OFFICE OF THE LEGISLATIVE AUDITOR
STATE OF MINNESOTA

EVALUATION REPORT

Department of Natural Resources: Deer Population Management

May 2016

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OFFICE OF THE LEGISLATIVE AUDITOR
STATE OF MINNESOTA • James Nobles, Legislative Auditor

May 2016

Members of the Legislative Audit Commission:

At your request, the Office of the Legislative Auditor evaluated the Minnesota Department of Natural Resources' management of deer populations in Minnesota. This report presents the results of our evaluation.

We found that aspects of the Department of Natural Resources' (DNR's) management of deer populations in recent years were commendable and reflected local stakeholders' interests. We also found that more work is needed to improve monitoring of deer populations and understanding their presence around the state. We make a number of recommendations to DNR to enhance deer statistics, strengthen the deer population goal-setting process, and develop a statewide deer management plan.

Our evaluation was conducted by Valerie Bombach (evaluation manager), with assistance by Caitlin Badger and Katherine Theisen. The Minnesota Department of Natural Resources fully cooperated with our evaluation.

Sincerely,

James Nobles
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Summary

While DNR has upgraded its deer population model, more work is needed to enhance deer statistics, improve the goal-setting process, and develop a statewide deer management plan.

Key Facts and Findings:

- The Department of Natural Resources (DNR) carries out a range of activities across Minnesota to manage and conserve the state's white-tailed deer populations. With an estimated one million white-tailed deer statewide in 2013, deer are found in every county. (pp. 1, 6-10)

- In recent years, DNR has used more sophisticated methods to estimate deer populations, and implemented processes to update deer population goals. (pp. 21-30)

- Staff from several DNR divisions are either directly or indirectly engaged in deer management; however, DNR does not have a formal deer management plan that defines DNR's responsibilities and prioritizes resources, goals, and objectives for managing deer. (pp. 45-47)

- DNR's current model is sound and aspects of DNR's methods to estimate deer populations are commendable and align with best deer management practices; however, we identified weaknesses in DNR's statistical methods, data resources, records management, and validation of its deer estimates. (pp. 26-35)

- In recent years, DNR has used more conservative deer permit area designations intended to limit how many deer hunters may kill, and to increase deer numbers in many areas. As of 2015, DNR estimates of deer populations and deer goals varied significantly around the state. (pp. 51-59)

- DNR adopted a majority of local deer goals proposed by Deer Advisory Teams in recent years. However, team members had mixed opinions about representation of local interests; some members wanted fewer deer and some wanted greater increases in deer populations. (pp. 47-49)

Key Recommendations:

- DNR should develop a deer management plan that defines and prioritizes DNR resources, goals, and objectives, and includes strategies to improve and maintain adequate deer hunting and wildlife viewing opportunities. (p. 63)

- DNR should improve its resources for estimating deer populations; specifically, DNR should conduct field research to collect and utilize more information about Minnesota's deer, and to validate DNR deer population estimates. (pp. 39-42)

- DNR should improve its statistical methodologies, deer model data, and records management system to better simulate changes in deer populations and reduce the risk of staff mistakes. (pp. 39-42)

- DNR should expand the data and information it uses and provides to Deer Advisory Team members when setting deer population goals. Such data would provide better insight on local deer environments, deer survival rates, deer impact on local environments, and individuals' perspectives about deer. (pp. 42-43)

- DNR should continue with its process to update deer population goals across the state, as defined within a formal deer management plan. (p. 65)

Report Summary

In accordance with federal and state law, DNR must manage, preserve, and protect white-tailed deer for the benefit of all people of the state. For these purposes, DNR must acquire and improve land for public hunting, and for food and cover for deer. DNR also must enforce wildlife protection laws; prevent and control wildlife disease; and prevent and reduce damage or injury by wildlife to people, property, agricultural crops, and state forests and parks.

White-tailed deer roam across Minnesota's landscape and their travel patterns change over time. Further, deer can thrive in a range of environments, including urban and suburban settings and private landowners' backyards. Active deer management by DNR is needed because environmental and other factors do not necessarily result in deer numbers that align with public interests and wildlife conservation principles. DNR must consider societal desires and tolerance regarding deer in local environments, as well as limitations in the quantity and quality of food, cover, and water to support deer populations.

Deer management in Minnesota relies on hunting to adjust deer numbers toward preferred levels in local areas. Minnesota's Constitution and statutes support the rights of Minnesotans to engage in recreational hunting. DNR uses two main administrative processes to guide its deer management decisions: (1) an annual process to determine hunting season regulations, dates, and other factors; and (2) a less- frequent process to gather public input when DNR sets longer-term deer population goals around the state.

DNR does not have a formal deer management plan that defines and prioritizes deer management resources, goals, and objectives.

DNR staff from several DNR divisions carry out activities that either directly or indirectly impact deer; however, DNR has not synthesized this work into a formal plan that defines DNR's purpose and objectives for managing deer. A written plan would help describe how DNR prioritizes deer goals relative to goals for other species—such as moose or elk—or for other purposes, such as the immediate need to mitigate deer impact in forests or long-term reforestation plans that might improve deer habitat.

Minnesota is a relatively large state, with a range of climates and ecological environments, a mix of public and private land, and varied public interests regarding deer. DNR directly administers just 10 percent of Minnesota's land area that might be considered natural deer habitat. A deer management plan would help lay out the range of actions needed to manage deer and help document and prioritize local issues, including areas of conflict about deer among private landowners and hunters. A plan also could lay out strategies to improve deer hunting and recreational opportunities in targeted public areas around the state.

For DNR staff, a written deer management plan also would more clearly identify DNR's priorities and long-terms actions among DNR's divisions and wildlife regions. From the public perspective, a deer management plan would define expectations and help assess DNR's progress toward goals.

In recent years, DNR enhanced its administrative processes and resources to update deer population goals and manage deer.

In 2012, DNR re-implemented a standardized process to update deer population goals for geographically defined local deer permit areas (DPAs). DNR enlists citizens to serve on its Deer Advisory Teams and propose desired goals and changes to the size of local deer populations. DNR uses the deer population goals when setting annual hunting season regulations.

Between 2012 and 2015, the majority of deer population goals set by DNR were to increase deer populations. DNR adopted deer population goals proposed by Deer Advisory Teams for 88 percent of deer permit areas reviewed in 2015; however, many members disagreed with the goals proposed by their team. A consensus among team members was reached for 33 of 40 DPAs. Some members wanted fewer deer, and some members wanted deer numbers to increase more than 50 percent over the next three to five years.

DNR in 2015 expanded the range of interests represented on Deer Advisory Teams to include area residents, hunters, farmers, foresters, and others. Members reported mixed opinions about the composition of their team. Many were satisfied, but some suggested that DNR needed an even broader representation of interests.

Aspects of DNR's methods to estimate deer populations were commendable and aligned with best management practices.

To help assess the size of and changes to deer populations around Minnesota, DNR in recent years improved its statistical model for estimating and forecasting deer populations. Specifically, DNR upgraded its technical capacity and methods for this purpose, and DNR's approach is more sophisticated than methods used in many other states.

