencies, and private organizations, with the goal of restoring Chesapeake Bay water quality and living resources (Chesapeake Bay Program 1983). In 1987 Chesapeake Bay Program partners set a goal to reduce by 40% the nitrogen and phosphorus entering the bay by the year 2000 (Chesapeake Bay Program 1987). By 1994 restoration efforts expanded to include nutrients in the tributaries, toxins, bay grasses, fish passages, and agricultural nonpoint source pollution (Chesapeake Bay Program 1994a).

Submerged Aquatic Vegetation

The total area of submerged aquatic vegetation (bay grasses) in the bay has increased by 72% since the low point of 15,390 hectares in 1984 (Fig. 1). By 1994 nearly 26,528 hectares of submerged aquatic vegetation existed in Chesapeake Bay (Orth et al. 1995). A decline in 1994 may have been caused by heavy precipitation in 1993 and 1994, which increased freshwater flow into the bay. Despite a baywide decline in 1994, substantial increases in submerged aquatic vegetation abundance occurred in the upper bay, even though previous increases had been concentrated in the lower bay (Orth et al. 1994). The density of many submerged aquatic vegetation stands also increased in 1994. At the current rate of recovery, the Chesapeake Bay Program expects 46,170 hectares of bay grasses to be restored by 2005 (Chesapeake Executive Council 1993.)

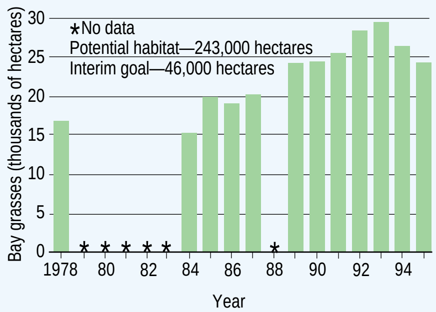


Fig. 1. Submerged aquatic vegetation produces oxygen in the water, provides food and shelter for a variety of animals, and traps sediments and absorbs nutrients such as phosphorus and nitrogen. After years of decline, the area of submerged aquatic vegetation has increased in recent years.

Forests

Forests originally covered as much as 95% of the Chesapeake Bay watershed. By 1900, though, less than 50% of the watershed was forested. Currently, about 16.7 million hectares, or about 59% of the watershed, are forested (Chesapeake Bay Program 1994b). Population growth and development constantly threaten the watershed's forests; for example, Maryland and Virginia lost as much as 5% of their forests to developed uses in just over a decade (Maryland Office of Planning 1991; Johnson 1992). Efforts to protect and restore forestland, especially streamside buffers, have begun throughout the watershed. Forest stewardship programs also help private landowners wisely manage their forest resources.

Striped Bass

Striped bass are a prized commercial and recreational fish in Chesapeake Bay. Fishing and habitat loss precipitated a decline in striped bass abundance, beginning in the mid-1970's. By the early 1980's, spawning stock (reproducing females) was at an all-time low (Chesapeake Bay Program 1989). In 1985 Maryland declared a moratorium on striped bass fishing; other northeastern coastal states followed with coordinated interjurisdictional management efforts. With careful management the striped bass population grew, as shown by increased catch-per-unit-effort and improved numbers and ages of spawners (Young-Dubovsky et al. 1993). The fishing mortality rate of striped bass in Chesapeake Bay (Chesapeake Bay Program 1995a) continues to be at or below the desired level, but the average size of captured striped bass has shifted upwards (Markham and Hornick 1994).

The Atlantic States Marine Fisheries Commission declared striped bass stocks restored as of 1 January 1995, when data showed that female striped bass spawning stock had reached the historical highs seen in the 1960's and early 1970's (Atlantic States Marine Fisheries Commission 1994; Fig. 2). A limited fishery opened in 1995, and the Atlantic States Marine Fisheries Commission will continue to conservatively manage striped bass.

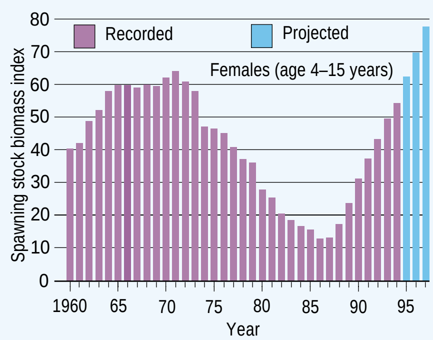


Fig. 2. Striped bass, an important commercial and recreational fish, which returns from the ocean to spawn in tributaries of Chesapeake Bay, has responded positively to decreased harvest pressure.

Shad

American shad and hickory shad are species that live at sea and spawn in freshwater tributaries (anadromous). Overharvest, habitat degradation, and stream blockages that prevent fish from reaching spawning grounds drastically reduced sport and commercial landings during the 1970's and 1980's (National Marine Fisheries Service, National Oceanic and

Atmospheric Administration, Annapolis, Maryland, unpublished data). To help restore shad populations, Maryland initiated a moratorium on shad fishing in Chesapeake Bay in 1980 and Virginia in 1994 (Chesapeake Bay Program 1995b). Pennsylvania, Maryland, and Virginia committed to providing fish passages at dams and to removing other stream blockages. By the end of 1995, watershed states had opened nearly 483 kilometers of river. Before the turn of the century, another 1,434 kilometers will be opened when the 30 projects under design or construction in the watershed are completed (Fish Passage Workgroup, Chesapeake Bay Program, Annapolis, personal communication; Fig. 3).

Maryland, Virginia, and Pennsylvania are restocking bay tributaries with hatchery-raised shad. Stocking efforts, combined with harvest restrictions and blockage removal, are succeeding—the shad population in the upper bay and Susquehanna River increased from fewer than 10,000 in 1980 to well over 300,000 shad in 1995 (Maryland Department of Natural Resources, Annapolis, unpublished data). However, the effects of ocean fisheries, which catch shad before they spawn, remain a concern.

Crabs

The blue crab population is declining in Chesapeake Bay. Although no accurate numbers of the bay's blue crab population exist, four different surveys indicate population declines. The Chesapeake Bay Winter Dredge Survey, conducted throughout Maryland and Virginia, shows a 34% decline in overall blue crab abundance since 1990 and an even greater decline in adult females (Vølstad et al. 1994). The Maryland Trawl Survey, conducted during summer and fall, suggests adult female abundance has been low since 1988 (Davis et al. 1995). The Virginia Trawl Survey, conducted in fall, shows decreasing abundance of all age classes of crabs since 1990 (Bonzek et al. 1995). In addition, Maryland commercial catch-per-unit-effort data indicate that the weight of crabs caught per pot has steadily declined since 1985 (Maryland Department of Natural Resources, unpublished data).

In late 1994 and 1995, Virginia implemented regulations that expanded crab sanctuaries and imposed limits on commercial and recreational fishing times and harvests. Maryland enacted emergency regulations with the goal of reducing the harvest of female crabs by 20%. In 1996 both states implemented additional restrictions on both recreational and commercial crabbers.

Eastern Oysters

Estimates suggest that a century ago billions of eastern oysters filtered the entire bay in around 4 days. Today, the bay's depleted oyster population requires more than a year to complete filtering (Newell 1988). Commercial landings of oysters declined from over 6 million bushels in the 1950's to fewer than 200,000 bushels in 1993 (Virginia Marine Resources Commission, Newport News, and Maryland Department of Natural Resources, unpublished data). The decline has resulted from harvest pressure, habitat destruction, water pollution, and diseases. MSX, a parasitic disease introduced to the bay in the 1950's, kills oysters within their first 2 years. Another parasitic disease, Dermo, has always been in the bay but did not begin killing significant numbers of oysters until the late 1950's. Nearly 100% of oyster beds in Maryland and Virginia are infected with the parasites (Chesapeake Bay Program 1994c). Maryland stock surveys find moderate numbers of juvenile oysters, but adult oysters are often killed before reaching market size (Maryland Department of Natural Resources, and Virginia Marine Resources Commission, unpublished data).

Harvesting techniques have removed oyster shell from the bay's oyster bars, leaving formerly three-dimensional oyster reefs reduced to flat beds. Oysters living on the bottom, without the benefit of shell reefs, can be killed by sedimentation. Artificial oyster reefs are being created by using recycled construction materials, old oyster shells, and other materials; by the end of 1995, 12 reefs were completed (Chesapeake Bay Program 1994d). The success of reef restoration is demonstrated by the colonization of natural oyster bars within a 1.6-kilometer radius of one of the first reef projects (J. Wesson, Virginia Marine Resources Commission, Newport News, personal communication).

Fig. 3. A fish passage (on the left) allows shad to migrate upstream.

Ducks

More than a million waterfowl migrate through or overwinter in Chesapeake Bay (Midwinter Waterfowl Survey, U.S. Fish and Wildlife Service, Arlington, Virginia, and Seaduck Survey, Chesapeake Bay Field Office, Annapolis, Maryland, unpublished data). Almost 40 years of Midwinter Waterfowl Survey counts reveal decreasing numbers of ducks in the bay, beginning in the early 1970's. Waterfowl management programs, however, are helping spur increases in Chesapeake Bay winter duck populations.

American black ducks compete with mallards for food and nesting sites. Although bay mallard populations have remained relatively stable over several decades, black duck numbers have declined (see box on American Black Ducks). In the late 1950's, around 95,000 black ducks were counted on the bay, but populations plummeted to around 32,000 by the mid-1970's, and numbers have remained fairly low since then (Midwinter Waterfowl Survey, unpublished data). Chesapeake Bay Program biologists hope to see the population reach 39,800 by the year 2000 as habitat restoration progresses (Chesapeake Bay Program 1990).

Diving ducks, such as redheads, are good indicators of water quality because they feed on bottom-dwelling plants and animals that depend on good water quality.

Redheads, which feed on submerged aquatic vegetation, have experienced population declines that roughly correspond with losses of submerged aquatic vegetation. Bay redhead populations dropped to around 1,500 in the early 1990's, down from 38,000 redheads recorded in the late 1950's. Scientists hope that current increases in the bay's submerged aquatic vegetation will help support more redheads. The Chesapeake Bay Program set a goal of 8,200 redheads by the year 2000 (Chesapeake Bay Program 1990).

Canvasbacks (Fig. 4) also feed on submerged aquatic vegetation but adjust their diet to include clams when such vegetation is not available. Chesapeake Bay canvasback populations dropped during the 1970's and 1980's, but in the mid-1990's numbers climbed to those seen in the late 1950's—around 62,000 to 63,000 birds, thus meeting the Chesapeake Bay Program goal of 62,000 birds; the total diving duck goal of 162,600 ducks was also reached (Chesapeake Bay Program 1990).

