6 Cultural Effects on Habitat Patterns

In addition to the physical influences on habitat patterns discussed in Chapter 5, there is a historical context associated with human activities that must be understood to explain changes in the vertebrate communities that we have observed over the past several hundred years and the patterns that we see today. Native Americans likely maintained more open landscape conditions through use of agriculture and fire than what may have been first described by European settlers (Boag 1992). Humans are a part of ecosystems and they have been on some continents for millennia. The influx of European humans into the North American environment led to changes in forest cover and distribution that were quite different from the historic conditions that occurred up to that point. There are several factors that have occurred since the arrival of European humans onto the North American continent that set the context for management of habitat in North American forests.

The distribution of vegetation is faced with three dominant current pressures that might change habitat quality for many species at a much more rapid rate than has occurred historically: (1) land use, (2) global climate change, and (3) invasive species. These forces represent a significant common ground between foresters and wildlife biologists. Discussions about how to manage forests for products and habitat for species fall silent when forests are replaced by other systems.

LAND USE

Urbanization

The effects of land use on habitat patterns have been apparent for centuries. But development, especially as reflected in urban sprawl, is occurring at a remarkable rate in many of our forests. In Massachusetts, 16 ha (40 acres) per day are converted from forest to housing (Foster et al. 2005). The rate is similarly as great in urbanizing areas across North America. One only need fly over Mexico city, Phoenix, Seattle, or Vancouver to see the effects of development and sprawl on forest, grassland, and desert ecosystems. Urbanization homogenizes what was a more complex mosaic of vegetation and physical features providing resources for multiple species (Pauchard et al. 2006). As human populations increase, the urban–rural interface expands and the effects of urbanization extend beyond that of the individual house footprints. The proliferation of roads, utility infrastructure, and human use of remaining fragments of forest land lead to marked changes in the function of these forests as habitat for many vertebrates (Theobald et al. 1997). Some species increase in abundance and expand their distribution in response to these changes. Two bird species, Carolina wrens and tufted titmice, have increased in abundance by 17% and 7% over the past 40 years in Massachusetts (Sauer et al. 2005). Many more species have declined significantly over that same time period, such as wood thrushes and black-and-white warblers (Sauer et al. 2005). Conversion of forest to subdivisions probably has at least some role in these changes, and consequently some native species face habitat loss from development. Certainly we see loss of potential production of wood products from these lands. The greatest threat to forest sustainability and biodiversity is conversion of forests to other land uses, which often results when markets value forest systems and the ecosystem services they provide less than the economic value of houses, industries, and production agriculture (NCSSF 2005). As urban areas are expanding and the remaining land and water resources are becoming more constrained, more attention is being paid to meeting the needs for species in urban areas. City planners, urban ecologists, and others are beginning to explore biodiversity conservation as one ecosystem service that some cities can provide with careful attention to urban design, roads and associated under- and overpasses, connected reserves, and riparian buffers. Such efforts mandate both ecological and social solutions to the challenges associated with providing these features in urban landscapes. We explore this topic more in Chapter 14.

FOREST CLEARING FOR AGRICULTURE

Agriculture currently occupies over 40% of Earth's land area and consumes 70% of available freshwater (McLaughlin 2011). Hansen et al. (2008) estimated that 27.2 million ha of humid tropical forest was cleared between 2000 and 2005. Forest clearing is concentrated in only a small part of the tropical forest biome though, so impacts in countries such as Brazil and Indonesia as well as some countries in Africa are particularly significant. In West Africa, approximately 80% of the original extensive tropical forest area is now an agriculture–forest mosaic (Norris et al. 2010). Clearing and conversion to agriculture can be to enable production of food crops, grazing areas, or biofuel production. Net loss of forest land over time is offset partially by land abandonment and return to a secondary forest; however, secondary forests do not typically function as a habitat for some species as well as primary forest, at least during the first few decades of recovery. The rate of recovery of those functions varies from one tropical forest system to the next and the degree to which the remaining forest has been fragmented. Secondary forests can recover some habitat functions for some species in 20–40 years and consequently can play an important role in biodiversity recovery, particularly when located near primary forests (Dent and Wright 2009). But land clearing continues to occur in many areas at a greater rate than agricultural land abandonment. Tilman et al. (2011) predicted a 100%–110% increase in global crop demand from 2005 through 2050 but they point out that this demand can be met in different ways with profound impacts on our ability to conserve primary forests for biodiversity conservation. If we continue current behaviors of greater agricultural intensification in rich nations and greater land clearing in poor nations, then Tilman et al. (2011) predicted that approximately 1 billion ha of land would be cleared globally by 2050. However, if this crop demand was met by intensification on croplands of all nations then less land might be cleared, approximately 0.2 billion ha. Regardless of the scenario, clearing of lands for agriculture will constrain our ability to conserve biodiversity associated with forests in many parts of the world.

