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New England's Forest Landscape

Ecological Legacies and Conservation Patterns Shaped by Agrarian History

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After a regionwide two-century period of deforestation and agrarian expansion, the dramatic reduction in agriculture in New England during the past 150 years generated a wave of land-cover change. Forest cover increased from less than 30% to more than 75% in many regions. Despite supporting one of the densest human populations in the nation, New England is among the most heavily forested regions in the United States. The story of this remarkable landscape transformation is one of recovery of nature, the legacy of past events in the details of modern ecosystems, and opportunity matched by challenge for conservation.

The reestablishment of forest ecosystem characteristics progressed unevenly, with compositional, structural, and functional attributes exhibiting different lags in development. In all cases, however, the modern distribution of vascular plant species, levels of forest biomass, and soil structure, chemistry, and fertility are strongly conditioned by legacies of a varied land-use history. The scale and grain of this landscape conditioning is controlled by the physical environmental template (e.g., topography, glacial geology, soils), geographical location relative to

population centers, and the specific cultural traditions of the regional population, which varies in subtle fashion. In general, however, the broad pattern has been for a homogenization of ecological characteristics at the site scale (resulting from uniformity in land use) and at the regional scale (resulting from broad-scale similar changes in land use and land cover), and for the development of a more patchy and heterogeneous structure characterized by abrupt ecological discontinuities at a landscape scale (resulting from the small-grained and patchy landownership and land-use pattern).

This changing landscape condition and pattern has generated distinctly different approaches to conservation and management, largely driven by individual value systems and the extent to which the legacies and lags are not only interpreted but also interpreted correctly. Each of these emerging traditions in conservation is based on different attitudes toward the history of agrarian transition and yields contrasting management strategies and ecological consequences. Four major traditions may be identified: (1) a preservationist approach in which either the forest landscape is read as near natural and therefore warranting complete protection, or a "rewilding" approach is taken toward the secondary forest and its developing natural attributes—represented by the wildlands approach and the approach seen in core areas in The Nature Conservancy (TNC) matrix forest; (2) an ancient natural landscape approach in which specific habitats and species assemblages are interpreted as relicts or descendants of pre-European landscapes, maintained prehistorically by fire and Native American activity and warranting active fire restoration and management today (this is a major approach to uncommon and high-priority grassland, shrubland, heathland, and savanna adopted by TNC, the National Park Service, and Heritage Programs); (3) a cultural landscape approach in which the ubiquitous legacies of European land use are recognized, and the maintenance and restoration of specific cultural landscapes and species assemblages [e.g., such as those mentioned in (2)] are sought by mimicking or reintroducing intensive traditional agricultural practices such as sheep grazing and mowing (which is a new perspective adapted by regional organizations and paralleling European conservation practice); and (4) a resource-based approach that seizes on the great annual wood increment in this region to argue for increased extraction, which is the working landscape approach that may well provide benefits to (1) and (3).

The landscape of New England has undergone one of the most remarkable histories of transformation worldwide. Once extensively covered with mature and old-growth forest, the land was cleared for agriculture, remaining forest areas were cut extensively for diverse wood products, and then, nearly as rapidly as it was cleared, the forest rebounded in extent and maturation after the regional decline in agriculture. This story is not unique in world history, as one can find roughly contemporaneous histories elsewhere in the eastern United States and portions of northwestern Europe, and an even greater landscape transformation in the Yucatan peninsula after the collapse of the Mayan empire. In New England there is a richness of scientific and historical details that offer great insights into major ecological, social, and conservational questions. In this chapter we explore this history and its human and ecological consequences, beginning approximately

500 years before European arrival. We combine social, biological, and physical science perspectives to address a series of broad fundamental and applied questions:

- What are the major physical, social, and biological drivers of change and how have these interacted through time?
- What are the ecological responses and consequences of the environmental changes that have occurred?
- How have these historical dynamics conditioned or constrained subsequent human activity and ecological dynamics?
- How can conservation and natural resource management integrate this history of ecological and social change into effective management strategies?
- What social, ecological, and conservation issues emerge from this historical-ecological consideration of the region's history?

Study Region

The Harvard Forest study focuses on three nested study regions: the New England region, the state of Massachusetts, and, in a few cases, subregions in central or coastal Massachusetts (Fig. 2.1A). The state of Massachusetts is the central focus because it captures much of the physical, biological, and cultural variation of New England. It provides a convenient scale for examining important cultural and environmental processes, and yet represents a feasible area for data collection and analysis. The Massachusetts study area is also relevant to a number of our major research programs (e.g., the Harvard Forest LTER; NSF funded), Harvard University National Institutes of Global Environmental Change (Department of Energy), Clark University Human Environment Research Observatory (NSF funded), and the Regional Forest Conservation Study (funded by TNC, the A. W. Mellon Foundation, and the USDA). In this work, broader regional contexts (e.g., New England, the entire United States, our global setting) and more local scales (e.g., town and family scales) are considered when they are pertinent to particular issues and drivers of change.

New England Region

The New England region (Maine, New Hampshire, Vermont, Massachusetts, Connecticut, and Rhode Island) displays considerable variation in vegetation and flora, natural disturbance regimes, and cultural history. The region has been strongly modified by many episodes of glaciation, and landscape patterns of soils, stream drainage, and topography have developed through interactions between the bedrock geology and the erosional and depositional history of the most recent glacial period, which ended approximately 15,000 years ago. New England is a predominantly hilly region of broad highlands ranging from 200 to 500 m above sea level (a.s.l.), with narrow valleys and a few broad lowlands and river valleys that extend below 200 m in elevation. On a broad scale and across local

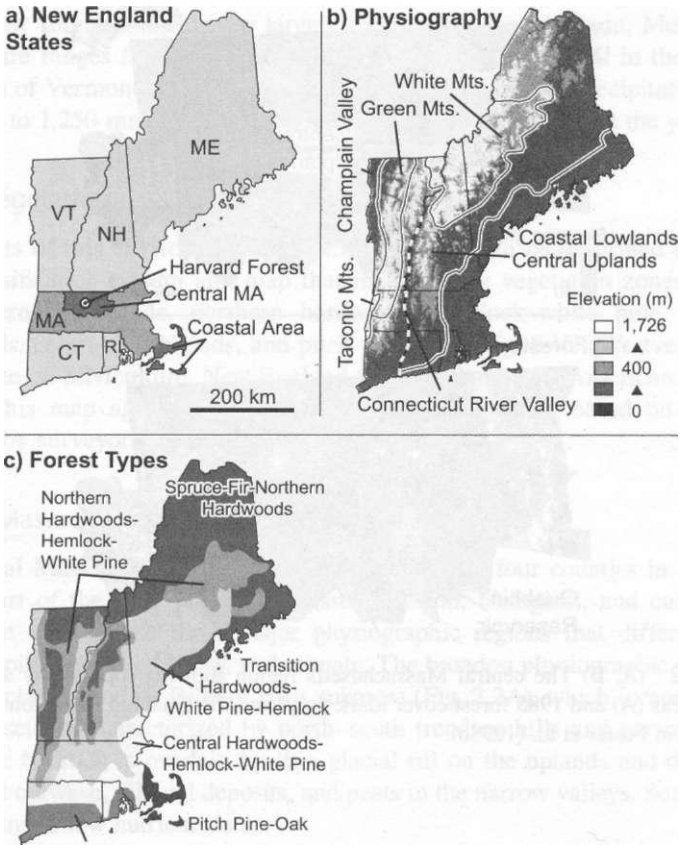

Figure 2.1 (A-C) A map of New England showing state boundaries and scales of research conducted by the Harvard Forest (A), elevation and physiographic areas (B), and forest vegetation zones (C) as described by Westveld and the Committee on Silviculture, New England Section, Society of American Foresters (1956).

landscapes, much of this variation occurs through alternating valleys and uplands that trend north to south because of the structure of the underlying bedrock.

Physiographic Divisions

Major physiographic areas that we have investigated in detail include the Green Mountain Uplands, Connecticut Valley, Central Uplands, and Coastal Lowlands (Fig. 2.1B).

The *Green Mountain Uplands* extend the length of New England. Metasedimentary and metavolcanic rocks constitute the bulk of these uplands. In general, this region has more productive soils and therefore a more diverse flora than the Central Uplands, including the area surrounding the Harvard Forest and the White Mountains.

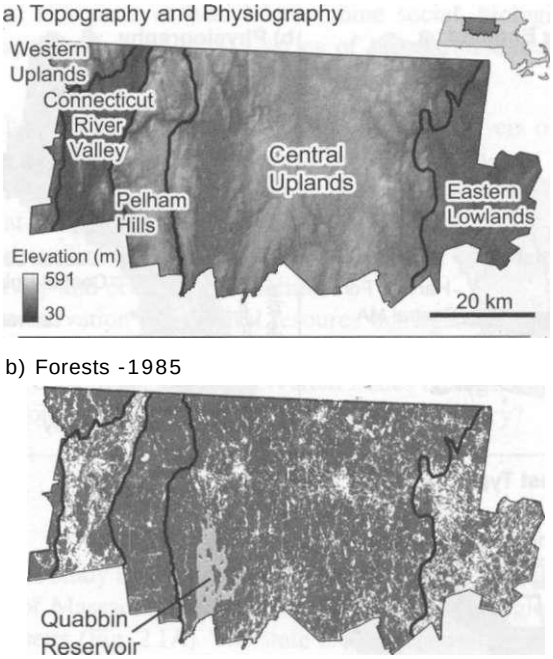

Figure 2.2 (A, B) The central Massachusetts region showing topography and physiographic areas (A) and 1985 forest cover (dark gray) and the Quabbin Reservoir (B). Based on data from Foster et al. (1998b).

The *Connecticut Valley* separates the two large upland regions in New England: the Green Mountains and the Central Uplands. It is underlain primarily by sandstone and shale to the south, and metasedimentary and metavolcanic rocks to the north.

To the east and north, the *Central Uplands* constitute the largest physiographic region and include the White Mountains, with the tallest peaks in New England, and the intensive study areas of the Harvard Forest LTER program (Fig. 2.2). The rocks of this region are variable but tend to be of metasedimentary and metavolcanic origin and produce acidic soils of low nutrient status.

The *Coastal Lowlands* form a 60- to 100-km-wide belt that extends from the shores of New Jersey to the central coast of Maine. Relief is generally low, the bedrock is highly variable, and the contact with the adjoining highland areas to the north and west is typically abrupt. The extensive coastal plain of New England is largely submerged off the Atlantic coast, where it forms the Continental Shelf.

Morainal and outwash deposits that have been modified by coastal processes since the last glaciation compose the areas from Cape Cod southward through the islands of Nantucket and Martha's Vineyard in Massachusetts, Block Island in Rhode Island, and Long Island in New York state. These coastal areas are dominated by sandy soils, low elevation, and varied relief.

Strong gradients in precipitation, temperature, and length of growing season across New England are driven largely by elevation and latitude. Mean annual temperature ranges from 11 °C in southern Connecticut to 4 °C in the northern highlands of Vermont, New Hampshire, and Maine, whereas precipitation ranges from 880 to 1,250 mm and is distributed fairly evenly throughout the year.

Forest Vegetation

The forests of this environmentally complex region can be described fairly well by a classification system and map that includes five vegetation zones: spruce-fir-northern hardwoods, northern hardwoods-hemlock-white pine, transition hardwoods, central hardwoods, and pitch pine-oak [Fig. 2.1C (Westveld and the Committee on Silviculture, New England Section, Society of American Foresters, 1956)]. This map agrees well with recent reconstructions based on tree data recorded by surveyors at the time of regional land settlement.