Canada Geese

In the 1970's, the Canada goose population in Chesapeake Bay reached well over half a million geese. Chesapeake Bay goose populations, which include both migratory Atlantic Flyway geese and nonmigratory geese, dropped below 300,000 in 1995 (Midwinter Waterfowl Survey, unpublished data). Although nonmigratory goose numbers remain healthy, breeding pairs in the entire Atlantic Flyway population have declined by 75% since 1988 (Maryland Department of Natural Resources 1995). Overharvest and poor weather in northern Canada during the breeding season have contributed to the alarming decline in Atlantic Flyway geese. International efforts to protect Canada goose populations resulted in a ban on migratory goose hunting for the 1995–1996 season throughout the Atlantic Flyway, including Chesapeake Bay. The hunting ban should help restore the Chesapeake Bay migratory Canada goose population.

Bald Eagles

At one time, as many as 3,000 pairs of bald eagles inhabited the Chesapeake Bay watershed. The effects of DDT, however, reduced the Virginia and Maryland bald eagle population to only 80–90 pairs by 1970 (Fraser et al. 1991), but after the 1972 ban on DDT use, populations increased (Fig. 5). Recently, both the national and Chesapeake Bay bald eagle populations crossed the threshold for downlisting from endangered to threatened. The Chesapeake Bay threshold was 175–250 nesting pairs in the basin, producing at least 1.1 eaglets per active nest. The number of nests in the Chesapeake Bay basin soared from 72 in 1977 to 332 in 1995. More than 500 young were produced in 1995, up from only 63 young in 1977 (Maryland Department of Natural Resources, Annapolis; Virginia Department of Game and Inland Fisheries, Richmond; and Pennsylvania Game Commission, Harrisburg; unpublished data). Continued success of the bald eagle depends on preservation of shoreline forests with suitable large trees for nesting.

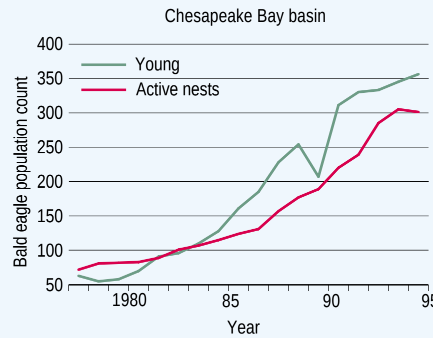


Fig. 5. Bald eagle populations have rebounded since the ban on DDT in 1972.

Living resources in Chesapeake Bay are still in jeopardy because of intensive human use of the bay and because of increasing human populations. Aggressive management and cooperation between federal and state agencies, though, have produced several successes in restoring habitat such as submerged aquatic vegetation and wildlife populations such as American black ducks and striped bass. Protection and restoration of the watershed and ecosystems of Chesapeake Bay continue under the guidance of the Chesapeake Bay Program.


Courtesy U.S. Fish and Wildlife Service

Fig. 4. Canvasbacks on Chesapeake Bay.

See end of chapter for references

Author

Tawna Mertz
University of Maryland Eastern Shore
Chesapeake Bay Program Office
U.S. Environmental Protection Agency
410 Severn Avenue, Suite 109
Annapolis, Maryland 21403

Coastal Maine: Island Habitats and Fauna

Maine's coastal islands, most of which can be reached only by boat, were once a series of mountains located many miles inland. As the last glacier receded 11,000 years ago and sea level began to rise, former mountaintops became isolated islands and former valleys were submerged to become bays and estuaries. Different bedrock types along the newly exposed mainland coast underwent thousands of years of weathering and erosion to become the complex shoreline seen today. Maine's coast stretches for more than 5,600 kilometers, ranging from sandy beaches and salt marshes in the south to cliffs and rocky shores at the Canadian border. In addition to a variety of shoreline habitats, the Maine coast contains more than 3,000 islands and thousands of intertidal ledges (Fig. 1). This multitude of habitats supports a rich assemblage of wildlife that has changed, and continues to change, through time.

Maine's present-day island biota is the result of thousands of years of human influence as well as geologic and climatic factors. The Red Paint people, who lived in Maine about 4,000 years ago, were among the first humans known to have used the coast's abundant natural resources. Probably the first seagoing fishermen in Maine, these Native Americans left their island camps to harvest large swordfish, Atlantic cod, and other fish from ocean waters 300 meters deep or more (Caldwell 1981). Like most of the tribes that followed, these people mostly lived inland but camped on the coast in summer. Their affinity for shellfish is evident from the massive shell mounds unearthed along the coast; these mounds consist primarily of oysters, which no longer occur naturally in Maine. In addition, Native Americans frequently hunted seals and seabirds and harvested seabird eggs for food. Even so, their management of coastal wildlife resources appears to have been one of sustainable use; some tribes were known to limit their hunting of seabirds to specific islands, harvesting from a given colony only once every three years (Conkling 1981). Although the Native Americans living on the islands and along the coast occasionally burned land for crops, the landscape remained largely forested.

Thus, when the Europeans first saw the Maine coast, they saw a land that appeared to support a limitless abundance of natural resources. Although spruce dominated the forests on Maine islands even in the 1600's, visitors to this region also commented on the abundance of commercially important tree species. Large hardwoods and white pines commonly occurred in the more complex island forests that were present before European colonization. During the following century, as Maine became the shipbuilding capital of the world, the islands' supplies of oak and other valuable timber trees were rapidly depleted (Conkling 1981). As each stand of timber was cut, the shipyards relocated to harvest new areas that still supported preferred species. Cut areas generally were cleared and used for agriculture; land that was not converted to crops or pasture reverted to the near monocultures of spruce seen on most forested islands today. Unforested islands often were used to graze livestock, especially sheep, which remain on some of the islands today.

Human colonization of the islands affected native wildlife both through habitat destruction and through the introduction of domesticated animals and other nonindigenous species. Far more devastating to many species, however, was the intensive harvest of both aquatic and insular wildlife. Huge cod and other large predatory fish, once found in abundance along the Maine coast, were harvested intensely throughout the nineteenth century, resulting in their virtual extirpation from coastal habitats (Steneck 1995). The loss of these predators may have precipitated a major change in the composition of the nearshore aquatic community by removing the principal predators on adult American lobsters, crabs, and sea urchins (Steneck 1995). This aquatic community continues to change even today, as harvesting of large invertebrates intensifies and new markets open for species such as urchins, seaweeds, and snails, which had been ignored by commercial fishing industries until recently.

Insular wildlife communities also have changed drastically over the past few centuries. Some species, such as the giant sea mink, were hunted to extinction, whereas others were extirpated from islands. Perhaps the most obvious effect of the Europeans on wildlife populations was on seabirds. Virtually every seabird species was hunted for food or feathers, so that Maine's coastal breeding colonies were in danger of total extirpation by the beginning of the twentieth century (Norton 1907).

The first European colonists relied heavily on the dense concentrations of nesting seabirds and the huge rafts of wintering birds for food. Many birds were sought for their feathers, down, and oil as well as for their meat. Thousands of birds, such as the common eider, were shot or killed in huge *drives* during their flightless summer molting stage (Conkling 1981). Because these colonists made no attempt to manage this resource for the future, they decimated local populations by overharvesting.

The decline in bird populations in the Gulf of Maine by the end of the 1800's was dramatic. The great auk, once so plentiful that islanders filled their boats with the birds


Courtesy C. M. Johnson, USGS

Fig. 1. An overview of a few of Maine's more than 3,000 coastal islands.

"as if they had been stones," was driven to extinction by 1842 (Conkling 1981). Those less palatable species that continued to nest in fairly large numbers were nearly eliminated by two campaigns of shooting for the millinery trade (Drury 1973). The few seabird colonies left on the Maine coast in 1900 nested on remote, difficult-to-reach islands. Double-crested cormorants continued to nest only on one large rock until 1896, when only two nests were found (Knight 1897)—the last record of cormorants nesting in New England for more than 30 years (Mendall 1936). Atlantic puffins also had stopped nesting in Maine by the beginning of the twentieth century, and only one colony each of laughing gulls and common eiders remained. Leach's storm-petrels, black guillemots, herring gulls, and terns managed to remain relatively abundant on a few isolated islands. These species, too, might have been extirpated from the state if not for legal protection offered seabirds on their breeding grounds in 1901 (Norton 1907).

Human populations declined rapidly on the islands after 1910, largely because of the development of inland transportation and the depletion of coastal resources. As a result of this shift of people to the mainland, and the legal protection provided seabirds, many species began to recolonize the islands. Cormorants, eiders, and herring gulls made an immediate and dramatic comeback (Fig. 2). By 1931, only 6 years after they began to nest again in the state, over 1,700 pairs of cormorants were observed (Norton and Allen 1931). Cormorants are opportunistic feeders, foraging mainly on small- to medium-sized benthic fish and other species as they become seasonally available (Mendall 1936; Blackwell et al. 1995). Although the effect of cormorants on commercially important fish species was questionable, the dramatic increase in cormorants was considered by many fishermen to be a partial cause for the fisheries decline; these fishermen pressured the government to institute a cormorant and herring gull control program in 1944 (Erwin 1979; Krohn et al. 1995). Despite this brief setback, cormorants continued to increase in numbers at least until the 1980's; herring gulls may have reached a peak in the 1970's, while great black-backed gulls continue to increase (Fig. 2).