ENERGY PRODUCTION AND BIOFUELS

The effects of climate change are evident in many parts of the world, and especially near the poles and at high elevations. The more direct effects of climate change on biodiversity conservation will be discussed in the next section, but these effects have led to a search for energy sources that are an alternative to fossil fuels. Biofuels represent any fuel feedstock that is derived from a biological source. Wood pellets, hog fuel, and firewood are biofuels, as is ethanol produced from corn, algae, switchgrass or other crops, including cellulose from trees and shrubs. Typical biofuel feedstock production is highly agricultural in design so agricultural lands are often used to produce fuel, replacing land that once produced food. As was noted earlier, demand for food will increase over the next 30–40 years, so if we produce more crops for fuel, we will need more land on which to do that. Reclearing lands that are now secondary forest is one alternative, but in many areas that is not sufficient to meet demands so primary forest is also cleared. Palm oil plantations are an example of a biofuel crop that now covers over 13 million acres of former native forest, largely in Southeast Asia (Danielson et al. 2009). Many of the impacts of biofuel production on biodiversity conservation are described in an earlier section on agricultural land clearing. Such impacts simply polarize those parts of our society wishing to find alternatives to fossil fuels from those trying to conserve biodiversity when both are often polarized from those that endorse greater fossil fuel production.

Tilman et al. (2009) summarized mechanisms for producing biofuels in a manner that would minimize these adverse impacts and produce up to 500 million tons of biofuel feedstocks per year in the United States alone:

1. Grow perennial plants on degraded lands abandoned from agricultural use.
2. More fully utilize crop residues.
3. Sustainably harvest wood and forest residues.
4. Double crops and use mixed cropping systems.
5. Utilize municipal and industrial wastes.

From a forest management perspective, sustainable harvest of wood and forest residues seems attractive, but even that approach must be taken with caution. Continual and intense removal of woody residues following a timber harvest has the potential to alter soil productivity and soil biota as well as species that use the forest floor (Anderson 2006). Consequently, guidelines have recently been developed to ensure that the adverse effects of biofuels production in forests and plantations can be minimized or reduced (Abbas et al. 2011). Abbas et al. (2011) categorized guidelines as those that would pertain to two conditions: Energy plantations (typically willows, cottonwoods, and eucalyptus) and forest residue removal in forest and timber management. Unfortunately, there are very few studies that have been conducted that document the relationship between wood biomass and habitat for one or more species, but that information is needed in order to develop guidelines for managers. The effects of biomass removal on forest floor fauna have been investigated in Scandinavia (Gunnarsson et al. 2004), but there has been a little work done recently to address effects elsewhere in the world.

CLIMATE CHANGE

In forested environments carbon is present in living and dead biomass, in soil, and in the atmosphere that surrounds the forest. Forests remove carbon from the atmosphere through photosynthesis, but forests also return a significant amount of carbon to the atmosphere through respiration. As trees die and decay or are burned, carbon is released back to the atmosphere in a pulse, and then the forest regrows and fixes carbon again until the next large disturbance. As forests age and as the trees slow in their growth, carbon fixed by photosynthesis is largely offset by losses due to respiration. Nonetheless, these old forests can store a large amount of carbon for long periods of time between disturbances and when a disturbance does occur that kills many of the trees, decomposition of wood is slow and so carbon is released slowly over time, even following large forest fires.