Central Massachusetts Subregion

The central Massachusetts area comprises portions of four counties in the north-central part of the state and encompasses physical, biological, and cultural gradients that vary across three major physiographic regions that differ in relief, geology, soils, land-use history, and climate. The broadest physiographic area is the Central Uplands (and its Pelham Hills subarea) (Fig. 2.2A), which in north-central Massachusetts is characterized by north-south trending hills and narrow valleys. The acidic bedrock is overlain by thin glacial till on the uplands and deeper and more level outwash, alluvial deposits, and peats in the narrow valleys. Soils are acid sandy loams of low nutrient status.

With the exception of developed areas, lakes, and marshes, the Central Uplands are forested, and there are few remaining farms. Upland villages with low population density are scattered across the forested hills, whereas larger, postindustrial towns and small cities border some of the major streams. The Quabbin Reservoir (10,000 ha; Fig. 2.2B), which was created in the 1930s and now provides drinking water for approximately 40% of the Massachusetts population living in the Boston metropolitan area, is surrounded by approximately 25,000 ha of land owned and managed by state agencies. The Quabbin Reservation forms the largest piece of an extensive, although loosely affiliated, conservation partnership—the North Quabbin Regional Land Partnership—which is composed of state agencies, nonprofit conservation organizations, and educational institutions, including the Harvard Forest. Most of the land in the area and, indeed, in New England is in small private ownership. Much of the forested land is actively managed for wood products and is extensively used for diverse recreation.

To the west is the Connecticut River Valley. The level to rolling plains at 30 to 75 m a.s.l. are underlain by sedimentary bedrock and support level deposits of outwash, alluvium, and glacial lake sediments. Soils range from excessively well-drained, sandy outwash to poorly drained, silty, floodplain sediments. A series of bedrock ridges composed mainly of volcanic basalt *(traprock)* emerges through

the valley bottom and reaches a maximum height of 400 m a.s.l. Its rich and fertile soils, level terrain, ease of river navigation, and long settlement history by Native Americans and Europeans have led to a modern cover of extensive farmland; concentrated urban, industrial, and residential areas; and discontinuous forests. In contrast, the traprock ridges remain largely wooded. The diverse environments from valley to ridgetop support a remarkable array of unusual plant assemblages. Along with its great cultural heritage, these make the Connecticut River Valley a priority area for state and national conservation.

To the east, the Central Uplands grade gradually into the Eastern Lowland, which is part of the extensive Coastal Lowland. This area of hills, gentle relief, and meandering rivers set in broad valleys ranges from 40 to 200 m a.s.l. Acidic bedrock is overlain by till, broad glacial lake sediments, alluvium, and marine deposits. The region grades eastward from rural, agricultural, and forested areas into the densely populated suburban and high-technology region adjoining Boston.

The physiographic variation across central Massachusetts yields subtle gradients in environment, history, and vegetation. The Connecticut Valley and Eastern Lowland have low elevations, gentle relief, and mild climates, with summer and winter temperatures that average 2 to 3 °C warmer than the intervening Central Uplands. In response to this climatic variation, southern plant species decline on the uplands, and the northern hardwoods-hemlock forest extends southward from New Hampshire onto this area of higher elevation. Broadly, the Connecticut Valley is lower, has more nutrient-rich soils, and is more agricultural than the Eastern Lowlands.

Precontact Native Land Use in New England

Any consideration of ecology or conservation in the New England landscape needs to consider the lengthy history of human activity and environmental change. Both have shaped the nature of the land and the vegetation, and both figure strongly in real-world discussions and decisions concerning conservation management and restoration.

Despite a long history of archaeological, historical, and paleoecological research, many fundamental questions remain regarding the activities of pre-European peoples. Addressing these questions provides a basis for extensive interdisciplinary collaboration within the Harvard Forest group. Major issues include the following:

- What were the environmental and social constraints to the size and subsistence patterns of native populations, and how did these patterns vary geographically and temporally?
- To what extent did human activities, including horticulture, hunting, and fire, modify the natural environment, vegetation patterns, and faunal abundance?
- What is the basis for the apparent discrepancy between archaeological data and ethnographic sources regarding population size, distribution,

subsistence patterns, and ecological impacts? Can these be reconciled through comparative multidisciplinary studies?

- Does our understanding of pre-European ecological and cultural patterns assist modern ecological interpretations and conservation planning?

Initial Colonization

The first people to arrive in the New England region encountered a boreal landscape that was dramatically different than today. The region's oldest archaeological sites date to 11,000 to 12,000 years before present (**BP**), a few thousand years after glacial ice had melted and large proglacial lakes had drained (Dincauze, 1990). The retreating glacier left large amounts of mineral sediments that filled river valleys and streams, and as a consequence of this and a higher water table overall, rivers flowed up to 60 m higher than they do today. Thus, many of the earliest archaeological sites have been buried or destroyed by postglacial river down-cutting.

Archaeological evidence for these first paleo-Indians indicates that they were hunter-gatherers living in fairly small family groups (20-50) who moved their encampments to exploit seasonally available resources.

Plant and animal life during this period were dynamic in response to deglaciation and relatively rapid climate change; the forests were dominated by northern conifer species, such as spruce and fir, and were interspersed with areas of patchy tundra (Dincauze, 1990; Foster and Zebryk, 1993; Gaudreau, 1988; Gaudreau and Webb, 1985; Lindbladh et al., 2007). Climatic warming and ameliorating conditions allowed white pine, spruce, fir, and temperate deciduous trees to migrate into southern New England at the time humans were arriving in the region (McWeeney, 2003).

Paleo-Indians apparently subsisted on a wide variety of plants and animals, including caribou, giant beaver, hawthorn seeds, wild grapes, and migratory birds (Dincauze, 1990; Chilton, 1999, 2002; Dincauze and Jacobsen, 2001). They relied on stone tools for a variety of tasks such as wood working, food processing, hunting, fishing, canoe building, and wigwam construction.

The Archaic Period

Through the Archaic period (11,000 to 3000 **BP**) native peoples continued to rely on hunting and gathering, but under greatly changing conditions. The environment ameliorated to temperate conditions, and the boreal forests were replaced first by white pine and oak forests, and then by a diverse forest of broad-leaf and conifer species (Dincauze, 1990; Foster and Zebryk, 1993).

During this period, people clearly adapted to diverse subregions: forested uplands, fertile valley bottoms, rich coastal environments, and interior wetlands. Evidence from many thousands of archaeological sites across New England indicate that population sizes grew, stone tools continued to predominate, and social groups occupied seasonal settlements within well-defined homelands. Fluted spear points were replaced by a diverse array of point types—side notched, stemmed,

corner notched—many of which exhibit subregional stylistic differences. The earliest evidence of houses dates to this period, presumably because evidence of earlier dwellings simply has not survived. It includes small, round structures that may have sheltered small, extended family groups. From archaeological evidence and ethnographic analogy, activity is interpreted as changing seasonally, with large groups coming together for social gatherings and to exploit concentrated resources, but splitting up into smaller groups to use widely dispersed resources (e.g., large spring fish runs vs. small winter hunting camps). These diverse site types are well represented in the archaeological record of the region.

Most archaeological sites of the Archaic period date to the Late Archaic period (7000 to 3000 **BP**), presumably as a result of an increase in population density as well as better preservation resulting from the stabilization of the sea level and riverbeds by about 5000 **BP**. Increased population is also reflected in the size of sites and evidence for multiseasonal use of certain sites. An increase in burial ceremonial artifacts may provide evidence for increased sedentism and a differentiation of social ranking that usually accompanies an increase in population.

In southern New England, people of the Archaic period clearly exploited the rich deciduous forests through the harvest, storage, and consumption of acorns, hickory nuts, beechnuts, and chestnuts. They carved dugout canoes from hollowed-out trees. Evidence exists of fishing in interior rivers and lakes, shellfish collecting, the hunting of deer and other terrestrial animals, and the collecting of hundreds of plant species for food, medicinal uses, and other purposes.

Indigenous Horticulture

Evidence supports the interpretation of a diverse foraging base for New England peoples. At the beginning of the Woodland period (3000 to 400 **BP**), archaeological evidence across eastern North America indicates intensive exploitation of weedy plants that grow in disturbed soils, particularly goosefoot *(Chenopodium berlandieri),* sumpweed *(Iva annu),* and sunflower *[Helianthus annuus* (Smith, 1992)]. The oily, starchy seeds of these plants were boiled and made into porridge, and the species were apparently modified genetically through selective breeding, representing the earliest phases of horticulture. Supporting evidence for these crops, beginning in 3000 **BP**, includes soapstone bowls and ceramic pots, which made superior cooking vessels for the boiling of nuts and starchy seeds to make them palatable and digestible.

There is suggestive, although inconclusive, evidence of forest management with fire by native peoples during the Woodland period (3000 to 500 **BP**) (Johnson, 1996; McWeeney, 1994, 2003). One effect of burning might have been the diversification of habitats that would support a wide variety of plants and animals, including berries, grasses, birds, and land mammals (Cronon, 1983).

Mobile Farming and Maize Horticulture

During the Late Woodland period (ca. 1000 to 400 **BP**), important innovations arrived in New England: (1) bow-and-arrow technology and (2) tropical cultigens

(maize, beans, and squash, which were originally domesticated in Mexico 5000 years **BP**). Although a few sites supporting maize horticulture date to 1000 **BP,** the earliest Accelerated Mass Spectrometry dates on maize kernels lie in the range of ca. **AD** 1300 to 1500 (Chilton and Doucette, 2002). Until contact with Europeans, maize was apparently only a dietary supplement to an otherwise diverse diet (Bernstein, 1999; Chilton, 1999, 2002; Chilton and Doucette, 2002; Chilton et al., 2000).

Although we know that maize horticulture was practiced by New England peoples, it may not have consumed much of their time or energy. After the planting of maize, groups would apparently disperse for 2 to 3 months as the maize ripened, to plant, hunt, and gather elsewhere (Cronon, 1983).

With regard to the interior of this region, the few postmolds located on Late Woodland sites appear to represent short-term wigwam-type structures. The overlapping pattern of these structures and other features, as well as a lack of well-defined middens, indicate repeated seasonal use of the same locations over time (e.g., Chilton et al., 2000).

The ethnohistorical literature supports an interpretation of diversity and flexibility in New England settlements. In 1674, Josselyn (1988/1674) reported: "Towns they have none, being always removing from one place to another for conveniency of food____I have seen half a hundred of their Wigwams together in a piece of ground and within a day or two, or a week they have all been dispersed" (p. 91). During the second quarter of the 17th century, Johan de Laet (cited in Jameson, 1909) said of Algonquian people living in the Hudson Valley: "some of them lead a wandering life in the open aire without settled habitation____Others have fixed places of abode" (pp. 105-109). Although it is clear that New England Algonquians were fairly mobile throughout their history, they were not nomadic. Rather, groups and individuals were moving within well-defined homelands and among interrelated communities.

When the English arrived, they likely misinterpreted their native pattern of mobile farming because this lifestyle and cultural practice would have been unfamiliar. It also would not have been viewed as a legitimate or proper use of land. In this light, it is easy to see the underlying justifications for the taking of Native American lands—whether implicit or explicit (see Chilton, 2005).

European Settlement History

The Rise and Fall of Agriculture, and the Fall and Rise of the Forest

The rise and fall of farming in New England, and the corresponding decline and recovery of the region's forest, is a familiar story. During the first half of the 17th century, a group of English settlers established agricultural communities on the coastal plain and in the lower Connecticut River Valley, often on former Native American village sites. With vigorous population growth, by the end of the colonial period these early towns had filled with farms, and new settlements were

spreading across the interior uplands. After the Revolution, a great wave of clearing occurred throughout the region, driven by continued population growth and expanding commercial opportunities. Farmland peaked at nearly three quarters of the landscape about the middle of the 19th century, after which time forest area began to rebound as New England agriculture adjusted to the new pressures of an integrated industrializing national economy. Marginal pastures were abandoned during the late 19th century as farming intensified, and more pastures and fields were abandoned throughout the 20th century as farm contraction continued. Tree growth paralleled the late expansion of forest cover as wood harvesting diminished. However, since about 1950, urban development has sprawled outward in a spatial pattern strikingly similar to the earlier expansion of agriculture, initiating a new wave of forest fragmentation and decline that presents a new challenge to conservation.