Most other seabirds also prospered following protection and have continued to increase in numbers to the present (Korschgen 1979; Krohn et al. 1992; Maine Department of Inland Fisheries and Wildlife, Augusta, unpublished data). However, good fortune for species such as the herring and great black-backed gull may have spelled disaster for others. Laughing

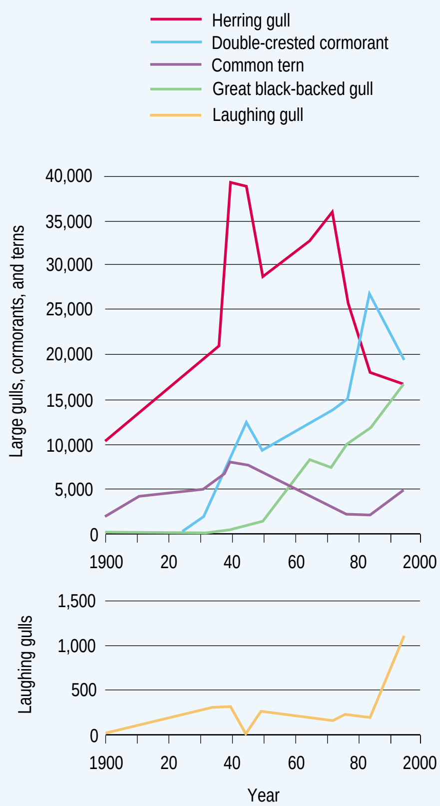


Fig. 2. Trends in the numbers of nesting pairs of five species of colonial seabirds nesting in Maine, 1900–1995. (Data from Norton and Allen 1931; Nisbet 1971; Drury 1973; and B. Allen, Maine Department of Inland Fisheries and Wildlife, unpublished data.)

gulls and terns began to recolonize many Maine islands early in the century, but because these colonies proved highly susceptible to predation and interference by the larger gulls, the laughing gulls and terns were driven from many islands by the late 1940's (Nisbet 1971). As a result, only a few islands now support colonies of laughing gulls, although intensive control of large gulls on those islands managed for terns has allowed both tern and laughing gull populations to increase (Fig. 2).

As of 1990, there were over 120,000 pairs of seabirds and waterfowl nesting on about 355 islands in Maine (Maine Department of Inland Fisheries and Wildlife, unpublished data). In a sense, we have come full circle during the twentieth century, so that large numbers of seabirds are once again characteristic of Maine's coastal landscape. It is now widely recognized that seabirds represent an intrinsic part of the ecology of Maine islands, yet their continued prosperity is again threatened as the demand for waterfront property rises and human use of the islands and adjacent waters for commercial and recreational purposes increases. Fortunately, through concentrated efforts to protect the most valuable seabird islands, many of these islands are owned by public or private conservation groups, including the islands that harbor most of the largest seabird colonies. Many other seabird islands, though, are privately owned and so are susceptible to development, and even protected islands are vulnerable to disturbances in adjacent aquatic habitats. As in the case of gull control, human intervention may be necessary again, this time in the form of conservation of important nesting habitats, to preserve the current status of seabird populations in Maine. However, conservation efforts directed at seabird nesting habitats alone may not be enough. Maine's seabirds depend on a variety of other habitats and wildlife communities for survival. Adult eiders, for example, feed heavily on mussels, sea urchins, and other coastal invertebrates, whereas their ducklings rely on snails and amphipods as critical food sources during their first few months of life (Cantin et al. 1974; Krohn et al. 1992). The effects of increased human pressure on these invertebrate resources could have unanticipated ecological consequences for these birds and other coastal wildlife species.

We hope we have learned enough from the historical trends of Maine's coastal resources to understand that effects upon any part of this complex system may be far-reaching. Although we have no control over the many environmental events that can dramatically affect local wildlife populations (for example, hurricanes and rising sea levels), we can attempt to minimize human impacts. Careful management of our coastal resources today is critical to the survival of this ecosystem, but regardless of our best efforts to understand it, the coast will remain dynamic and unpredictable. It is this unpredictability that makes the island habitats of coastal Maine such mysterious and special places.

See end of chapter for references

Authors

Catherine M. Johnson
William B. Krohn
U.S. Geological Survey
Biological Resources Division
Maine Cooperative Fish and Wildlife
Research Unit
University of Maine
Orono, Maine 04469-5755

species. Peregrine falcons have been raised in captivity and released into the wild by the U.S. Fish and Wildlife Service. Some of these falcons have been observed nesting in urban centers, where an abundance of rock doves provides a consistent food source for urban peregrine populations. Large suspension bridges that exist in most northeastern cities may be especially important nesting sites for peregrine falcons because they offer isolation and a clear view for the birds. In fact, nesting peregrine falcons have already been observed on the Throgs Neck and Verrazano Narrows bridges in New York City. Because of this adaptation to a changing landscape, the expected trend of the peregrine population size is upward (Cade and Barclay 1984).

Canada Goose

Canada geese have also learned to use urban and suburban landscapes and have become so successful that they are considered a nuisance in many areas. Beginning in 1948, Canada geese densities increased sharply and have doubled approximately every 20 years (Trost and Malecki 1985). Grazing geese congregate in large numbers on short grass; golf courses provide excellent habitat. Densities on golf courses are greater than 30 geese per course in New England and 250 geese per course in the mid-Atlantic states. In the coastal states from Maryland to Massachusetts, more than 50% of the respondents to a poll classified the geese as a nuisance, and all Northeast states except Maine reported some nuisance problems. Most complaints about the geese focus on their droppings, which kill grass, are unsightly, and are perceived as a health threat (Conover and Chasko 1985).

Status of Other Urban Wildlife

Comparatively little research has been done on the wildlife and communities of the growing cities of the Northeast. Little attention has been given to reptiles and amphibians (herptiles) in urban areas, even though destruction, fragmentation, isolation, and alteration of habitats have caused a low abundance of herptile species in these settings (VanDruff et al. 1994). A 1987 survey of North American colleges and universities revealed that only 5% of wildlife research during the 1983–1984 school year was devoted to urban wildlife, and only 2% of the schools' wildlife research budgets was devoted to urban species (Adams and Dove 1989). This effort was greater than that of state and federal agencies during the same period, and, in fact, the U.S. Fish and Wildlife Service assigned only one person to urban wildlife study during the 1970's and 1980's (VanDruff et al. 1994). Research priorities include the species-specific extinction or colonization rates typical of urban parks of varying sizes. In addition, more research is needed on the effectiveness of wildlife habitat corridors (Adams and Dove 1989).

Urban areas are especially important environments for biotic resources because they bring many species into close contact with humans. For good or ill, the contact of humans with plants and wildlife in urban habitats shapes societal values about our biotic resources and influences the political process. Perhaps the best example today is the white-tailed deer, a species that is causing significant upheaval in societal values, as discussed previously.

Fragmented Landscapes

Human Activities

The first Europeans in the Northeast sought to break up the vast forest into farmlands and settlements. This trend continues today, and the landscape is becoming an increasingly complex mosaic of forest, city, farmland, and wetland. Fragmentation occurs when a block of one vegetation type is divided into two or more smaller parcels. Fragmented habitats are now so widespread and support such a characteristic array of wildlife that they deserve recognition as a major habitat type in the Northeast.

Fragmentation Favors Invasive Species

Fragmentation caused by human activities variously alters the landscape and its biotic components. Disturbance of an existing environment can give aggressive invaders a competitive advantage. Nonindigenous plants and animals invade more rapidly because trucks inadvertently carry seeds from one part of the country to another and canals link previously separated watersheds. A 1950 survey revealed that 20% of the plant species in the Northeast were nonindigenous (Guntenspergen 1995). In the state of New York alone, more than 200 species of nonindigenous plants have been recorded in the past 20 years. In West Virginia, 400 plant species (19% of total) are nonindigenous, and in New England, 821 (29%) of the plant species are considered nonindigenous. This trend is probably increasing for plants and vertebrates, but figures on nonindigenous species are not available in many states (U.S. Congress, Office of Technology Assessment 1993; Table 10).

Change in Distribution of Native Species

Fragmentation also changes the distribution of native species. In the Northeast, the Delmarva peninsula fox squirrel is one of only two extant mammals on the federal list of

Table 10. Loss of native vertebrates and introduction of nonindigenous vertebrates in Massachusetts, Pennsylvania, and Ohio (Whitney 1994).

Class State	Number of nonindigenous	Number of extinct natives	Percent of native species now extinct
Mammals			
Massachusetts	5	8	14
Pennsylvania	2	8	11
Ohio	2	13	20
Birds			
Massachusetts	5	3	2
Pennsylvania	6	8	4
Ohio	6	8	4
Fish			
Massachusetts	27	1	2
Pennsylvania	7	28	15
Ohio	15	9	6

endangered species (the other is the Indiana bat). This is a subspecies of the fox squirrel that historically ranged over parts of Delaware, Maryland, New Jersey, and Pennsylvania. Today it is restricted to the Delmarva peninsula and prefers ecotones where forest grades into scrub or grass. The clearing of woodlots for more intensive agriculture and for residential development not only changed its habitat but also allowed a competitor, the gray squirrel, to expand (Mathews and Moseley 1990). The gray squirrel is more adaptable than the Delmarva peninsula fox squirrel, and competition between the two species may have led to the decline of the Delmarva peninsula fox squirrels. A recovery plan has been completed, and reestablishment of this squirrel is possible (Thornback and Jenkins 1982).

Highways are an important component of fragmentation because they make traveling easier for some species. Highways also provide food in the form of animals that are killed by cars (Lazell 1989). The coyote may be taking advantage of this food source, because it is the only large predator with a significant range expansion in the past 30 years. This species has expanded its range eastward from the central plains and now occurs throughout the Northeast, except in Delaware and in the Philadelphia urban areas (Chambers 1987). The coyote is broadly adapted to forest, agricultural, and suburban environments. The highest densities of coyotes occur in Maine (22 per 100 square kilometers). The coyote is the largest predator in many parts of the Northeast, and its presence raises many concerns by the public because of perceived threats to deer, livestock, humans, and pets (Chambers 1987). As coyotes become more common, management and education will be important for mitigating conflicts between this species and humans.

As in the urban landscape, no species is as visible or as controversial in the fragmented landscape as the white-tailed deer. Deer populations in Virginia, Maryland, New Jersey, Pennsylvania, New York, Connecticut, and Massachusetts have increased significantly during the last few decades, and today the estimated population size in this region is 3 million animals (Storm and Palmer 1995). Densities as high as 70 deer per square kilometer occur in Pennsylvania (Storm et al. 1989).

Some people find deer in urban areas attractive and others view them a nuisance. Each year, as many as one million deer are killed on the highways of the Northeast (Decker et al. 1990); deer also cause more than $10 million in damage to orchards and other vegetation (Connelly et al. 1987). Concerns for effects on park areas (Porter et al. 1994; Underwood et al. 1994) are heightened by the possibility that deer play a role in the incidence of Lyme disease, which can cause serious health problems in humans (Anderson 1988). The conflict is leading to new technology for managing deer in these environments (for example, remote-delivery contraceptives), expanded education programs (for example, ecology of wildlife), and debate of societal values (for example, animal rights), all of which may influence how deer are managed in rural and urban landscapes.