Burning of fossil fuels is adding carbon to the atmosphere that is in addition to what is released through respiration, decomposition, and other mechanisms in carbon cycling that has occurred for thousands of years (Figure 6.1). Land use that converts forests (which store large amounts of carbon) to agriculture or urban areas, contributes to additional atmospheric carbon, but burning of fossil fuels continues to be the largest human-caused addition (IPPC 2001). Why is addition of carbon in the form of carbon dioxide, methane, and other forms important? These gases allow less heat to escape into space and in so doing influence changes in temperature, airflows, and other processes on the surface of the Earth. Temperatures may increase in some areas (the poles seem to be a good example now), or be more variable as changes occur in the jet stream, as offshore ocean currents alter, and other global processes respond to the fact that less heat is escaping the atmospheric envelope around the Earth (Figure 6.2). Consider the change in CO_2 concentration in the atmosphere over the past few thousand years (Figure 6.3), and the contributions of carbon to the atmosphere are continuing.

Climate change has the potential to alter the distribution of animals through changes in patterns of vegetation as well as through changes in the physical environment. These changes are quite likely to lead to marked changes in the ability of plants and animals to tolerate conditions as temperature and precipitation patterns change more rapidly than they have historically. The result will likely be a shift north for many southern species or a shift to higher elevations for species currently restricted

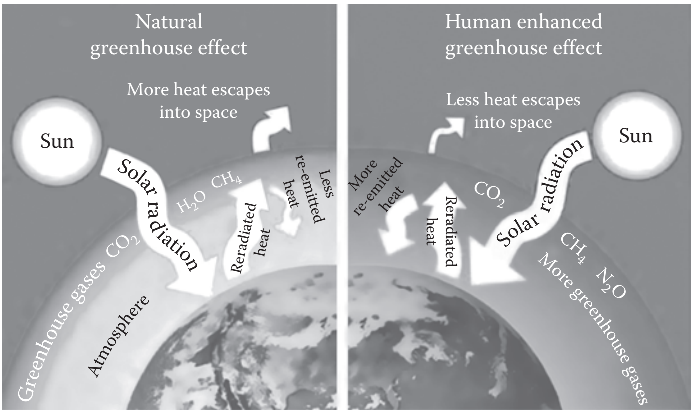
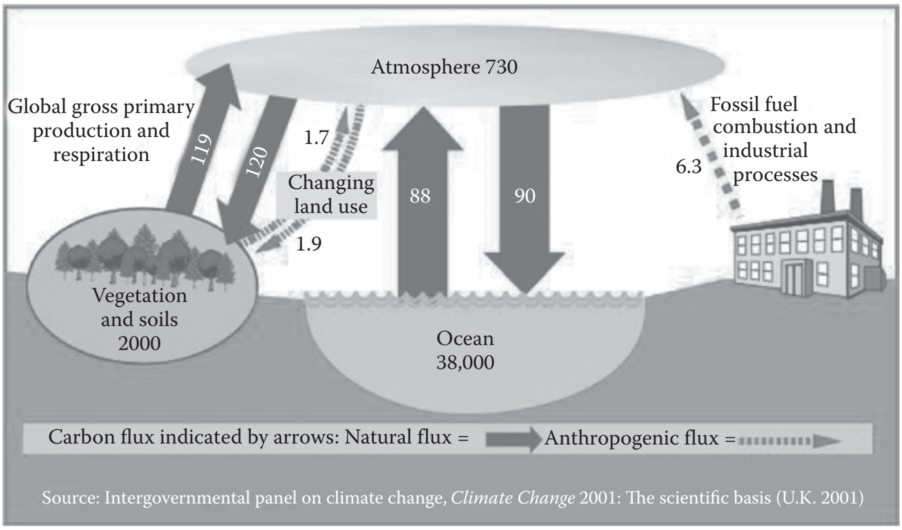


FIGURE 6.1 Contributions to atmospheric carbon from various sources. (From http://www.esrl.noaa.gov/research/themes/carbon/.)

to lower elevations. The area that would be available to meet the needs of species at high elevations or high latitudes will be increasingly compressed.

