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Managing White-tailed Deer: Midwest North America

Kurt C. VerCauteren and Scott E. Hygnstrom

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It easily can be said that the white-tailed deer is the most important species of wildlife in the midwestern United States. Approximately 10 million white-tailed deer inhabit the Midwest, which is more than any other region in North America. Further, many of the most impressive whitetails have come from the Midwest (Figure 17.1). Dramatic changes have occurred on the landscape since European settlement that influenced populations of white-tailed deer in this regiou. Timber harvest in the north and east and agricultural tillage and residential development throughout the region have had both positive and negative impacts on deer numbers. White-tailed deer were over-harvested through unregulated subsistence and market hunting in the 1800s and were nearly extirpated from many areas in the Midwest (Gladfelter, 1984; Menzel, 1984). Populations rebounded over time, however, to current record highs, due to an interested

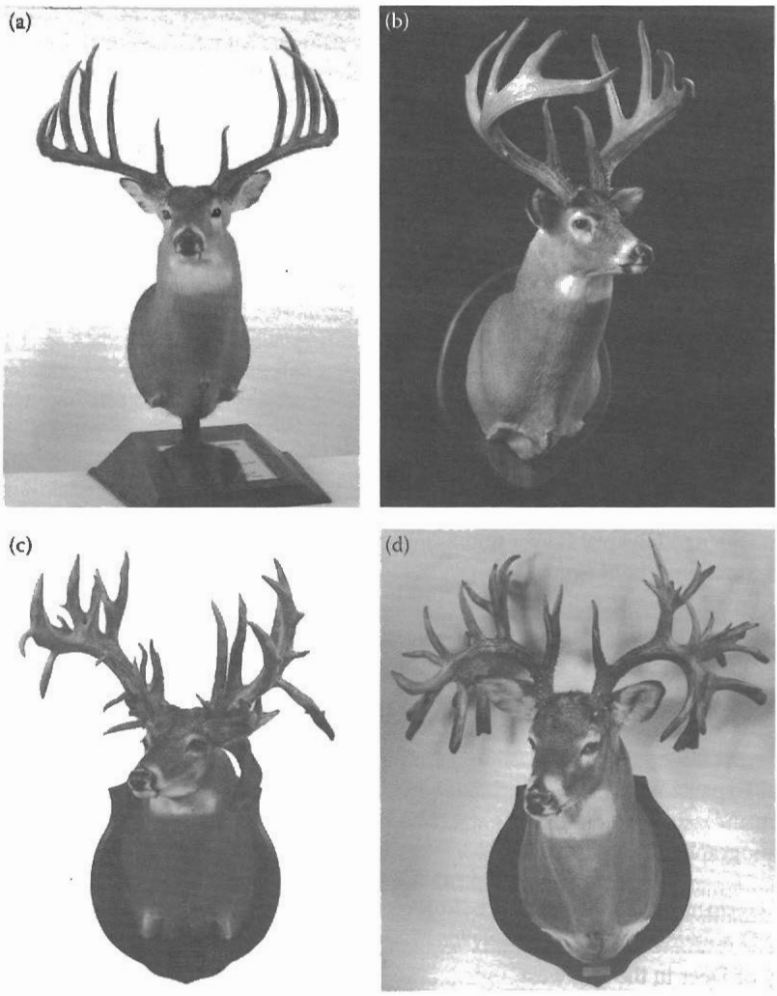

FIGURE 17.1 (a) Milo Hanson World's Record typical white-tailed deer, 213–6/8 points, Biggar, Saskatchewan. (b) James Jordan. Number 2 typical white-tailed deer, 206–1/8 points from Burnett County, Wisconsin. (c) World's Record nontypical, 333 7/8 points, St. Louis County, Missouri. (d) Tony Lovstuen. Number 3 nontypical, 307 5/8 points from Monroe County, Iowa. (Images courtesy of Boone and Crockett Club [www.booneandcrockettclub.com]. With permission.)

public and the diligent efforts of management agency personnel. White-tailed deer have also expanded their range westward and now occupy areas of the Great Plains that they never have before.

Public interests in whitetails are high, as over 4 million deer hunters and untold numbers of deer watchers take to the field every year in the Midwest. An entire culture has grown out of sport hunting of white-tailed deer, especially in the upper Midwest where it is not uncommon for schools to be closed on opening day of the firearm deer season. Traditional meat poles that were once the center of attention every autumn in towns across the upper Midwest still exist and are used in some communities. Deer camps, where generations of hunters congregate every autumn, are still common across the North Woods (Willging, 2008), carrying on the hunting tradition and keeping the interest in wildlife, the outdoors, and our natural world alive. Public concerns also are high, thus crop damage and deer–vehicle collisions (DVCs) are major drivers in the management of local deer numbers. Managers are also concerned about the impacts of high populations of white-tailed deer on plant communities, ecological succession, and forest regeneration. The times for those interested in white-tailed deer in the Midwest are better than ever and the outlook is good, but even greater diligence and effort will be required to properly manage populations of white-tailed deer in the future.

Climatic and Geographic Description of the Region

Climate is the most significant over-riding environmental factor that affects the distribution and population levels of white-tailed deer in North America. North–south and east–west gradients exist in the Midwest for solar radiation, temperature, and moisture. The Midwestern range of white-tailed deer in North America occurs across a diverse array of subregions that includes all or parts of 14 states and three provinces (Figure 17.2). Low temperatures and deep snow in the north and western alpine regions limit the distribution of white-tailed deer. Highly adverse weather conditions such as drought, tornadoes, and rain-associated floods may have direct impacts on local populations of white-tailed deer. Climate in the Midwest also affects the distribution, density, and physio-chemical features of plants and plant communities which in turn, directly affect deer. Predictions of impending climate change could impact plant communities and agricultural production in the future, which will also directly affect deer in the Midwest.

Northern Plains Subregion

The Northern Plains Subregion is the northwestern extent of white-tailed deer range in the Midwest (Figure 17.2). Elevations range from 200 m on the rolling plains to about 1000 m in southwestern South Dakota (Petersen, 1984). Wooded draws, lowlands, and floodplains are preferred habitats of white-tailed

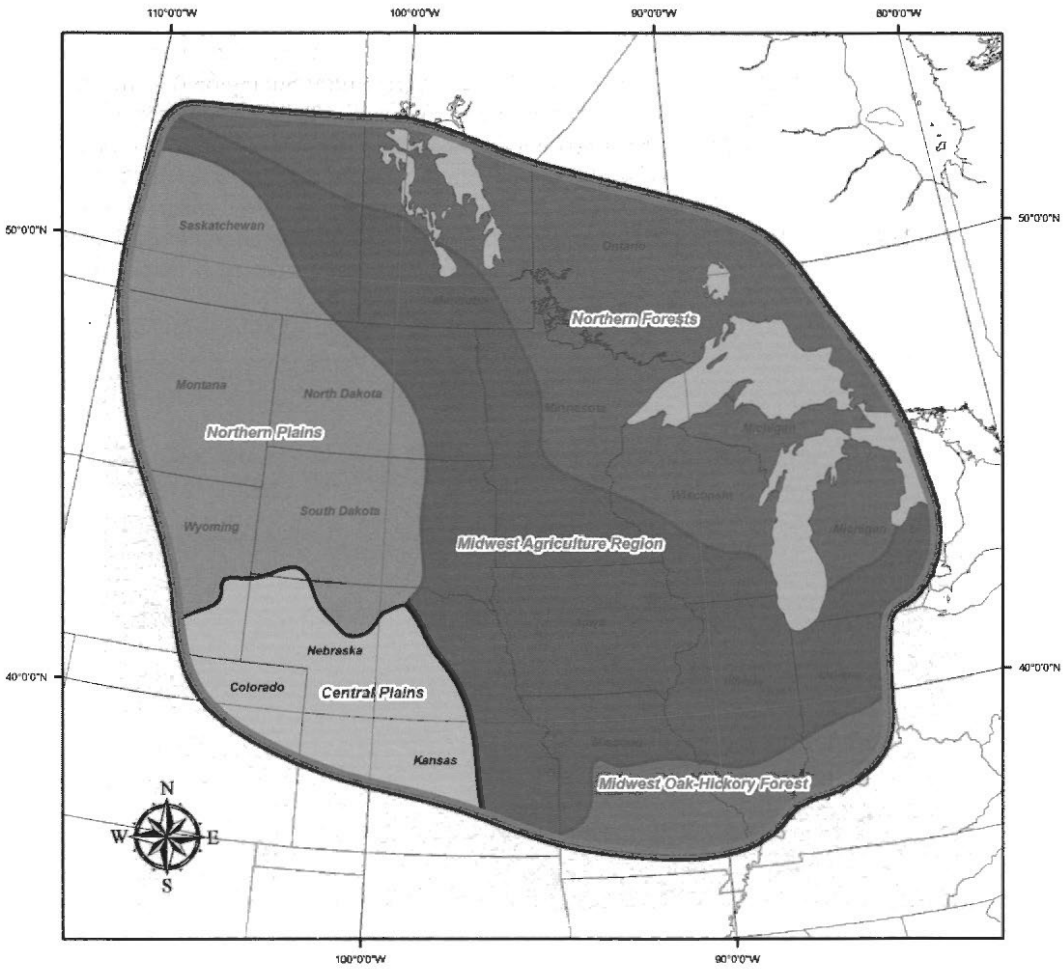

FIGURE 17.2 Geographic boundaries and ecoregions of midwestern North America.

deer (Petersen, 1984). Although less prevalent, mountainous terrain is found in parts of eastern Wyoming and southwestern South Dakota. White-tailed deer range overlaps with mule deer and elk in many locations across the Northern Plains. Common trees in the lowlands include green ash, American elm, and boxelder with Rocky Mountain juniper and ponderosa pine in draws and uplands (Petersen, 1984). Shrubland vegetated with western snowberry, silver buffaloberry, and common chokecherry provides valuable year-round cover and food (Petersen, 1984). Cattle ranching is the most prevalent land use in the region though dry-land and irrigated agriculture has increased in recent decades. Primary crops include alfalfa, winter wheat, corn, and sunflowers. Coal and uranium mining are relatively common and energy development including oil, gas, hydro, and wind are becoming more prominent across the landscape.

Average winter temperatures in the far northwest range from –20–9°C in January to 9–23°C in July (Saskatoon, Saskatchewan; Pearce and Smith, 1984). Average winter temperatures in the far southeast range from –13–0°C in January to 19–59°C in July (Rapid City, South Dakota) with a growing season of 90–240 days/year (Harlow and Guynn, 1994). The subregion receives 25–38 cm of rainfall annually in the northwest to 46–58 cm in the southeast (Harlow and Guynn, 1994).

Midwest Agricultural Subregion

A large central section of midwestern white-tailed deer range consists of the Midwest Agricultural Subregion (Figure 17.2), which covers much of what once made up the mixed- and tall-grass prairie ecosystems of the United States. The prairie ecosystem contributed to deep and fertile soils that enable the agricultural productivity seen today. Agricultural crops are nearly unlimited and make up the majority of the diets of white-tailed deer in the Midwest Agricultural Subregion (Gladfelter, 1984; Nixon et al., 1991). Primary crops produced include corn and soybeans although winter wheat, sorghum, alfalfa, and oats are also grown. Most land is privately owned with over 75% currently in crop production. Permanent cover is extensively fragmented and deer must adapt to the dramatic seasonal changes in available cover and food associated with harvest of crops (Nixon et al., 1991). Riparian woodlands and wooded uplands provide year-round cover that is especially vital during autumn and winter after crop harvest (Figure 17.3). Common trees species include red and white oak, sugar maple, American

FIGURE 17.3 Highly fragmented landscapes in the Midwest provide excellent habitat for white-tailed deer, especially along riparian areas where blocks of woodland and adjacent cropfields are sonrces of cover and food. (Photo by G. Clements. With permission.)

beech, paper birch, American elm, green ash, and cottonwood. The topography is low, flat, and gently rolling.