Gaps in Knowledge and Directions for the Future

Uneven Knowledge of Resources

The knowledge of biological resources is uneven. More is known about the larger and more obvious plants and animals. Although many people believe that biologists have a thorough understanding of most species, this is still far from true. Significant gaps occur in the basic inventory of existing species, availability of long-term data describing population change, and knowledge of how species interact. Biologists have a rudimentary understanding of the basic biology of many organisms, but little is known about most species, and much of the microflora and microfauna may be undescribed. Perhaps more importantly, biologists have only a preliminary grasp of how these species interact to produce the various characteristics of northeastern environments.

Small Species

Small mammals, amphibians, reptiles, insects, and other invertebrates are largely unrepresented in many state and federal inventories (Flather and Hoekstra 1989). These same groups are also underrepresented in the wildlife literature. Insects are an enormous group for which status and trend data are lacking. Of the northeastern states, only New York has an all-insect list, and this dates from 1926. In addition, surveys of butterflies and moths of Maine, New York, New Jersey, and Pennsylvania exist, and surveys are in progress in Maryland, West Virginia, and Ohio (Hodges 1995). Population information on pest species is sometimes available, but the typical unobtrusive insect of the forest or suburb is relatively unknown. A good resource for endangered insects and invertebrates in general is the *IUCN Invertebrate Red Data Book* (Wells et al. 1983), which summarizes most information about many endangered invertebrates.

Most gaps in information about a group exist not only in the Northeast but also usually across the country. This is particularly true of amphibians, which are experiencing national and perhaps worldwide declines. Although declines are not thought to be as drastic or widespread in the Northeast as they are in the West, basic information on the status and health of amphibians is nearly nonexistent. Efforts to monitor amphibian populations are just starting.

Inconsistent Record Keeping

Surprisingly, gaps in our knowledge occur even about some of the more popular mammal and bird species. Many state agencies monitor populations of game species through harvest reports of hunters. Properly analyzed, such records can be good indicators of population size trends, especially when linked with data on the intensity of hunting. Record keeping, however, is inconsistent and data are poorly stored and difficult to access. This is unfortunate because reporting by hunters is one of the most economical and extensive methods for collecting information. Where populations of special concern are monitored by formal surveys, good statistical design is lacking, and the ability to detect changes in species abundance of less than 30% is therefore rare.

Fungi and Lichens

Trees, rare plants, and species of economic importance are reasonably well studied, but much information is lacking on two groups in particular, fungi (molds, rusts, mildews, smuts, and mushrooms) and lichens (plants that consist of an algae and a fungus). Biological information on these groups is so incomplete that determination of whether a species is threatened, endangered, or has disappeared cannot be made. Checklists of North American fungi or comprehensive regional treatments of the species do not exist. European studies suggest a relation between forest health and successful reproduction of fungi, and although this may be an important phenomenon in the Northeast, no rigorous study has been conducted (Mueller 1995).

Lichens are similarly ignored. Of the northeastern states, only Connecticut and New York have lichen checklists, and these are incomplete. Although lichens have become scarce or have disappeared in parts of Connecticut, Pennsylvania, and Ohio because of acid rain or air pollution, the effects of the pollutants are poorly studied. On the whole, research on lichens is not encouraged at universities, in part because of poor funding (Bennett 1995). A lack of attention to these sensitive environmental indicators, though, may mean a missed opportunity for early warnings of environmental problems, or even the disappearance of species before they are ever described.

Conclusions

Reports such as those of the U.S. Geological Survey's GAP program are beginning to provide summaries of what is and what is not known about the nation's biological resources (Edwards 1995; Scott et al. 1995). Other federal programs, such as the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program, are designed to collect extensive data on the current state of species. A partnership between a private organization, The Nature Conservancy, and state natural resource agencies created the Natural Heritage Program, a state-by-state database of information on native species. Although somewhat decentralized, this program has one of the most promising summaries of the status of our biological resources.

The development of a strong scientific foundation for management requires techniques for the early recognition of environmental degradation, a determination of the ability of northeastern environments to recover from repeated human disturbance, and an understanding of the means to maintain biological diversity. The complexity of the environment poses extraordinary challenges for the scientific community and seems to require a shift from the study of individual species to investigations of systems of interacting species.

Recent planning and thinking are providing a foundation for a new approach to the science and management of biotic resources. Just as F. E. Clements' *Plant Succession* (1916) and Aldo Leopold's *Game Management* (1933) shaped the early notions about the degree to which changes in populations or communities are discernable, predictable, and ultimately controllable, new ideas are initiating a rapid evolution of the way we think. Works such as Daniel Botkin's *Discordant Harmonies* (1990), Stuart Pimm's *Balance of Nature* (1991), and Carl Walters' *Adaptive Management* (1986) are central to this new way of thinking. Examples that illustrate the integration of this new thinking into research are plans such as the Sustainable Biosphere Initiative of the Ecological Society of America (Lubchenco et al. 1991) and the National Research Council reports on science in the national parks and national forests (Gordon 1990; Risser 1992).

Recent reports and publications have noted common threads that can be seen as major gaps in knowledge for confronting the challenges of the next 20–30 years, including:

- In the absence of frequent disturbance, a few species or groups of species control environmental change. Some environments are limited by plant production and others are limited by consumers. Still other environments seem able to switch back and forth between limitations. Evidence suggests that biodiversity in an environment is one key to understanding the behavior of environments and to predicting their abilities to cope with disturbance. Researchers should focus on the effects of how the loss of species or drastic increases in the relative abundance of species affect other species in the system. The ways in which interactions among species shape environmental change must be determined.
- Past researchers focused almost exclusively on single, specific disturbances. Increasingly, we are aware that the frequency of the disturbance is crucial. For instance, the character of eastern forests is often determined by the time elapsed since the last hurricane. To predict and manage the response of various components of an ecological system requires an understanding of the frequency of disturbance, the type of disturbance, and its geographic extent. The influence of the frequency, geographic extent, and quality of disturbance on the dynamics of populations, communities, and environments must be determined.
- Because fluctuation may be normal and disturbance is common, scientists must determine the existence and identity of thresholds to major shifts in the bounds of fluctuation. The first signs of environmental stress are probably evident at the population level, and their timely detection requires the study of long-term population data sets. Characteristics of stressors that are great enough to cause drastic and potentially irreversible changes in environments must be identified.
- The protection of species diversity and ecological systems from varying anthropogenic impacts requires the identification of a viable reserve or cluster of reserves for maintaining a genetic pool, species, or environment type. The importance of shape and size of reserves and corridors for determining long-term environmental behavior must be recognized. Researchers must examine the direct and indirect influences of the surrounding landscape in areas of concern. The goal must be the identification of factors that convey increased resistance to invasion by nonindigenous species, decreased risk of extinction, and the benefit to cost ratio of restoring native species. The value of seminatural environments as biotic reserves relative to natural environments must be defined.
- Although the complexity of any one of these areas is still beyond comprehension, the scientific community must begin to learn more about the interactions among these units because they are the context within which sustainable use must operate. Researchers must define the relationships among societal values, land-use policies, and socioeconomic conditions with the intent of establishing management that encompasses a broader environment. The linkages among economic, social, and ecological systems must be identified.

Authors

William F. Porter
Jennifer A. Hill
State University of New York
College of Environmental Science
and Forestry
1 Forestry Drive
Syracuse, New York 13210

Acknowledgments

We thank the following people for their kind assistance on this report: D. Allen, G. Baldassarre, R. Burgess, R. Brocke, R. Fewster, D. Leopold, S. McNulty, M. Pike, R. Raynal, C. Smith, and R. Werner.

Cited References

Adams, L. W., and L. E. Dove. 1989. Wildlife reserves and corridors in the urban environment: a guide to ecological landscape planning and resource conservation. National Institute for Urban Wildlife, Columbia, Md. 91 pp.

Allen, A. W. 1987. Habitat suitability index models: gray squirrel, revised. U.S. Fish and Wildlife Service Biological Report 82(10.135). 16 pp.

Anderson, J. F. 1988. Mammalian and avian reservoirs for *Borrelia burgdorferi*. Pages 180–191 *in* J. L. Benach and E. M. Bosler, editors. Lyme disease and related disorders. New York Academy of Sciences, New York.

Applegate, R. D. 1993. Trends in Maine mourning dove populations. Pages 139–142 *in* W. M. Healy, editor. Transactions of the Northeast Section of the Wildlife Society 50. Amherst, Mass.

Bailey, R. G. 1978. Description of the ecoregions of the United States. U.S. Forest Service, Ogden, Utah. 77 pp.

Baker, J. P., W. J. Warren-Hicks, J. Gallagher, and S. W. Christensen. 1993. Fish population losses from Adirondack lakes: the role of surface water acidity and acidification. Water Resources Research 29:861–874.

Baldassarre, G. A., and E. G. Bolen. 1994. Waterfowl ecology and management. John Wiley & Sons, New York. 609 pp.

Bellrose, F. C., and R. A. Heister. 1987. The wood duck. Pages 381–397 *in* R. L. Di Silvestro, editor. Audubon Wildlife Report 1987. Academic Press, New York.

Beltz, E. 1993. Distribution and status of the eastern massasauga rattlesnake, *Sistrurus catenatus catenatus* in the United States and Canada. Pages 26–31 *in* B. Johnson and V. Menzies, editors. International symposium and workshop on the conservation of the eastern massasauga rattlesnake. Metro Toronto Zoo, West Hill, Ontario, Canada.

Bennett, J. P. 1995. Lichens. Pages 194–196 *in* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S.

Department of the Interior, National Biological Service, Washington, D.C.

Bosakowski, T. 1986. Winter population trends of the house finch and ecologically similar species in northeastern New Jersey. American Birds 40(4):1105–1110.

Botkin, D. B. 1990. Discordant harmonies: a new ecology for the twenty-first century. Oxford University Press, New York 241 pp.

Bouta, R. P. 1991. Population status, historical decline, and habitat relationships of spruce grouse in the Adirondacks of New York. M.S. thesis, State University of New York, College of Environmental Science and Forestry, Syracuse. 117 pp.

Boyd, H. P. 1991. A field guide to the pine barrens of New Jersey. Plexus Publishing, Inc., Medford, N.J. 423 pp.

Breisch, A. R. 1992. Summary of state/provincial regulations concerning the timber rattlesnake. Pages 7–8 *in* T. F. Tyning, editor. The timber rattlesnake in the Northeast. Massachusetts Audubon Society, Lincoln.