These shifts in distribution are assumed to occur if the organism is mobile enough and adaptable enough to allow movement in response to these climatic changes. For example, changes in vegetation as a result of elevated temperatures have been linked to the current and likely future distribution of animal species (e.g., Figure 6.4). Clearly, plant species face issues of coping with movement rates that will keep up with changing temperatures, but even some vertebrates (e.g., salamanders) likely will not respond quickly enough. Further, these organisms face obstacles as they are forced to change in their geographic ranges (e.g., roads, farms, and cities). Of course as urban and agricultural areas expand, and as fossil fuel demands increase worldwide, the effects of climate change will likely worsen until alternative energy sources begin to dominate. The changes that occur due to increases in carbon dioxide concentration will likely be largely irreversible for 1000 years after emissions stop (Solomon et al. 2009). It is clear that conservation biologists and wildlife managers will need to work



Source: Intergovernmental panel on climate change, *Climate Change* 2001: The scientific basis (U.K. 2001)

FIGURE 6.2 Impacts of increase greenhouse gases on the Earth's climate. (From http://www.nps.gov/goga/naturescience/climate-change-causes.htm.)

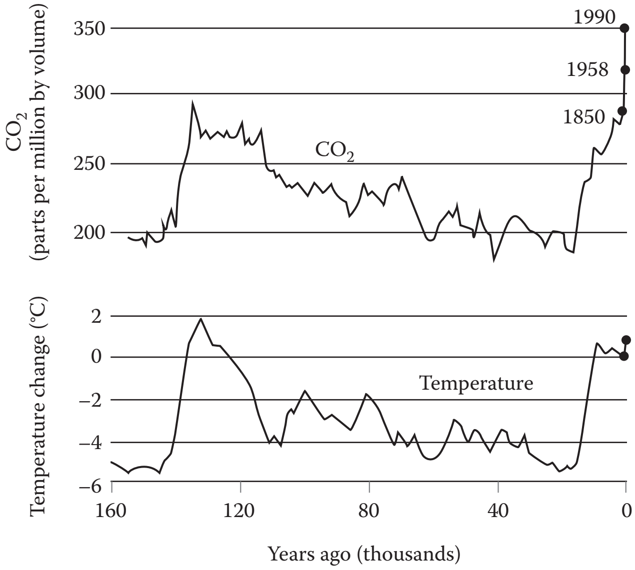


FIGURE 6.3 Carbon dioxide concentrations over the past 160,000 years. Circles represent changes due to human activities. (Reprinted from Schneider, S.H., and T.L. Root. 1998. *Status and Trends of the Nation's Biological Resources*. Pages 89–116. USDI U.S. Geol. Surv. publication, Reston, VA.)

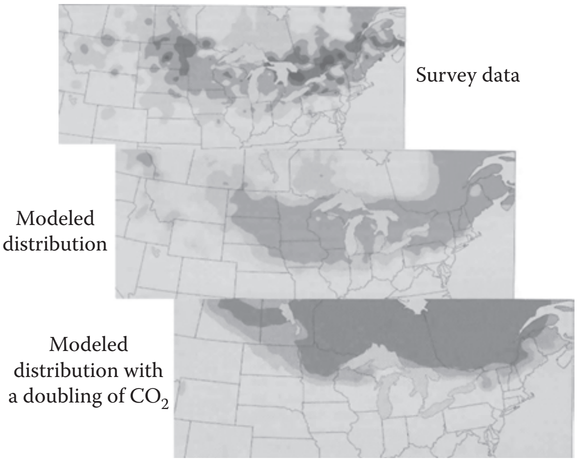


FIGURE 6.4 Current range of the northern bobolink (upper frame), predicted range based on current carbon dioxide levels (middle frame), and predicted range under doubled carbon dioxide concentrations (lower frame). (Reprinted from Schneider, S.H., and T.L. Root. 1998. *Status and Trends of the Nation's Biological Resources*. Pages 89–116. USDI U.S. Geol. Surv. publication, Reston, VA.)

with forest ecologists and forest managers to develop the active management approaches to address these profound and long-lasting changes that we will see over many human generations.

INVASIVE SPECIES

We are homogenizing the planet. As we move plants, animals, microbes, and the materials in which they occur purposefully or inadvertently to different parts of the Earth, we allow some of them to find conditions in that new part of the world to be suitable for them. For many species, that is not the case. But for some, landing in a new place at a similar elevation or latitude to their native geographic range (e.g., starlings in the United States once formerly restricted to Europe) allows them to proliferate. Once in that new environment they may fill a niche that was not previously occupied or may be a better competitor than a native species for a given niche. These species new to the scene and having a competitive advantage are considered invasive in that they often will displace one or usually many native species. The number of invasive species occurring across ecoregions is increasing. Alien species are the second leading cause of extinction in the United States and cost approximately $120 billion annually (Crowl et al. 2008). These invasive species are often exotic, those that are brought into an area from other countries or continents. Chestnut blight fungus, gypsy moth, Scotch broom, European starlings, and house sparrows are examples of exotic species that have become invasive in North America.