Many factors affect the number of deer in the environment, including hunting, disease, winter severity, availability of food, and predation by other animals, such as wolves. In 2015, DNR used state-of-the-art statistical resources and data that were sufficient for basic modeling purposes and appropriate for estimating deer in northern U.S. climates. DNR's methods in 2015 reflected other positive features, given the complex nature of this work.

DNR should improve its statistical methods and data to better simulate dynamics of deer population growth and to fully utilize its new model.

DNR's deer modeling compared favorably with certain best management practices, but several aspects fell short of expected methods. DNR has missed an important data source by not collecting and utilizing age data from hunter-killed deer. DNR's model has relied primarily on deer data reported by hunters, but not all deer that are killed are reported, or may be reported to the incorrect area. DNR did not have adequate documentation to support its estimates of non-registered and illegal killing of deer; in particular, why these estimates would not vary over time or around the state.

In recent years, DNR has addressed deficiencies in its deer model data; however, more work is needed to improve deer statistics and the goal-setting process. DNR also should modify its statistical methods to improve workflow, reduce the risk of staff mistakes, and better simulate a potential range of deer densities. From our findings, we could not determine whether actual deer numbers differed from DNR's published estimates.

DNR's recent aerial surveys of deer were scientifically sound and met or exceeded industry standards, but DNR's infrequent use of these and other surveys limited their value.

DNR recently improved some of its modeling data; however, the department did not sufficiently carry out some other activities that are considered to be best practices when implementing a new model. For example, DNR did not take steps to fully validate model results against independent observations, such as those obtained from surveys of deer populations from helicopters. DNR surveys hunters and landowners as another resource for understanding deer populations around the state. However, DNR could improve its surveys by obtaining a broader range of public opinions.

For setting deer goals, DNR's information does not sufficiently address the availability of deer habitat and the impact of deer in local environments.

Since 2012, the information provided by DNR to Deer Advisory Team members has increased and evolved to include general educational materials, statistical data on deer and hunter success, and references to national and local research. DNR could compile and provide more information that provides context about available local deer habitat, such as trends in human population density and changes in land use. Other information would help assess the impact of deer on local environments, such as the number of deer-vehicle crashes or data on the impact of deer on forests, agricultural land, and state parks. Such information may help discussions about whether deer may be managed for higher or lower numbers in local areas.

Beginning in 2011, DNR generally used more conservative deer permit area designations that were intended to increase deer populations.

When compared with hunting seasons prior to 2011, DNR has reduced its use of deer permit area designations that allow hunters to shoot more than one deer. This approach was intended to allow deer populations to gradually increase in many areas, and generally aligned with recent deer goals.

Still, hunting and wildlife viewing opportunities vary significantly across Minnesota's varied environments. According to DNR, deer estimates ranged from 1 to 2 deer per square mile in some areas of the state, to 24 to 38 deer per square mile in one other area. The number of deer killed as reported by hunters during the 2014 hunting season also varied statewide, from 6,737 deer in one northwestern deer area, to 29 deer in one northern deer area. DNR season limits on hunting may impact reported hunter success; however, hunters reported harvesting 139,442 deer in 2014, the lowest in several decades. More work is needed by DNR to assess and manage deer populations in targeted areas across Minnesota.

Introduction

The Department of Natural Resources (DNR) is responsible for managing Minnesota's white-tailed deer population for the common benefit of the public. In Minnesota and elsewhere, deer management is controversial among residents due to competing concerns about wildlife viewing, hunting opportunities, deer impact on crops and forest regeneration, and deer-vehicle collisions. DNR uses various strategies to balance individuals' interests and conserve deer as a wildlife resource across Minnesota's many distinct ecological environments. DNR estimated there were about one million white-tailed deer statewide in 2013; however, hunting enthusiasts have reported unacceptable declines in deer in recent years. They asserted that DNR should do more to monitor and increase deer numbers across the state.

The Legislative Audit Commission in April 2015 directed the Office of the Legislative Auditor to evaluate the Department of Natural Resources' management of Minnesota's deer populations. Our evaluation addressed the following questions:

- **How much does DNR spend on deer population management? How are these activities funded?**

- **How does DNR estimate and monitor Minnesota's deer population? How do these methods compare with recommended practices?**

- **How does DNR establish the state's deer population goals and hunting permit strategies? To what extent do DNR's deer population goals reflect various stakeholders' interests?**

To answer these questions, we examined the extent to which DNR used appropriate data, tools, and techniques for monitoring and estimating deer populations between 2012 and 2015. We also reviewed certain aspects of DNR's processes to set goals for deer populations and DNR management decisions to adjust deer numbers in local environments. In our work, we did not determine the "optimal" size of deer populations across Minnesota or calculate alternative deer population estimates, nor did we identify "better" hunting season and permit strategies.

Assessing DNR's methods for estimating deer populations and trends required unique technical expertise. For this task, we hired Wildlife Management Institute, Inc., (WMI) to evaluate the performance of DNR's statistical modeling used to simulate deer population dynamics. Among other tasks, WMI examined whether DNR: (1) followed wildlife industry accepted practices for surveying white-tailed deer populations; (2) used scientifically valid statistical models, assumptions, and methods to forecast changes in deer populations; and (3) compiled and utilized sufficient data to provide reasonable deer population estimates.

We interviewed many people from around Minnesota to obtain their perspectives on DNR's deer management, its processes to set deer goals, and deer presence in local environments, generally. We heard from and spoke with hunters, private landowners, and farmers, as well as representatives from forestry interests, agriculture, American Indian tribal nations, private game refuges, and conservation organizations. We also interviewed staff from the

Lessard-Sams Outdoor Heritage Council and Legislative-Citizen Commission on Minnesota Resources on this topic.

To gain insight into DNR's activities and challenges for managing deer, we conducted site visits and spoke with DNR administrators and staff located across the state, including DNR Section of Wildlife staff, regional and area wildlife managers, conservation officers, and staff involved in wildlife damage control, finance and budgeting, and public policy and engagement. To help provide context for deer management concerns in Minnesota, we interviewed wildlife biologists and administrators from wildlife agencies in a sample of northern U.S. states about their deer modeling, deer goals, and management practices. We reviewed national and local scientific research literature about deer and deer management in northern climates.

We assessed DNR's processes for setting deer population goals in recent years, including the information compiled and provided by DNR to Deer Advisory Team members, and the outcomes of these processes. DNR relied on deer population estimates and goals to guide its annual regulatory process for hunting seasons and permit strategies, and we briefly analyzed DNR deer permit area designations that defined the number and types of deer that could be killed during recent hunting seasons.

Chapter 1 of this report provides an overview of the legal framework that guides deer management. We also explain the roles and responsibilities of DNR and other government entities to support and advance deer management objectives. We then briefly describe why deer management can be controversial, and we identify key wildlife management principles referenced for this evaluation. In Chapter 2, we discuss DNR's administrative processes and information it utilizes to determine annual deer hunting season regulations and to set deer population goals. We also summarize key findings and recommendations from our consultant's technical review of DNR's deer population modeling and methods for surveys of deer populations. (The complete report by Wildlife Management Institute, Inc., is attached as Appendix A at the back of this report.) In Chapter 3, we discuss and make recommendations regarding DNR's deer management decisions in recent years, including issues we think impede evaluating progress towards deer goals. We also briefly address funding and spending for deer management.