Brocke, R. H. 1994. The prognosis for cougar restoration in northeastern North America—inferences from a feasibility study. Pages 20–21 *in* Eastern cougar conference proceedings. Erie, Pa. Abstract.

Brocke, R. H., and K. A. Gustafson. 1992. Lynx (*Felis lynx*) in New York state. Reintroduction News 4, May 1992:6–7.

Burnham, C. R. 1988. The restoration of the American chestnut. American Scientist 76(5):478–487.

Cade, T. J., and J. H. Barclay. 1984. The current state of peregrine recovery in the eastern United States. Transactions of the Northeast Section of the Wildlife Society 41:85–91.

Chambers, R. E. 1987. Status of the coyote in the northeastern United States. Proceedings of the Eastern Wildlife Damage Control Conference 3:318–319.

Chen, B., G. H. Choi, and D. L. Nuss. 1994. Attenuation of fungal virulence by synthetic infectious hypovirus transcripts. Science 264:1762–1764.

Clements, F. E. 1916. Plant succession: an analysis of the development of vegetation. Carnegie Institute of Washington Publication 242:1–512.

Connelly, N. A., D. J. Decker, and S. Wear. 1987. Public tolerance of deer in a suburban environment: implications for management and control. Pages 207–218 *in* N. R. Holler, editor. Proceedings of the Eastern Wildlife Damage Control Conference 3.

Conover, M. R., and G. G. Chasko. 1985. Nuisance Canada goose problems in the eastern United States. Wildlife Society Bulletin 13(3):228–233.

Cooper, E. L. 1985. Fishes. Pages 169–256 *in* H. H. Genoways and F. J. Brenner, editors. Species of special concern in Pennsylvania. Trustees of the Carnegie Institute, Pittsburgh, Pa.

Crawford, B. T. 1987. Bobwhite quail. Pages 299–303 *in* H. Kallman, editor. Restoring America's wildlife 1937–1987. U.S. Fish and Wildlife Service, Washington, D.C.

Cumberland, R. E., and J. A. Dempsey. 1994. Recent confirmation of a cougar, *Felis concolor*, in New Brunswick. Canadian Field-Naturalist 108:224–226.

Daugherty, A. B. 1991. Major uses of land in the United States. U.S. Department of Agriculture, Rockville, Md. 34 pp.

Davis, G. D. 1988. 2020 Vision—fulfilling the promise of the Adirondack Park 1: biological diversity: saving all the pieces. The Adirondack Council, Elizabethtown, N.Y. 64 pp.

Decker, D. J., K. M. Loconti Lee, and N. A. Connelly. 1990. Incidence and costs of deer-related vehicular accidents in Tompkins County, New York. Human Disturbance Research Unit, Department of Natural Resources, Cornell University, Ithaca, N.Y. 22 pp.

DeGraaf, R. M., M. Yamasaki, W. B. Leak, and J. W. Lanier. 1989. New England wildlife: management of forested habitats. Northeastern Experiment Station, U.S. Forest Service, Radnor, Pa. 271 pp.

Dein, J. 1995. Captive propagation, introduction, and translocation programs for wildlife vertebrates. Pages 405–407 in E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C.

Dickson, J. G., editor. 1992. The wild turkey: biology and management. Stackpole Books, Harrisburg, Pa. 463 pp.

Dickson, J. G. 1995. Return of wild turkeys. Pages 70–71 *in* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C.

Distefano, J. J. 1987. Wild furbearer management in the northeastern United States. Pages 1077–1090 *in* M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch, editors. Wild furbearer management and conservation in North America. The Ontario Trappers Association, Ontario, Canada.

Dunwiddie, P., D. Foster, D. Leopold, and R. Leverett. 1996. Old-growth forests of southern New England, New York, and Pennsylvania. *In* M. Davis, editor. Eastern old growth. Island Press, Washington, D.C.

Dwyer, C. P., and G. A. Baldassarre. 1994. Habitat use by sympatric female mallard and American black duck in forested environment. Canadian Journal of Zoology 72(9):1538.

Edwards, T. C., Jr. 1995. Protection status of vegetation cover types in Utah. Pages 463–464 *in* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C.

Egler, F. 1986. Commentary: "Physics envy" in ecology. Bulletin of the Ecological Society of America 67:233–235.

Flather, C. H., and T. W. Hoekstra. 1989. An analysis of the wildlife and fish situation in the United States 1989–2040: a technical document supporting the 1989 USDA Forest Service RPA assessment. U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo. 146 pp.

Fox, L. B. 1990. Ecology and population biology of the bobcat, *Felis rufus*, in New York. Ph.D. dissertation, State University of New York, College of Environmental Science and Forestry, Syracuse. 184 pp.

Genoways, H. H. 1985. Mammals. Pages 355–423 *in* H. H. Genoways and F. J. Brenner, editors. Species of special concern in Pennsylvania. Trustees of the Carnegie Institute, Pittsburgh, Pa.

George, J. L. 1982. Urban wildlife: a problem analysis for environmental forestry research. Agricultural Experiment Station, Pennsylvania State University College of Agriculture, University Park, Pa. 22 pp.

Gordon, J. C., chair. 1990. Forestry research: mandate for change. National Research Council Report, National Academy Press, Washington, D.C. 84 pp.

Graham, F., Jr. 1978. The Adirondack Park: a political history. Alfred A. Knopf, New York. 314 pp.

Groombridge, B. 1982. The IUCN Amphibia–Reptilia red data book, part 1. IUCN, Gland, Switzerland. 426 pp.

Grover, A. M. 1993. Influence of beaver on bird and mammal species richness within wetlands of different sizes in south-central New York. M.S. thesis, State University of New York, College of Environmental Science and Forestry, Syracuse. 41 pp. + appendixes.

Guntenspergen, G. R. 1995. Plants. Pages 189–190 *in* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C.

Heusman, H. W. 1991. The history and status of the mallard in the Atlantic Flyway. Wildlife Society Bulletin 19:14–22.

Hill, N. P., and J. M. Hagan III. 1991. Population trends of some northeastern North American landbirds: a half century of data. Wilson Bulletin 103(2):165–182.

Hodges, R. W. 1995. Diversity and abundance of insects. Pages 161–163 *in* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C.

Jenkins, S. R. 1983. Mid-Atlantic states raccoon rabies outbreak. Pages 293–297 *in* D. J. Decker, editor. Proceedings of the first eastern wildlife damage control conference. Cornell Cooperative Extension, Ithaca, N.Y.

Johnson, G., and A. R. Breisch. 1993. The eastern massasauga rattlesnake in New York: occurrence and habitat management. Pages 48–54 *in* B. Johnson and V. Menzies, editors. International symposium and workshop on the conservation of the eastern massasauga rattlesnake. Metro Toronto Zoo, West Hill, Ontario, Canada.

Johnson, J. E. 1995. Imperiled freshwater fish. Pages 142–144 *in* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C.

Kennamer, J. E., and M. Kennamer. 1990. Current status and distribution of the wild turkey, 1989. Pages 1–12 *in* W. M. Healy and G. B. Healy, editors. Proceedings of the sixth national wild turkey symposium. National Wild Turkey Federation, Edgefield, S.C.

Kerlinger, P., and C. Doremus. 1981. Habitat disturbance and the decline of dominant avian species in the pine barrens of the northeastern United States. American Birds 35(1):16–20.

Koehler, G. 1987. The bobcat. Pages 399–409 *in* R. L. Di Silvestro, editor. Audubon wildlife report 1987. Academic Press, New York.

Küchler, A. W. 1964. Potential natural vegetation of the conterminous United States. Map and booklet. American Geographic Society Special Publication 36. 39 pp.

Lazell, J., Jr. 1989. Pushy wildlife: animals that thrive on human habitat. National Parks 63(9–10):19–25.

Leopold, A. 1933. Game management. C. Scribner's Sons, New York. 481 pp.

Lubchenco, J., A. Olson, L. Brubaker, S. Carpenter, M. Holland, S. Hubbell, S. Levin, J. MacMahon, P. Matson, J. Melillo, H. Mooney, C. Peterson, H. Pulliam, L. Real, P. Regal, and P. Risser. 1991. The sustainable biosphere initiative: an ecological research agenda. Ecology 72(2):371–412.

Malecki, R. 1995. Purple loosestrife. Pages 458–459 *in* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C.

Manski, D. A., L. W. VanDruff, and V. Flyger. 1981. Activities of gray squirrels and people in a downtown Washington, D.C. park: management implications. Pages 439–454 *in* K. Sabol, editor. Transactions of the forty-sixth North American wildlife and natural resources conference. Wildlife Management Institute, Washington, D.C.

Mathews, J. R., and C. J. Moseley. 1990. The official World Wildlife Fund guide to endangered species of North America. Beacham Publishing, Washington, D.C. 560 pp.

Maynard, C. A. 1994. The American chestnut and test tubes. The New York Forest Owner, March/April:7.

McCabe, T. L. 1995. The changing insect fauna of Albany's pine barrens. Pages 166–168 *in* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C.

McCorkle, C. O., Jr., and J. E. Halver, co-chairs. 1982. Impacts of emerging agricultural trends on fish and wildlife habitat: National Research Council. National Academy Press, Washington, D.C. 303 pp.

Merendino, M. T., C. D. Ankney, and D. G. Dennis. 1993. Increasing mallards, decreasing black ducks: more evidence for cause and effect. Journal of Wildlife Management 57(2):199–208.

Metcalf, R. L., and R. A. Metcalf. 1993. Destructive and useful insects: their habits and control. 5th edition. McGraw-Hill, New York. 1082 pp.

Milstein, M. 1990. Unlikely harbingers: the sudden worldwide disappearance of amphibians alerts scientists to ecological breakdown. National Parks 64(7–8):19–24.

Morse, L. E., J. T. Kartesz, and L. S. Kutner. 1995. Native vascular plants. Pages 205–209 *in* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C.

Moseley, C. J., editor. 1992. The official World Wildlife Fund guide to endangered species of North America. Volume 3. Beacham Publishing, Washington, D.C. xxi + 466 pp.

Mueller, G. M. 1995. Macrofungi. Pages 192–194 *in* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C.

National Acid Precipitation Assessment Program. 1993. 1992 report to Congress. NAPAP Office of the Director, Washington, D.C. 130 pp.

Nealis, V. G., and S. Erb. 1993. A sourcebook for the management of the gypsy moth. Minister of Supply and Services Canada, Ottawa, Canada. 48 pp.