Annual rainfall within the Midwest Agricultural Subregion averages 64 cm in the west to 152 cm in the east. Snow cover is rarely substantial enough to present detrimental effects on winter survival as can occur in northern parts of the Midwest. Average northern temperatures in Winnipeg, Manitoba range from –25–14°C in January to 13–26°C in July (Pearce and Smith, 1984). Farther south in Kansas City, Missouri, temperatures range from –6–3°C in January to 21–32°C in July (Pearce and Smith, 1984) and an average of 160 growing days/year occur (Harlow and Guynn, 1994).

Northern Forests/Great Lakes Subregion

The northeastern reaches of white-tailed deer range in the Midwest comprise the Northern Forests/Great Lakes Subregion (Figure 17.2). Topography is generally flat to rolling and hilly with elevations from near sea level to 350 m. The majority of the subregion consists of managed deciduous and coniferous forests. Farmland makes up less than 25% of the laud area. Predominant tree species include quaking aspen, paper birch, red maple, jack pine, black and white sprnce, northern white cedar, balsam fir, American beech, and eastern hemlock. Important deer foods include northern white cedar, red maple, hemlock, American mountain ash, alternate leaf dogwood, yellow birch, mountain maple, and serviceberry (Harlow and Guyun, 1994).

About a third of the land is publicly owned and managed for timber production and recreation. Privately owned lands such as hunt clubs, weekend homes, and vacation resorts are also common. In the mid-1930s hunt clubs began purchasing inexpensive marginal lands. One particular hunt club formed in Michigan in 1938 encompassed >11,000 contiguous hectares and approximately 250 other such clubs originated thereafter (O'Brien et al., 2006). Privately owned captive cervid facilities are also common in this subregion with white-tailed deer being the most common species raised. Mining of iron, copper, and nickel is relatively common, yet involves a small percentage of the landmass (Blouch, 1994).

Precipitation ranges from 64 to 81 cm of rain and 127 to 508 cm of snow (Harlow and Guynn, 1994). Average temperatures range from –14–0°C in January to 17–28°C in July with a growing season of 80–135 days/year. Extreme winter conditions define the northern extent of white-tailed deer range. Seasonal movements to yarding areas where thermal cover exists are common in response primarily to deep snow and secondarily to cold temperatures (Dahlberg and Guettinger, 1956). The extent and quality of winter range is the main limiting factor for deer populations in this subregion (Dahlberg and Guettinger, 1956). Gray wolves have become more common here aud contribute substantially to deer mortality (Nelson and Mech, 1986a), particularly during periods when snow inhibits mobility of deer (Nelson and Mech, 1986b).

Midwestern Oak and Hickory Forest Subregion

The southeastern reaches of white-tailed deer range in the Midwest are made up of the Midwestern Oak and Hickory Forest Subregion (Figure 17.2). Topography is largely unglaciated, rolling, and hilly with elevations from near sea level along the Mississippi River to over 600 m in moderately rugged mountains (Torgerson and Porath, 1984). Deciduous forests once covered much of this subregion; however, millions of hectares have been cleared for a variety of purposes (Torgerson and Porath, 1984). Croplaud is relatively common with corn, soybeans, and wheat serving as high-quality sources of food for deer. Common tree species include hickory, oak, gum, cypress, and pine. In addition to agricultural crops, other important foods for deer include dogwood, redbud, serviceberry, sumac, blueberry, strawberry bush, elderberry, spice bush, farkleberry, black haw, deciduous holly, yaupon, and oak mast (Harlow and Guynn, 1994).

Weather itself is not a limiting factor for deer in tbis subregion although it can impact the abundance of foods such as acorns, which deer may rely upon for building energy reserves to sustain themselves through winter (Torgerson and Porath, 1984). Precipitation ranges from 89 to 127 cm annually (Harlow and Guynn, 1994). Average temperatures rauge from –4–3°C during January to 24–27°C in July with a growing season of 170–220 days/year.

Central and Southern Plains Subregion

The southwestern extent of white-tailed deer range in the Midwest is made up of the Central and Southern Plains Subregion (Figure 17.2). Topography is generally flat to rolling and hilly with elevations from near sea level to over 1800 m. Much of this subregion was once under short- to mixed-grass prairie with occasional riparian corridors providing habitat for white-tailed deer. Rugged terrain of limestone escarpments with dramatic geological formations are forested with ponderosa pine and eastern red cedar providing diversity throughout much of this subregion where mule deer, elk, and white-tailed deer ranges overlap. Although much of this landscape is grazed by livestock, a considerable amount has been converted to the production of crops such as corn and alfalfa through the use of center-pivot irrigation (Menzel, 1984). Common tree species in wooded riparian areas include cottonwood, green ash, burr oak, and eastern red cedar. Important foods for deer include snowberry, rose, grape, western soapberry, cottonwood, juniper, scrub oak, and agricultural crops (Harlow and Guynn, 1994).

Precipitation ranges from 28 to 89 cm of rain (Harlow and Guynn, 1994). Average temperatures range from –7–7°C in January to 18–29°C in July with a growing season of 120–220 days/year. Adverse weather conditions rarely occur long enough to significantly impact deer survival.

White-tailed deer have steadily expanded their range westward in recent history. Human manipulation and control of rivers in the Great Plains has enabled permanent wooded cover to become established along riparian corridors and center-pivot irrigation has allowed for crop production, especially corn. These two human-induced factors are the primary reasons whitetails extended their range westward and now thrive in many areas of the Great Plains.

Deer Impacts in the Midwest

The popularity of hunting and viewing white-tailed deer has created year-round entertainment for participants and an entire industry in the Midwest. In the past 25 years, the number of deer hunters has increased in the region and they clearly enjoy spending their leisure time and money on activities related to deer. Hunter participation within the Midwest (6–12%) exceeds the national average (5%) (U.S. Fish and Wildlife Service, 2006). Besides pursuing deer during hunting seasons, many people spotlight deer in summer and collect shed antlers in late winter. In spring, some put out mineral blocks or plant foodplots for deer and they tend these plots throughout the growing season. With the advent of trail cameras, scouting for deer has become a year-round endeavor for many whitetail enthusiasts.

Willingness of hunters to invest money to harvest deer has also been a boon to the agricultural community and local economies. Farmers and ranchers earn extra income from their land by leasing hunting rights. They are also selling agricultural products like corn and root vegetables to be used for baiting and feeding deer (Dorn and Mertig, 2005; O'Brien et al., 2006), though laws associated with these activities are tightening. In 2006 19.2 million Americans fed wildlife (other than birds) and 9.6 million maintained plantings for wildlife (U.S. Fish and Wildlife Service, 2006). In Michigan, prior to the bovine tuberculosis (TB)-related ban on feeding deer, over 50% of survey respondents fed deer (Dorn and Mertig, 2005) and it was a $50 million market in Michigan in the early 1990s (Winterstein et al., 1995). Some people provide feed to increase the opportunity to simply view wildlife while others provide supplemental food to decrease the potential for starvation during harsh winters. Others provide feed (bait) strategically to increase their hunting success or in an attempt to keep deer from leaving a property to seek food sources elsewhere (Garner, 2001; O'Brien et al., 2006). Prior to the bovine TB-related deer baiting ban in Michigan, 72% of nonresidents and 87% of residents hunted deer over bait (Dorn and Mertig, 2005). Feeding sites in northern Michigan have been observed to contain tons of food items such as corn, root vegetables, and hay (O'Brien et al., 2002). The occurrence of chronic wasting disease and bovine TB in several states that once allowed baiting and feeding (i.e., Minnesota, Wisconsin, Michigan) has prompted bans and restrictions on placement of food for deer to minimize potential for disease transmission (O'Brien et al., 2006). In the Midwest, hunting directly over bait is unregulated in just Kansas and Ontario and some form of regulated baiting is allowed in five states and provinces (Michigan, North Dakota, Wisconsin, Wyoming, and Saskatchewan) while it is completely banned in the remaining 10 states and provinces.

Several other economic benefits are associated with deer and deer hunting. Four of the largest companies that deal in retail and catalogue sales of outdoor equipment (Bass Pro Shops Incorporated, Cabella's Incorporated, Gander Mountain Company, and Scheels All Sports) are based in the Midwest. Combined, they account for over $8 billion/year in retail sales and 40,000 employees (Answers.com, 2010). Whitetails Unlimited is a Wisconsin-based organization established in 1982 with over 90,000 members across North America that has spent over $50 million on educational programs, habitat conservation, and preservation of the huuting tradition to benefit white-tailed deer and other wildlife (www.whitetailsunlimited.com). *Deer and Deer Hunting* magazine was established in Wisconsin 1977 to provide practical and comprehensive information to hunters of white-tailed deer, especially in the upper Midwest. Current circulation is about 120,000 and the organization has branched out to include a television show, website, videos, books, and other information (www.deeranddeerhunting.com). Another growing and thriving venture made possible by the importance of deer to hunters is outfitting. Outfitters and guides service hunters by gaining access to land, setting up stands, providing food and lodging, and taking care of the needs of their hunting clientele, who are willing to pay for the service and the opportunity to hunt in prime areas withont the time and effort associated with finding and settiug up their own hunting grounds. In some areas, the presence of deer increases the value of land considerably. Once categorized as "agricultural land," snch sites are now marketed to hunters at much higher prices as "recreational property."

The popularity of white-tailed deer across the Midwest is not limited to those deer that are free ranging. The captive deer industry also has grown substantially in the last 25 years in the Midwest. Over 7800 facilities occnr across the nation, of which roughly 40% are iu midwestern states (Frosch et al., 2008). The market is driven primarily by the demand for opportunities to harvest large bucks, albeit behind high fences. Captive facilities range from small breeding operations of just a few hectares to large "hunt" properties of several thonsand hectares. In addition to income derived from harvest of deer, the captive industry also profits from selling breeding stock, antlers, antler velvet, nrine, photographic opportunities, venison, and other deer-derived products and deer-related activities. It is uot legal to sell venisou from deer harvested in the wild in the United States, but marketing of commercially produced venisou is legal. Sale aud consumption of commercially produced venison in the United States, though, is so low that it is not tracked by the U.S. Department of Agriculture.

While many positive attributes are associated with white-tailed deer, many negative impacts occur as well (Chapter 13). Deer cause more agricultural damage than any other species of wildlife iu the United States (Conover, 2002). In the Midwest, they are responsible for about a third of the damage caused to corn by wildlife, which amonnted to over $30 million in 1993 (Wywialowski, 1996) (Figure 17.4). Some states aud provinces in the regiou provide support to agricultural prodncers that experience damage from deer. Aid may be compensatiou for crops damaged (Wagner et al., 1997), provision of damage abatement tools (i.e., frightening devices, fence), or advice on how to alleviate damage (Craven

FIGURE 17.4 Extensive deer damage in cornfields in late-June leads to significant economic impacts for some midwestern farmers. Note that the plants should be over head-high. (Photo by S. Hygnstrom. With permission.)

and Hygnstrom, 1994; Hygnstrom et al., 2008b). After crop harvest, damage by deer continues to be a threat with consumption of stored feed, though one study showed amounts consumed to be minimal (VerCauteren et al., 2003).