The Crucial Role of History in Ecology and Conservation

Within this well-known story lay two sets of questions that have not been well addressed, but are crucial to conserving the landscape of New England today. One set pertains to historical ecology, whereas a parallel set concerns environmental history. The first inquires into the particular patterns of land use across the region, how those patterns changed over time, and how they shape current and future environmental conditions. The second set asks what social forces shaped these patterns and drove these transformations, and how they changed through time. These questions are crucial because history matters; we are part of it, and our modern landscape bears its legacies and imprints. The better we understand past patterns of land use and their continuing influence on the landscape, the better we can work with these evolving systems to provide desired ecological conditions and ecosystem services.

Similarly, the way land was farmed and then abandoned in New England was not a simple reflexive response to outside technological and economic signals, but a much more complicated cultural evolution and accommodation. Rural society changed its economic and ecological organization over time, and constrained its behavior in various ways. Conservation today must work across a complex political landscape of public and private landownership that is subject to evolving cultural pressures. To accomplish anything, conservationists must tell a coherent and compelling story: one that places our situation today in the midst of an ongoing history of engagement with the land, not outside it. In both cultural and ecological terms, the simplistic conservation model of defending a pristine natural landscape from human disturbance has little meaningful place in New England. •

Changing Drivers of Land-Use Change

The primary driver of landscape change in New England has been the progressive integration of local land-use practices into an expanding market economy. Throughout four centuries the region has undergone a shift from production for household use and local exchange toward production for larger regional

commercial markets, paralleled by a shift from consumption of local resources toward consumption of imported resources. During the course of this transformation, land use has moved from highly diversified to satisfy local needs, to highly specialized to increase cash income, to largely unused for production but valued instead for residential and commercial development or environmental amenities. The transformation has been shaped by the rise of increasingly powerful industrial technologies of extraction and transportation, and the growth of an affluent urban and suburban population. The land did not simply respond to external market forces in a mechanical fashion. Massachusetts landowners played an active role in developing new attitudes and opportunities as they engaged the market. Along the way, they obeyed or overcame various cultural constraints, and the land itself changed in the opportunities and limitations it presented. All these factors conditioned how the land was used.

All the while, the dominant tendency for land use to be determined by short-term market calculus has been restrained by subordinate but strongly held cultural values that might be defined as different historical versions of "conservation." These countertendencies are important both because they helped shape the landscape in every period and because they form the basis of the modern conservation movement. They might be summarized as agrarian, utilitarian, and romantic. Understanding their history is as important as understanding changes in the land itself.

Historical Stages

Colonial Agrarian Economies, 1600-1775

The "Great Migration" between 1620 and 1640 brought fewer than 20,000 English settlers to New England, where they established agricultural communities along the coastal plain of Massachusetts, Rhode Island, and Connecticut, and up the Connecticut River Valley. The settlers rapidly gained a strong foothold because diseases, including smallpox, reduced the Native American population from some 100,000 to about 10,000, and left them in disarray. Thereafter, the newcomers' astounding fecundity (doubling in population every 25 years), their aggressive drive for land and resources, and their view of Native Americans as heathen savages with little moral claim to the land because they failed to "improve" it ensured their expanding control of the region. Nevertheless, resisting native groups (later backed by the French from Canada) kept the northern and western frontiers of New England a dangerous place until the mid 18th century. In the meantime, the second and third generations of English settlers filled the coastal region with farms and established the basic agricultural pattern of the colonial period.

That pattern was a close adaptation of European mixed husbandry to New England soils and climate. Although it incorporated elements of the Native American ecological system—existing settlement sites and planting grounds; cultivation of pumpkins, beans, and maize; low-lying meadows of native grass; abundant fish, game, and berries; and a forest rich in white oak, hickory, and

chestnut—its fundamental organization, the close integration of tilled crops and livestock, was English. The pattern of mixed husbandry revolved around producing a wide range of agricultural and artisanal goods for local economies organized at the household and community levels.

The Puritans were enterprising and not averse to participating in the market and economic improvement—as long as they did not become too "worldly." To maintain their accustomed level of material comfort, they imported textiles, metalware, sugar, rum, and tea, and engaged in a broad Atlantic trading network that focused on exports to the sugar islands of the West Indies, including fish, ship timber, pine masts, oak barrel staves, pine lumber, and cattle. Commercial production was hampered by the high cost of inland transport: It cost less to ship an iron pot from London to Boston than from Boston to Worcester, Massachusetts. New England, with its long winters and stingy, acidic soils, never developed a staple export crop like Virginia tobacco, South Carolina rice, or Pennsylvania wheat. Beyond that, New England was settled by middling families who lived in tight, religious communities and were less interested in maximizing individual wealth than in gaining a solid economic independence, providing a comfortable subsistence, and settling their many offspring successfully in the community. As a result, these yeomen produced secondarily for outside markets, but primarily for household consumption and trade with neighboring farmers and artisans such as blacksmiths, coopers, and tanners. In this way, the economies of New England towns grew mostly "within themselves," filling with farms that generated a small surplus for exchange (Donahue, 2004).

The system of husbandry that developed to fill these needs varied regionally, but included the following basic elements: tillage, mowing, pasture, orchard, and woodland. Most farmers possessed these in similar proportions, arrayed upon the landscape in similar ways.

Tillage was not the main use of agricultural land, but it was necessary for subsistence and therefore was practiced by virtually all farmers. Less than 10% of most towns was plowed in any given year: 10 acres/farm or less. Indian corn and rye were the principal bread grains. Little wheat was grown except in the Connecticut Valley, and little was consumed except by the wealthiest New Englanders. Some barley was grown for beer, although apple cider became the more common beverage. Potatoes, introduced by Scotch-Irish immigrants in about 1720, spread rapidly and became an important subsistence crop, doing well in poor acidic soils. Pumpkins and beans were grown in many corn fields, and most farmers also grew a little flax. Farm women tended gardens that produced many vegetables and herbs. The New England diet grew steadily more diverse and nutritionally complete as the generations passed (McMahon, 1985).

On the coastal plain, tillage land focused on sandy soils, which' were light, easily worked, and well adapted to corn and rye. In upland regions dominated by stony till, farmers sought out patches of sandy outwash or fairly level sites from which stones could be most easily removed, often along ridgetops. The latter gave rise to distinctive double stonewalls with small stone in-fill, bounding tillage fields. The most intensive tillage was usually located close to the barn so that the corn crop could be easily manured. These factors, strong kinship bonds,

and the practice of "trading work" for farm and household tasks gave rise to a pattern typical of many New England towns: small neighborhoods of farms surrounding patches of good tillage soil at intervals along the road, with extensive pastures and woodlots reaching back into the countryside. Manure was essential for corn and potatoes, whereas rye was seldom manured and was often sown after corn or in back fields broken out of pasture. Although much tillage land suffered some soil erosion, many fields likely *improved* in fertility over time. Given the thin, highly leached condition of native spodosols, the continual concentration of manure and incorporation of plant residues may have increased levels of organic matter and nutrients in many home fields. If crop yields were flat or declining in older towns by the end of the colonial period, it was probably the result not of soil exhaustion but rather of the fact that manure supplies were inadequate for increasing amounts of cultivated land.

Mowing land provided hay, which was critical to this mixed husbandry system, feeding livestock during the long winter and supplying manure to plowed land. During the colonial period, hay was largely supplied by native grasses in coastal salt marshes and wet meadows inland. These wetlands required considerable hydrological manipulation to make them productive, and they were transformed to a carefully managed resource in many towns. Extensive systems of drainage ditches, sometimes connecting for miles, rendered the meadows firm and accessible for teams during the mowing season, whereas dams, dikes, and road causeways provided hydrological control and augmented fertilization from natural flooding. Mowing, burning, and grazing, in combination with manipulation of the water table, shifted the composition of many wetlands from tree and shrub dominated to a cover of desirable grasses and sedges. The meadows returned a reliable yield of rather coarse hay, along with rich muck that was cleaned from the ditches in the fall, dried, and carted to the barnyard or plow land.

By the end of the colonial period, as the demand for hay steadily increased, native meadows were augmented by upland plantings of "English hay," consisting of red top, timothy, and red clover. This was especially true in upland regions where wet meadows were scarce.

Cattle were the principal stock in the pastoral New England economy. Many farms had a small flock of sheep (mostly for homespun wool), prosperous farmers kept a horse, and omnivorous swine ran at large in many areas. However, cattle were the economic mainstay, providing milk (converted to butter and cheese), meat, leather, locomotion, and manure. They also served as the main cash crop: Once fattened on pasture, they were driven to the ports. Farmers in most towns kept a small beef herd as a natural extension of their herd of six or eight milk cows. By the late colonial period, the Connecticut Valley, with its great surplus of hay and grain, even made a specialty of stall-fattening cattle that had been reared in surrounding hill towns (Garrison, 2003).

Pasture covered another quarter or more of most towns. Many different lands were grazed during the course of the season, including fallow plow land and mowing land after the hay was removed. But the great bulk of pasture was found on rough backland, after it emerged from the forest. During the 17th century, many older towns ran common herds on unsettled outlands, including woodlands

that were being gradually harvested or cleared and burned. As regeneration was suppressed and larger trees disappeared, this created open "wood pasture," which gave way to enclosed pasture with a few lingering shade trees. These were subsequently divided into private property and settled by younger generations. European sod-forming grasses (bluegrass, bentgrass, and white clover) were sometimes planted, but often simply spread in the dung of grazing stock. As farmers pushed into upland regions, they discovered that stony till soils, although ill-suited for the plow, had good water-holding capacity and made excellent pasture. At the end of the colonial period, pasturage was increasing in most towns.

Orchards also did well on soils derived from glacial tills, and most colonial farmers grew an acre or so of apple trees, primarily for cider. Cider replaced beer as the normal daily beverage throughout New England.

Woodland was also critical to local economies as an essential source of timber, fencing, and, above all, fuel, and most towns retained significant forest—anywhere from 30% to 50% in older towns, and of course much more in the younger hill towns (Donahue, 2004). Wood products were an initial by-product of forest clearance, but as remaining forest became scarce, woodland rose in value and was husbanded. Farmers moved toward renewable woodlot management—cutting clean on rotations of several decades, which encouraged strong sprouters such as oak and chestnut, and maximized production. Because there was still a great deal of escaped fire (from its use to clear woods, brush, and stubble in fields), pitch pine continued to find a place in colonial woodlands, especially on sandy soils in southeastern Massachusetts. Woodland was concentrated on the roughest land—rocky hills, swamps, and soils too droughty for grain or grass to thrive. Certain highly valuable resources could not be quickly regenerated, such as large oak and pine timber and white cedar, and these grew scarce through time, but most towns retained adequate wood resources.

By the end of the colonial period, New England supported a mixed husbandry and woodland ecological system that was reasonably stable. It was heavily slanted toward pasture and forest, as befitted the region's soils and climate. It supported a comfortable population. A set of ecological constraints, which we might call *agrarian,* were built into this system. On a practical level, because these local economies had to supply a wide range of goods, they tended to conserve a diverse landscape that included plenty of woodland. They also lived within deeply embedded social constraints: New England yeomen thought less in terms of their own immediate profit than in terms of the long-term comfort and economic independence of their families, and they fully expected one son to occupy the land they were farming, and other daughters and sons to settle nearby. The charge that they wore down their farms and moved on to cheaper frontier land is not reflected in their behavior, which reveals the same families occupied the same farmland for generations, often prospering.