Invasive species can also be excellent predators, or they can introduce new parasites or diseases into populations that had not previously encountered these new diseases. When red foxes and house cats were introduced into Australia, midsized marsupials in the drier parts of that country were vulnerable to the more effective and efficient placental predators than they had been to native marsupial predators (Johnson and Isaac 2009). Cat and fox control measures in conjunction with relocating some midsized marsupial species to offshore islands that did not have these nonnative predators allow many, but not all, species of native marsupials to survive, though for many species their current range is only a fraction of their geographic range prior to the arrival of these predators (Kinnear et al. 2002).

Invasive organisms can also come in the form of bacteria, viruses, and fungi that lead to morbidity and mortality in native populations. Frick et al. (2010) describe a recent emerging disease, white-nose syndrome, in North American bats that probably originated in Europe and was spread to the United States. West Nile virus in birds, myxomatosis in rabbits, and chytridiomycosis in amphibians all represent the forms of pathogenic pollution spread from one location to another, most likely by humans as vectors. Emergence of infectious diseases seems to be related to loss of biodiversity. Biodiversity loss may increase disease transmission, but on the other hand, areas with high levels of biodiversity may serve as a source for new pathogens (Keesing et al. 2010).

But species need not come from another continent to be invasive. Species native to a continent can also be invasive when they are placed in a new location. Bullfrogs moved to the west coast from eastern North America are likely responsible for declines in some western native amphibians (Figure 6.5). And not all exotics are invasive. In fact most are not. Ring-necked pheasants are an example of an exotic species that colonized the Midwest but that probably does not displace any

FIGURE 6.5 Bullfrogs were introduced to the west coast from eastern North America and are likely responsible for declines in some western native amphibians. (Photo by Mike Jones. With permission.)

native species. The landscape planting industry annually uses thousands of species of plants that are not native and only a few escape to become invasive. Increasing expansion of suburbia leads to increasing spread of landscaping plants around houses and can become invasive, such as Norway maple. In addition, as climate changes, some invasive plants and animals that may not be a problem now may become a problem under new climatic conditions, or the current problem may be reduced under new climatic conditions.

How do these exotic plants and animals find their way into our forests? Most arrive on this continent at port cities (Figure 6.6). States that have ports rank high in the number of these species that have been introduced. Some were introduced for purposes of soil stabilization and wildlife habitat improvement: multiflora rose and autumn olive, for example. Now biologists are trying to eradicate the very species that were imported and planted for habitat purposes! The continuation of introductions of exotic species in the landscaping industry and some forest products industries is raising more and more concerns about homogenization of our globe that could lead to a net loss in biodiversity (Richardson et al. 1997). The direct effects of invasive species on habitat quality can be quite apparent. The competitive advantage that invasives have over other species can lead to homogenization of the site and the displacement of native species into more isolated patches. For instance, pines were once only found in the northern hemisphere, but over 19 species are now established in the southern hemisphere through use of exotic species in plantations and for erosion control (Richardson 1998). The Australian paperbark tree was introduced in Florida during the early 1900s. Prolific seed production, flood tolerance, and rapid regrowth following fire enabled this species to invade wetlands and eliminate native plants and the animal species that rely on them (Figure 6.7; Hofstetter 1991). Once established, invasive species such as false brome can eliminate native vegetation and can be very difficult to control (Figure 6.8).

If society wishes to maintain habitat for various wildlife species, then biologists and foresters must first work together to address issues of development, climate change, and invasive species. Else the discussion of how to manage forests becomes moot.