Chapter 1: Background

The white-tailed deer is one of Minnesota's most recognizable mammals and one of its most popular big game animals.[1] Deer also are a natural resource, to be managed and conserved by the state for the benefit of the public. Although several different types of deer exist in North America, Minnesota's deer population is exclusively white-tailed deer (or, *Odocoileus virginianus*).[2] With an estimated one million white-tailed deer statewide in 2013, deer are found in every county in Minnesota.[3]

Generally, managing deer populations involves the use of wildlife conservation principles, balanced against societal conditions and expectations, to shift the number and composition of deer within a certain area. For example, deer management activities might decrease or increase the deer population within a specific region, establish a more balanced ratio of male and female deer, or increase the number of older, larger antlered bucks. Our evaluation focused on the Department of Natural Resources Division of Fish and Wildlife's resources and methods used to estimate and adjust white-tailed deer populations around the state.

In this chapter, we describe certain federal and state wildlife laws that guide deer management. We also explain the roles and responsibilities of the Department of Natural Resources (DNR) and other government entities to support and advance deer management objectives. We then briefly describe why deer management can be controversial, and we identify key wildlife management principles referenced for this evaluation.

MANAGEMENT AUTHORITY

Management of Minnesota's deer population is guided by federal statutes and case law, as well as state statutes and rules. As we describe in this section, much of this legal framework applies to the management of wildlife, generally, but is supplemented with directives specific to white-tailed deer. We then describe how the DNR Fish and Wildlife Section is primarily responsible for deer management and related activities, but other DNR divisions also play a role. Governmental entities other than DNR also are engaged in deer management for either broad or specific purposes.

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[1] *Minnesota Statutes* 2015, 97A.015, subd. 3, defines big game as deer, moose, elk, bear, antelope, and caribou.

[2] Elk and moose are in the same family as white-tailed deer and also exist in Minnesota.

[3] DNR estimates of Minnesota's total deer population between 2000 and 2013 ranged from a high of about 1.1 million deer in 2006 to a low of about 940,000 deer in 2011. We discuss DNR deer population estimates in Chapter 2.

Deer Management Laws

Governance over wildlife management in the United States is divided between the federal government and individual states. There are a range of federal laws pertinent to wildlife; three particular federal laws that directly impact deer population management include the Lacey Act, the Federal Aid in Wildlife Restoration Act, and the Endangered Species Act.[4]

Enacted in 1900, the Lacey Act made it illegal to "import, export, transport, sell, receive, acquire, or purchase" wildlife, such as deer, that are "taken, possessed, transported, or sold in violation" of state, tribal, or federal law.[5] In effect, the Lacey Act strengthens state enforcement authority by making state wildlife offenses—including those pertaining to deer—a federal crime. The Federal Aid in Wildlife Restoration Act (also called the Pittman-Robertson Act) was enacted in 1937 and established annual federal funding for state wildlife programs.[6] We further discuss funding for deer management in Chapter 3.

In addition to federal statutes, federal case law has guided the role of governmental entities in the management of wildlife, including deer. In particular, an 1842 U.S. Supreme Court case examined issues regarding the rights of private individuals to exclusive ownership of wildlife in public areas. The court determined that wildlife is a public good, to be held in trust by the state for the common benefit and advantage of the whole community.[7] Today, the court's decision is referenced as the basis for the "Public Trust Doctrine" in the United States.

Under federal law, states must manage wildlife for the common use and benefit of the public.

Except in certain cases—such as issues of interstate commerce where the U.S. Constitution provides for federal oversight—states must hold wildlife in trust for the benefit of present and future generations. Minnesota statutes align with this principle:

> "The ownership of wild animals of the state is in the state, in its sovereign capacity for the benefit of all the people of the state. A person may not acquire a property right in wild animals, or destroy them, unless authorized…."[8]

[4] Federal legislation pertinent to wildlife includes laws to protect specific species or types of species, such as the Endangered Species Act; laws to strengthen state, tribal, or foreign wildlife laws, such as the Lacey Act; laws that implement the terms of international wildlife treaties, such as the Migratory Bird Treaty Act; laws to assist states in the restoration of wildlife resources, such as the Federal Aid in Wildlife Restoration Act; laws to protect specific habitats, such as the National Wilderness Preservation System; and laws aimed at general conservation and environmental protection, such as the Clean Air Act.

[5] *Lacey Act of 1900*, ch. 553, 31 Stat. 187 (1900); and *53 U.S. Code*, secs. 3371-3378 (2015).

[6] *Federal Aid in Wildlife Restoration Act of 1937,* ch. 899, Stat. 50, 917-919; and *16 U.S. Code*, sec. 669 (2015).

[7] In Martin v. Waddell, 41 U.S. 367 (1842), the U.S. Supreme Court found that the right to fish for oysters in the public rivers and bays of New Jersey was not exclusive to a private landowner, but that wildlife is a public good held in trust for all.

[8] *Minnesota Statutes* 2015, 97A.025.

Both federal case law and state statutes hold that wildlife—including deer—are a public resource that cannot be taken into private ownership. The legal responsibilities to manage wildlife are limited to the state, and do not impose obligations on private landowners to provide for wildlife.

The federal Endangered Species Act also affects deer management in Minnesota.[9] In its oversight of wildlife, the federal government may designate certain wildlife species as "endangered" or "threatened"; these designations frame management options for controlling their number and presence.[10] The current federal listing of "threatened" species includes grey wolves in Minnesota—a natural predator of deer.[11] The federal designation means that only individuals acting under authority of the U.S. Fish and Wildlife Service may take wolves, and only under certain circumstances; for example, if pets or livestock are threatened, attacked, or killed.[12] Meanwhile, white-tailed deer are afforded a different, "protected" status in Minnesota, which allows for regulated hunting of the species.[13]

State Duties and Objectives

Deer population management in Minnesota also is guided by state statutes and the Minnesota Constitution. By law, DNR is the state agency responsible for overseeing the deer population in Minnesota. Minnesota statutes grant the DNR commissioner "charge and control of all the public lands, parks, timber, waters, minerals, and wild animals of the state and of the use, sale, leasing, or other disposition thereof…."[14]

In addition to granting DNR charge over wild animals, state statutes outline DNR's wildlife management responsibilities. Exhibit 1.1 lists some of DNR's key wildlife-related duties; for example, the department must prepare wildlife management plans designed to conserve and enhance wildlife resources through planned scientific management.[15] Exhibit 1.1 also illustrates that DNR must carry out deer management within the context of many other natural resources objectives.

DNR manages deer for several reasons: to conserve and protect deer as a wildlife resource, balance citizens' interests, provide and regulate hunting opportunities, preserve the ecosystem, and protect public safety.

[9] *The Endangered Species Act of 1973*, as amended, P.L. 108-136, November 24, 2003; and 16 U.S. Code, secs. 3371-3378 (2015).

[10] "Endangered Species" means any species that is in danger of extinction throughout all or a significant portion of its range. "Threatened Species" means any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

[11] *50 CFR*, sec. 17.40(d) (2015); and *Minnesota Statutes* 2015, 97B.645, subd. 9.

[12] The federal "threatened" listing means that wolves cannot be hunted. Minnesotans cannot legally kill a wolf except in the defense of human life.

[13] *Minnesota Statutes* 2015, 97A.015, subd. 39.

[14] *Minnesota Statutes* 2015, 84.027, subd. 2.