Another real and significant concern is the potential for disease transmission from deer to livestock via direct contact as well as contamination of crops and feed (VerCauteren et al., 2003). Deer also play a role in transmission of zoonotic diseases (those that affect humans and wildlife). Lyme disease was first observed as arthritic conditions of children in Lyme, Connecticut in the early-1970s, but it was not actually identified until 1981 (Centers for Disease Control and Prevention [CDC], 2010). Since then, it has expanded across the country (Hoen et al., 2009). White-tailed deer are not effective reservoirs of Lyme disease but are hosts and vectors of black-legged ticks (*Ixodes scapularis*) that carry it (Brown and Burgess, 2001). Over 20,000 human cases of Lyme disease have occurred annually across the United States since 2002, with highest prevalence occurring in the Northeast and Midwest (CDC, 2010). In some midwestern states, such as Minnesota and Wisconsin, the range of black-legged ticks is expanding and the number of reported cases of Lyme disease in humans is increasing (Bacon et al., 2008). In addition, white-tailed deer carry various agents that can contaminate fruits and vegetables destined for human consumption (Rice, 2009), such as *Escherichia coli* 0157:H7 (Renter et al., 2001) and *Salmonella* (Renter et al., 2006).

Collisions between deer and vehicles cause considerable property damage and are a serious threat to human health and safety. Roughly 1.5 million DVCs occur annually across the United States, resulting in over $1 billion in damage, at least 200 human fatalities, at least 29,000 injuries to humans, and more than 650,000 deer fatalities (Conover, 1997) (Chapter 13). Illinois, Iowa, Michigan, Minnesota, and Wisconsin experienced a 22.7% increase in DVCs from 1993 to 2002, peaking at nearly 123,000 (Knapp, 2005). An average of 21 fatalities and 4715 injuries to humans occurred annually in these states during the study (Knapp, 2005). Annual vehicle-related mortalities of deer in the Midwest ranged from a low of 987 in Wyoming to a high of 76,626 in Wisconsin between 1982 and 1991 (Romin and Bissonette, 1996). In addition, 712 deer–aircraft (civilian) collisions occurred between 1990 and 2007 (Dolbeer and Wright, 2009).

Interestingly, deer attacks on humans have been documented in recent years in the Midwest. On 13 occasions people were attacked by deer on an Illinois campus (Hubbard and Nielson, 2009). The incidences were the result of many contributing factors including fawning period, relatively high deer densities, habituation to humans, and restriction of hunting (Hubbard and Nielson, 2009). Aggression toward humans by female white-tailed deer may occur when there is a perceived threat toward fawns (Grovenburg et al., 2009), as occurs when researchers capture fawns for tagging. Human-raised deer also attack people, likely because of habituation to humans.

White-tailed deer in the Midwest are considered a "keystone species," based on their affects on other species and the overall community structure in which they exist (Waller and Alverson, 1997; Rooney and Waller, 2003). Overabundant populations of deer can have deleterious impacts on entire biotic communities, impacting flora and fauna (Waller and Alverson, 1997; Wisdom et al., 2006). In 1947, Aldo Leopold, the "Father of Wildlife Management," predicted the impact that overabundant populations of deer could have on their habitat (Leopold et al., 1947). Deer populations can detrimentally impact both natural and induced forest regeneration (Waller and Alverson, 1997). They can damage trees at any developmental stage, and even at maturity trees continue to be shaped and scraped by deer browsing and rubbing. Ornamental trees and shrubs are particularly susceptible to deer damage, with nursery stock sustaining particularly high levels of economic loss (Hygnstrom et al., 2009). Production of Christmas trees has proven economically impractical in some areas without protection from browsing deer (Beringer et al., 1994). Deer not only inflict economic damage to plantings, but also may deplete particular tree species from entire areas (Côté et al., 2004). Overabundant deer are detrimentally affecting Canada yew and associated plant communities on the Apostle Islands in northern Wisconsin (Beals et al., 1960; Allison, 1990). Overabundant deer can actually lower the carrying capacity for their own species by removing preferred plant species and leaving only less-preferred species to prevail. Some unpalatable ferns, for example, have the potential to interfere with forest regeneration by outcompeting shrub and tree seedlings (Horsley et al., 2003; Côté et al., 2004).

High densities and expanding ranges of white-tailed deer increase interactions with other cervids including moose, elk, and mule deer in some areas of the Midwest. The interspecies interaction can

lead to a greater risk of disease transmission, competition for resources, and, in the case of mule deer, hybridization. White-tailed deer and mule deer live sympatrically in the western half of the Midwest region. Competition for resources between the two species has been hypothesized to be a contributing factor in the decline of mule deer populations throughout their range. Studies suggest that while there may be some common exploitation of food resources, little direct competition occurs between the two species (Martinka, 1968; Krämer, 1973; Swenson et al., 1983). Exploitation of common food resources was most common during winter when food availability was lowest (Martinka, 1968). Differences in preferred habitats minimized most of the interactions between the two species during the remainder of the year (Martinka, 1968). Interestingly, we observed that indirect contact between mule deer and white-tailed deer in western Nebraska was higher during summer (mean overlap = 79%) than winter (mean overlap = 53%), a response to smaller home ranges and greater niche segregation during winter (W. D. Walter, USDA-National Wildlife Research Center, unpublished data).

Mule deer and white-tailed deer are able to interbreed and produce reproductively viable offspring (Krämer, 1973; Wishart, 1980). The potential for hybridization coupled with declining mule deer populations in parts of their range has led to some concerns about the negative effects hybridization may have on mule deer populations. Male white-tailed deer are more likely to breed with female mule deer than are male mule deer likely to breed female white-tailed deer, due to the persistence of whitetail bucks and more approachable manner of mule deer does (Wishart, 1980; Stubblefield et al., 1986). In addition, white-tailed deer generally produce more fawns/doe than do mule deer. The western portion of the Midwest was historically dominated by mule deer, but habitat is transitioning into wooded cover in some areas, which favors white-tailed deer. As whitetail populations increase in these areas, hybridization may increase. Recommendations to minimize the risk of continued hybridization include reversing habitat succession and increasing harvest of white-tailed deer (Stubblefield et al., 1986; Wiggers and Beasom, 1986). Some state wildlife agencies have attempted to protect less robust populations of mule deer by suppressing white-tailed deer through increased harvest.

Landscape Influences

Landscape

One might ask why white-tailed deer are distributed across the Midwest landscape as they are. In general, white-tailed deer are found throughout the Midwest, but their abundance is greatly influenced by the amount of forested cover and agricultural food available (VerCauteren and Hygnstrom, 2004; Walter et al., 2010). In addition, their home ranges, seasonal movements and use areas, and daily movements are influenced by the environment that surrounds them (VerCauteren and Hygnstrom, 1994; Hygnstrom et al., 2008a). White-tailed deer classically are considered an "edge species" (Swift, 1946; Williamson and Hirth, 1985; Alverson et al., 1988). They do best in mixed landscapes where cover and food are juxtaposed and readily available. Much of the Midwest provides excellent habitat because it consists of a mix of forest and agricultural lands (Zwank et al., 1979; Compton et al., 1988; VerCauteren and Hygnstrom, 1998; Figure 17.3). Lowest densities of deer in the Midwest are found in the heavily forested area of the northern Great Lakes region, the western Great Plains that is dominated by grasslands, the "Corn Belt" where wooded cover is sparse, and the inner city where there isn't a tree behind which to hide and 8-cylinder predators from Detroit abound. Several environmental and anthropomorphic factors have shaped the Midwest that influence the distribution and abundance of white-tailed deer across the landscape.

Climate and Land-Use

The Midwest landscape follows an east–west gradient in precipitation that influences plant communities. High rainfall in the east supports lush deciduous forests with dense and diverse understories and ground covers. Low rainfall in the west limits distributions of plants to include drought-tolerant species generally associated with arid shortgrass prairies. Expansion of agricultural crops in the Midwest followed timber harvest in the east, conversion of prairie in the center, and irrigation development in

the west. High densities of white-tailed deer are found in the agro-forest complexes found throughout the Midwest. Large areas of predominantly agricultural land, however, do not sustain large populations of white-tailed, due to the lack of permanent cover. Large grassland areas of the western Midwest have relatively low densities of white-tailed deer because forest and agricultural covertypes are limited.

Ecological Succession

Agro-forest ecosystems can support high densities of white-tailed deer, but foraging activities by deer can have serious and far-reaching effects on plant and animal communities (deCalesta, 1994a,b). White-tailed deer can pose a direct threat to forest structure and composition (Rooney, 2001; Russell et al., 2001). In the early 1990s, Diamond (1992) noted that overabundant deer were degrading habitat at Fontenelle Forest, Nebraska and causing "reverse succession." Persistent browsing by deer was preventing regeneration of climax canopy species, which were being replaced by mid-level and invasive species. Diversity of woody plants in the forest understory declined, but grasses increased (Gubanyi et al., 2008). Alverson et al. (1988) suggested that repeated browsing by white-tailed deer has prevented regeneration of Canada yew, eastern hemlock, and white cedar in northern Wisconsin. Others have reported, however, that although extremely high densities of deer and associated browsing negatively affected many forest species, including eastern hemlock, a multitude of factors influence hemlock regeneration in the upper Great Lake region, including climate, disturbance, hemlock life history, ecosystem processes, and historical land use (Mladenoff and Stearns, 1993).

Timber Harvest

Forests and forestry practices in the Midwest have had a huge impact on populations of deer historically, especially in the northern, eastern, and Great Lakes regions where climax forest types dominated the landscape prior to European settlement. Biological carrying capacity of these old-growth forests for deer was relatively low and densities of deer were much lower than they are today. Extensive timber harvest and associated wildfires in the late-1800s and early-1900s led to the widespread regression of seral stages, expansion of agriculture, and the resnltant creation of edge. Populations of white-tailed deer responded and peaked in the 1930s and 1940s at 14 deer/km^2 in Wisconsin and other Great Lakes states (Swift, 1946; Alverson et al., 1988). Through the twentieth century, eastern deciduous and southern boreal forests regrew and now provide high-quality cover for white-tailed deer.

Habitat management is needed in northern forests where deer numbers are relatively low due to seral stages nearing climax, low biological carrying capacity, and winter severity. Lesage et al. (2000) maintain that the limiting factor for white-tailed deer in tbeir northern range is adequate wintering areas, and that these areas are highly vulnerable to insect epidemics, forest fires, and logging. In specific situations when food resources are limiting, the potential for considerable winter mortality exists. In northern reaches of the Midwest, over-browsed winter range can be detrimental to local populations when weather conditions prompt deer to congregate in areas that are deficient in quality food sources (Dahlberg and Guettinger, 1956; Van Deelen et al., 1997). Losses due directly to starvation are observable while delayed impacts, such as reduced neonatal survival, can be equally, if not more devastating (Blouch, 1994). Critical wintering areas (i.e., deeryards) should be protected from timber harvest to maintain current deer populations and provide sources for future populations at northern latitudes (Van Deelen et al., 1998; Lesage et al., 2000; Morrison et al., 2003). Millions of hectares of public and commercial forests in the North are managed for the production of timber and other forest products, which benefits white-tailed deer. In large blocks of forests, agencies created forest openings to increase edge and forage production (McCaffery, 1984). In addition, yarding areas were protected from timber harvest to sustain these critical winter habitats.