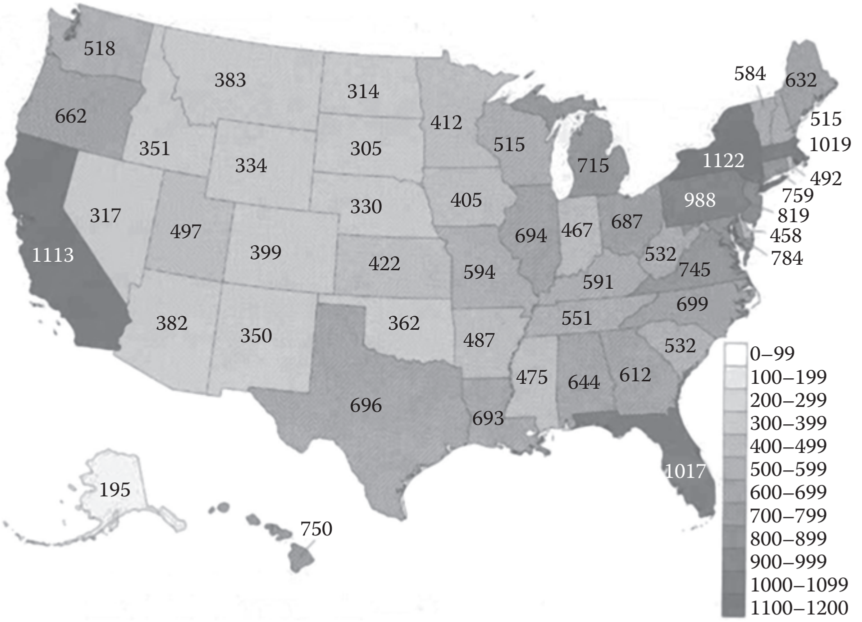


FIGURE 6.6 Numbers of nonnative plant species that have been introduced into each state in the United States. (Reprinted from Williams J.D., and G.K. Meffe, 1998. *Status and Trends of the Nation's Biological Resources*. Pages 117–130. USDI, U.S. Geol. Surv. publication, Reston, VA.)

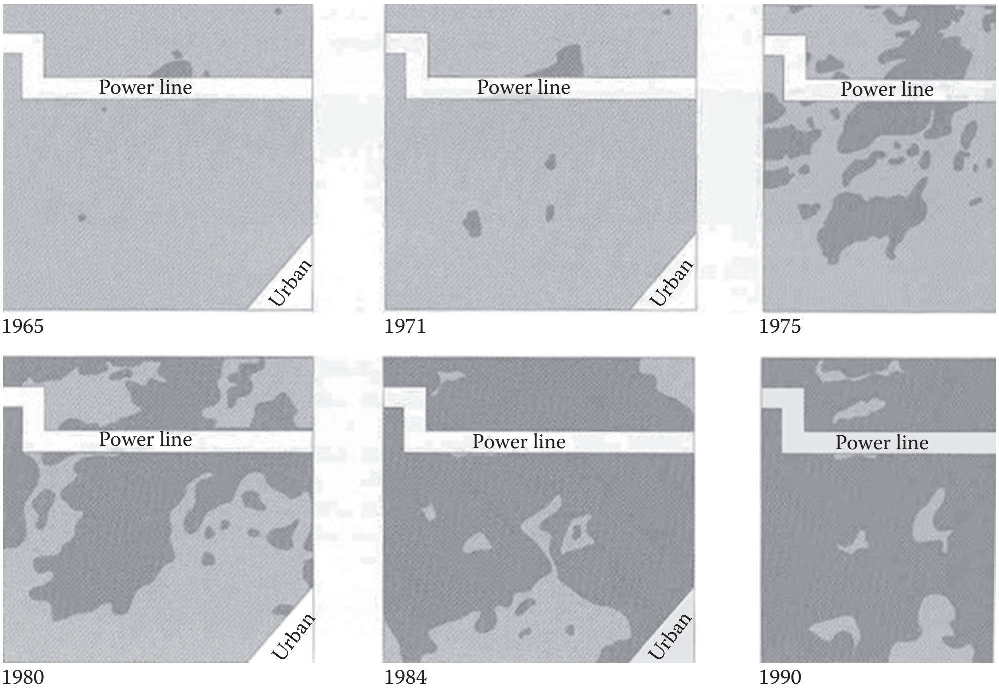


FIGURE 6.7 Changes in native plant species cover over time following invasion by the Australian paperbark tree (dark gray). (Reprinted from Williams J.D., and G.K. Meffe, 1998. *Status and Trends of the Nation's Biological Resources*. Pages 117–130. USDI, U.S. Geol. Surv. publication, Reston, VA.)

FIGURE 6.8 Understory of a Douglas-fir stand dominated by the invasive exotic grass, false brome. Note the absence of native understory plants in this stand.