These yeomen also lived within tightly knit communities in which certain norms of behavior were expected, and some resources were managed in common—in particular, water. Drainage and flow of wet meadows by brooks and rivers were carefully regulated, and anadromous fish runs were zealously guarded and integrated with the management of mill ponds. All these factors put limits

on the way individuals could readily use their land. On the other hand, there were some native ecological elements for which this agrarian society had little use, and these were in steep decline—for example, wolves, deer, beaver, pigeons, old-growth forests, and slow-growing forest trees like hemlock and beech. It was considered natural that such things should be heavily exploited or eliminated from the improved agrarian landscape. [See Cronon (1983) and Merchant (1989) for a somewhat different interpretation of New England's colonial environmental history.]

There was one aspect of this agrarian ecological system that was not at all stable: human reproduction. Family labor was extremely valuable on the land and in the house, and New Englanders reared large families. An emerging problem, of course, was how to establish grown children with farms or trades as the towns filled up and only one son could inherit the homestead. This demographic pressure led to ecological and social stress and a gradual decline in birthrates by the time of the Revolution. It also drove farmers increasingly into the cash economy as a means of giving children a start in life.

The Market Revolution, 1775-1850

As the generations after the American Revolution developed new upland towns across southern New England and pushed rapidly into the more difficult hill country of Maine, New Hampshire, and Vermont, they were part of a world undergoing powerful economic and cultural change. On the one hand, increasing population pressure in settled regions threatened many with marginalization. Farm families and new generations had to scramble to support themselves, and they had to engage deeper in the cash economy to acquire land or become established in a trade. At the same time, aspirations were changing. Far more consumer goods were available, and many rural people were eager to take part in the new economy. The maritime trading boom at the turn of the century, the rapid expansion of manufacturing along New England rivers, and an increasing urban population provided strong markets for farm produce. Improved roads and bridges, a handful of canals, and (toward the end of the period) the first railroads cut the cost of inland transportation.

New towns emerged to access water power at locations along major rivers as well as minor streams, and many existing towns that had been established on well-drained hilltops during the early agricultural period developed new industrial villages in the valleys (Fig. 2.3) (O'Keefe and Foster, 1998). The lasting landscape impacts of the mill towns followed from their infrastructural developments, particularly roads, which would shape transportation and land use in the following centuries as the urbanization process moved into the interior uplands (Kulik et al., 1982). With the building of railroads, the cost of transporting heavy, low-cost goods declined significantly.

Better farm tools and implements became available, and crop varieties and livestock breeds improved. All this crystallized by the second quarter of the 19th century in a *market revolution.* Farm families began to shift their focus to commercial cash sales. The opening of the Erie Canal in 1825, connecting

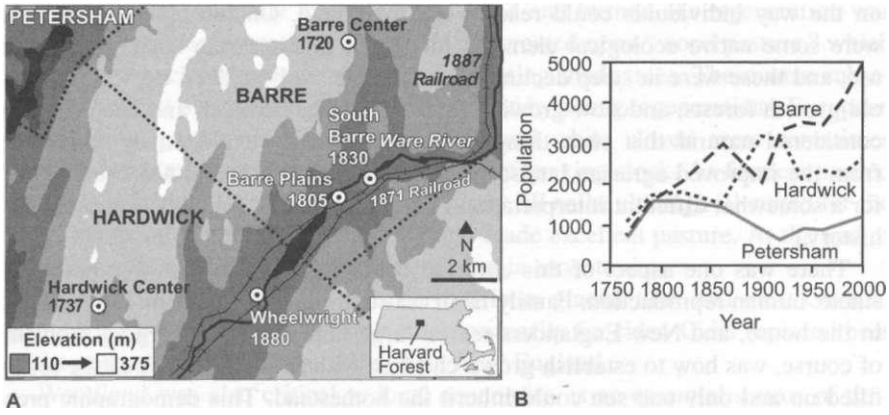

Figure 2.3 (A) Development of the towns of Barre and Hardwick, Massachusetts, showing the original agricultural town centers on high elevations during the early 18th century and subsequent creation of 19th-century industrial village centers in the valley bottoms. Because the best agricultural lands are on the broad upland ridges, and the rivers provided power for industry, the towns' population centers literally moved downhill through time. The presence of waterpower and railroads transformed towns during the 19th century. (B) Although the rural hill town of Petersham shows a population decline as agriculture waned, the industrial development of Barre and Hardwick allowed their populations to have a net increase through the mid to late 1800s (based on population data from U.S. censuses).

Lake Erie and the Hudson River, reduced the transport cost of food supplies from the Midwest to one 30th its previous cost (Van Royen, 1928). Rural communities began to meet many of their material needs through imports: wheat flour from the West replaced corn and rye meal, factory-made cotton and wool fabrics replaced homespun linsey-woolsey, shoes from Lynn replaced brogues made by a neighborhood cordwainer, coal from Pennsylvania (burned in a manufactured iron stove) augmented firewood, sawn pine two-bys (fastened with machine-cut nails) from Maine began to replace local oak and chestnut timber frames, and tea and coffee replaced hard cider as farmers became sober, calculating businessmen. The purchasing of basic commodities both allowed and required farmers to concentrate their own efforts on a few marketable crops, and the tight social and ecological constraints that had bounded the yeoman world began to dissolve.

Farmers adjusted by doing everything—from expanding their output of established crops to trying new specialty crops. Forests came under commercial pressure to supply proliferating wood industries. Almost every species spawned its own little business: spruce for the manufacture of ladders, witch hazel for liniment, and so forth. Remaining woodlands were typically cut on short rotations. However, the driving force in the commercial expansion of agriculture was pasture and hay for livestock, including the sheep boom that swept the forest from many hill towns in a generation or two. But just as important, throughout much of southern New England, was an increase in beef and dairy production.

The same transportation revolution that supported commercial production also exposed New England to the burgeoning national marketplace, bringing ruinous price pressure on traditional agricultural commodities such as meat and grain. By the 1830s, New England sheep were unable to compete with flocks raised on cheaper land in Ohio and beyond.

Ecological difficulties abounded. Rapid clearing drove forest cover to a low of perhaps no more than 25% across the region by mid century, and forest cover in some older towns fell to 10%. There were no more farms in these towns, but there was much more cleared land (Donahue, 2004; Hall et al., 2002). Deforestation was driven by the strong market for firewood and other wood products, coupled with the ability to ship in lumber, coal, and even firewood itself. The conservation of local woodlands was no longer an economic necessity. Rapid deforestation led to the population decline and even extirpation of many native wildlife species, and led (some have argued) to increased stream flooding, soil erosion, and sedimentation—all subjects worthy of investigation (Bernardos et al., 2004; Foster et al., 2002). Meanwhile, proliferating mill dams interrupted anadromous fish runs, and drowned many once-prized meadows (Cumbler, 2004; Donahue, 1997).

The expansion of upland grass proved unsustainable. Abundant English hay broke the limitations imposed by native meadows, and allowed larger livestock herds and greater manuring of plow lands. However, upland mowing ground was not recharged by annual floods, and many hayfields suffered rapid declines in yield. Pastures were also steadily drained of nutrients, and continuous grazing encouraged brushy native weeds and invasive species. Most of New England lies on acidic bedrock, which stealthily undercuts the efficacy of legumes such as red and white clover at restoring nitrogen to hayfields and pastures. It was not until the late 19th century that either the understanding or the means existed to apply lime (and other mined fertilizers such as phosphate) in sufficient quantity to counteract the downward trend. Consequently, by mid century, much of upland New England—so laboriously cleared of trees and stones—was filled with low-quality fields and scrub on its way back to forest. The land was pushed to greater productivity than during the colonial period by creating an ecologically precarious situation that was noted with alarm by many observers at the time. This was the landscape that inspired the warnings of George Perkins Marsh and Henry David Thoreau (Donahue, 1999; Foster, 2001).

Concentrated Products, 1850-1920

By the second half of the 19th century, the industrial revolution had followed the market revolution, greatly accelerating the trend toward consuming imported resources and specialized farming in New England—and in the process, reversing the trend from extensive to intensive use of the land. This was the age of rapid urban growth, and of iron, coal, and steam. New England became tightly connected to the national economy by rail and coastal steamer. The introduction of steam power, first in 1840, but more intensively in the early 1860s, fostered the rise of multiple factory complexes that filled in the industrial sections of large

cities, such as Lowell and Worcester. These factories were supported by a supply of immigrant labor from Europe along with female workers from the rural hill towns (Balk, 1944). With the increases in production and population, the industrial cities of southern New England became the center of manufacturing in the country.

The shift from an agricultural to an industrial economy was complete by the beginning of the 20th century. Roads were improved, increasing labor mobility and attracting more industry (Balk, 1944). The dramatic increase in urban-industrial populations during the early 20th century, especially in Boston, necessitated the major impoundment and diversion of water from central Massachusetts. The Wachusetts and Quabbin reservoirs were opened in 1908 and 1938 respectively, totaling a combined 44 sq. mi. and associated with more than 100,000 acres of protected watershed forest (Greene, 1981). Four towns, with populations that had all declined significantly during the previous decades, were removed for the Quabbin Reservoir.

Many rural hill towns began to lose farms and population during this period, and *farm abandonment* became a concern. But this was not true regionwide. Instead, farmers focused even more narrowly on what agricultural leaders called *concentrated products*—high-value, often perishable commodities for which they enjoyed a comparative advantage in nearby urban markets. The value (and yield) of farm output actually increased—peaking in Massachusetts, for example, in about 1910 (Bell, 1989; Donahue, 1999). Farmers concentrated their production on vegetables, fruits, poultry, and hay—the last too bulky for long-distance transport, and in high demand for city horses. But above all, New England farmers produced milk—perhaps four times as much in 1900 as in 1850. They did this, paradoxically, while abandoning most of their pasture—half of it by 1900, and three quarters of it by 1920. This was accomplished by buying cheap feed grain for their cattle from the western states, turning it into milk—concentrating its value—and applying the augmented manure to corn silage and the best hay fields, while letting exhausted pastures return to forest. Again, there were not dramatically fewer farms—just much less cleared land. Agriculture had become a thoroughly businesslike profession, integrated into the national economy and increasingly divorced from household production and local exchange. Farms were surrounded by rebounding forest and a declining rural population, rather than a vigorous local economy and majority agrarian culture, a twilight atmosphere captured in the poetry of Robert Frost (Barron, 1988; Black, 1950; Wilson, 1936).

Abandoned pastures initially supported red cedar, white pine, paper and gray birch, and some red spruce at higher elevations. Because markets for wood products remained reasonably strong, these new forests and older woodlots were frequently cut. A new industry, cutting pasture pine for wood boxes and containers, provided many hill towns (including Petersham, the site of the Harvard Forest) with a major new agricultural sector by the late 19th century. By 1920, forest cover had returned to encompass nearly 50% of the landscape, where it stood at the end of the colonial period—a century and a half earlier. But it was a much younger forest, undergoing dramatic compositional changes that are still evident today.

Suburbanization and Agricultural Decline, 1920 to Present

During the 20th century, industrial capitalism evolved from the *paleotechnic* world of iron, steam, and coal into a *neotechnic* era of oil, electricity, and chemistry. The years of World War I proved to be the zenith in Massachusetts's industrial production. Between the 1930s and 1970s, the golden age of mass production for other industrial regions in the country, southern New England experienced a period of sustained economic decline (Harrison and Kluver, 1989a). Manufacturing firms closed and traditional mill-based industries relocated entirely.