Agricultural Expansion

Removal of much of the native forests in the eastern and northern portions of the Midwest resulted in a landscape that was available for conversion to agriculture (Ramankutty and Foley, 1999; Turner and Rabalais, 2003) and the untilled prairie was a sea of opportunity to early farmers and settlers.

Early settlement precipitated small farms and fields with a relatively high degree of edge. The crosscut and horse were replaced by the chainsaw and tractor as increased mechanization led to more land converted from forests and grasslands to agriculture throughout the Midwest. Diverse small fields gave way to large fields, monocultures, and simple rotations of corn and soybeans. Much of the native tallgrass prairie in Illinois, Iowa, Kansas, and Nebraska fell to the plow. The Midwest became known as the "Cornbelt" and "America's breadbasket" in the mid- to late-1900s.

Agricultural crops in the Midwest compliment the annual cycle of nutrient requirements of white-tailed deer (Mautz, 1978). Demand for digestible energy, protein, and other nutrients is high during spring when deer are recovering from winter food shortages and pregnant does are nearing parturition. Winter and spring wheat, as well as alfalfa, are used extensively by deer during spring green-up (Vecellio et al., 1994; Frost et al., 1997), when the winter snows subside, because these crops are available, palatable, and provide a highly needed source of nutrition at a time when other foods are lacking. Nutrient requirements also are high during summer and early autumn as does nurse fawns and bucks produce antlers. Both sexes also must accumulate fat reserves for winter and be healthy going into the fall breeding season. Agricultural crops such as corn and soybeans are abundant and high in carbohydrates, protein, and other nutrients during the growing season. Deer eat corn at all stages of growth, especially during the silking–tasseling stage in early- to mid-summer and when ears are ripe in autumn (VerCauteren and Hygnstrom, 1998). Deer eat soybeans, especially during the early stages of growth up to flowering and pod set (Nixon et al., 1970; deCalesta and Schwendeman, 1978). During winter, deer experience a negative energy balance because of low temperatures, snow depths, and limited forage resources (Mautz, 1978). Waste grain in fields after harvest provides a forage base for deer in agricultural areas throughout the winter (Figure 17.5). A plethora of specialty crops also are highly preferred and eaten year-round by white-tailed deer, including nursery crops, fruit trees, vineyards, vegetables, ornamentals, and organic farm prodnce.

Today, many areas of the Midwest are so intensively farmed that populations of white-tailed deer are relatively low. Where agriculture exceeds about 75% of the landscape, populations of white-tailed deer decline, but deer thrive in areas where at least 25% of the landscape exists in forest. West of the 100th meridian the Midwest is too arid for extensive forest growth and sustained dryland farming. Instead, shortgrass and mixed-grass prairie dominate the landscape. Since the mid-1900s, irrigation has led the

FIGURE 17.5 White-tailed deer use agricultural crops in the Midwest to satisfy their nutritional requirements throughout the year which has contributed to overabundance of white-tailed deer, a problem in many areas of the Midwest. Concerns about crop damage and deer–vehicle collisious offset the demand for high densities of deer for hunting and viewing, a concept biologists call "sociological carrying capacity." (Photo by G. Clements. With permission.)

way to expansion of agricultural crops westward, especially corn and soybeans. Human interests in western land and water led to the damming, channelization, diversion, and stabilization of rivers and streams in the west for flood control, irrigation, and power development. Stabilization led to expansion of western riparian forests and increased continuity of riparian forested corridors. Recent colonization by white-tailed deer has occurred in the western Great Plains, primarily along forested riparian areas (Kufeld and Bowden, 1995; Colorado Division of Wildlife, 2008) such as the Missouri, Platte, and Republican Rivers and their tributaries. In addition, suppression of fire in the grasslands, because of agriculture and human development, often has resulted in the increase of woody vegetation.

Rangeland is an important component of American agriculture. Over 60% of the western landscape consists of grasslands, most of which are grazed by livestock. These rangelands are not very suitable for white-tailed deer and typically forested cover is lacking, except along riparian areas. White-tailed deer are browsers first and do not do as well where grazing and grasslands predominate. Deer tend to avoid cattle and so are often displaced from the most desirable areas in rangeland–forested cover and watering areas.

Conversion of cropland to grassland through government agricultural programs, such as the Soil Bank Program in the 1950s and 1960s led to dramatic changes in the midwestern landscape. More recently, the Conservation Reserve Program, established by the Federal Food Security Act of 1985, resulted in conversion of up to 16 million hectares of cropland to grassland and other conservation plantings. Grasslands are not ideal habitat for deer, but they can provide food, cover, and vast areas of undisturbed space.

Development

Concrete and blacktop are not good deer habitat. However, in recent times, deer have acclimated to urban sprawl and suburban development (Cornicelli et al., 1996; Hygnstrom and VerCauteren, 1999; DeNicola et al., 2000; Etter et al., 2002; Grund et al., 2002) and more recently exurban development (Storm et al., 2007). Urbanites enjoy the aesthetic benefits of trees, grass, flowers, ornamentals, gardens, and ponds. Many "green spaces" (i.e., parks, arboretums, wetlands) create a mosaic with edge, providing sufficient food, water, and shelter for deer. Deer have moved into developed areas and development has moved into traditional deer habitat. The human population of Michigan is expected to increase 12% between 1990 and 2020, which equates to a 63–87% increase in the amount of land devoted to urban use (Smyth, 1995). Hunting is often restricted in developed areas due to concerns about public safety (DeNicola et al., 2000). Populations of deer can increase to extremely high levels in developed areas where deer are not actively managed through hunting or some other intervention.

Human Demographics

Archaeological evidence indicates that sizable communities of Native Americans and extensive agriculture existed in the Midwest long before Columbus brushed the shores of the North American continent (Mann, 2005). It appears that rampant diseases associated with early European explorers and settlers led to dramatic declines in these prehistoric societies. According to recent history (within the last 400 years), the Midwest went from periods of relatively low densities of Native Americans, settled and nomadic, to the high densities of our urbanized and diverse culture of today. Exploration of the Midwest by the French started in the mid-1600s. The most notable explorers, Meriwether Lewis and William Clark, traversed the Midwest in 1801–1804 by way of the Missouri River and brought back stories of the untamed and bountiful landscape to the then President Thomas Jefferson (Moulton, 2003). The Mormon Trail, Oregon Trail, and other routes followed, bisecting the western Midwest and provided settlers access to many areas that had little evidence of human development. The Homestead Act of 1862 encouraged hundreds of thousands of European settlers to fill the landscape of the Midwest and Great Plains (Cross, 1995). By law, they had to build homes and break the land to raise crops. Railroads eventually crossed the Midwest and provided a steady stream of meat from deer, elk, and bison eastward to feed a growing nation. The market hunting era (i.e., unrestricted hunting for commercial use) led to decimation of many populations of wildlife in the Midwest in the late 1800s. By 1900, only 50 deer were left in all of Nebraska (Menzel, 1984). In 1930, about 1.6 million people occupied the state of Nebraska

and surprisingly, the human population is about the same today. The difference, however, is the distribution of those people. In the 1930s, people were scattered throughout the state, living on homesteads and in the small communities of rural Nebraska. After World War II, a shift of people occurred from the farms and rural areas to the bright lights of the big cities. Cities such as Chicago, Des Moines, Detroit, Kansas City, Milwaukee, Minneapolis, Omaha, and St. Louis grew at remarkable rates. The shift of people from rural to urban areas left large rural landscapes relatively vacant, both spatially and culturally (Berry, 1977).

Refugia

In the urban areas, city planners protected greenspaces from development. City parks, arboretums, wooded corridors, and wetlands were relatively undeveloped and deer colonized these areas where hunting was restricted or prohibited (Figures 14.19 and 14.20). The 1980s saw a movement of people out of the cities and iuto the nearby country. Development of 1–20 ha sized lots and ranchettes became popular and these periurban areas often provide ample food and cover for deer and other wildlife. In addition, absentee landowners purchased blocks of prime deer habitat, often for hunting and other recreational purposes. Hunting typically is limited to family or friends, if at all, in these areas, so mortality rates of local deer herds are much lower than surrounding areas. These refugia led to expanding populations of deer that have often exceeded carrying capacity and caused significant problems for adjacent landowners. Ou the other hand, wildlife refuges, such as those managed by the U.S. Fish and Wildlife Service, play an important role iu sustaining populations of white-tailed deer in the Midwest, once adjacent croplands are cleared during harvest (Hanseu et al., 1991; VerCauteren, 1998; Walter et al., 2009). VerCauteren (1998) found densities of deer on DeSoto National Wildlife Refuge (DNWR) in the Missouri River Valley of eastern Nebraska to be nearly four times greater than on surrounding agricultural lands (19 vs. 5 deer/km^2). Organized public hunts are conducted on DNWR, yet densities of deer exceed those of surrounding areas. Areas where hunting is not permitted and suitable deer habitat exists, such as suburban developments and larger city parks, allow deer densities to soar (DeNicola et al., 2000).

Predators

In most areas of the Midwest, nearly all mortality of white-tailed deer can be attributed to human-related causes, primarily hunting and DVCs. Disease, predation, starvation, and occasionally old age encompass the remaining mortality factors. The wide distribution and increase in abundance of white-tailed deer throughout the Midwest have aided in recolonization and increased densities of predators, primarily coyotes and gray wolves.

Coyotes are the most widely distributed predator–scavenger in the Midwest (Figure 8.7). Although relatively small, they have the ability to take even healthy white-tailed deer and probably consume more deer than the other predators. Coyotes commonly prey upon young fawns and old, sick, or injured individuals. Coyote predation was reported as the leading cause of fawn mortality in Illinois (69%) (Nelson and Woolf, 1987), and Iowa (54%) (Huegel et al., 1985). However, Bryan (1980) and Schulz (1982) reported little or no mortality caused by predation in Missouri and Minnesota, respectively. White-tailed deer are especially important to coyotes during fawning, during and after hunting seasous, and in late winter (Huebschman et al., 1997). White-tailed deer are vulnerable to predators during late winter due to the prolonged effects of winter weather and reduced forage.

Populations of gray wolves in Minnesota, Wisconsin, and Michigan have increased in recent years and are expanding into areas that have been unoccupied by wolves since the early 1980s. Recolonization in Michigan and Wisconsin likely occurred from a large and stable population of wolves in northeastern Minnesota (Fuller et al., 1992; Wydeven et al., 1995). As their range has continued to expand in recent years, states such as Illinois, Indiana, Nebraska, and South Dakota have documented the presence of wolves: these isolated iucidents likely reflect transient or dispersing individuals that have moved south from Minnesota or Wisconsin. Predation of white-tailed deer by wolves contributes significantly to mortality in some locations such as northern Minuesota (Nelson and Mech, 1986a,b; Kunkel aud Mech, 1994), yet less so in Wisconsin and Michigan where wolf populations are still in recovery

(Blouch, 1994; Van Deelen et al., 1997). The frequency of kills by a wolf pack varies depending on pack size, deer density, snow conditions, and abundance of alternative prey. In Minnesota, where wolves eat white-tailed deer almost exclusively, estimated kill rates range from 15 to 20 deer/wolf/year. Deer are the primary prey of wolves, so it is reasonable to assume that wolves compete with hunters for deer in the area. The extent to which wolf predation and human hunting actnally compete, however, may depend on the intensity and compensatory nature of each. Nelson and Mech (2000) found inconsistent relationships between wolf numbers and harvest of male white-tailed deer. They suggest that competition between hunters and wolves is probably greatest in areas of poor quality habitat where deer densities are low.