New York Sea Grant. 1994a. North American range of the zebra mussel. *Dreissena polymorpha.* Information Review 5(3):6–7.

New York Sea Grant. 1994b. North American range of the zebra mussel. *Dreissena polymorpha.* Information Review 5(4):6–7.

Ono, R. D., J. D. Williams, and A. Wagner. 1983. Vanishing fishes of North America. Stone Wall Press, Washington, D.C. 257 pp.

Opler, P. A. 1978. Insects of American chestnut: possible importance and conservation concern. Pages 83–85 *in* W. L. McDonald, F. C. Cech, J. Luchok, and C. Smith, editors. Proceedings of the American chestnut symposium. West Virginia University, Morgantown.

Opler, P. A. 1993. The U.S. Endangered Species Act: conservation and research for aquatic insects. Aquatic Conservation 3:289–291.

Parker, K. E. 1988. Common loon reproduction and chick feeding on acidified lakes in the Adirondack Park, New York. Canadian Journal of Zoology 66:804–810.

Pimm, S. L. 1991. The balance of nature: ecological issues in the conservation of species and communities. Chicago University Press, Ill. 434 pp.

Pokras, M. A., R. M. Chafel, and M. Gibson. 1991. Environmental pathology of the common loon in New England. Pages 31–38 *in* R. M. DeGraaf, editor. Transactions of the Northeast section of the Wildlife Society 48. Amherst, Mass.

Porter, W. F., M. A. Coffey, and J. Hadidian. 1994. In search of a litmus test: wildlife management in U.S. national parks. Wildlife Society Bulletin 22(2):301–306.

Pullman, G. D. 1994. Dose rate calculations for selective plant control with sonar aquatic herbicide. Lake Reservoir Management 1994(9)2:106

Reinert, H. K., and L. M. Bushar. 1993. The massasauga rattlesnake in Pennsylvania: continuing habitat loss and population isolation. Pages 55–59 *in* B. Johnson and V. Menzies, editors. International symposium and workshop on the conservation of the eastern massasauga rattlesnake. Metro Toronto Zoo, West Hill, Ontario, Canada.

Risser, P., chair. 1992. Science and the national parks. National Academy Press, Washington, D.C. 122 pp.

Schaffner, W. R., and R. T. Oglesby. 1978. Limnology of eight Finger Lakes. Pages 313–470 *in* J. A. Bloomfield, editor. Lakes of New York state. 1. Ecology of the Finger Lakes. Academic Press, New York.

Scott, J. M., E. T. LaRoe, and M. D. Jennings. 1995. Gap analysis: a geographic approach to planning for biological diversity. Page 462 *in* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C.

Slack, N. G. 1992. Rare and endangered bryophytes in New York state and the eastern United States: current status and preservation strategies. Biological Conservation 59:233–241.

Smith, C. R., D. M. Pence, and R. J. O'Connor. 1993. Status of Neotropical migratory birds in the Northeast: a preliminary assessment. Pages 172–188 *in* D. M. Finch and P. W. Stangel, editors. Status and management of Neotropical migratory birds. U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Stechert, R. 1992. Distribution and population status of *Crotalus horridus* in New York and northern New Jersey. Page 1 *in* T. F. Tyning, editor. Conservation of the timber rattlesnake in the Northeast. Massachusetts Audubon Society, Lincoln, Mass.

Storm, G. L., and W. L. Palmer. 1995. White-tailed deer in the Northeast. Pages 112–115 *in* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C.

Storm, G. L., R. H. Yahner, D. F. Cottam, and G. M. Vecellio. 1989. Population status, movements, habitat use, and impact of white-tailed deer at Gettysburg National Military Park and Eisenhower National Historic Site, Pennsylvania. National Park Service Technical Report NPS/MAR/NRTR-89/043. 123 pp.

Thompson, D. Q., R. L. Stuckey, and E. B. Thompson. 1987. Spread, impact, and control of purple loosestrife (*Lythrum salicaria*) in North American wetlands. U.S. Fish and Wildlife Service Fish and Wildlife Research 2. 55 pp.

Thornback, J., and M. Jenkins. 1982. The IUCN mammal red data book 1. IUCN, Gland, Switzerland. 516 pp.

Trost, R. E., and R. A. Malecki. 1985. Population trends in Atlantic Flyway Canada geese: implications for management. Wildlife Society Bulletin 13:502–508.

Twardus, D., M. Miller-Weeks, and A. Gillespie. 1993. Forest health assessment for the northeastern area. Northeastern Forest Research Experiment Station, Radnor, Pa. 61 pp.

Twardus, D. B., editor. 1994. Gypsy moth news, issue 35. U.S. Forest Service, Morgantown, W. Va. 15 pp.

Underwood, H. B., K. A. Austin, W. F. Porter, R. L. Burgess, and R. W. Sage, Jr. 1994. Interactions of white-tailed deer and vegetation at Saratoga National Historical Park. State University of New York, College of Environmental Science and Forestry, Syracuse, N.Y. 33 pp. + tables.

U.S. Congress, Office of Technology Assessment. 1993. Harmful non-indigenous species in the United States. U.S. Congress, Office of Technology Assessment, Washington, D.C. 391 pp.

U.S. Fish and Wildlife Service. 1994. Endangered and threatened wildlife and plants. U.S. Fish and Wildlife Service, Washington, D.C. 42 pp.

VanDruff, L. W., E. G. Bolan, and G. J. San Julian. 1994. Management of urban wildlife. Pages 507–530 *in* T. A. Brookhout, editor. Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, Md.

Vaughan, M. R., and M. R. Pelton. 1995. Black bears in North America. Pages 100–103 *in* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C.

Vickery, P. D. 1991. A regional analysis of endangered, threatened, and special-concern birds in the northeastern United States. Pages 1–10 *in* R. M. DeGraaf, editor. Transactions of the Northeast section of the Wildlife Society 48. Amherst, Mass.

Walters, C. 1986. Adaptive management of renewable resources. Macmillan Publishing Company, New York. 374 pp.

Warren, M. L., Jr., and B. M. Burr. 1994. Status of freshwater fishes of the United States: overview of an imperiled fauna. Fisheries 19(1):6–18.

Wells, S. M., R. M. Pyle, and N. M. Collins. 1983. The IUCN invertebrate red data book. IUCN, Gland, Switzerland. 632 pp.

Whitney, G. G. 1994. From coastal wilderness to fruited plain: a history of environmental change in temperate North America 1500 to the present. Cambridge University Press, Cambridge, U.K. xviii + 451pp.

Williamson, R. D. 1983. Identification of urban habitat components which affect eastern gray squirrel abundance. Urban Ecology 7:345–356.

Zipperer, W. C., R. L. Burgess, and R. D. Nyland. 1989. Patterns of deforestation and reforestation in different landscape types in central New York. Forest Ecology and Management 36:103–177.

Birds and Landscape Changes in Northeastern Forests

Butcher, G. S. 1990. Audubon Christmas Bird Counts. Pages 5–13 *in* J. R. Sauer and S. Droege, editors. Survey designs and statistical methods for the estimation of avian population trends. U.S. Fish and Wildlife Service Biological Report 90.

Droege, S., and J. R. Sauer. 1989. North American Breeding Bird Survey annual summary 1988. U.S. Fish and Wildlife Service Biological Report 89:1–16.

James, F. C., C. E. McCulloch, and D. A. Wiedenfeld. 1996. New approaches to the analysis of population trends in land birds. Ecology 71:13–27.

Peterjohn, B. G. 1994. The North American Breeding Bird Survey. Birding 26:386–398.

Powell, D. S., J. L. Faulkner, D. R. Darr, Z. Zhu, and D. W. MacCleery. 1994. Forest resources of the United States, 1992. U.S. Forest Service General Technical Report RM-234. Fort Collins, Colo. 132 pp.

Price, J., A. Price, and S. Droege. 1995. The summer atlas of North American birds. Academic Press, New York. 364 pp.

Robbins, C. S., J. R. Sauer, R. G. Greenberg, and S. Droege. 1989. Population declines in North American birds that migrate to the Neotropics. Proceedings of the National Academy of Sciences 86:7658–7662.

U.S. Forest Service. 1995. Shifts in stocking reveal forest health problems. U.S. Forest Service Northeast Experiment Station NA-TP-0795. 328 pp.

Northeastern Spruce–Fir Forests

Hopkins, A. D. 1901. Insect enemies of the spruce in the Northeast. U.S. Department of Agriculture Bulletin 18 (new series). 48 pp.

Irland, L. C., J. B. Dimond, J. L. Stone, J. Falk, and E. Baum. 1988. The spruce budworm outbreak in Maine in the 1970's—assessment and directions for the future. Maine Agricultural Experiment Station Bulletin 819. 119 pp.

Jacobson, G. L., Jr., T. Webb, and E. C. Grimm. 1987. Patterns and rates of vegetation change during the deglaciation of eastern North America. Pages 277–288 *in* W. F. Ruddiman and H. E. Wright, Jr., editors. The geology of North America. Volume K-3. North America and adjacent oceans during the last glaciation. Geological Society of America, Boulder, Colo.

Lorimer, C. G. 1977. The presettlement forest and natural disturbance cycle of northeastern Maine. Ecology 58:139–148.

Seymour, R. S. 1992. The red spruce–balsam fir forest of Maine: evolution of silvicultural practice in response to stand development patterns and disturbances. Pages 217–244 *in* M. J. Kelty, B. C. Larson, and C. D. Oliver, editors. The ecology and silviculture of mixed-species forests. Kluwer Publishers, Norwell, Mass. 287 pp.

Seymour, R. S., and M. L. Hunter, Jr. 1992. New forestry in eastern spruce–fir forests: principles and applications to Maine. Maine Agricultural Experiment Station Miscellaneous Publication 716. 36 pp.

Westveld, M. 1953. Ecology and silviculture of the spruce–fir forests of eastern North America. Journal of Forestry 51:422–430.

American Woodcock

Britt, T. L. 1971. Studies of woodcock on the Louisiana wintering ground. M.S. thesis, Louisiana State University, Baton Rouge. 105 pp.

Brooks, R. T., and T. W. Birch. 1988. Changes in New England forests and forest owners: implications for wildlife habitat resources and management. Transactions of the North American Wildlife and Natural Resource Conference 53:78–87.

Bruggink, J. G., and W. L. Kendall. 1995. American woodcock harvest and breeding population status, 1995. U.S. Fish and Wildlife Service, Laurel, Md. 15 pp.