By the 1970s, New England's once-powerful industrial centers had become modern-day brownfields, with more than 1,100 contaminated former industrial sites in central Massachusetts alone (Rideout and Adams, 2000). The 230 contaminated sites in Worcester occupy almost 24.3% of that city's land area, inhibiting redevelopment of much of the city (Hoover, 2001). The contamination of former industrial parcels, and the liability issues associated with their redevelopment, has made commercial/industrial and new residential development in New England's older cities extremely difficult, adding to the many factors that are pushing growth outside urban areas.

The automobile became the symbol of the age, replacing the railroad as the dominant mode of transportation. American agriculture was transformed and enhanced in productivity by new technologies: chemical fertilizers and pesticides, hybrid seeds, broad-scale irrigation, and mechanization. New England farmers could no longer compete in this world of large-scale industrial production and long-distance transport. The market for hay collapsed as cars and tractors replaced horses. Fruit and vegetable production declined with increasing land costs near cities and competition from refrigerated produce shipped in from large growers in warmer climates. Poultry production consolidated to enormous confinement facilities in other regions, and eventually—during the second half of the century—dairy farms went the same way. Consequently, the number of farms and amount of land in agricultural production declined steadily in New England through the 20th century [a mere 7% of the Massachusetts landscape is farmed today (Hall et al., 2002)]. As a result, New England farmland continued to return to forest, reaching a plateau about 1950, since which time the ongoing expansion of forest in the highlands has been roughly balanced by the loss of forest to development in the coastal lowlands (Fig. 2.4). Although older agricultural industries such as dairy farming continue to decline, recent decades have seen a resurgence in small-scale organic farming, often on land protected by the purchase of development rights. Although this trend has done little as of yet to stem the overall slow but steady loss of farmland, it does offer some hope of retaining a portion of the landscape within an economically viable agrarian tradition.

Suburban development accelerated when the Massachusetts economy experienced a resurgence in the mid 1970s. Fueled by a venture capitalist community working in collaboration with the universities and research centers in the Boston area, the economic base shifted to services and high-tech manufacturing. This economic resurgence and its associated landscape change took place in the eastern half of the state first, driving land speculation as it expanded westward.

State Forest Cover and Population Trends in New England

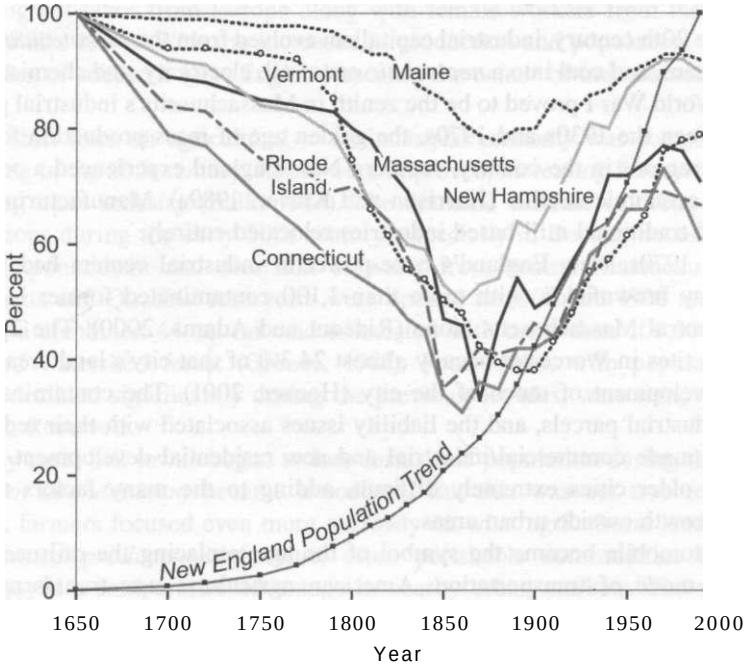

Figure 2.4 Changes in forest cover in each of the New England states and changes in population for New England as a whole.

Almost 90% of the high-tech growth in the 1980s was located in the triangle between Boston, Worcester, and Lawrence (Harrison and Kluver, 1989a). The new economy rekindled population growth, this time centered in suburban and periurban locations, filling in the spaces between old mill towns. During the 1980s, construction contracting grew twice as fast in the state as in the nation as a whole, and residential construction grew four times as fast, fueled by a high level of speculation in the housing market (Harrison and Kluver, 1989b). By the turn of the 20th century, this expansion had moved west of interstate highway 495, Boston's outer ring, making central Massachusetts one of the hottest real estate markets in the country and reawakening commuter trains from central Massachusetts to the greater Boston area.

The landscape consequences have been large. Periurban residential development, characterized by 2-acre residential lots located near major highways and junctions, is increasingly common to the east of Worcester. This pattern of development, which reflects a consumer preference for low-density housing near open space, has driven a decrease in forest cover and an increase in land fragmentation during the past few decades (Foster, 1993). From 1971 to 1999, 66,707 ha of forest and 11,648 ha of cropland were lost. During the same period, residential land use increased by 69,545 ha and commercial/industrial use increased by 12,028 ha.

The "industrial-service" economy transition of New England has had significant land-cover consequences for central Massachusetts and central New England, sustaining declines in agricultural land uses and reversing trends in forest regrowth established during the 19th- and early-20th-century industrial era. The post-World War II shift to a service-high-tech economy is linked to new "rural" pressures from expanding suburban and periurban settlement.

The past century and a half has seen a dramatic change in forest composition. Abandoned farmland is first dominated by early successional species such as white pine, cherry, birch, and red maple. Some of these species decline as the forest matures or encounters subsequent disturbances, but others persist for a long time. Meanwhile, some species common before the agricultural transformation, such as beech, have been very slow to recover. This has given rise to a forest not only very different from the frequently cut woodlands of the 19th century, but also distinct in composition from the forest of pre-European times. Suppression of fire in the landscape has favored some species, such as white pine and red maple, at the expense of others, such as pitch pine and white oak. Exotic pests such as chestnut blight and now hemlock wooly adelgid virtually eliminated some dominant trees from the forest canopy. Meanwhile, wood harvesting has declined steadily since the early 20th century, allowing the recovered forest to grow increasingly large and mature.

The practice of conservation has also evolved with the 20th century. During the 19th century, land use was largely determined by market forces and farmers' abilities to respond to those forces, as social constraints embodied in the older agrarian order dissolved. As a result, both farmland and forest were overused and degraded, in the short term. The conservation movement arose in response, with two main branches finding their roots in the figures of Henry Thoreau and George Perkins Marsh. The romantic branch emphasized the importance of a direct emotional connection with nature and appreciation of nature's wildness for itself, beyond human control or utility. The more utilitarian branch emphasized the sustainable use of resources through scientific management. These ideas have exerted considerable restraint on land use during the 20th century, beyond mere economic calculation. They have found expression in the acquisition of public forest and open space, the protection of wetlands, the promotion of sustainable practices in forestry and farming, and efforts to protect endangered species.

Today, conservation in New England faces formidable challenges in pressure for land conversion through suburban sprawl, as well as the continued influx of exotic pests, air pollution, and the likelihood of rapid climate change. But the ideals of conservation also face their own internal conflicts and contradictions, which might be alleviated by historical reflection. The romantic branch of conservation is plagued by what has been called the *illusion of preservation*, which begins with a broad misunderstanding of how "pristine" pre-European ecological systems functioned, and a simplistic wish to restore those supposedly stable conditions. A desire to "preserve" as much of New England as possible in a wild, unmanaged state is often combined with a refusal to examine seriously where the resources that support a rich material life come from. The suburban drive itself is an example of this illusion, being the impossible wish to live in an undeveloped

rural landscape by means of industrial extraction, a large residential lot, and a long commute. But the utilitarian branch of conservation is equally guilty of what might be called the *illusion of management.* This can be defined as a chronically weak appreciation of the value of wild nature, combined with overconfidence in the ability of science to understand fully and control complex ecological systems, let alone the cultural forces that persist in influencing ecological development in unpredictable ways.

With an understanding of history, it is possible to imagine how these two attitudes could be combined to create the conditions for successful long-term conservation—especially if some agrarian virtues were revived as well. That is, there is room in New England for the setting aside of substantial wilderness "old-growth" preserves, the productive and sustainable management of forests that support a wide range of biodiversity, and the revival of an agrarian cultural landscape that provides habitat for open-land species, along with healthy and rewarding human engagement with the land (Foster, 2002; Foster et al., 2005). Such a landscape would be ecologically diverse and flexible, and deeply satisfying to many New Englanders. A better understanding and inculcation of our fascinating and convoluted environmental history might not only improve our ability to design and "manage" such a landscape in its ecological particulars, but also give us a better chance of inspiring the cultural ability to pull it off.

Twentieth-Century New England Forest History: Growth and Utilization

Today, Massachusetts is a forested land. These woods, though, are very different from the ones that dominated the landscape before European settlement. Although forests have displayed great resilience in the face of human impact and have reclaimed much of their former ground following agricultural abandonment, human use of the land, both historical and ongoing, has imposed strong spatial and temporal signatures on woodlands. In a dynamic fashion, people continue to react to changes in the forest, and their actions shape the forest of the future.

The Dynamic Extent of Forest

At the beginning of the 20th century, much of New England was dominated by a relatively young and rapidly growing forest as a consequence of either agricultural abandonment in southern and central parts of the region or large-scale clear-cutting during the 19th century. In many cases, the forests naturally established on old farmland in the mid 1800s were clear-cut at the onset of the 20th century. The net effect of these human activities was a thick, brushy woodland dominated by stump sprouts and rapidly growing species. Patches of more mature woodland were scattered across perhaps 20% of the landscape (Cogbill et al., 2002). A small subset of these forests had escaped direct human influence and were generally located in remote small stands of old-growth and virgin woods (Cogbill et al., 2002).

Forest area continued to increase until approximately 1960, at which point competing land uses progressively reversed this trend, although existing forest continued to grow in stature (Fig. 2.4). By the mid 1990s, despite considerable population and economic growth in much of New England, the prevailing land use remained forest (59% of Rhode Island, 60% of Connecticut, 62% of Massachusetts, 78% of Vermont, 84% of New Hampshire, and 90% of Maine). However, many of these woodlands are small and barely offer more than a shady area. Spatial analysis of all forest in Massachusetts indicates that if pieces or fragments of forest smaller than 10 acres are omitted, the total amount of forest declines by 2.5%. If pieces smaller than 50 acres are not considered, the total amount of forest declines by roughly 7%. The story is somewhat different in more heavily forested New Hampshire. Exclusion of all forest pieces smaller than 10 acres reduces the statewide area of forest by only 1%, and failure to consider pieces 50 acres or less reduces overall statewide area by only 2.5%. The Massachusetts Audubon Society estimates that the state loses 44 acres of undeveloped open space per day, resulting in an annual loss of more than 16,000 acres (Steel, 1999).

Forest conversion is only part of the story, however. Interior forest is that part of the landscape that is free of effects that penetrate in from adjacent nonforest conditions. Factors such as elevated light and temperature; invasive exotic plants; higher populations of "generalists" such as gray squirrels, raccoons, skunks, and blue jays; ranging house cats and dogs; and accumulated lawn debris and old Christmas trees all occur to a greater degree in the forest around developed lands. These "edge effects" alter predator-prey relationships and can negatively affect native plant communities. Some wildlife requires interior forest conditions free of these edge effects. In a landscape study of 19 rural towns in western Massachusetts, although total forest declined by only 2% between 1971 and 1985, the amount of interior forest declined by 6%, 12%, or 21%, depending on an edge effect distance of 400, 1,000, or 2,000 ft., respectively (Kittredge and Kittredge, 1999). Although Massachusetts is heavily forested, it also has the third highest population density in the nation. Human influences penetrate the woods and shape its size and extent.