Black bears also prey on white-tailed deer, primarily young fawns that cannot yet escape search and pursuit (Kunkel and Mech, 1994; Carstensen et al., 2006). Compared to wolf predation though, which is a continual threat to fawns, bear predation is generally a minor contributor to fawn mortality (Nelson and Mech, 1986a). In most studies, mortality of fawns due to black bears was low (Ozoga et al., 1982; Ballard et al., 1999); however, Vreeland et al. (2004) reported that black bears were responsible for 31% of all mortality by predators.

Mountain lions were extirpated from most of the Midwest in the early 1900s but they have been observed throughout the region with increasing frequency in the last decade (The Cougar Network, 2010). Mountain lions can prey on white-tailed deer of any sex–age class, but lion numbers currently are so low that they have little impact on populations of white-tailed deer. Bobcats also have been documented to kill fawns (Ballard et al., 1999; Vreeland et al., 2004; Carstensen et al., 2006). They are not, however, considered an important predator of white-tailed deer.

Disease

In the Midwest, a few diseases of deer have state and federal biologists seeking solutions (Figure 17.6). Bovine TB became established in a five-county area in the northern portion of the Lower Peninsula of Michigan in the 1990s. The disease was likely introduced by cattle and is now maintained in free-ranging deer. High densities of deer and supplemental feeding likely contributed to the establishment and spread of bovine TB in Michigan (O'Brien et al., 2002, 2006). Deer densities in the core of the bovine TB area of northern Michigan were 19–23 deer/km^2 (Schmitt et al., 1997). The Michigan Department of Natural Resources adjusted hunting regulations to increase harvest and reduce deer density. Although much higher densities of deer have been documented elsewhere in the United States, concentrating deer over limited food supplies provides the means needed for a disease outbreak to occur (O'Brien et al., 2002). More reasonable goals of 8–15 deer/km^2 in areas of the Midwest, such as Missouri, represent popnla-tions that satisfy needs of the general public while still maintaining a healthy population (Hansen and Beringer, 1997).

FIGURE 17.6 Diseases such as epizootic hemorrhagic disease-bluetongue (EHD-BT) have caused significant mortality in white-tailed deer in localized areas in the Midwest. (Photo by G. Clements. With permission.)

Chronic wasting disease (CWD) is another disease of white-tailed deer, occurring in free-ranging and captive popnlations, that is currently found in some parts of the Midwest. It also affects mule deer, elk, and moose. The disease typically leads to illness and death in infected individuals within 18 months (Chapter 7). Although prevalence is usually low, up to 35% prevalence has been observed in some free-ranging populations of white-tailed and mule deer (Williams, 2005; Farnsworth et al., 2006; Joly et al., 2006). Mobility of deer may play a role in transmission of CWD across the landscape (Frost et al., 2009; Clements et al., 2011). Levels of prevalence up to 79% have been documented in captive white-tailed deer facilities (Keane et al., 2008). Eradication of CWD in free-ranging popnlations may not be possible without eradicating the host (Wasserberg et al., 2008) and the disease agent can be remarkably persistent in the environment (Miller et al., 2004). Computer-based models that facilitate prediction of disease spread and impact on deer populations are contributing information for developing management plans (e.g., Frost et al., 2009). One model shows the importance of managed harvest in CWD-infected herds in Wisconsin and predicts that CWD may eventually compete with recreational hnnting (Wasserberg et al., 2008). Unfortunately, CWD appears self-sustaining in deer populations, a treatment for the disease has not been identified, and the disease is spreading across the landscape.

Hemorrhagic disease (HD) is the most important viral disease affecting populations of white-tailed deer in the United States: it is seasonal, cyclic, and herd immunity is highly variable (Davidson, 2006). Hemorrhagic disease, caused by EHD and BT virus is common in the Midwest (Beringer et al., 2000) and occasionally has substantial impacts on local populations of deer (Gaydos et al., 2004). Although other species are susceptible to HD, white-tailed deer experience the highest mortality (Matschke et al., 1984). It is an arthropod-borne disease and outbreaks typically occur during late summer and early fall in association with Culicoid midges. It is not uncommon for hundreds of deer to fall victim to the disease when an outbreak occurs (Matschke et al., 1984). Global warming has been suggested as playing a role in its distribution and spread, especially into northern latitudes (Gibbs, 1992; Sleeman et al., 2009). Management agencies can do little to prevent HD and local populations of deer typically rebound quickly, so harvest regulations often are not modified following an outbreak.

White-tailed deer and moose are both hosts to a parasitic meningeal worm (*Parelaphostrongylus tenuis*). Eggs of this parasite are expelled in the feces of deer and are ingested by gastropods that come into contact with the fecal matter. Deer and moose ingest the metacercarial stage when they inadvertently consume infected gastropods while feeding (Anderson and Lankester, 1974). Worms mature and migrate into the central nervous system, often coming to rest in the meninges in deer, where they have a limited effect on overall health (Alibasogulu et al., 1961; Anderson, 1963; Anderson et al., 1966). In moose, however, the worms more often migrate throughout the brain, leading to radical changes in behavior and death. Until the 1980s, researchers hypothesized that moose populations were in decline because of increasing deer densities and resultant higher infection rates in moose from meningeal worm (Lenarz, 2010). Recent research, however, indicates that meningeal worms are not a major cause of mortality in moose populations (Whitlaw and Lankester, 1994; Murray et al., 2006). Further, increased deer numbers have not led to an increase in the prevalence of meningeal worm in the environment (Thomas and Dodds, 1988; Bogaczyk et al., 1993).

Recent History of Deer in the Midwest

In the early 1800s, populations of white-tailed deer across the Midwest were in recovery following extensive harvests for trade by indigenous people. However, by the mid-1800s, market hunting became a lucrative endeavor, thus populations of white-tailed deer again were on the decline. Reports from across the upper Midwest include details such as "in the fall of 1877 Ivory Livermore and three companions hunted on the North Fork of the Eau Claire River and killed for the market 118 deer and 26 bears from September 1–December 1" (Young, 1956). A single shipment of deer meat from Litchfield, Minnesota in December 1877 carried 5443 kg of venison and was destined for Boston, Massachusetts (Young, 1956). The advent of repeating rifles and the westward spread of railroads provided means for more efficient harvest and shipping, intensifying the decline of white-tailed deer. Prior to 1900 and the passage of the Lacey Act, restrictive game laws were only considered a nuisance (Young, 1956). The Lacey Act

provided means for prosecuting individuals involved in transport of illegally taken wild game across state borders and combined with scarcity of deer resulted in the beginning of the end of market hunting for white-tailed deer (McCabe and McCabe, 1984).

Several factors contributed to the steady rise in deer populations throughout the twentieth century, including widespread predator suppression, a focus on hunting bucks, decreasing hunter access, moderate climates (Côté et al., 2004), and high-intensity agriculture, abandonment of small farms, forest protection, and suburban development. It was estimated that white-tailed deer numbered between 24 and 33 million around 1500 (McCabe and McCabe, 1984; VerCauteren, 2003). Surveys of deer biologists from state wildlife agencies suggest the current population of white-tailed deer in the United States is about 28.5 million (Figure 11.1), with over a third (about 10 million) in the Midwest (Table 17.1).

When populations began to rebound, they did so quickly and a review of over-populated deer ranges conducted in the 1940s revealed several locations across the Midwest where high densities were leading to habitat damage or starvation of deer (Leopold et al., 1947). Decades later, habitat loss across the Midwest associated with suburban sprawl and increased agricultural development created concerns over the potential for population declines (Hansen and Beringer, 1997). Concerns were unjustified; populations continued to climb as deer readily adapted and even thrived in the newly fragmented landscape. High-quality agricultural crops were now in greater abundance, reducing reliance on natural forage and enabling deer populations to increase (Figure 17.5). Deer are increasingly managed at social carrying capacity, with target densities based on landowner tolerances relative to damage inflicted by deer (Hansen and Beringer, 1997). Increased disease, DVCs, and damage to agricultural crops, landscapes, gardens, and habitat all serve to lower sociological carrying capacity in many areas across the Midwest (DeNicola et al., 2000). Ecological carrying capacity, K, the number of deer the habitat can support, is still relevant although often not a key component in developing management strategies for deer. For example, food often is the limiting factor in northern reaches of the Midwest, which in the past led to supplemental feeding. Supplemental feeding is a tradition in parts of this region and not only allows populations to exceed what their habitat can sustain, but also facilitates disease transmission (O'Brien et al., 2006).

TABLE 17.1

Number of White-tailed Deer and Deer Hunters and Harvest Data, by State, in the Midwestern United States

	Number of White-tailed Deer	Number of Deer Hunters	More Hunters Now Than 25 Years Ago?	Number of White-tailed Deer Harvested/ Year	Maximum Number of White-tailed Deer a Hunter Can Harvest/ Year
Colorado	15,000	90,000[a]	No	1826	2
Illinois	775,000	275,000	Yes	195,000	Unlimited antlerless
Indiana	550,000	229,000	Yes	130,000	~400
Iowa	340,000	180,650	Yes	140,000	Unlimited antlerless
Kansas	568,000	115,000	Yes	77,500	7
Manitoba	125,000	34,000	No	18,329	4
Michigan	1,700,000	735,000	Yes	480,000	Unlimited in some areas
Minnesota	1,000,000	500,000	Yes	340,000	Unlimited in some areas
Missouri	1,400,000	500,000	Yes	300,000	Unlimited antlerless
Montana	250,000	150,000[a]	Yes	65,000	11
Nebraska	300,000	60,000	Yes	68,600	Unlimited antlerless
North Dakota	500,000	110,000	Yes	100,000	~20
Ontario	450,000	185,000	Yes	85,000	6
Saskatchewan	355,000	53,325	Similar	32,793	4
South Dakota	200,000	81,500	Yes	74,000	45
Wisconsin	1,500,000	670,000	Similar	450,000	Unlimited antlerless
Wyoming	57,027	26,143	Yes	14,792	2

[a] Includes both white-tailed and mule deer.

Current Management

Deer are the economic engine of most state wildlife agencies in the Midwest, as revenue generated from the sale of hunting permits typically supports most state agency personnel and management programs, including those for nongame species. State and provincial wildlife agencies primarily manage, or manipulate the size of deer populations by regulating hunter harvest. Agencies typically have limited jurisdiction to manage deer habitat on a broad scale, but have advisory input to state, provincial, and federal land management agencies. As such, wildlife agencies directly influence one component of deer mortality, hunter harvest, but may only indirectly influence habitat factors that contribute to both survival and recruitment. Hunter harvest is a powerful management tool, however, that can impact both survival and recruitment through density-dependent processes. Hunter harvest also can be used to alter the sex–age structure of deer populations to achieve management goals.