[15] *Minnesota Statutes* 2015, 84.941; and 84.942, subd. 1.

Exhibit 1.1: Key Department of Natural Resources Wildlife-Related Responsibilities and Other Authority

The Department of Natural Resources must:

- Preserve, protect, and propagate desirable species of wild animals.
- Prepare fish and wildlife management plans designed to conserve and enhance fish and wildlife resources through planned scientific management, protection, and utilization.
- Ensure recreational opportunities for anglers and hunters.
- Collect, compile, publish, and disseminate statistics, bulletins, and information related to conservation.
- Restrict the release of data that identify the specific location of protected, threatened, or endangered wild animals, in accordance with data practices laws.
- Acquire and improve land for public hunting, game refuges, and food and cover planting.
- Execute and enforce the laws relating to wild animals.
- Issue and sell licenses.
- Establish a statewide program to provide technical assistance to persons for the protection of agricultural crops from destruction by wild animals.
- Establish a statewide course in the safe use of firearms and identification of wild mammals and birds.

The Department of Natural Resources may allow hunting of wild animals:

- To prevent or control wildlife disease.
- To prevent or reduce damage or injury by wildlife to people, property, agricultural crops, or other interests.
- In state refuges or state parks under certain conditions, including to mitigate excessive feeding by deer on plants.

SOURCES: *Minnesota Statutes* 2015, 84.0872; 84.941; 84.942, subd. 1; 97A.028, subd. 2; 97A.045, subds. 1, 6, and 11; 97A.091, subd. 2; 97A.135, subd. 1(a); 97A.201, subd. 1; 97A.401, subd. 5; 97A.485, subd. 1; and 97B.015, subd. 1.

Conservation

Most notably and as required by federal law, DNR manages deer to conserve the species and to protect deer from being killed at an unsustainable rate. Modern-day North American conservation efforts arose and expanded largely due to human exploitation of natural resources during the 1800s. By the late 1800s, deer were rare across much of the United States, including Minnesota. Because people have an interest in seeing and hunting deer, and because deer are considered an important natural resource, DNR is responsible for ensuring that the deer population will remain viable into the future. Related to this purpose, state statutes require DNR to acquire and improve land for food and cover for wildlife.[16]

Public Interests

As outlined in Exhibit 1.1, DNR manages deer populations to serve diverse public interests and desires. Hunters and wildlife watchers, for example, may be interested in seeing or hunting deer for recreational enjoyment. Others, such as farmers, may be concerned about the impact foraging deer may have on their agricultural production and livelihoods. Some may be interested in deer because of their impact on ecological diversity and public safety, or their effect on hunting businesses, tourism, and hunting equipment sales.

[16] *Minnesota Statutes* 2015, 97A.135, subd. 1.

As we discuss later in this report, Minnesota relies primarily on hunting as the method to manage deer populations. The Minnesota Constitution supports the rights of Minnesotans to engage in recreational hunting activities, and states that "Hunting and fishing and the taking of game and fish are a valued part of our heritage that shall be forever preserved for the people and shall be managed by law and regulation for the public good."[17] Within its scope of deer management duties, DNR carries out an array of activities to both regulate and utilize hunting as a management tool; we discuss these actions in the remaining chapters of this report.

Ecosystem Preservation

As part of deer management, DNR must consider the needs of other species and wildlife habitat, and DNR's actions may include mitigating the impact of deer on the ecosystem. At high population densities, foraging deer may negatively affect wildlife biodiversity by excessively feeding on young trees and preferred plant species. Meanwhile, plants that are not preferred food by deer—such as invasive buckthorn—may spread, thereby increasing the difficulty in regenerating or maintaining native ecosystems. Large deer populations also may deplete their own food sources and habitat—sometimes resulting in starvation—and can spread wildlife diseases both within the deer population and to other species.

Public Safety and Health

DNR also manages deer to protect public safety and health. Vehicle collisions with deer can result in property damage and human injury or death. In 2014, deer collisions reported to the Minnesota Department of Public Safety (DPS) totaled 1,912, resulting in 297 individuals injured and 1 fatality.[18] In addition to traffic accidents, deer facilitate the spread of some tick-borne diseases. In the Midwestern United States, white-tailed deer are a host mammal for ticks, which spread diseases—such as Lyme disease and anaplasmosis—to humans.[19]

DNR Administrative Structure

The ability to successfully manage deer necessitates some form of administrative structure to develop and implement relevant laws, policies, and management activities. In Minnesota, the DNR Section of Wildlife is tasked with managing deer populations. Other DNR divisions also carry out activities related to deer management.

Section of Wildlife

The DNR Section of Wildlife—housed under the Division of Fish and Wildlife—is responsible for most state deer population management activities. As shown in Exhibit 1.2, the Section of Wildlife has an administrative Central Office supported by regional and area offices. There are 38 area offices located across the state, and area staff have a range of responsibilities related to managing deer in their region.

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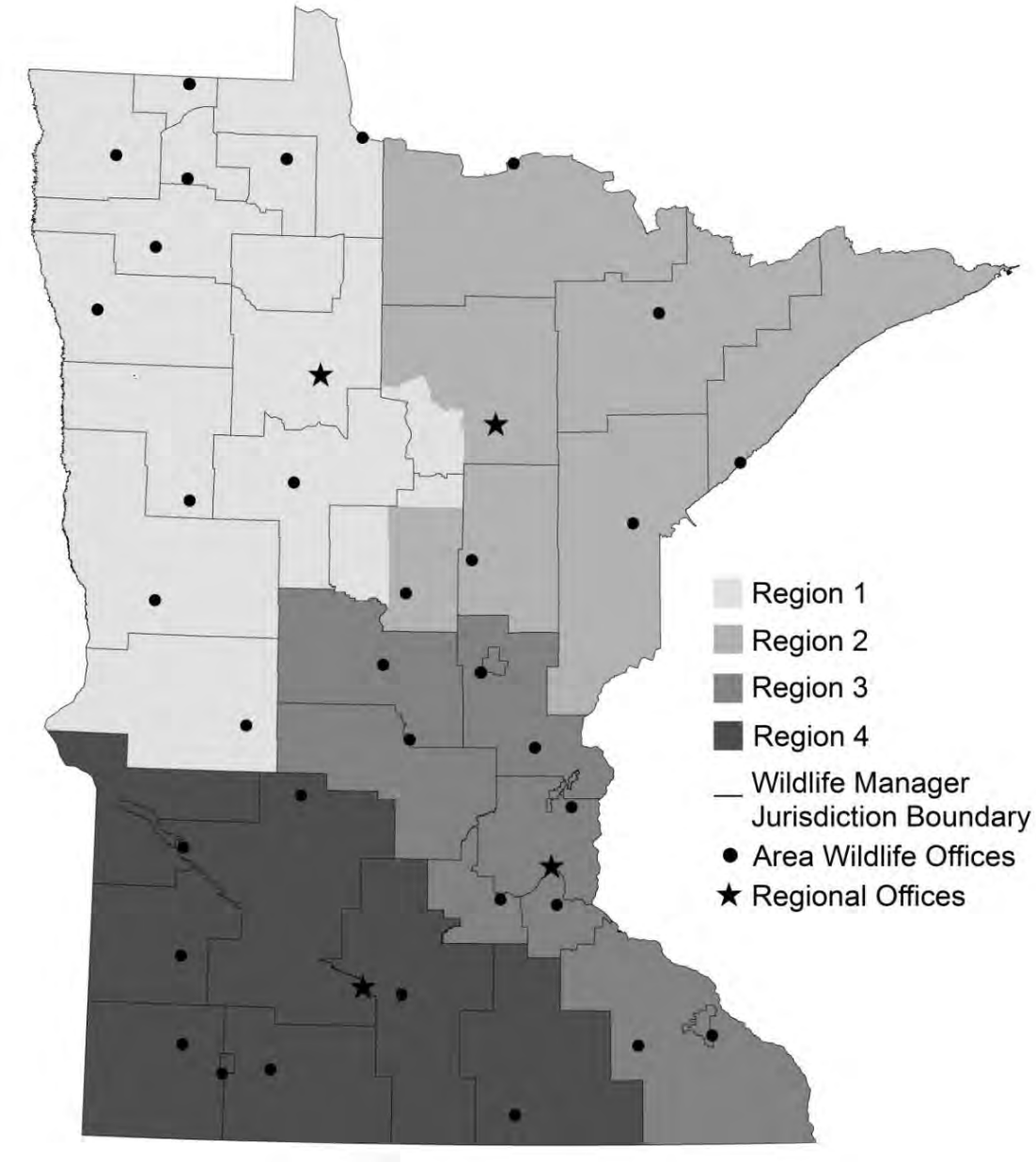
[17] *Minnesota Constitution,* art. XIII, sec. 12. *Minnesota Statutes* 2015, 97A.021, define "taking" to include pursuing, killing, capturing, trapping, snaring, and spearing, among other actions. "Game" includes "big game" –including deer—and "small game."