SYNERGISTIC EFFECTS

The climate will change and some of those changes could last for 1000 years or more. The population of humans on the planet is increasing and each will demand a place to live and food to eat so land use will continue to shift to cities and agriculture. People continue to move around the planet and carry with them diseases, propagules, and animals, homogenizing our flora and fauna. All a bit overwhelming isn't it? Now consider that these three stressors, caused by people, interact to create even further uncertainty in the future of the planet. Consider the likely effects of climate change on invasive species. Hellmann et al. (2008) identified five possible effects of climate change on invasive species: (1) novel mechanisms for species introduction, (2) changes in the conditions that allow establishment of new invasive species, (3) emerging impacts of invasive species on the ecosystems in which they occur, (4) shifts in the distribution of established invasive species, and (5) changes in strategies needed to control invasives. And on top of the changes induced by climate change, consider how changes in our climate will influence other forces such as disturbances (see Chapter 7) and water levels in oceans, streams, and rivers. And the changes are not always in the direction of exacerbating invasive species issues—in some places, changes will help reduce the risk of invasion or spread while in other areas these risks will increase (Bradley et al. 2010). Indeed the common approach to addressing invasives in the face of such uncertainties is to try to assess the relative risks of changes we might see and of control measures we might use and select those that are most likely to be effective with the least risk.

For instance also consider the effects of changing land use on invasive species spread. As we urbanize areas and bring exotic plants into environments for landscaping purposes, some may naturalize and spread. Some that are here now may find a new pathway to spread as climate changes. There are feedback loops as well. Simply the conversion of forests to alternative land uses can add greenhouse gas contributions to the atmosphere and exacerbate the rate of climate change. What can we possibly do to conserve biodiversity or manage habitat for certain species in the face of such an uncertain future? Some scientists view these complex problems as "wicked" having many disciplinary issues, all interacting, with social, biological, and physical components (Mooney et al. 2009). The irony of today's predicament is that we merely need to look at our own histories to see similar synergistic effects of environmental stressors that led to extinction of species.

CASE STUDY: PASSENGER PIGEONS, HUMANS, AND FORESTS

Contemporary decision makers could learn about the roles of physical and cultural influences on habitat quality for selected species from patterns and changes in habitat elements that have occurred during the recent history of the United States. The passenger pigeon extinction represents a classic example of how a species was not able to persist when faced with a suite of pressures on the populations, especially changes in habitat conditions that were imposed by European humans.

Prior to European settlement, passenger pigeons were nomadic, occurring in flocks of millions of birds moving over vast areas of contiguous eastern deciduous forests (Ellsworth and McComb 2003) (Figure 6.9). Acorn production in the forests varied considerably from year to year and place to place (Healy et al. 1999) so the large flocks of pigeons provided many eyes to search for available food. Once a member of the flock found food, the remainder of the flock would follow, using a process known as social facilitation to locate patches of high acorn production near nesting and roosting areas. In the spring, pigeons followed the receding snowmelt northward to the nesting areas, relying largely on red oak acorns and beechnuts as food during these movements (Bucher 1992). Red oaks, unlike white oaks, undergo a winter stratification period and germinate in the spring. White oaks germinate in the fall so are less available to pigeons following snowmelt. Consequently, pigeons were well adapted to the extent and variability in patterns of acorn production in oak forests across the eastern United States and southern Canada.

European settlers cleared the forests initially for agriculture and eventually for cities and industries. Farmers often allowed domestic pigs to forage for mast (acorns, chestnuts, and beechnuts) in