By necessity, management of white-tailed deer is evolving and dynamic in most midwestern jurisdictions, transitioning from an emphasis on recovering deer herds from historic overexploitation to that of sustaining deer populations in balance with ecological and sociological carrying capacities. Current regulations across the Midwest suggest a need to reduce white-tailed deer on at least localized scales. All midwestern states currently allow hunters to take antlerless deer and many have liberal seasons of extended length that allow harvest of several antlerless deer (Table 17.1). Several states have "urban" hunts to reduce numbers of deer in urban/suburban areas using hunting under specific regulations (Hansen and Beringer, 1997; Doerr et al., 2001). Other sensitive areas such as military bases, industrial parks, wildlife refuges, and national parks (Fulton et al., 2004) have begun using managed hunts to control white-tailed deer populations.

Wisconsin, Illinois, South Dakota, Colorado, and Saskatchewan will be highlighted here as examples of how and why management philosophies and techniques need to vary among jurisdictions to achieve goals. Deer management and hunting in Wisconsin has a long and storied history (Swift, 1946; Wisconsin Department of Natural Resources [WDNR], 2009d). Illinois is particularly interesting because a task force appointed by the General Assembly recently recommended that deer management quotas be determined based on the number of DVCs by county (Joint Task Force, 2008) and because it is one of the last jurisdictions that continues to manage CWD by aggressively reducing the density of local deer herds. South Dakota removed antler-point requirements in the Black Hills in favor of reduced numbers of deer permits to increase numbers of bucks, unlike Missouri, where antler-point restrictions imposed in some units require hunters to harvest bucks with a minimum number of antler points, to increase numbers of mature bucks and balance sex ratios. Colorado allows liberal harvest of white-tailed deer in its eastern plains to reduce the number of white-tailed deer relative to sympatric and declining mule deer. Saskatchewan was the only Midwestern jurisdiction that depended primarily on aerial surveys to estimate the size of deer populations (Saskatchewan Ministry of Environment [SME], 2009). These jurisdictions represent the broad diversity in philosophy, goals, and objectives that exist today in midwestern deer management.

Wisconsin

Millspaugh et al. (2009) described Wisconsin's deer management process as the most comprehensive and transparent among comparable states, and credited it for the variety and quantity of biological data acquired as well as for the thoroughness with which these data are used. Wisconsin has 133 deer management units (DMU) (WDNR, 2009a). Population goals for DMUs are set every three years and antlerless harvest quotas and permit numbers are set annually (WDNR, 2001). Population goals are set with consideration of both ecological and sociological carrying capacities. Extensive public input has been included in the goal-setting process for decades. In forested DMUs, goals are approximately 60–65% of ecological carrying capacity (WDNR, 2009b) to ensure conservative harvest where environmental uncertainty causes highly variable winter mortality, particularly in the northern region of the state (WDNR, 2001). In largely agricultural and urbanized DMUs, population goals are less than 50% of ecological carrying capacity, reflecting reduced sociological carrying capacity due to crop damage

and the risk of DVCs (WDNR, 2001). Despite intensive management of deer in Wisconsin, the overall trend in the statewide postharvest population has progressively exceeded annual goals since 1986 (Rolley, 2008; WDNR, 2009c) and deer numbers were 38% over goal in 2008.

The size of prehunt and posthunt deer populations are estimated statewide and by DMU using the sex–age–kill (SAK) model, which relies heavily on data from mandatory hunter registration and inspection of harvested deer (Eberhardt, 1960; Creed et al., 1984; Skalski et al., 2005; Millspaugh et al., 2009). In DMUs where the SAK model is inappropriate because of temporally inconsistent harvest rates of bucks, population estimates are based on accounting-type population models and/or aerial surveys (Rolley, 2008). Post-hunt populations are projected forward to estimate population size prior to the next hunting season, which is used along with various subjective considerations to set annual antlerless harvest quotas. The number of antlerless permits to be issued is determined using DMU-specific nonlinear models of estimated antlerless harvest as a function of number of permits (WDNR, 2001). To reduce crop damage and manage CWD, Wisconsin has also used DMU-specific opportunities and incentives (e.g., early antlerless-only seasons, unlimited antlerless permits, and inexpensive or free antlerless licenses) and special requirements (e.g., earn-a-buck, which requires hunters to harvest an antlerless deer before harvesting a buck) to increase harvests beyond those attainable under regular buck and antlerless permitting (Van Deelen, 2010). The quota-setting process is intensive and highly data driven, yet open to informed subjective modification, reflecting hoth the science and art of deer management.

Finding CWD in three deer harvested in south-central Wisconsin in 2001 (WDNR, 2009a) complicated deer management in the state. Beginning in 2002, CWD has been managed in portions of the state using combinations of special reduced population goals, increased quotas and numbers of permits, special collection periods, exceptional methods of shooting deer, and additional or extended harvest seasons (WDNR, 2002; Wisconsin Natural Resource Board [WNRB], 2002; WDNR, 2009a,h). In 2002, a core "Eradication Zone" (enclosing all cases of CWD-positive harvested deer) was established with a goal of 0 deer/km^2 and a surrounding huffer area or "Management Zone" with a radius of 64 km from the center of the Eradication Zone was established with a goal of 26 deer/km^2 (WDNR, 2002; WNRB, 2002; Wisconsin Legislative Audit Bureau, 2006). Objectives were to eradicate CWD from the area where it was known to exist and to reduce risk of further spread by reducing densities of deer in the surrounding area. In mid-2003, CWD was detected in a wild deer outside the original Eradication Zone near the border with Illinois, which led to the designation of a second Eradication Zone (both renamed as "Disease Eradication Zones," or DEZs) and an expanded "Herd Management Zone" (HRZ, formerly Management Zone) for the 2004 hunting season (WDNR, 2004). Population goals were relaxed to a target of <13 deer/km^2 for DEZs in mid-2004 (WNRB, 2004). A CWD Stakeholder Advisory Group (CWDSAG) was established in 2007 to seek public input and provide recommendations for future management directions (CWDSAG 2008). Subsequently, DEZs and the HRZ were combined into a single CWD Management Zone, 2008 goals were revised to DMU-specific densities of 26–62 deer/km^2, and season structure in the CWD Management Zone was shortened to better align with those of other over-goal DMUs in the state (WNRB, 2008a,b,c). These changes reflected the evolving recognition that CWD cannot be eradicated from Wisconsin using existing technology under prevailing sociological constraints (WDNR, 2009a; Garner et al., 2009). Saskatchewan also discontinued their CWD eradication program recently (SME, 2009a).

Estimates of deer densities in CWD units indicated a stable or slightly declining trend since 2002 (WDNR, 2009a). However, the number of deer in CWD units were never reduced to near goal in 2002–2007 and remained more than two-fold greater tban the revised higher goal for 2008 (Garner et al., 2009). Wisconsin hunters have the opportunity to kill more deer but chose not to, partly because tbey remain unconvinced of risks posed by CWD (Holsman and Cooney, 2007; WDNR, 2009a). Unless hunters can be convinced that disease management is a higher priority than traditional factors that motivate them, it will be difficult to achieve harvest goals established for management of CWD.

Illinois

The Illinois Department of Natural Resources (IDNR) estimates fecundity, mortality, and age structure of white-tailed deer from annual or periodic snrveys (Millspaugh et al., 2006). These data are used to estimate the size of county-specific populations of deer when analyzed within an accounting-type

population model that can be simultaneously calibrated against various indices. The IDNR uses rates of DVCs, deer depredation complaiuts, hunter harvest data, bowhunter observatious, and spotlight surveys to generate indices for the deer population. Beginning in 2009, Illinois began using rates of DVCs (number of collisions aud deer-related accidents/1.6 billion vehicular km traveled) as the objective for measuring status of deer populations at county and statewide levels (Joint Task Force, 2008). Initial objectives were determined as the midpoint between minimum and maximum annual DVCs during 1994–2007 (Joiut Task Force, 2008). Biological data and modeling continue to be considered, along with tolerable levels of DVCs when setting harvest quotas and season structures, as well as for assessing whether county DVC goals are reasonable. In general, counties well above DVC goals are managed using liberal antlerless harvest during all firearm deer seasons (Joint Task Force, 2008). In addition, late-winter antlerless seasons are used to increase harvest in counties above or near DVC goals. The approach in Illinois to managing deer is novel because efficacy of deer management is assessed directly against the number of DVCs.

Illinois shares a CWD outbreak area with Wisconsin. As of January 2010, IDNR continues aggressive management, using both public hunting and agency sharpshooting, to reduce deer herds in CWD counties irrespective of DVC levels. Liberal quotas (exceeding demand) during archery and firearm seasons have been in place since 2003 in CWD counties (Shelton and Hulin, 2004, 2005, 2006; Shelton and McDonald, 2008a,b, 2009). Beginning in January 2006, a special late CWD season concurrent with late-winter seasons in some non-CWD counties was established in four CWD counties. During CWD seasons, hunters can use unfilled permits from previous firearm seasons, and/or purchase inexpensive additional antlerless-only permits (Shelton and Hulin, 2006). Following public hunting seasons, sharpshooters have annually removed deer from CWD counties since January 2004 to further reduce deer populations and to increase CWD surveillance, particularly in areas inaccessible to public hunters. Sharpshooting has focused on areas of winter deer concentrations on or near CWD-infected properties. Helicopter surveys have been used to count deer in CWD management areas during winter and identify wintering areas for sharpshooting. Preliminary results suggested that sharpshooting sustained over multiple years had reduced local densities of deer when culling intensity was above a minimum threshold (not quantified) (Shelton and McDonald, 2009). Shelton and McDonald (2009) also observed that overall patterns of CWD distribution and intensity changed little during 2005–2008, and that declines in prevalence have occurred in fawns, yearlings, and adult female deer in sharpshooting areas. Based on recommendations of the Joint Task Force (2008), late winter deer season and the special CWD season were expanded from three to seven days, beginning in 2009 (Shelton and McDonald, 2009). It appears that IDNR will continue to aggressively manage CWD through liberal hunting regulations and focused use of sharpshooting to reduce densities of deer.

South Dakota

White-tailed deer and mule deer occur throughout South Dakota (South Dakota Game, Fish and Parks [SDGFP], 2009i). Management objectives and practices are specific to deer hunting units, that correspond to counties east of the Missouri River (East River Units, SDGFP, 2009e) and subdivisions of counties or combined portions of multiple counties west of the Missouri River (West River Units, SDGFP, 2009g; Black Hills units, SDGFP, 2009b). Statewide, white-tailed deer are more abundant than mule deer and are most common east of the Missouri River (SDGFP, 2009f), while mule deer are most common west of the river (SDGFP, 2009i).

The SDGFP conducts several types of annual surveys that provide information for modeling deer populations (SDGFP, 2009i). Species-sex composition and spatio-temporal distribution of the harvest, hunter success rates, days of hunting recreation, and hunter satisfaction are estimated from hunter report cards that are randomly allocated to deer license holders by management unit. Hunter success rates are used to estimate numbers of deer harvested. Each September (sometimes into October) a minimum of 30 independent classification surveys per management unit are used to estimate species-specific age–sex structure (fawn:doe and buck:doe ratios) of prehunt populations. Additional population surveys may be conducted for select areas to acquire information on reproduction and other factors. Data are used in models to estimate survival and to simulate population sizes and trends (SDGFP, 2009i).