[18] Minnesota Department of Public Safety, *2014 Deer/Motor Vehicle Traffic Crashes, Fatalities, and Injuries, June 2015* (St. Paul), 3. These data represent only those incidents reported to DPS.

[19] These diseases cause symptoms in humans, including fever, headache, muscle aches, arthritis, rash, facial palsy, and meningitis.

Exhibit 1.2: DNR Section of Wildlife Administrative Boundaries and Area Offices



NOTES: DNR is the Minnesota Department of Natural Resources. Wildlife manager jurisdiction boundaries and related offices include offices overseen by both area wildlife managers and wildlife management area managers. An Area Wildlife Office is located in the same city as the Regional Offices in both regions 1 and 2 (Bemidji and Grand Rapids, respectively). There are two area offices located in Watson and Forest Lake. The DNR Section of Wildlife Central Office and one regional office are both located in Saint Paul.

SOURCE: Minnesota Department of Natural Resources.

DNR relies on research staff, wildlife managers, park administrators, foresters, and conservation officers located around the state to assist with managing Minnesota's deer populations.

Staff from several DNR divisions are involved in various aspects of deer management, as shown in Exhibit 1.3. Staff in the Central Office, Division of Fish and Wildlife's Section of Wildlife, carry out a wide range of activities. Located in Saint Paul, these staff establish Section-wide policy—such as annual rules related to deer hunting—and coordinate and consult with other DNR divisions on deer management issues. Central Office staff also are responsible for consulting with American Indian tribal nations regarding deer harvest management, deer initiatives, and priorities.

Regional and area offices represent the DNR Section of Wildlife across the state. There are four regional offices, each led by a regional wildlife manager who provides supervisory and administrative direction for activities in the region. Regional managers provide input into the formulation of state wildlife management policies and regulations, among other responsibilities.

At the direction of regional wildlife managers, area office staff carry out deer management activities at the local level. For example, area wildlife managers supervise professional and technical staff, promote wildlife habitat management activities, and plan and direct communication to the local public. Area staff also are expected to monitor deer populations and habitat trends at a local level, as well as listen to and assess local residents' opinions about deer.

Finally, DNR research staff support deer management efforts at multiple administrative levels. Research staff gather data and conduct scientific research on deer, among other activities. For example, they have evaluated deer population dynamics and movements in select areas of the state.

Involvement of Other DNR Divisions

While the DNR Section of Wildlife assumes primary responsibility for deer population management, some other DNR divisions also play a role, as shown in Exhibit 1.3. The DNR Division of Enforcement is the primary agency responsible for natural resource and recreational law enforcement in Minnesota, including laws related to deer. For example, conservation officers write citations and warnings for deer-related crimes ranging from shooting deer from the roadway to unlicensed killing of deer (poaching), and more.

The Division of Forestry is responsible for promoting the conservation, enjoyment, and use of Minnesota's forests, including providing a long-term yield of forest resources from state forest lands. Deer impact the division's success by causing damage to trees on state property, particularly by feeding on newly planted seedlings. Forestry staff, for example, take steps to protect seedlings from deer and collect limited data on deer damage to state plantations. They also consider deer habitat needs in forestry plans; in particular, whether deer have adequate conifer tree cover during winter in northern Minnesota.

The Division of Parks and Trails is involved in deer population management activities as a result of its responsibility to manage state parks and recreation areas. The division may work with the Section of Wildlife to host special hunts in state parks to mitigate issues of public safety or ecological damage caused by large deer populations, for example.

Exhibit 1.3: DNR Deer Management Activities

DNR Division	Activities
Division of Fish and Wildlife	
Central Office	• Provide administrative and program support to regional and area staff. • Establish section wide policy—such as annual deer hunting rules. • Coordinate and consult with other DNR divisions regarding deer issues. • Consult with American Indian tribal nations regarding deer management. • Respond to legislative requests for information. • Request funding or changes to statutes. • Oversee the hunting season. • Gather public opinion on deer. • Acquire, improve, and manage wildlife habitat. • Carry out activities to mitigate property damage caused by deer, and help landowners design private property that supports deer.
Regional Offices	• Supervise activities in the region and oversee area wildlife offices. • Assist with developing state wildlife management policies and rules. • Direct and monitor certain special hunts, population surveys, land acquisition efforts, and area-level wildlife activities. • Monitor hunting season results and deer depredation issues such as deer feeding on crops or residential landscape.
Area Wildlife Offices	• Carry out deer management activities at the local level. • Supervise professional and technical staff. • Promote wildlife habitat management activities. • Plan and direct communication to the local public. • Develop and oversee wildlife population surveys, wildlife depredation solutions, and special hunts in designated areas. • Make hunting season recommendations to the Central Office.
Research Staff	• Gather data and estimate deer populations around the state. Conduct scientific research and evaluate deer population dynamics. • Conduct surveys of hunters and landowners. • Evaluate deer population management practices. • Develop techniques to reduce or prevent deer damage. • Provide technical assistance to other DNR staff and to the public.
Division of Enforcement	• Write citations for deer-related offenses and hunting violations. • Provide education and information services to hunters and recreationalists. • Support the Section of Wildlife deer population management activities by providing helicopter pilots for aerial surveys of deer.
Division of Forestry	• Protect seedlings from deer and collect limited data on deer damage to state plantations. • Collaborate with Section of Wildlife staff to create timber harvest plans that do not adversely affect wildlife, such as deer.
Division of Parks and Trails	• Work with the Section of Wildlife to host special hunts in state parks to mitigate issues of public safety or ecological damage caused by large deer populations.
Division of Ecological and Water Resources	• Collect and communicate information related to native plant communities and sensitive species.