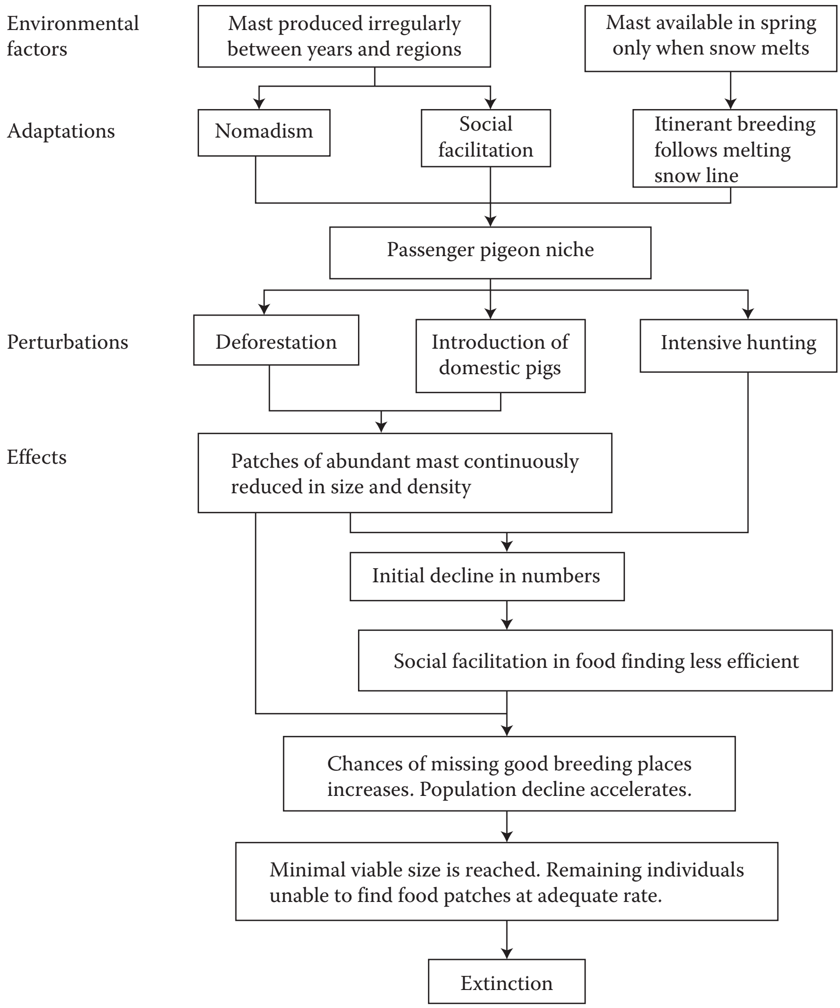


FIGURE 6.9 Factors leading to the extinction of the passenger pigeon in North America. Although many processes were at work, habitat loss was a primary driver. (With kind permission from Springer Science+Business Media: *Current Ornithology*, The causes of extinction of the passenger pigeon, 9, 1992, 1–36, Bucher, E.H.)

the forest, and pigs are a bit like 200 lb mammalian vacuum cleaners in the forest, eating mast, and digging roots (Henry and Conley 1972). The combination of clearing of oak forests, foraging by domestic livestock for acorns, and increased levels of harvest of pigeons as food caused pigeons to be less abundant. Patches of food became more widely dispersed and despite the pigeons' social facilitation behavior, food became more difficult to find. Hunting of the pigeons reduced their numbers, thereby making social facilitation as a mechanism for finding food patches even more ineffective because there were fewer eyes to find the more dispersed food. Nest sites also became less available, and because passenger pigeons only laid one egg per year, and both parents helped with incubation and rearing, there was a high energy investment in reproduction but a low reproduction rate. This low reproductive rate exacerbated the issues associated with reduced abilities to find food and nesting sites and so populations began to decline. Declines accelerated as the population entered what population biologists call the *extinction vortex* (Westemeier et al. 1998). Before long the population was simply not able to persist. The last nesting birds were seen in the Great Lakes region in the 1890s. The last individuals were killed in the wild in 1900, but some individuals remained in captivity until 1914. Martha, the last passenger pigeon, died at the Cincinnati Zoo on September 1, 1914. The ultimate demise of the passenger pigeon was more a result of habitat loss than other factors, although overhunting contributed to the declines. Habitat loss occurred through cultural activities on a template of physical features and vegetation to which the species was well adapted. This classic example of species extinction should be one that we continue to learn from and consider how we should “save all the pieces” if we do not want additional species to have a similar fate.

SUMMARY

Humans have had a remarkable impact on the patterns of vegetation on the planet. Historically, these have largely been through land use changes that continue to proliferate as more and more humans inhabit Earth. Development pressures, proliferation of invasive species, and climate change all threaten the extent and function of forests in the world, and hence will influence our ability to provide wood products and habitat elements to support conservation of biodiversity. These pressures on our forests provide common ground for foresters and wildlife biologists to work together if society continues to demand both wood products and biodiversity conservation.

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