Forest Change over Time

The structure of the woods has undergone great changes through time. In Massachusetts there has been substantial net accumulation of wood since the 1950s (Fig. 2.5). Since the late 1920s, forest structure has shifted from 80% in the seedling/sapling size class (Cook, 1929) to roughly 3% by 1998. Larger trees increasingly dominate the forest, and the brushy expanses of the early 20th century have been relegated to the history books (Hall et al., 2002). With individual forests accumulating on the order of 2 metric tons of carbon/ha/year, one globally important consequence of this forest growth is that New England (and much of the eastern United States) serves as a major sink for carbon and offsets some of the potential increase in atmospheric carbon dioxide (Barford et al., 2001; Pacala, 2001).

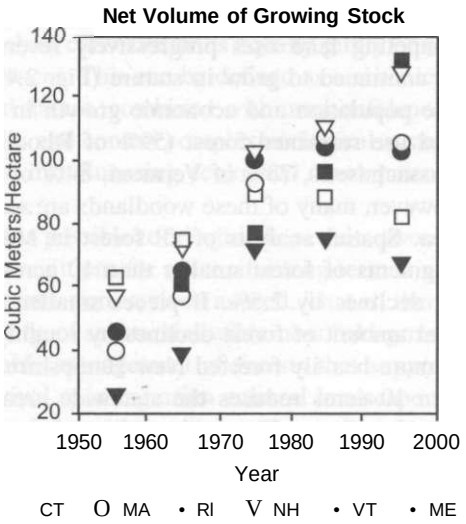

Figure 2.5 Net volume of growing stock (measured in m^3/ha) of six New England states from 1950 to 2000. Based on data from USDA Forest Service (2002).

Removals/Utilization

At the beginning of the 20th century, an active timber industry produced more than one hundred million board feet (bd. ft.) of lumber annually for local secondary manufacturing (Steer, 1948). Much of the timber came from white pine stands that had established on old agricultural lands 50 to 70 years earlier. Harvesting focused on converting standing softwood timber to cash and operated without any long-term plan or silvicultural design. Lumber production peaked between 1900 and 1920, and dropped precipitously through the 1930s, when regional forests entered a period of regrowth after heavy utilization. This heavy cutting generated a shift in species composition. In southern and central New England, logging of white pine on old fields initiated a change back toward a more natural species composition of mixed hardwoods (e.g., oak, maple, birch, ash), hemlock, and white pine (Hall et al., 2002).

By the early 1970s, Forest Service inventories reported average annual growing stock removals of between 0.54 and 0.96 m^3/ha forest (Connecticut, 0.54 m^3/ha forest; Rhode Island, 0.58 m^3/ha forest; Massachusetts, 0.87 m^3/ha forest; Vermont, 0.75 m^3/ha forest; and New Hampshire, 0.96 m^3/ha forest), with Maine considerably higher at 1.69 m^3/ha forest. By the mid 1990s, annual removal rates had virtually doubled, indicating the maturation of the timber and emergence of commercially valuable diameter classes. Despite increased removal rates, the forest continues to accumulate wood. Average annual net growth exceeds removals in all New England states except Maine by a factor of between 27% (in New Hampshire) to more than 130% (in Vermont). A recent study in north-central Massachusetts indicates that from 1984 to 2001, approximately 1.5% of the forest was harvested annually, in a spatially random pattern of relatively small patches in which perhaps only 25% of the forest volume was removed (Kittredge et al.,

2003). This pattern of chronic, low-level disturbance is probably representative of harvesting across much of the Northeast. The forest-processing industries have undergone similar shifts through time

Ownership

Unlike many wooded regions of the United States that have large state and federal ownerships or extensive industrial ownerships, most of the New England forest is owned by nonindustrial private families, individuals, and nonprofit organizations.

One consequence of this ownership pattern is that management decisions concerning the forests lie collectively in the hands of hundreds of thousands of individuals. With few local to regional controls, each owner is making relatively independent and unconstrained decisions. As a result, the New England forest landscape is strongly susceptible to two transforming influences: land conversion to nonforested use, and parcelization into smaller ownership units. These processes strongly interact; as increasingly small parcels become difficult to manage, they often become prone to land conversion.

Over time there have been a growing number of individuals who are responsible for New England forest land. In Massachusetts the number of owners of nonindustrial private forestland increased from 103,900 in 1976 to 235,000 in 1985, whereas the total area of forest declined slightly. The long-term result has been a decline in average ownership size from 9.5 ha to 3.6 ha between 1976 and 1993 (Fig. 2.6). Meanwhile, the land is becoming more valuable for development (e.g., for residential use) and is increasing only slightly in value for its timber (Fig. 2.7). Only increasingly wealthy private owners may be able to resist or defy market trends and financial logic of selling, dividing, or converting their land to a developed use. As ownerships decrease in size, forest landscape functions and values such as wildlife habitat, hydrologic and nutrient cycling, and outdoor recreation potential are compromised.

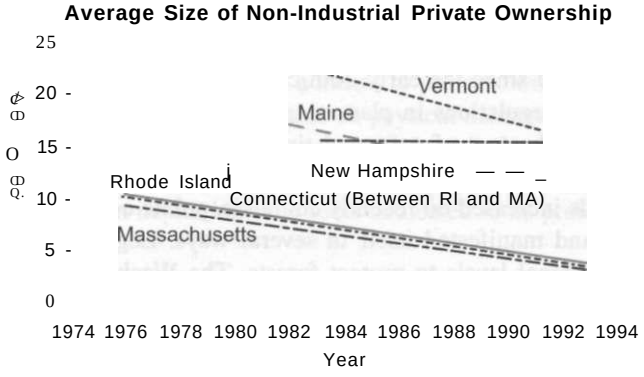

Figure 2.6 Average size of nonindustrial private ownership, by state and over time. Data modified from Kingsley (1976) and Birch (1996).

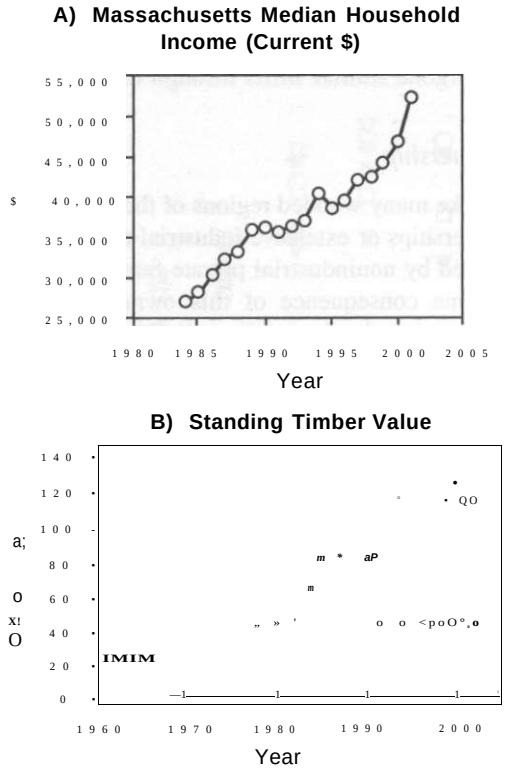

Figure 2.7 (A, B) Massachusetts median household income (A) and standing timber value (B) based on data from the U.S. Census Bureau, and SNESPR (Southern New England Stumpage Price) (2003).

Social/Human Responses to Perceived Threats and Utilization

The conservation context, major issues, and institutional setting for New England forests have evolved since the early 20th century. In the early 1900s, there were no environmental regulations in place to protect water quality or wildlife habitat, and the heavy harvest of softwood timber left large amounts of flammable material, resulting in increased fire frequency and intensity. As early successional brushfields increased on recently cut lands, public concern over forest degradation grew and manifested itself in several ways. Legislation was passed at the state and national levels to protect forests. The Weeks Act, passed in 1911, authorized the establishment of eastern national forests for purposes of watershed protection and resulted in the Green Mountain National Forest in Vermont and the White Mountain National Forest in New Hampshire and western Maine. In Massachusetts, the State Forest Commission was created in 1914 and was charged with acquiring land suitable for timber cultivation and forest reclamation (Rivers, 1998). Today, state forests cover a total of 211,000 acres. The Massachusetts

Forestry Association promoted the creation of local town forests throughout Massachusetts and other states, and in 1913 legislation was passed that authorized communities to own and manage their forests (McCullough, 1998). By the 1960s, 147 of 352 Massachusetts communities had town forests, totaling more than 43,000 acres (McCullough, 1998).

State legislation was also passed to protect forests through regulation. In 1914, the Massachusetts Slash Law required timber harvesters to leave slash in a condition that would not promote the spread of fire (Rivers, 1998). In 1945, the Forest Cutting Practices Act was passed in Massachusetts (Rivers, 1998).

In addition to public sector conservation actions, many private organizations were started in response to forest and environmental degradation. The Massachusetts Forestry Association began in 1897, in response to clear-cutting on Mount Greylock, the state's highest peak (Rivers, 1998), and similar associations were founded in other New England states (e.g., Connecticut Forestry Association in 1895, Society for the Protection of New Hampshire Forests in 1901, Forestry Association of Vermont in 1904) (King, 1998). The Massachusetts Audubon Society was founded in 1896, with an original interest in protecting birds and their habitat (Fox, 1998), and the New England Forestry Foundation was founded in 1944 to promote forestry to the thousands of nonindustrial private forest owners. The foundation sought to demonstrate good forestry practices and advocated the use of private consulting foresters to encourage sustainable management.

The early 20th century initiation of organizations and regulations to "protect forest" has evolved with newly perceived threats. During the past 20 years, distress over forest conversion to other uses has led to the strategic application of tools like easements to stem and focus the tide of widespread development and the overall loss of open space. Ironically, the perceived threat of forest destruction in the early 1900s was largely an illusion. History has shown forests to be resilient to hurricanes, fire, and harvest (Foster et al., 1997; Hall et al., 2002). In contrast, the development threat of the late 20th century is a new and different agent of change. State agencies and conservation groups have responded and are now buying private land, or the development rights to the property in the name of biodiversity (EOEA, 2001). Even the New England Forestry Foundation and conservation organizations like TNC actively pursue easements as a means to protect "working forest." Forest regulations have shifted from an emphasis on physical damage, to provision of tax breaks as incentives to landowners to retain their land in forest use (DEM, 2003). Although the New England forest has transformed greatly during the past century, so, too, have the human institutions and tools dedicated to its protection.

Future

Two parallel messages emerge from a 20th-century review of New England forest use and change: both the forest itself and corresponding human institutions have evolved in response to diverse stimuli. Perceived threats to forest have initiated public and private efforts at protection. These in turn have influenced forest

trajectories. Public forests originally established to prevent deforestation are now oases from development and valued open spaces for recreation and revitalization. The large watershed of the Quabbin Reservoir was purchased to provide clean water for metropolitan Boston, but it currently serves as the largest and most intensively harvested public ownership in southern New England (Barten et al., 1998) and acts as an "accidental wilderness" (Conuel, 1990) that provides a diverse landscape for wildlife, natural processes, and human leisure. Land protection activities have curtailed the development rights on an increasing amount of private forest, and regulations have influenced harvest practices.

Future forest and societal interactions are conjectural because of the complexity of private landowner patterns and the unpredictability of social and environmental concerns. It is unlikely that governments will be able to buy a significant portion of this land, although there may be better prospects for the purchase of development rights. Furthermore, it is improbable that land-use zoning and regulation, implemented at the local level by hundreds of different volunteer boards in an environment that favors private rights, will stem the tide of forest conversion in the face of increasing population, affluence, and mobility. The future of the forest will result from the cumulative actions (or inactions) of tens of thousands of individuals, whose decisions in turn will be influenced by their relative affluence, seemingly unrelated external economic factors, and their attitudes about their land. Only if these grassroots inclinations can be marshaled into a region-wide passion for land conservation will it be possible to retain a majority of New England forest on the land (Foster et al., 2005).