NOTE: DNR is the Minnesota Department of Natural Resources.

SOURCE: Office of the Legislative Auditor, summary of Department of Natural Resources documents.

Other Government Entities

Through federal and state legal authority, other government entities influence DNR's management of deer. We discuss the role of other governmental stakeholders, including American Indian tribal nations, local governments, local law enforcement, and the Board of Animal Health, below.

American Indian Tribal Nations

Both the federal and state government have a unique political and legal relationship with American Indian tribal nations as provided by the U.S. Constitution, treaties, court decisions, and federal laws. Tribal nations are sovereign governments with the authority to self-govern, including managing tribal lands and resources, such as deer. Because of variations in the legal history and relationship of each tribal nation with the state, deer population management activities vary widely among Minnesota's 11 tribal nations.[20] For example, some tribal nations own large reservations and hire professional wildlife biologists to manage deer on reservation lands and ceded territories; other nations do not own large tracts of land and, thus, do not formally engage in deer management.

Treaties with tribal nations commonly include language preserving hunting rights of tribal citizens. Each nation has a unique approach to articulating hunting rights of Minnesota's tribal citizens and regulating members hunting activities. For example, some tribal nations require their citizens to purchase deer hunting licenses or permits through the tribal government, and some nations' citizens must purchase deer hunting licenses through DNR. DNR consults with Minnesota tribal nations and inter-tribal commissions on relevant aspects of deer population management, including population goal-setting activities and off-reservation harvest data collection.

Local Governments

Deer are mobile across the Minnesota landscape and reside in many types of environments, including special park districts, county parks and forests, and city neighborhoods. As such, local governments have an interest in deer management, too. DNR works with local governments—some more than others—to address deer issues on an as-needed basis. With certain exceptions and as approved by the DNR commissioner, state law generally allows deer hunting statewide, but gives cities the authority to regulate the discharge of firearms.[21] While municipalities may establish firearms ordinances to promote public safety, such ordinances hamper hunting activities and thereby restrict DNR's ability to manage deer in those areas.

To address deer population issues, municipalities and other local entities may request that DNR approve hunting in designated areas—such as a game refuge, city park or neighborhood, or airport—outside of the regular hunting season, or that differs from the DNR hunting season rules pertaining to the surrounding area.[22] State law allows DNR to

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[20] Minnesota's 11 tribal nations include 7 Anishinaabe nations (Bois Forte, Fond du Lac, Grand Portage, Leech Lake, Mille Lacs, Red Lake, and White Earth) and 4 Dakota nations (Lower Sioux, Prairie Island, Shakopee Mdewakanton, and Upper Sioux).

[21] *Minnesota Statutes* 2015, 471.633. For example, Northfield city ordinance states "No person shall discharge a firearm…within city limits." *Northfield, Minnesota City Code* 2015, ch. 50, art. III, sec. 50-56 (b).

[22] Some cities—such as Bemidji—have their own deer management plan and monitor local deer herds.

issue special permits and establish special hunting seasons within designated areas.[23] We discuss DNR's activities regarding special hunts and localized deer population control later in this report.

State and Local Law Enforcement

While the DNR Division of Enforcement is primarily responsible for enforcing conservation laws, any Minnesota law enforcement agency can issue citations for wildlife-related crimes. DNR conservation officers also may coordinate with state and local law enforcement in upholding conservation laws. For example, local law enforcement might contact a conservation office if they receive tips on wildlife crimes. Similarly, a conservation officer might rely on local law enforcement to help collect information and keep people at the scene of an alleged wildlife crime.

State and local law enforcement officers may also assist with deer-vehicle collisions. As outlined in statute, the local road authority—such as county and town boards—is responsible for removing deer killed by motor vehicles on public roads.[24] However, if a deer killed by a motor vehicle is salvageable, state or local law enforcement may issue a deer possession permit to the driver, another individual at the scene, or a public benefit organization.

Board of Animal Health

In addition to the approximately one million deer living in the wild, nearly 6,000 white-tailed deer live as livestock on farms across Minnesota.[25] State statutes consider the act of raising deer on a farm to be agricultural production that is regulated by the Minnesota Board of Animal Health.[26] The Board of Animal Health inspects deer farms annually, including surveillance for animal diseases, such as chronic wasting disease. The Board of Animal Health plays the lead role in responding to deer disease in instances in which disease is detected inside of a captive-deer facility.

MANAGING MINNESOTA DEER

DNR directly administers just 10 percent (about 5.6 million acres) of Minnesota's land area that might be considered deer habitat. This includes: 66 state parks and 9 state recreation areas; 1.3 million wildlife management acres; 185,000 scientific and natural area acres, and 58 state forests covering 3.8 million acres. However, white-tailed deer exist within human settings around the state as they are an adaptive species and can thrive in a range of environments, including urban and suburban settings and private landowners' backyards. Thus, deer management requires understanding the local environment in the application of deer management principles and actions.

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[23] *Minnesota Statutes* 2015, 97A.401, subd. 4; and 97B.311.

[24] *Minnesota Statutes* 2015, 97A.502(a). The road authority may also be the Minnesota Department of Transportation.

[25] Minnesota Board of Animal Health, *Annual Report Fiscal Year 2015* (St. Paul, 2015), 10.

[26] *Minnesota Statutes* 2015, 17.452, subd. 5; and 35.155. Primary regulatory responsibility for farm-raised deer lies in the Board of Animal Health; however, *Minnesota Statutes* 2015, 35.155, subd. 7, also authorizes the commissioner of agriculture to inspect farm-raised deer, facilities, and records.

Local Environment

Minnesota residents have a broad range of opinions about deer populations in their environment (an issue we discuss further in the following chapters). Most individuals are interested in seeing at least some deer, although some individuals may welcome this experience in their own backyard, while others may not. Even among neighbors—and among hunters, too—individuals' preferences can vary greatly.

Active deer management is needed because environmental and other factors do not necessarily result in deer numbers that align with public interests or wildlife conservation principles.