Primary goals of big game management in South Dakota are to manipulate populations toward the highest possible level consistent with ecological and sociological carrying capacity, utilize surplus animals, and provide recreational and hunting opportunities for the public (SDGFP, 2009i). Population objectives in East and West River Units primarily are determined by tolerance of deer by landowners, while objectives in Black Hills Units primarily are determined by habitat conditions with increasing consideration of landowner tolerance in specific areas. In a 2006–2007 survey of landowner attitudes regarding the number of white-tailed deer on their land, 47% reported that deer numbers were acceptable, 17% thought too few deer existed, and 36% thought there were too many deer (Gigliotti, 2007). Hunter harvest is managed to address landowner tolerance. Liberal numbers of permits for hunting white-tailed deer have been available since 2001, reflecting increasing populations. Archery, youth antlerless, mentored youth, general muzzleloader, and landowner permits had unlimited quotas in 2008, while muzzleloader permits in certain areas and firearm season permits had limited quotas (SDGFP, 2009f). In 2009 a variety of permits reflecting variable bag limits were liberally offered to both residents and nonresidents (SDGFP, 2009a,b,d,e,g,h). For example, any deer (either species or sex), any antlerless deer (either species), any white-tailed deer, and antlerless white-tailed deer permits were available individually or in combination (including one–three antlerless permits), depending on season and management unit. Archery and muzzleloader hunters were allowed to harvest up to five deer. Rifle hunters were allowed to acquire up to five permits during three different drawings (nonresidents limited to third drawing) and unlimited numbers of leftover permits were available after the third drawing. In addition, East and West River permits not filled during the regular seasons converted to antlerless permits during a late season. Individuals can hunt and harvest deer in all seasons (archery, muzzleloader, and rifle) with appropriate permits.

Most white-tailed deer in South Dakota are harvested during rifle seasons in East and West River Units, although archery seasons account for substantial harvest as well (SDGFP, 2009f). Since 2001 (2008 latest year data available), white-tailed and mule deer numbers in East River and West River Units, combined, have remained relatively stable (SDGFP, 2009f). Managers are concerned, however, that hunters focus too much on harvesting bucks and not enough on harvesting antlerless deer (SDGFP, 2009c). From 2001 to 2008, thousands of unsold firearm permits were available in the East and West River Units (SDGFP, 2001–2009). Deer hunter success rates remained relatively stable during this period, ranging between 50–59% and 50–56% for rifle seasons in the East and West River Units, respectively. Liberalized availability of permits has brought populations of white-tailed deer closer to goals in some units recently and permits there were more limited in 2009. Currently, deer managers are trying to increase the number of white-tailed deer in the Black Hills, stabilize numbers in several East River Units, and reduce numbers in most of the western half of the state (T. Benzon, South Dakota Department of Game, Fish and Parks, personal communication).

Colorado

White-tailed deer in Colorado primarily occur on the eastern plains and foothills. None were year-round residents prior to 1948; although small groups of white-tailed deer had been reported earlier in eastern Colorado (Hunter, 1948, cited in Kufeld and Bowden, 1995). In 1964, two groups of white-tailed deer were introduced in northeastern Colorado: 20 near Weldona along the South Platte River and 22 in the foothills northwest of Fort Collins (Anonymous, 1965; cited in Kufeld and Bowden, 1995). Growth of the white-tailed deer population was facilitated by changing habitats along river bottoms in eastern Colorado, including increased woody vegetation and irrigated agriculture (Kufeld and Bowden, 1995). White-tailed deer in eastern Colorado appear to be more mobile than those in other parts of the United States and are common in some areas that were previously dominated by mule deer (Kufeld and Bowden, 1995). Wildlife managers of the Colorado Division of Wildlife (CDOW) aud interest groups are concerned about interspecific competition and hybridization between these species (Stratman, 2006, 2007). Colorado deer hunters traditionally have preferred mule deer and mule deer are more vulnerable to rifle hunters due to preferences for open habitats. Therefore, harvests under either-species licensing tend to be skewed toward mule deer (Stratman, 2006, 2007).

Big game are managed by the CDOW to achieve population aud sex-ratio objectives within Data Analysis Units (DAUs) Stratman, 2006, 2007). Each DAU consists of one or more Game Management

Units (GMUs), and approximately encompasses all of the seasonal ranges of big game herds with minimal interchange among adjacent herds (Stratman, 2006, 2007). Objectives are set for 10-year intervals (Stratman, 2006, 2007) and season structures are set for five-year intervals (CDOW, 2009c). Concerns and ideas of land management agencies and the public are integrated into planning processes for DAUs (Stratman, 2006, 2007). Deer population sizes for DAUs are projected using computer models parameterized with harvest data from hunter surveys, sex and age composition data from field surveys, and mortality factors such as wounding loss and winter severity approximated from field observations (Vieira, 2007). Ground surveys are typically used to estimate sex–age structures (Stratman, 2006, 2007). Model-projected population levels are compared to objectives to determine the harvest structure required to achieve objectives.

All deer hunting permits in Colorado have been issued by drawing since 1999 (CDOW, 2000). Deer permits are not species specific in GMUs, but where white-tailed deer are perceived to be encroaching on mule deer, white-tailed deer only (WTO) permits are issued in sufficient quantities to increase harvest of white-tailed deer without risk of overharvesting mule deer (Stratman, 2006, 2007). Special WTO seasons were held during 2003–2005 in conjunction with established deer seasons to evaluate efficacy of selective harvest for managing species ratios. Desired outcomes were achieved and separate WTO seasons were discontinued in favor of integrating WTO permits into existing season structures. Harvest management of white-tailed deer has become more aggressive over time. In 2004, 130 antlerless permits were allotted across three GMUs during the Late Plains WTO season. Either-sex permits were added in 2005, with a total quota of 135 in the same GMUs (CDOW, 2005). By 2009, 2230 WTO (antlerless or either-sex) permits were allocated across various seasons, in 29 GMUs (CDOW, 2009b). The deer hunting seasons in 2010–2014 will continue with those management options and also may include experimental season-choice private landowner permits and over-the-counter either-sex permits in select GMUs (CDOW, 2009c).

Although CWD was originally discovered in Colorado and exists in cervid populations across much of the state (CDOW, 2009a), it has not been a specific management issue for white-tailed deer. Other than monitoring for CWD and informing the public of disease status, management of CWD by the CDOW has focused primarily on foothills mule deer (Conner et al., 2007; Vieira, 2007).

Saskatchewan

White-tailed deer are at the northern edge of their range in Saskatchewan and as such are limited by winter severity (SME, 2008b). They are the most abundant big game species, however, with a total population of over 350,000 (SME, 2008b). The Saskatchewan Ministry of Environment manages hunting seasons for white-tailed deer in the southern two-thirds of the province (SME, 2008b). The priority for permit allocation is: species conservation, treaty and aboriginal rights, Saskatchewan resident hunters, Canadian resident hunters, and nonresident hunters. In farmland areas of southern Saskatchewan, landowner tolerance of crop damage and depredation to stored hay by deer are considered when establishing population objectives. The SME has an informal set of objectives for managing white-tailed deer that includes maintaining a province-wide winter population of 325,000 + 10% with an autumn herd structure of greater than 40 bucks:100 does:90 fawns (Arsenault, 2005).

Saskatchewan is divided into 42 white-tailed deer management units (WDMUs) and each is comprised of at least one of 76 wildlife management zones (WMZs) (Arsenault, 2005; SME, 2008b). Population modeling and status assessments are conducted at the WDMU level and harvest management is implemented at the WMZ level.

Population estimates are obtained during winter for select WDMUs, WMZs, or subdivisions of WMZs using aerial surveys with a precision target of no more than 20% (Arsenault, 2005; SME, 2008b, 2009). The aerial surveys are spatially and temporally sparse (SME, 2009) and trends in abundance of surveyed units typically are applied to adjacent units that are not surveyed (Arsenault, 2005). The sex–age structure of the population in each WMZ is estimated annually through the Cooperative Deer Management Survey, where citizens and SME staff quantify numbers of deer observed by sex, age, antler configuration, and habitat during September–November (Arsenault, 2005; SME, 2008b). Surveys of hunter harvest provide data on the sex–age structure of the population of harvested deer and hunter effort (SME, 2008b). Spotlight surveys are conducted in 13 WMZs, using consistent methods and time of year, to develop

indices of population abundance and structure (SME, 2009). Data from these surveys are included in population models to predict deer numbers within WDMUs (Arsenault, 2005). Population status is evaluated annually, based on deer abundance and population structure; weather severity; habitat conditions; results from biological sampling and necropsies; and field reports from the general public, landowners, and SME staff (Arsenault, 2005). Harvest goals are based on perceived effects of management strategies versus other environmental factors on deer numbers relative to long-term average levels (Arsenault, 2005).

In 2009, hunters were allowed to harvest one adult buck, adult doe, or fawn (either-sex permit) in any WMZ, except three large WMZs in the far north where no deer seasons were established. In four farmland WMZs and in all forested WMZs, where recent winters had reduced deer herds, no additional permits were available. However, in the remaining southern WMZs, residents were allowed an additional permit to harvest one antlerless deer. In a further reduced subset of southern WMZs, hunters were allowed a second additional permit to harvest two antlerless deer (up to four deer). All permits were offered over-the-counter, could be purchased in any order, and were valid for archery, muzzleloader, and rifle seasons, where archery seasons began on September 1 and rifle seasons ended December 7. Nonresidents of Saskatchewan also were allowed one over-the-counter either-sex permit, for a limited number of WMZs with somewhat reduced seasons compared to those available for residents. In-season depredation permits and Big Game Management Licenses also are available to provide greater flexibility for directing hunting pressure and reducing deer numbers where deer damage is a concern (Arsenault, 2005; SME, 2007a).

Chronic wasting disease was first discovered in Saskatchewan's wild mule deer in 2000 and in wild white-tailed deer in 2002 (SME, 2010b). Herd reduction areas (HRAs) were established where CWD was found and free CWD control permits were issued to reduce herd sizes and provide samples for CWD testing (SME, 2002). In 2004, a formal statement by the SME on the CWD control program included herd reduction and sampling of deer in known CWD affected areas, planning for future sampling to monitor spread, and continuous intensive herd reduction in infected areas (SME, 2004). The number and size of HRAs increased as CWD was detected in additional areas of the province (SME, 2004, 2005, 2006, 2007b). By 2008, the focus of management shifted from CWD eradication to province-wide sampling to determine distribution of CWD, along with monitoring and managing prevalence of CWD in areas where it was known to exist at that time (SME, 2008a). Despite several years of aggressive harvest management using cooperative efforts of hunters and landowners, it was concluded that CWD could not be eradicated from Saskatchewan's herds of wild deer and elk (SME, 2010a). Herd reduction efforts previously initiated to eradicate CWD were discontinued in 2009 (SME, 2010a). However, population goals will be reduced on WMZs in which CWD is endemic and collection of samples from hunter harvest will continue to monitor prevalence and distribution of the disease.

Research Needs

The thriving population of white-tailed deer in the Midwest presents many challenges and questions that wildlife biologists must address. Overabundant deer populations threaten human health and safety and have economic and ecological ramifications as related to, for example, increases in human injuries and fatalities from DVCs, damage to crop fields and natural ecosystems, and transmission of zoonotic diseases (Chapters 12 and 13). Conversely, deer are also recognized as a valuable natural resource and positively impact society in the forms of wildlife viewing, hunting, venison, and ecosystem diversity (Conover, 1997). For these reasons and others, timely research is a high priority so that wildlife managers are provided the knowledge and tools they need to optimally manage deer (Figure 17.7).