Studies of private owner attitudes in New England reveal that aesthetics, wildlife habitat, recreation, privacy, and a place to live are overriding goals for ownership that far outweigh timber revenue (e.g., Belin, 2002; Birch, 1996; Kingsley, 1976; Rickenbach et al., 1998). Finley and Kittredge (2006) indicate that landowners do harvest, but at a relatively moderate intensity level. This chronic, and random disturbance may homogenize forest conditions and species composition (Cogbill et al., 2002; Fuller et al., 1998), and may create forests dominated by red maple, which commonly increases with light harvest (Abrams, 1998).

The future extent, distribution, and composition of the forest will result in large part from the decisions private owners make about their land. Decisions about land protection made by agencies and conservation organizations will also exert a lasting effect, especially on the character of large blocks of forest. The success of these groups depends in part on the way they approach private owners, and the receptivity of the message. Golodetz and Foster (1997) showed that land protection during the 20th century in central Massachusetts was haphazard and opportunistic. Conservation can have a more significant impact, and be more cost-effective, if these measures are applied in a more strategic and meaningful way (Forman 1995).

How the New England forest transforms in the coming century will depend on the pressures brought to bear by an increasing human population, a variety of external ecological factors such as climate change and invasive species, and the cumulative effects of an increasingly large and dynamic population of private owners.

The Ecological Consequences of New England's History

For more than 300 years, changing land-use activities have interacted with natural environmental and disturbance processes to generate major changes in the New England landscape. In the modern landscape, the legacies of this history shape ecological patterns and processes, condition ecosystem response to ongoing and future disturbances and stresses, underlie current dynamics in plant and animal populations, and provide the environmental context for ongoing human activities. More important, the nature of these historical effects on ecological patterns varies with spatial or ecological scale. For example, at any scale the composition and structure of modern vegetation are substantially different than they were before European arrival. However, at some spatial scales, including the site scale and subregional scale, land-use history has served to homogenize the natural patterns, whereas at a landscape scale a more patchy and heterogeneous condition has resulted.

Vegetation Response to Land-Use History

Across New England, the intensive utilization of wood products, coupled with the history of deforestation, reforestation, and other anthropogenic impacts, including burning and drainage, have produced major changes in forest composition and structure when compared with the forests first encountered by Europeans. Although forests per se have been highly resilient to repeated intense disturbances, there has been a shift toward more fast-growing, early successional, and shade-intolerant species (e.g., paper birch, red maple, white pine, and formerly chestnut) and a decline in long-lived mature-forest species (e.g., beech, hemlock, spruce, and yellow birch). Structurally, there have been accompanying declines in average stand age and an increase in the extent of even-age forests. Across the region, this substantial shift in species composition apparently has not been associated with major changes in species distributions or the geography of major forest zones. At a regional scale, major vegetation patterns are largely controlled by strong, broad-scale climatic variation, tied to latitude and elevation, and the basic patterns witnessed hundreds of years ago appear to hold in the modern landscape. Thus, in a consideration of the presettlement forests, Cogbill et al. (2002) identified a regional pattern composed of distinct distributions of northern and southern tree species that met in a fairly well-defined tension zone stretching across north-central Massachusetts. In their interpretation, this tension zone has been relatively stable through to the present despite notable shifts in temperature (+1.40.°C) and the intervening period of land-use history.

In contrast, at the subregional scale, for example across the Connecticut Valley to upland transition in central New England, it appears that the striking broad-scale variation in forest composition at the time of settlement, with oaks predominating at lower, southern localities and beech and hemlock dominating in the cooler northern higher areas, has disappeared as a consequence of land-use history. In this case, vegetation patterns were associated with fairly subtle climatic

gradients. The imposition of a broadly similar land-use history across this subregion served both to shift and to homogenize forest composition. Across the region today, red maple, oak, birch, pine, and hemlock are distributed in a rather uniform pattern. Although species abundances exhibited strong, significant relationships with climate variation at the time of settlement, only a few weak relationships are detected in current distributions. One complicating, though intriguing, factor in this history is that the trend toward a more regionally homogeneous forest composition was actually initiated by climate changes approximately 550 years ago (Fuller et al., 1998). Thus, the observed shifts are evidently a consequence of the interaction between environmental change and human activity.

At a landscape scale, across hills, valleys, and township-size (i.e., 10 x 10 km) areas, land-use history has clearly created a more patchy and heterogeneous pattern of vegetation. On this scale, abrupt shifts in vegetation cover, species composition, and forest age and size are strongly tied to such factors as the specific land-use type (e.g., woodlot, pasture, tillage), the date of field abandonment or last harvesting, and the specific details of recent use of the area. The result is a complicated landscape mosaic in which transitions from hardwood forests to white pine or mature forest to sprout hardwoods are abrupt and only generally tied to edaphic conditions. At this scale, vegetation analyses indicate that land-use impacts convey an enduring effect on species distributions and community characteristics (Donohue et al., 2000; Motzkin et al. 1996, 1999a,b, 2002). Studies of soil properties demonstrate a similar lasting imprint of land use on such features as soil structure and carbon and nitrogen content (Compton and Boone, 2000, 2004; Compton et al., 1998).

There has been little work done to evaluate the consequences of land-use history at the scale of an individual stand or forest, but it is likely that within a given area of consistent vegetation, historical activities have simplified and homogenized soil conditions, vegetation patterns, and microenvironmental conditions. Although pre-European conditions would have reflected the complexities of subtle edaphic variation and prior disturbance by windthrow, animals, and other factors, most land-use activities serve to create uniform within-stand conditions. Forest clearance, tillage, pasturing, and fencing all impose fairly uniform treatments on areas frequently delimited by stone walls, other fencing systems, or property boundaries. Whether the impact was homogenization of the upper soil layers by plowing or removal of coarse woody debris by fire and decomposition, the tendency toward more consistent conditions in the individual patches within the patchwork of agrarian sites would be passed on to the modern forested landscape.

Discussion

Consequences of Land-Use History for Conservation

One of the major ecological lessons that inevitably emerges from a long-term perspective is that natural ecosystems are inherently dynamic (Davis, 1986; Whitlock and Bartlein, 1997). More important, however, a variety of studies that

have assessed vegetation change over very long timescales have found that the rates of compositional change for both terrestrial and aquatic ecosystems have been, and presumably will continue to be, greater since European settlement than at any time since the last Ice Age (Foster and Zebryk, 1993; Fuller et al., 1998; Jacobson et al., 1987). In prehistory, climate and associated environmental change, as well as disturbance by pathogens, wind, ice storms, fire, and Native Americans, produced changes in vegetation composition and presumably in its structure and pattern as well. Plants and animals responded individualistically, rather than in any concerted group response to the unique combinations of environments and biotic factors that resulted. Consequently, as recently noted by Lawton (1997), although there is a relatively long fossil record of stability in the morphology of most individual plant species, the actual combinations and assemblages of species that form communities, ecosystems, and landscape patterns have no record of long-term coherency. The massive and very rapid change in land cover and land-use practices within the recent 300 to 400 years in the eastern United States have accelerated this process of natural change and recombination (Jacobson et al., 1987). The result has been a series of very transient assemblages derived from a relatively constant regional flora (Fuller et al., 1998; McLachlan et al., 1998)

One major question that concerns the reforested northeastern landscape is whether these "new" forests are similar in composition to those that occupied the same land areas at the time of European settlement (Raup, 1964; Whitney, 1994). A range of studies across New England suggest that modern plant (and animal) assemblages in upland, wetland, and lake ecosystems are historically anomalous, differing from those of four centuries earlier (Engstrom et al., 1985; Patterson and Backman, 1988). Not only do the modern groupings of species show little resemblance to their antecedents, they also show little tendency to revert in that direction as time passes and forests mature (Fuller et al., 1998). At a regional scale, for example across central Massachusetts, the forests that have formed after agricultural abandonment are remarkably more homogeneous than those of four centuries earlier, and they include more sprouting and shade-intolerant species and fewer long-lived mature-forest tree species (Foster et al., 1998b). Modern forests also exhibit much weaker relationships to regional variation in physiography, climate, and soils. At a landscape scale, the arrangement and structural and compositional characteristics of plant communities are largely the consequence of species-specific response to land-use histories and edaphic factors (Foster, 1995; Motzkin et al., 1996, 1999a). At a stand level, it has been possible to use the analysis of pollen from soils and small topographic depressions to interpret vegetation composition and disturbance histories over many centuries or even millennia, and thereby assess the extent of change (Bradshaw and Miller, 1988; Foster and Zebryk, 1993; Foster et al., 1996; McLachlan et al., 1998). Although limited in number in New England, these studies confirm that even the least disturbed sites, for example forests that were cut early during colonial history but never cleared, have been dramatically changed by human disturbance. Thus, these sites have often supported two or three distinctly different types of vegetation during the past 350 years, and the current forests generally bear little compositional resemblance to those that occupied the area when the land was first settled by Europeans.

These conclusions concerning the historical rates and types of vegetation change have many ramifications for conservation biology and the development of management policies. Primary among these is the recognition that there are no static baseline conditions that exist or have existed for comparison with current conditions or for use as a target for restoration activities. Ecologists, conservation biologists, and the public frequently use the pre-European period as a convenient benchmark for comparison with modern or historical conditions (as we have done earlier); however, this period was clearly characterized by change and flux in forest composition and structure, even if less dramatic than in the recent past. As we interpret modern landscapes or evaluate restoration and management approaches, we therefore need to recognize that forests have always been dynamic and that there is no single, ideal state to which forests should be restored. Nature changes and frequently people are a factor in this change. Thus, in our search for goals and objectives in conservation management, we should not be thinking of saving or restoring static examples of what nature is, was, or should be. These are transient entities, unreal concepts, and futile objectives (Foster et al., 1996).

The Inevitability of Future Change

The extent of human disturbance coupled with the ongoing change in global environments (climate, atmospheric composition, disturbance regimes, biota) result in the inevitability of future change in all landscapes. As a consequence, land managers of all types need to acknowledge change and anticipate future dynamics. Most New England landscapes are still in the process of recovering from past land-use activity while also responding to new changes in the physical or biotic environment, ranging from subtle stresses associated with changes in the atmospheric concentrations of nitrogen and carbon dioxide to defoliation by the gypsy moth and hemlock woolly adelgid, an insect species introduced from Asia in the 1920s (Aber, 1993; Bazzaz, 1996; Foster et al., 1997; Orwig and Foster, 1998). Hemlocks are the third most prevalent tree species in the New England forests, and they provide food for deer and protection from soil erosion along streams and rivers.

Paleoecological studies (e.g., Foster and Zebryk, 1993) and modeling approaches (Pacala et al, 1996) suggest that forest stands may take up to 500 years to recover from moderately severe disturbances such as fire, pathogens, harmful introduced species, or substantial cutting and thus we should anticipate that all vegetation, even if effectively protected from recent or future disturbance, will continue to change as it adjusts to its history of past impacts. In addition, natural disturbance and natural variation in the environment will inevitably promote future, unexpected dynamics in all ecosystems.