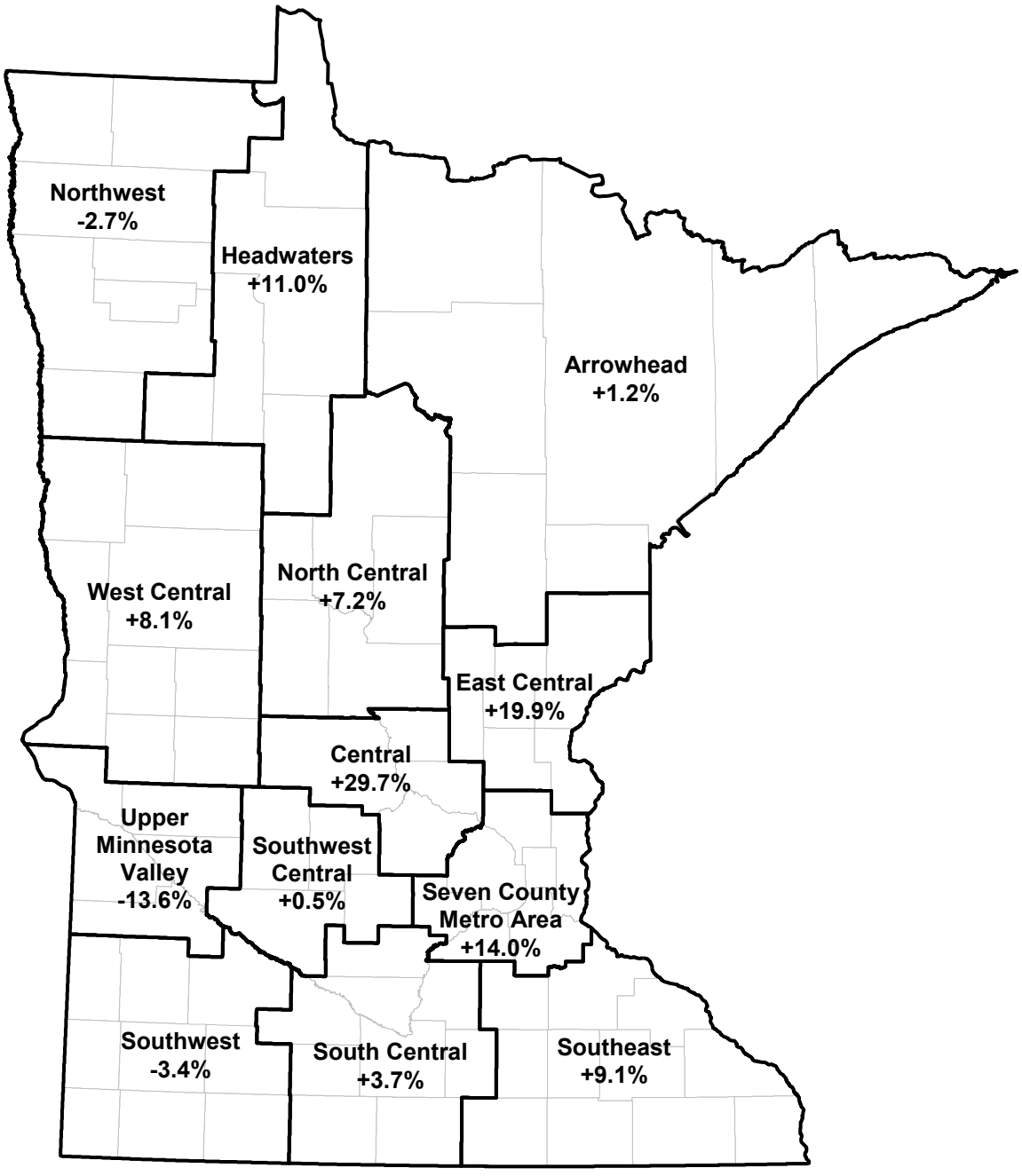
In Minnesota and elsewhere, shifts in human populations and changes in land use impact deer environments and, thus, the potential for human interaction with deer. For example, Minnesota's total human population increased by nearly 12 percent, or an estimated 570,000 individuals, between 2000 and 2015. As shown in Exhibit 1.4, trends in human population density varied greatly among economic development regions of the state during this time period. Human population per square mile of land increased by nearly 30 percent in the Central Region of Minnesota, and decreased by nearly 14 percent in the Upper Minnesota Valley Region located on the western edge of the state. Such changes in human population density may involve changes in land use, either through housing development or expansion of agriculture. In the following chapters, we examine how DNR periodically reassesses local environments and preferences regarding deer.

Within local environments, deer numbers are influenced by many factors, individually and collectively, in particular, the availability of habitat and food sources, the "irruptive behavior" (that is, rapid growth and crash) of the species, and the presence or absence of predators.[27] Additionally, Minnesota has a wide range of distinct—and changing—ecological environments, including forest, prairie, parkland, urban, suburban, and agricultural. Severe winters in Minnesota's northern regions are challenging environments for white-tailed deer and other species for finding adequate food and cover from the weather. Research on deer survival has found that hunting is a principal cause of deer mortality; however, winter severity also increases the risk of deer death by wolves in Minnesota.[28] Overall, the state's various environments require different strategies to manage deer.

[27] See, for example, Dale R. McCullough, *The George Reserve Deer Herd* (Ann Arbor: University of Michigan, 1979), 1-9.

[28] Glenn D. Delgiudice, Michael R. Riggs, Pierre Joly, and Wei Pan, "Winter Severity, Survival, and Cause-Specific Mortality of Female White-Tailed Deer in North-Central Minnesota," *The Journal of Wildlife Management* 66, no. 3 (2002): 698-717; and Glenn D. Delgiudice, John Fieberg, Michael R. Riggs, Michelle Carstensen Powell, and Wei Pan, "A Long-Term Age-Specific Survival Analysis of Female White-Tailed Deer," *The Journal of Wildlife Management* 70, no. 6 (2006): 1556-1568.

Exhibit 1.4: Percentage Change in Minnesota Human Population Density, by Economic Development Region, 2000-2015



NOTE: Minnesota's human population density increased 11.6 percent statewide, from 4.9 million in 2000 to nearly 5.5 million in 2015.

SOURCE: Office of the Legislative Auditor, analysis of U.S. Census Bureau data.

White-tailed deer, as a species, require some level of monitoring to achieve conservation objectives that may vary among local environments, in particular, due to the presence or absence of predators. Wildlife research on white-tailed deer has found that:

> "Most white-tailed deer populations have a high rate of increase and require some form of removal to keep them in balance with year-round habitat resources. When natural predators are absent, some other form of population regulation, such as hunting, must take place. Otherwise, the deer populations will exceed the capability of the range to support it, with the inevitable results of habitat deterioration, lowered deer reproduction and health, and frequent deer die-off."[29]

In Minnesota, natural predators of deer include coyote, bobcat, bear, and the grey wolf. The federal government has placed hunting restrictions on wolves, thereby limiting the DNR's wolf management options relative to deer populations. Due to federal authority over this issue, we did not evaluate wolf management or the impact of wolves on deer populations. We note, however, that the most significant factor on deer populations statewide in Minnesota is hunting.

KEY DEER MANAGEMENT PRINCIPLES

Deer management in Minnesota is shaped by national wildlife conservation and management principles. These principles have been enhanced over time through scientific research, and today include efforts to understand societal expectations and tolerances for deer in the environment.

North American Model of Wildlife Conservation

Earlier we explained that the "Public Trust Doctrine" establishes states as trustees of wildlife—including deer—which must be managed for the benefit of all people of the state. This principle is reflected in the North American Model of Wildlife Conservation (NAMWC), a set of seven principles that has been the basis and foundation of wildlife conservation and management in the United States and Canada.[30] Each of these principles is grounded in historical doctrines, federal case law and regulations, and societal tenets. The model also represents the culmination of work dating back to the late-1800s by conservation groups, wildlife experts, biologists, and government leaders. These principles are briefly described in Exhibit 1.5.

One component of the NAMWC model recognizes that "science is the proper tool to discharge wildlife policy." The Wildlife Society, a long-standing national wildlife conservation organization, also affirms that science is a cornerstone for establishing wildlife

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[29] Lowell K Halls, ed., *White-Tailed Deer: Ecology and Management* (Washington, DC: Wildlife Management Institute, 1984), 577; and Dale R. McCullough, "Growth Rate of the George Reserve Deer Herd," *The Journal of Wildlife Management* 46, no. 4 (October 1982): 1079-1083.