DeGraaf, R. M., M. Yamasaki, W. B. Leak, and J. W. Lanier. 1993. Management of New England northern hardwoods, spruce–fir, and eastern white pine for Neotropical migratory birds. Pages 363–373 *in* D. M. Finch and P. W. Stangel, editors. Status and management of Neotropical migratory birds. U.S. Forest Service General Technical Report RM-229. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Dunford, R. D., and R. B. Owen, Jr. 1973. Summer behavior of immature radio-equipped woodcock in central Maine. Journal of Wildlife Management 37:462–468.

Dwyer, T. J., D. G. McAuley, and E. L. Derleth. 1983. Woodcock singing-ground counts and habitat changes in the northeastern United States. Journal of Wildlife Management 47:772–779.

Dwyer, T. J., G. F. Sepik, E. L. Derleth, and D. G. McAuley. 1988. Demographic characteristics of a Maine woodcock population and effects of habitat management. U.S. Fish and Wildlife Service, Fish and Wildlife Research 4. 29 pp.

Dyer, J. M., and R. B. Hamilton. 1977. Analysis of several site components of diurnal woodcock habitat in southern Louisiana. D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the sixth woodcock symposium, October 4–6, 1977, 6.51–62, Fredrickton, New Brunswick, Canada.

Glasgow, L. L. 1958. Contributions to the knowledge of the ecology of the American woodcock (*Philohela minor* Gmelin) on the wintering range in Louisiana. Ph.D. dissertation, Texas A & M University, College Station. 158 pp.

Gregg, L. E., and J. B. Hale. 1977. Woodcock nesting habitat in northern Wisconsin. Auk 94:489–493.

Hudgins, J. E., G. L. Storm, and J. S. Wakeley. 1985. Local movements and diurnal-habitat selection by male American woodcock in Pennsylvania. Journal of Wildlife Management 49:614–619.

Keppie, D. M., and R. M. Whiting, Jr. 1994. American woodcock (*Scolopax minor*). *In* A. Poole and F. Gill, editors. The birds of North America 100. Academy of Natural Sciences, Philadelphia, Pa. American Ornithologists' Union, Washington, D.C. 28 pp.

Krohn, W. B., F. W. Martin, and K. P. Burnham. 1974. Band recovery distribution and survival estimates of Maine woodcock. 8 pages *in* Proceedings of the fifth American woodcock workshop, December 3–5, 1974. Athens, Ga..

Liscinsky, S. A. 1972. The Pennsylvania woodcock management study. Pennsylvania Game Commission Research Bulletin 171. 95 pp.

Martin, F. W. 1964. Woodcock age and sex determination from wings. Journal of Wildlife Management 28:287–293.

Martin, F. W., S. O. Williams, J. D. Newsom, and L. L. Glasgow. 1969. Analysis of records of Louisiana–banded woodcock. Proceedings of the third annual conference of the Southeastern Association of Game and Fish Commissioners 23:85–96.

McAuley, D. G., J. R. Longcore, G. F. Sepik, and G. W. Pendleton. 1996. Habitat characteristics of American woodcock nest sites on a managed area in Maine. Journal of Wildlife Management 60:138–148.

Mendall, H. L., and C. M. Aldous. 1943. The ecology and management of the American woodcock. Maine Cooperative Wildlife Research Unit, University of Maine, Orono. 201 pp.

Morgenweck, R. O. 1977. Diurnal high use areas of hatching-year female American woodcock. D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the sixth woodcock symposium, October 4–6, 1977, 6:155–160. Fredrickton, New Brunswick.

Owen, R. B., Jr., J. M. Anderson, J. W. Artmann, E. R. Clark, T. G. Dilworth, L. E. Gregg, F. W. Martin, J. D. Newsom, and S. R. Pursglove. 1977. American woodcock (*Philohela minor* = *Scolopax minor* of Edwards 1974). Pages 149–186 *in* G. C. Sanderson, editor. Management of migratory shore and upland game birds in North America. International Association of Fish and Wildlife Agencies, Washington, D.C. 385 pp.

Owen, R. B., Jr., and W. B. Krohn. 1973. Molt patterns and weight changes of the American woodcock. Wilson Bulletin 85:31–41.

Rabe, D. L. 1977. Structural analysis of woodcock diurnal habitat in northern Michigan. D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the sixth woodcock symposium, October 4–6, 1977, 6:125–134, Fredrickton, New Brunswick.

Sepik, G. F., and E. L. Derleth. 1993. Habitat use, home range size and patterns of moves of the American woodcock in Maine. Pages 41–49 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the eighth American woodcock symposium. U.S. Fish and Wildlife Service Biological Report 16.

Sepik, G. F., D. G. McAuley, and J. R. Longcore. 1993. Critical review of the current knowledge of the biology of the American woodcock and its management on the breeding grounds. Pages 98–104 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the eighth American woodcock symposium. U.S. Fish and Wildlife Service Biological Report 16.

Sepik, G. F., R. B. Owen, Jr., and M. W. Coulter. 1981. A landowner's guide to woodcock management in the Northeast. Maine Agricultural Experiment Station, Miscellaneous Report 253. 23 pp.

Sepik, G. F., R. B. Owen, Jr., and T. J. Dwyer. 1983. The effect of drought on a local woodcock population. Transactions of the Northeast Fish and Wildlife Conference 40:1–8.

Sheldon, W. G. 1967. The book of the American woodcock. University of Massachusetts Press, Amherst. 227 pp.

Sperry, C. C. 1940. Food habits of a group of shorebirds: woodcock, snipe, knot, and dowitcher. U.S. Biological Survey, Wildlife Research Bulletin 1. 37 pp.

Straw, J. A., Jr., D. G. Krementz, M. W. Olinde, and G. F. Sepik. 1994. American woodcock. Pages 97–114 *in* T. C. Tacha and C. E. Braun, editors. Migratory shore and upland game bird management in North America. International Association of Fish and Wildlife Agencies, Washington, D.C. 223 pp.

U.S. Department of the Interior. 1990. American woodcock management plan. U.S. Fish and Wildlife Service, Washington, D.C. 11 pp.

U.S. Fish and Wildlife Service. 1996. American woodcock management plan. U.S. Fish and Wildlife Service, Region 5. 11 pp.

Waddell, K. L., D. D. Oswald, and D. S. Powell. 1989. Forest statistics of the United States, 1987. U.S. Forest Service Research Bulletin PNW–RB–168. Pacific Northwest Research Station, Portland, Oreg. 106 pp.

American Black Duck

Addy, C. E., and R. K. Martinson. 1968. Black duck population management. Pages 183–189 *in* P. Barske, editor. The black duck. Evaluation, management and research: a symposium. Atlantic Waterfowl Council and Wildlife Management Institute, Brew Printing.

Anderson, D. R., and K. P. Burnham. 1976. Population ecology of the mallard. VI: The effect of exploitation on survival. U.S. Fish and Wildlife Service Resource Publication 128. 66 pp.

Barske, P., editor. 1968. The black duck. Evaluation, management and research: a symposium. Atlantic Waterfowl Council and Wildlife Management Institute, Brew Printing, Chestertown, Md. 93 pp.

Bellrose, F. C. 1976. Ducks, geese and swans of North America. A Wildlife Management Institute book sponsored jointly with the Illinois Natural History Survey. Stackpole Books, Harrisburg, Pa. 543 pp.

Blandin, W. W. 1982. Population characteristics and simulation modelling of black ducks. Ph.D. dissertation, Clark University, Worcester, Mass. 345 pp.

Bowman, T. D., and P. W. Brown. 1992. Site fidelity of male black ducks to a molting area in Labrador. Journal of Field Ornithology 63:32–34.

Boyd, H. 1988. Recent changes in waterfowl hunting effort and kill in Canada and the USA. Canadian Wildlife Service, Progress Notes 175. 11 pp.

Cottam, C., J. J. Lynch, and A. L. Nelson. 1944. Food habits and management of American sea brant. Journal of Wildlife Management 8:36–56.

Dickson, K. M. 1995. Breeding waterfowl survey in eastern Canada and the state of Maine. Progress Report (Revised August 19, 1995). A component of the Black Duck Joint Venture. Canadian Wildlife Service, Ottawa, Ontario. 11 pp.

Frayer, W. E. 1991. Status and trends of wetlands and deepwater habitats in the conterminous United States, 1970's to 1980's. Michigan Technological University. 31 pp.

Gabrielson, I. N. 1947. A program for the black duck. Pennsylvania Game News 17(1):8–9, 31.

Geis, A. D., R. I. Smith, and J. P. Rogers. 1971. Black duck distribution, harvest characteristics, and survival. U.S. Fish and Wildlife Service Special Scientific Report 139—Wildlife. 241 pp.

Grandy, J. W. 1983. The North American black duck (*Anas rubripes*): a case study of 28 years of failure in American wildlife management. International Journal for the Study of Animal Problems, Supplement 4:1–35.

Kortright, F. H. 1942. The ducks, geese and swans of North America. Wildlife Management Institute and Stackpole Books, Washington, D.C. 476 pp.

Lincoln, F. C. 1950. The American brant—living bird or museum piece. Audubon Magazine 52:282–287.

Martinson, R. K., A. D. Geis, and R. I. Smith. 1968. Black duck harvest and population dynamics in eastern Canada and the Atlantic Flyway. Pages 21–56 *in* P. Barske, editor. The black duck. Evaluation, management and research: a symposium. Atlantic Waterfowl Council and Wildlife Management Institute, Washington, D.C.

Munro, W. T. 1968. A review of the literature on the black duck (*Anas rubripes*). First draft, complete report 02-1-8. Canadian Wildlife Service, Ottawa, Ontario. 116 pp.

Nichols, J. D. 1993. Responses of North American duck populations to exploitation. Pages 498–525 *in* C. M. Perrins, J.-D. Lebreton, and G. J. M. Hirons, editors. Bird population studies: their relevance to conservation and management. Oxford University Press, Oxford, England.

Nichols, J. D., M. J. Conroy, D. R. Anderson, and K. P. Burnham. 1984. Compensatory mortality in waterfowl populations: a review of the evidence and implications for research and management. Transactions of the North American Wildlife and Natural Resources Conference 49:535–554.

Ringelman, J. K., and J. R. Longcore. 1980. Computer simulation models as tools for identifying research needs: a black duck population model. Transactions of the Northeast section of the Wildlife Society 37:182–193.