Wildlife Dynamics and Feedback in Perspective

Recent changes in many wildlife populations constitute one important, although often underappreciated, component of landscape change in the eastern United States that has strong implications for conservationists, natural resource managers,

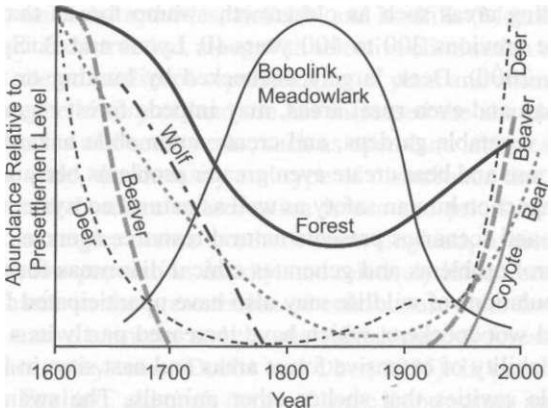

Figure 2.8 Schematic depiction of the historical changes in representative wildlife species and forest cover through time in New England. Although the wolf has been eliminated, open-field species like the bobolink and meadow lark peaked in abundance during the 19th-century period of open agriculture; the coyote is a new species in the landscape; and the deer, beaver, and bear have recovered greatly since elimination or very low historical abundance. Modified from O'Keefe and Foster (1998) and Bickford and Dymon (1990).

and many residents. As a consequence of historical variation in the relative extent and type of land cover, along with cultural and economic changes that have encouraged conservation, wildlife introductions, and regulation of hunting, the New England region is undergoing a major transformation in wildlife abundance and composition (DeGraaf and Miller, 1996; Fisher, 1929; Hosley, 1935). Although many large mammals and forest birds were eliminated during the 17th to 19th centuries and were replaced by the open-land species of meadows, fields, and shrublands, we are currently witnessing a major resurgence of native woodland species (Fig. 2.8). Some of these animals have been resident throughout the historical period and are simply expanding from small residual populations, others were locally or regionally eliminated and are immigrating from northern and western regions, whereas others have appeared as a consequence of successful programs of reintroduction. Although many of these species were important throughout the Northeast at the time of European settlement, others, such as the coyote, were originally native in other parts of the country and represent new arrivals that have been able to capitalize on changing landscape conditions and the absence of competitors or predators such as the wolf.

The recent increase in woodland species is often heralded, quite rightly, as an environmental success, but the burgeoning populations of woodland wildlife are also bringing many unexpected and occasionally undesired consequences to the landscape and to the largely suburban human population of New England. Beavers impound water creating wetlands, killing trees, and flooding roads, yards, and sewage systems while also producing important habitats for other animals and plants that utilize the resulting ponds, wetlands, and dead trees. There is evidence that the population of beavers in some regions may be surpassing presettlement

levels and flooding areas such as old-growth swamp forests that have not been inundated in the previous 300 to 400 years (P. Lyons and B. Spencer, personal communication, 2000). Deer, largely unchecked by hunting or major predators in many suburban and even rural areas, may impede forest regeneration, browse ornamental and vegetable gardens, and create automobile hazards. Larger mammals such as moose and bear create even greater problems because of their potential for major impact on human safety as well as natural ecosystems. Each of these wildlife species and scenarios presents natural resource agencies and landowners with major control problems and generates ethical dilemmas for society.

The new populations of wildlife may also have unanticipated impacts on other species. Pileated woodpeckers, which have increased partly as a consequence of the greater availability of extensive forest areas and nest sites in large dead trees, create large bole cavities that shelter other animals. The swamps, ponds, and meadows that alternate through the cycle of beaver damming and abandonment provide a highly dynamic environment that presents considerable heterogeneity within a largely forested landscape. The extensive stands of dead trees produced by this flooding also provide nest sites, resulting in the large heron rookeries that have reappeared across the New England states.

Human health may also be indirectly affected by the changes in land-use, land-cover, and wildlife dynamics. The increase and spread of lyme disease has resulted, in part, from the increase in mouse and deer populations during the past several decades; a similar connection is noted between the incidence of *Giardia* (a parasitic protozoan) and beaver and other mammal populations in New England. A historical perspective on these wildlife dynamics is necessary to understand them and to anticipate how they may change in the future. Such a perspective is also extremely useful in educating a human population that is increasingly separated from nature about the changes that are occurring throughout the landscape, including their own backyard. Clearly a better understanding of these dynamics and their causes improves the ability of natural resource managers and conservationists to manage them and their consequences.

New England Is a Cultural Landscape

An evaluation of the past and current dynamics of the northeastern United States suggests that we must embrace wholeheartedly and realistically the notion that we live in a cultural landscape that is shaped in a broad pattern and controlled in fine detail in part by a history of human impacts. Recognition of this fact helps us to appreciate that humans have been, and still are, a major force and part of the functioning ecosystems that we call nature. It also helps us to shed the notion that we can somehow preserve or restore a nature independent of human history. On a regional to landscape scale, many habitats have been selectively eliminated or converted to some new status. Wetlands have been drained on a widespread basis on inland as well as coastal sites, and changes in local hydrology have left us with distinctly different habitats and vegetation cover than have occurred historically (Tiner, 1988). Across New England upland areas, sites such as the level sand plains that occupy outwash and deltaic deposits have been extensively converted to

industrial and commercial activities, airfields, and landfills (Motzkin et al., 1999a). This selective habitat destruction, along with selective elimination of species, leaves us with a highly altered landscape representation of plant and animal communities. At the same time, the history of land use has increased the abundance and importance of many species and ecosystems, such as open-land and weedy taxa.

On a regional scale, the intensity and type of disturbance that has occurred is highly variable, and therefore conservation issues and priorities may vary geographically. For example, across northern New England, a history of logging, large ownerships, low population density, and relatively intact forest cover has led to a recent emphasis on the preservation of continuous, older forest; the reintroduction of large native animals; and the reestablishment of forest processes typical of large, intact ecosystems (Dobbs and Ober, 1995). In contrast, in southern and central New England, although many of these same values are embraced, the history of intense agriculture has been extremely important for the generation of a landscape of open fields and highly fragmented forests. This, in turn, has led to increased focus on rare species in limited habitats and on the maintenance of many open-habitat plants, animals, and landscapes (Dunwiddie, 1992).

Recognition of the selective creation and destruction of habitats and the tendency toward change forces us to acknowledge that the maintenance of species and habitats that were common 50 to 100 years ago will require active management either by encouraging or subsidizing historical practices such as agriculture, or by replacing them with other management regimes (Birks et al, 1988; Dunwiddie, 1992; Foster and Motzkin, 1998). In some cases, such as the conservation of open-land species of plants and animals, we may need to maintain cultural artifacts or legacies that were much less common or even absent from the landscape 300 years ago. Perhaps the best example of this phenomenon lies in the efforts to conserve grassland and shrubland habitat and species across southern and central New England and other parts of the Northeast (Foster and Motzkin, 2003). Presumably, before European arrival, few areas were large enough to maintain some of the highly restricted and rare bird species that are the current focus of major conservation efforts but that may require more than 50 ha of open grassland for the maintenance of successful populations. However, as a consequence of forest cutting and agricultural activities such as burning, plowing, planting, and grazing, extensive upland grasslands, freshwater meadows, shrublands, and heathlands were created during the 18th and 19th centuries, resulting in a dramatic increase in open-land wildlife and plants (DeGraaf and Miller, 1996; Dunwiddie, 1989). The prominence of these species is quite clear in contemporary descriptions, such as the journal notations from Henry Thoreau in which bobolinks, meadowlarks, and song sparrows are described as common (Foster, 2001). Currently, many of these taxa are in decline, which presents an interesting dilemma to land managers and conservationists who are faced with the challenge of restricting tree invasion and growth on open lands, and are confronted by the basic question of whether such cultural landscapes should be conserved.

Should these uncommon and presumably historically rare or nonnative taxa be allowed to go locally extinct as the extent of forest land increases and agriculture declines? Or should we expend increasing effort on their maintenance, based on

the notion that some of these species may be native, that many have become an important or characteristic part of the landscape, and that others may be threatened elsewhere in their range? During the past decades, grassland and shrubland taxa have emerged as a major priority for conservation organizations such as TNC, Massachusetts Audubon Society, and state natural heritage programs, which are seeking to conserve such birds as the grasshopper sparrow, upland sandpiper, and meadowlark through management programs based on burning, mowing, and grazing (Scheller, 1994; Sharp, 1994). Ironically, one of the most effective protection strategies for these species has been for conservationists to work with managers of highly artificial cultural landscapes to maintain appropriate habitat. The list of top sites for open-land bird species in Massachusetts provides an indication of the precarious status of these species and the surprising nature of the remaining "prime" habitat (Jones and Vickery, 1993). Among these sites, eight are commercial airports or military air bases, one is a landfill, one is a drained cedar swamp that was converted to grassland for agricultural and industrial purposes, one is a military training ground, and only two are in a seminatural condition, albeit one that is strongly shaped by historical land use. A historical perspective reveals the landscape dynamics that enabled the development of these habitats and wildlife assemblages. It also allows us to make the conscious decision, as has been done throughout northwestern Europe, that there may be great value in maintaining diverse cultural landscapes and the aesthetic and biological qualities that they support (Birks et al., 1988; Peterken, 2003).

Consequences of the Enduring Legacies of History

Land use, like other disturbance processes, can generate legacies in terms of ecosystem structure, composition, or function that are not easily erased or changed through time or even through subsequent disturbance (Foster et al., 1998a). As a consequence, it is often erroneous to conclude that the adoption of a new management regime, even one that follows the presumed natural disturbance or environmental regime, will necessarily lead to the re-creation of "natural" conditions or the vegetation structure and composition that might have developed in the past as a result of such disturbance (Seymour et al., 2002). For example, in the study of pitch pine and scrub oak vegetation on sand plains in the Connecticut River Valley, Motzkin et al. (1996) documented that the single most important factor controlling many aspects of the modern vegetation and site conditions was the legacy of different land use across these areas. Modern soil features, such as the presence of a "plow" horizon and vegetation characteristics, including species composition and structure, reflected the prior site history even 50 to 100 years after the land-use activity ceased and despite a history of subsequent disturbance by fire. Other studies have shown a similar pattern of persistence of historical legacies in the face of hurricane impacts or other disturbances (Foster, 1993). These observations suggest that even though many management regimes are prescribed for natural areas in an effort to increase their natural character, such as prescribed burning in pine-, oak-, or grassland-dominated landscapes, the vegetation may actually be slow to respond to such disturbances or may change in unexpected and even

undesirable ways (Niering and Dreyer, 1989; Patterson and Backman, 1988). The outcome of such management may not be an enhancement of "original" attributes of the area (Motzkin et al., 1999a), although it may contribute to other objectives, such as the maintenance of rare species habitat and regional biodiversity.

> Conclusion and Recommendations

Much of the eastern United States has witnessed an increase in forest cover in this century as a result of a reduction in agricultural activity and natural resource extraction, presenting new opportunities and challenges for conservation planning. These changes in land-use practice have resulted from the fact that the food, energy, building materials, and natural resources for the region are no longer obtained primarily from our local landscapes, but are derived instead from highly distributed global sources. Consequently, although regions like New England are experiencing population growth and historically high levels of residential expansion, they have also reverted to a more natural condition with more extensive cover of maturing forests and more native fauna than at any time during the previous 200 years.

The rapidity and extent of change, the ongoing dynamics in the landscape resulting from recovery from prior land use as well as ongoing impacts, and the enduring legacy of past land use necessitate that historical perspectives become an essential part of all ecological study and an important basis for the development of conservation strategies. Using these perspectives we can recognize the inevitability of change and the cultural imprint on most landscapes and on many seemingly natural features. We can also recognize that many plant communities and landscapes that are of great conservation value are actually novel, highly humanized, and of recent development. As we understand the transitory and highly cultural origins of many parts of our land, we can also appreciate the relative roles of science versus social values in determining policy and management objectives. Using both historical and ecological science we can interpret and understand change, monitor and evaluate conditions and processes, and develop and inform management techniques. Ultimately, however, the decision of what we conserve or restore lies in the cultural values that we bring to this decision-making process. Thus, in New England we can retain a cultural landscape of fields and forests that support open-land and edge species, or we can allow a culturally derived forest to develop and age and harbor forest interior species. Science does not give us absolute guidelines for making these decisions, but it does inform us that either decision will produce a new landscape with a history that includes people and that is characterized by features that are not original or pristine but are constantly undergoing change.

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