Research is needed to develop alternative methods to estimate white-tailed deer population densities, sex ratios, and age structures. Current methods include drive and spot-light counts, aerial surveys, infrared cameras, pellet counts, mark-recapture techniques, and harvest-based estimates (Roberts et al., 2005; Skalski et al., 2005; Yamamura et al., 2008). As deer populations are often at or above ecological and sociological carrying capacities (Waller and Alverson, 1997), improved means of monitoring populations are needed by wildlife managers responsible for setting harvest quotas, maximizing recreational opportunities, minimizing DVCs and damage caused by deer, and maintaining sustainable populations of white-tailed deer at tolerable levels.

FIGURE 17.7 More research is needed to answer questions about population monitoring, harvest management, damage management, diseases, and human dimensions. Field work involves capturing deer in cagetraps (a) and by chemical immobilization (b), ratio-telemetry equipment (c), and radio-marked animals (d). (Photos by G. Clements. With permission.)

Harvest management strategies have been the cornerstone of deer management across North America, but hunting has failed to control populations of white-tailed deer in many areas of the Midwest. Impediments to effective herd management include overly conservative population goals, limited hunter access, public and private refugia, adequate behavior and motivation of hunters, declining nnmbers of hunters, lack of effective alternative control methods, and our lack of understanding of natural and human-modified systems. We need to apply the research principles associated with adaptive management to evaluate the impacts of current management goals, objectives, and techniques to enable managers to improve management programs in the future (Walters, 1986; Lancia et al., 1996).

Populations of deer in urban/suburban landscapes have increased across North America. Further research is needed to develop new techniques that are socially acceptable, yet effective at alleviating conflicts in these environments. Highly controlled hunting has been effective in nrban situations (Butfiloski et al., 1997) but concerns about public safety and acceptance need to be addressed (Kilpatrick et al., 2002, 2007). Sharpshooting is effective in reducing numbers of deer in a highly selective manner, but public acceptance is a concern (DeNicola et al., 1997, 2008). More research is needed on methods of population reduction in these environments, as it appears that urban/suburban areas are the wave front of all our current concerns regarding publicly acceptable herd control.

Prevention and control of deer damage will always be a research need as long as deer adversely affect society. Habitat modification, exclusion, repellents, frightening devices, and population reduction (i.e., legal harvest, depredation permits, fertility control, capture, and removal) are current tools available to wildlife managers to reduce damage caused by deer, but not all of these tools are effective or fully developed and new tools and techniques are needed. Recent advances in fertility control have led to the development of GonaCon, a fertility control agent for white-tailed deer that is registered by the U.S. Environmental Protection Agency (2010; Miller et al., 2008; National Wildlife Research Center, 2010). Application, delivery, side effects, and cost-effectiveness remain a concern for this and other methods of fertility control.

Research is needed to develop an improved understanding of how disease and parasites affect midwestern deer populations. Both can cause morbidity and mortality in deer, sometimes impacting local populations significantly. Deer can also serve as reservoirs and vectors, transmitting disease to other wildlife, livestock, and humans. As diseases such as CWD and bovine TB are becoming more prominent in the Midwest, additional research is needed to devise strategies for managing and controlling them over the long term. As the global community continues to expand, we anticipate that foreign animal diseases (FADs) such as foot and mouth disease will be an even greater concern and problem in the future. Current research and development of surveillance procedures, epidemiological models, and management strategies will aid in control of future outbreaks of FADs.

Outlook

Throughout this chapter, we have identified how the beliefs, attitudes, and opinions of various publics impact deer management in the Midwest. In essence, many aspects of white-tailed deer management are actually more aptly directed at management of human activities than deer. The cornerstone of deer management is the use of hunter harvest to attain population levels that are low enough to minimize public concern associated with deer damage (e.g., agricultural crops, landscapes, plant communities, vehicles) and human health (e.g., human death and injuries from DVCs, Lyme disease) while also providing ample opportunities for hunting and viewing deer.

Over 10 years ago, McCabe and McCabe (1997) pointed out that populations of white-tailed deer in North America were at all-time historic highs of 16–17 million. More recent estimates put the nationwide population at about 30 million (VerCauteren, 2003). By necessity, management of white-tailed deer has evolved from establishing and allowing herd expansion to controlling and reducing population growth. New tools are needed to help reduce densities of deer and manage them at population goals. To date, agencies have primarily used public hunting to manage and control deer populations, but the ability of hunting to control deer populations has come into question (Brown et al., 2000). Brown et al. (2000) identified several factors that may limit hunting as a control mechanism for white-tailed deer populations in the future, including: (1) continued increase in deer distribution and abundance, (2) stable or declining number of hunters, (3) reduced access to private hunting lands that act as refuges during hunts, (4) overabundant urban and suburban deer populations, and (5) diminished social acceptability of hunting. Human dimensions also play an important role when dealing with issues such as controlling disease in deer. For example, recent outbreaks of CWD in the Midwest were followed by liberalized hunting to facilitate rapid population reductions within and around the locality of the outbreak. Even though it had been theorized that this was the most appropriate method for containing the disease, minimizing spread, and protecting overall herd health, resentment existed among certain interest groups. Supplemental feeding and baiting have become commonplace in many areas across the Midwest, and especially in areas where deer densities are relatively high. Biologists have recognized that these activities facilitate disease transmission and habitat degradation and therefore should be curtailed. Enacting restrictions on these activities, however, have been met with considerable resistance (O'Brien et al., 2006).

Recreational hunting is and will remain the primary mechanism to control populations of white-tailed deer, though means to increase hunter harvest need to be identified and explored. In many areas even the most liberal of hunting seasons are not effectively managing populations and the need to decrease deer densities is urgent for several reasons (i.e., DVCs, habitat/landscaping destruction, intense crop damage, disease control). Currently, most hunters only harvest one–two deer/year (which is the number their families will consume), not taking nearly as many deer as they could legally harvest (Table 17.1). To increase harvest, agencies and hunters are developing venison dispersal programs (e.g., the Nebraska Deer Exchange program [http://www.ngpc.state.ne.us/hunting/programs/deerexchange/] and Hunters for the Hungry [e.g., http://www.nrahq.org/hunting/hunterhungry.asp]) where hunters are provided means to donate deer that they harvest to others interested in consuming venison (Figure 17.8). Development of a new culture that facilitates and accepts the ample harvest and distribution of deer from hunters to others in a community may serve to increase local deer harvest and reduce their negative impacts. Also, outreach and extension efforts to develop, recruit, and retain new hunters will become more important.

FIGURE 17.8 Co-author Scott Hygnstrom donates two harvested antlerless white-tailed deer to an interested recipient through Nebraska's Deer Exchange Program, one of the many programs in the Midwest designed to increase deer harvest, reduce deer densities, provide food for the needy, and improve hunter–public relations. (Photo by S. Vantassel. With permission.)

Programs to encourage harvesting deer as a means to obtain "green" and locally grown lean protein should be considered.

A more radical alternative to decrease local deer densities would be a highly regulated form of licensed commercial harvest of deer for sale of venison and other deer products (Thogmartin, 2006). A hypothetical version may look like this: after completing state agency sponsored training, a deer harvester purchases a license from the agency to harvest a number of does (harvesters would be quite competent so the number of male fawns harvested could be minimal). Harvest would occur where dictated by the agency and the harvester would be given a quota of the maximum number of deer he or she is allowed to take. The harvester, then, can sell the deer he harvests for profit. An analogy would be timber harvests on state-owned lands. It is common practice in Midwestern states for state agencies to manage their forests and achieve their goals by contracting with private timber harvesters who pay the agency for the privilege to harvest (and therefore manage) the timber and then sell and profit directly from its sale. Our paradigm would allow for entrepreneurship and small-business opportunity while benefiting agricultural producers, home owners, motorists, and others. Note that commercial hunting would be dramatically different from "market hunting" because it would be highly regulated. The program would need to be controlled and dynamic. As densities of deer approach management goals, harvesters would stop taking deer and move to the next designated area. Commercial harvesting would have to achieve additive mortality in local areas to reduce densities to pre-determined levels set by the state agency. No loss of opportunity for hunters would occur. Recreational hunting would continue to be the primary means of managing deer populations.

Another realization is that more value can be derived from white-tailed deer than generally is obtained. Deer are a renewable natural resource and hunters and consumers of deer can use more of deer carcasses than just the meat for culinary enjoyment and antlers for fond memories. The hides, bones, and other wastes from processing could be put to better use than landfill material in the form of leather products, fertilizer, repellents, and other value-added products.

In the near future conversion of agricultural lands from traditional row crops into biomass crops could have significant impacts on deer and other wildlife species (Bies, 2006; Tilman et al., 2006; Walter et al., 2009). As global demand and prices for energy increase, alternative sources of energy (i.e., biofuels) will become increasingly important (Energy Information Administration, 2009). From 2006 to 2030, world consumption of marketed energy is projected to increase 44% (Energy Information Administration, 2009). To meet this demand, biofuels produced from biomass (i.e., forestry residues, agricultural crops and residues,

FIGURE 17.9 The outlook for white-tailed deer in the Midwest is very promising—We have healthy and abundant populations throughout much of the region and human interest may be at an all-time high. (Photo by G. Clements. With permission.)

wood, livestock, and municipal wastes) are being used to create ethanol and biodiesel (Bies, 2006). Current ethanol production is primarily from corn grain. New techuology in cellulosic digestion may also enable use of corn husks and stalks and switchgrass residues as energy sources. Walter et al. (2009) reported that decreasiug the amount of crops by 44% in Desoto National Wildlife Refuge, Iowa and converting these fields to native grasses reduced size of resident deer home ranges, but percentages of crops in home ranges increased. Increased biofuel production in the Midwest could impact deer negatively by limiting forage in corn fields after harvest and removing hiding and thermal cover by harvesting switchgrass.

Urban and suburban areas will continue to grow in size as the human population in the United States continues to increase. Approximately 64% of the United States population lived in urban areas in 1950. Today, more than 80% lives in urban areas (Hobbs and Stoops, 2002) and there is a trend for urbanites to disperse from urban ceuters to suburbia. A principal result of suburban growth (i.e., urban sprawl) is more vehicular traffic. Complex road networks are needed to connect large tracts of low-density neighborhoods and suburban residents to cities. People living in suburbs often must drive to work, putting them at risk to DVCs. Urbanization may also create and enhance deer habitat compared to previously rural areas. Notably, as residential acreages and subdivisions iucrease in exteut, so could refugia for suburban deer populations and potential conflicts.

To sum, as Gladfelter (1984) pointed out in the first compilation of white-tailed deer research and management, white-tailed deer are flourishing iu the Midwest (Figure 17.9). He could not have been more correct and it would have been difficult to predict just how successful deer would be early iuto the twenty-first century. Our predecessors did an excellent job of restoring and fostering reestablishment and expansion of white-tailed deer. Now it is our duty to manage our wonderful and dear deer resource as best possible. We have the expertise and continue to learn more, but the scieutific aspects of managing deer are only a component. We must work toward increasing the understanding of our publics and politicians about the complexities associated with deer management, for their support and wherewithal will be required into the future as our management efforts will inevitably need to be intensified.

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