Serie, J. R., compiler. 1994. Atlantic Flyway, waterfowl harvest and population survey data. U.S. Fish and Wildlife Service, Laurel, Md. 85 pp.

Serie, J. R. 1996. Results of the 1996 Midwinter Waterfowl Survey in the Atlantic Flyway states. Preliminary Report, February 1996. Office of Migratory Bird Management, U.S. Fish and Wildlife Service, Laurel, Md. 7 pp.

Serie, J. R., R. E. Trost, and J. R. Sauer. 1997. Effects of harvest restriction on black duck harvest and population trends. Pages 25–26 *in* P. Kehoe, editor. Proceedings of the American black duck symposium, 1990, St. John, New Brunswick, Canada.

Snell, E. A. 1987. Wetland distribution and conversion in southern Ontario. Canada Land Use Monitoring Program Working Paper 48. Inland Waters and Lands Directorate, Environment Canada. 53 pp.

Wright, B. S. 1947. The black duck in eastern Canada. A report to the chief naturalist, Ducks Unlimited (Canada). Progress Report June 22, 1945–February 28, 1947. Fredericton, New Brunswick. Unpaginated.

Trends in the Chesapeake Bay Watershed Wetlands

Tiner, R. W., I. Kenenski, T. Nuerminger, D. B. Foulis, J. Eaton, G. S. Smith, and W. E. Frayer. 1994. Recent wetland status and trends in the Chesapeake watershed (1982 to 1989): technical report. Cooperative interagency technical report prepared for the Chesapeake Bay Program. U.S. Fish and Wildlife Service, Region 5, Ecological Services, Hadley, Mass. 70 pp. + appendixes.

Status of Living Resources in Chesapeake Bay

Appleton, E. L. 1995. A cross-media approach to saving the Chesapeake Bay. Environmental Science & Technology 29(12): 550A–555A.

Atlantic States Marine Fisheries Commission. 1994. Policy statement of the Atlantic States Marine Fisheries Commission Striped Bass Management Board. Press release, 18 May 1994. Atlantic States Marine Fisheries Commission, Washington, D.C.

Bonzek, C., P. J. Geer, and H. Austin. 1995. Virginia Institute of Marine Science juvenile fish trawl survey: juvenile indices 1979–1994. Virginia Institute of Marine Science, Gloucester Point, Va. 15 pp.

Chesapeake Bay Program. 1983. Chesapeake Bay Agreement of 1983. Chesapeake Bay Program Office, U.S. Environmental Protection Agency, Annapolis, Md. 1 p.

Chesapeake Bay Program. 1987. 1987 Chesapeake Bay Agreement. Chesapeake Bay Program Office, U.S. Environmental Protection Agency, Annapolis, Md. 7 pp.

Chesapeake Bay Program. 1989. Chesapeake Bay striped bass management plan. Chesapeake Bay Program Office, U.S. Environmental Protection Agency, Annapolis, Md. 33 pp.

Chesapeake Bay Program. 1990. Chesapeake Bay waterfowl policy and management plan. Chesapeake Bay Program Office, U.S. Environmental Protection Agency, Annapolis, Md. 38 pp.

Chesapeake Bay Program. 1994a. Agreement of federal agencies on ecosystem management in the Chesapeake Bay. Chesapeake Bay Program Office, U.S. Environmental Protection Agency, Annapolis, Md. 6 pp.

Chesapeake Bay Program. 1994b. Phase III watershed model, appendix E—land use and selected parameter values. Chesapeake Bay Program Office, U.S. Environmental Protection Agency, Annapolis, Md.

Chesapeake Bay Program. 1994c. Chesapeake Bay 1994 oyster fishery management plan. Chesapeake Bay Program Office, U.S. Environmental Protection Agency, Annapolis, Md. 74 pp.

Chesapeake Bay Program. 1994d. Aquatic reef habitat plan. Chesapeake Bay Program Office, U.S. Environmental Protection Agency, Annapolis, Md. 30 pp.

Chesapeake Bay Program. 1995a. Chesapeake Bay striped bass fishery management plan: annual progress report 1994. Chesapeake Bay Program Office, U.S. Environmental Protection Agency, Annapolis, Md. 36 pp.

Chesapeake Bay Program. 1995b. Annual progress report on fishery management plans 1994. Chesapeake Bay Program Office, U.S. Environmental Protection Agency, Annapolis, Md. 81 pp.

Chesapeake Executive Council. 1993. Directive 93–3. Submerged aquatic vegetation restoration goals. Chesapeake Bay Program Office, U.S. Environmental Protection Agency, Annapolis, Md. 2 pp.

Davis, G., B. Daughtery, and J. Casey. 1995. Blue crab management project analysis of blue crab (*Callinectes sapidus*) stocks in the Maryland portion of Chesapeake Bay, from summer trawl data 1977–1994. Maryland Department of Natural Resources, Tidal Fisheries Division, Annapolis, Md.

Fraser, J. D., D. A. Buehler, G. D. Therres, and J. K. D. Seeger. 1991. Bald eagle (*Haliaeetus leucocephalus*). Pages 21-1–21-9 *in* S. L. Funderburk, J. A. Milhursky, S. J. Jordan, and D. Riley, editors. Habitat requirements for Chesapeake Bay living resources. 2nd edition. Chesapeake Bay Program Office, U.S. Environmental Protection Agency, Annapolis, Md.

Johnson, T. 1992. Forest statistics of Virginia, 1992. U.S. Forest Service Research Bulletin SE-131. 61 pp.

Markham, J. L., and H. T. Hornick. 1994. Maryland Department of Natural Resources fall and winter stock assessment and commercial fishery monitoring. Page 51 *in* Striped bass study annual workshop 1994. National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Silver Spring, Md. Abstract.

Maryland Department of Natural Resources. 1995. Canada geese in the Atlantic Flyway status report. Maryland Department of Natural Resources, Annapolis.

Maryland Office of Planning. 1991. Maryland's land 1973–1990: a changing resource. Maryland Office of Planning, Baltimore. 13 pp.

Newell, R. I. E. 1988. Ecological changes in Chesapeake Bay. Are they the result of overharvesting the American oyster (*Crassostrea virginica*)? Pages 536–546 *in* M. P. Lynch and E. C. Krome, editors. Understanding the estuary: advances in Chesapeake Bay research. Publication 129. Chesapeake Research Consortium, Solomons, Md.

Orth, R. J., R. A. Batiuk, and J. F. Nowak. 1994. Trends in the distribution, abundance, and habitat quality of submerged aquatic vegetation in Chesapeake Bay and its tidal tributaries: 1971 to 1991. Chesapeake Bay Program, U.S. Environmental Protection Agency, Annapolis, Md. 170 pp.

Orth, R. J., J. F. Nowak, G. F. Anderson, D. J. Wilcox, J. R. Whiting, and L. S. Nagey. 1995. Distribution of submerged aquatic vegetation in the Chesapeake Bay and tributaries and Chincoteague Bay—1994. Chesapeake Bay Program Office, U.S. Environmental Protection Agency, Annapolis, Md. 95 pp.

Vølstad, J. H., B. J. Rothschild, and T. Maurer. 1994. Abundance estimation and population dynamics of the blue crab in the Chesapeake Bay. Final report to Maryland Department of Natural Resources, the Chesapeake Bay Stock Assessment Committee, and the National Oceanic and Atmospheric Administration, Annapolis, Md.

White, C. P. 1989. Chesapeake Bay: nature of the estuary, a field guide. Tidewater Publishers, Centreville, Md. 212 pp.

Young-Dubovsky, C., G. R. Shepherd, D. R. Smith, and J. Field. 1993. Striped bass research study report for 1993. Final report to the National Biological Service and the National Marine Fisheries Service. National Marine Fisheries Service, U.S. Department of Commerce, Silver Spring, Md.

Coastal Maine: Island Habitats and Fauna

Blackwell, B. F., W. B. Krohn, and R. B. Allen. 1995. Foods of double-crested cormorants in Penobscot Bay, Maine, USA: temporal and spatial comparisons. Colonial Waterbirds 18:199–208.

Caldwell, B. 1981. Islands of Maine: where America really began. Guy Gannett Publishing Company, Portland, Maine. 241 pp.

Cantin, M., J. Bedard, and H. Milne. 1974. The food and feeding of common eiders in the St. Lawrence estuary in summer. Canadian Journal of Zoology 52:319–334.

Conkling, P. W. 1981. Islands in time—a natural history of the islands of Maine. Down East Books, Camden, Maine. 222 pp.

Drury, W. H. 1973. Population changes in New England seabirds. Bird-Banding 44:267–313.

Erwin, R. M. 1979. Coastal waterbird colonies: Cape Elizabeth, Maine to Virginia. U.S. Fish and Wildlife Service FWS/OBS-79/10. Washington, D.C. 212 pp.

Knight, O. W. 1897. A list of the birds of Maine, showing their distribution by counties and their status in each county. Kennebec Journal Print, Augusta, Maine. 184 pp.

Korschgen, C. E. 1979. Coastal waterbird colonies: Maine. U.S. Fish and Wildlife Service FWS/OBS-79/09. 83 pp.

Krohn, W. B., R. B. Allen, J. R. Moring, and A. E. Hutchinson. 1995. Double-crested cormorants in New England: population and management histories. Pages 99–109 *in* D. N. Nettleship and D. C. Duffy, editors. The double-crested cormorant: biology, conservation, and management. Colonial Waterbirds 18 (Special Publication 1).

Krohn, W. B., P. O. Corr, and A. E. Hutchinson. 1992. Status of the American eider with special reference to northern New England. U.S. Fish and Wildlife Service Fish and Wildlife Research 12. Washington, D.C. 12 pp.

Mendall, H. L. 1936. The home-life and economic status of the double-crested cormorant (*Phalocrocorax auritus auritus*) (Lesson). University of Maine Studies. Second Series, 38. Maine Bulletin 39(3):1–159.

Nisbet, I. C. T. 1971. The laughing gull in the Northeast. American Birds 25(4):677–683.

Norton, A. H. 1907. Report of Arthur H. Norton on colonies of birds in Maine receiving special protection in 1907. Bird-Lore 9:319–327.

Norton, A. H., and R. P. Allen. 1931. Breeding of the great black-backed gull and double-crested cormorant in Maine. Auk 48:589–592.

Steneck, R. S. 1995. Case study—the Gulf of Maine. Pages 209–212 *in* M. L. Hunter, Jr., editor. Fundamentals of conservation biology. Blackwell Science, Cambridge, Mass. 482 pp.