[30] To read more about the North American Model of Wildlife Conservation, see Theodore A. Bookhut, ed., *The North American Model of Wildlife Conservation, The Wildlife Society and The Boone and Crockett Club Technical Review 12-04* (Bethesda: The Wildlife Society, 2012).

policies and making management decisions.[31] The Wildlife Society further states that the role of science in policy and decision-making is to *inform* the decision process, rather than to prescribe a particular outcome. In Chapter 2, we discuss DNR scientific research and the information it uses to help manage deer.

Exhibit 1.5: Key Wildlife Management Principles

Principles	Description
North American Model of Wildlife Conservation	1. Wildlife resources are a public trust; wildlife is owned by no one individual and is held in trust for the benefit of all. 2. Markets for game are eliminated to prevent declines in commonly held wildlife resource. 3. Allocation of wildlife is by law to help ensure access to wildlife is equitable. 4. Wildlife can be killed only for a legitimate purpose, requiring "fair chase" principles and noncommercial use, without waste, of all game killed. 5. Wildlife is considered an international resource. 6. Science is the proper tool to discharge wildlife policy, integrating biological and social sciences. 7. Democracy of hunting is standard and not restricted to only those who have special status.
Social Carrying Capacity	The maximum population of a particular species that humans will tolerate based on the negative impact of the species, such as agricultural damage, vehicle collisions, loss of biodiversity, and damage to property.
Human Dimensions	Human dimensions research involves evaluating individuals' preferences and tolerance regarding wildlife against the relative abundance of a particular species and the positive and negative impacts of the species on the environment.
Biological Carrying Capacity	The maximum population of a particular species that a given area of habitat can support over a given period of time based on its supply of resources, such as nutrients, energy, and living space.

SOURCES: Theodore A. Bookhut, ed., *The North American Model of Wildlife Conservation, The Wildlife Society and The Boone and Crockett Club Technical Review 12-04* (Bethesda: The Wildlife Society, 2012); Dale R. McCullough, *The George Reserve Deer Herd* (Ann Arbor: University of Michigan, 1979), 149-157; Daniel J. Decker, Shawn J. Riley, and William F. Siemer, *Human Dimensions of Wildlife Management 2nd Ed.* (Bethesda: John Hopkins University, 2012), 3-5; and Daniel J. Decker and Ken G. Purdy, "Toward a Concept of Wildlife Acceptance Capacity in Wildlife Management," *Wildlife Society Bulletin* 16, no. 1 (1988): 53-57.

NAMWC principles also are reflected in Minnesota statutes. For example, restrictions on the release of specific location data about the whereabouts of wildlife—including deer—by DNR supports the NAMWC tenet that wildlife can only be killed for a legitimate purpose and, when hunting, must afford game a "fair chase."[32] A fair chase requires that hunted big game animals be free ranging, without giving the hunter an improper advantage over such

[31] The Wildlife Society, "Standing Position Statement: The Use of Science and Management Decisions" (http://wildlife.org/wp-content/uploads/2015/04/SP_UseofScience1.pdf, accessed December 15, 2015). The Society states that science is the knowledge resulting from structured inquiry. Further, policy and decision-makers may make determinations that do not always provide maximum benefits or minimize impacts to wildlife and their habitats. Such determinations are appropriate if the best available science and likely consequences from a range of management options have been openly acknowledged and considered.

[32] *Minnesota Statutes* 2015, 84.0872, subd. 2.

animals. The NAMWC principles are generally the most recognized conservation standards among wildlife managers, conservationists, hunters, and other wildlife enthusiasts.

Carrying Capacity

Wildlife management—and the management of white-tailed deer populations, in particular—has been widely researched over many decades. Such research has yielded important management concepts.

To help frame decisions about the desired numbers and presence of deer around the state, important concepts—such as biological carrying capacity and social carrying capacity—guide deer management.

In particular, the concept of "biological carrying capacity" (BCC) considers the thresholds at which wildlife populations are limited by environmental factors—such as quantity, quality, and distribution of food, cover, and water. Generally, there is an overabundance of deer in an area if their numbers exceed this capacity.

A similar concept—social carrying capacity (SCC)—is useful for assessing how wildlife population management decisions are affected by public opinion.[33] SCC reflects the maximum wildlife population level in an area that people find acceptable and will tolerate based on the negative impacts of a species, such as agricultural damage, vehicle collisions, loss of biodiversity, and damage to property.

Wildlife managers may use one or a variety of management actions to move deer populations towards preferred social and biological carrying capacity. These actions increase, decrease, or stabilize deer numbers through lethal and nonlethal means and could include: feeding deer, particularly during severe winters; habitat improvement; reintroduction or control of predators; contraception for deer to restrict reproduction; relocation of deer to other geographic areas; and harvest of deer through hunting.[34] The effectiveness and costs for each of these options vary. Some options, such as relocation of deer, generally result in poor outcomes for deer and are not used in Minnesota. In the remainder of this report, we focus on the primary management action—hunting—that is supported by state statutes and utilized by DNR. We also consider DNR's management of deer in the context of certain wildlife conservation principles.

[33] Analogous concepts include "wildlife acceptance capacity" or "cultural carrying capacity."

[34] For example, *Minnesota Statutes* 2015, 97A.075, subd. 1, provides for funding for emergency deer feeding.

Chapter 2: Deer Population Estimates and Goals

Managing deer requires understanding the abundance of deer in a particular area and the capacity of the environment to support deer populations, balanced against wildlife conservation goals and social desire and tolerance for deer. These factors provide context for whether there should be more or fewer deer, or whether the number of deer is acceptable. Further, sound deer management should include a conceptual framework and administrative processes that are guided by clearly defined deer management goals and objectives. Management decisions also should be informed by reliable data on deer population demographics and their local environments.

In this chapter, we examine the Department of Natural Resources' (DNR's) administrative processes to collect and utilize statistical and other information to manage Minnesota's deer population between 2012 and 2015.[1] We also review the adequacy and scope of resources developed to obtain public input on the desired number of deer at the local level.[2] We then make recommendations that address weaknesses in DNR's processes and resources.

LOCAL DEER PERMIT AREAS

To help DNR manage deer and evaluate environments and interests at the local level, Minnesota is divided up into "deer permit areas." By statutes and rule, deer permit areas (DPAs) are areas used by DNR to help manage deer numbers and hunting seasons.[3] Generally, DNR compiles information and data at the DPA level to help administrators make decisions whether to increase, stabilize, or decrease the number of deer in a particular DPA. Information about the number of deer in each DPA also informs hunters about hunting prospects.

Exhibit 2.1 illustrates that Minnesota was divided into 128 deer permit areas as of 2015; nearly all DPAs included both public and private land. For deer management purposes, DNR also categorizes DPAs into forested regions, farmland regions, farmland-forest transition regions, and a metro area based on ecological characteristics. DNR periodically reconfigures the geographic boundaries of deer permit areas to better align with deer habitat areas, changes in land-use (such as housing development), hunters' desires to know more precise deer hunting opportunities, and other factors. Between 2008 and 2010, DNR changed the boundaries of many DPAs.[4] DNR also has created specific deer permit areas to more directly manage disease in deer populations, including chronic wasting disease and bovine tuberculosis.

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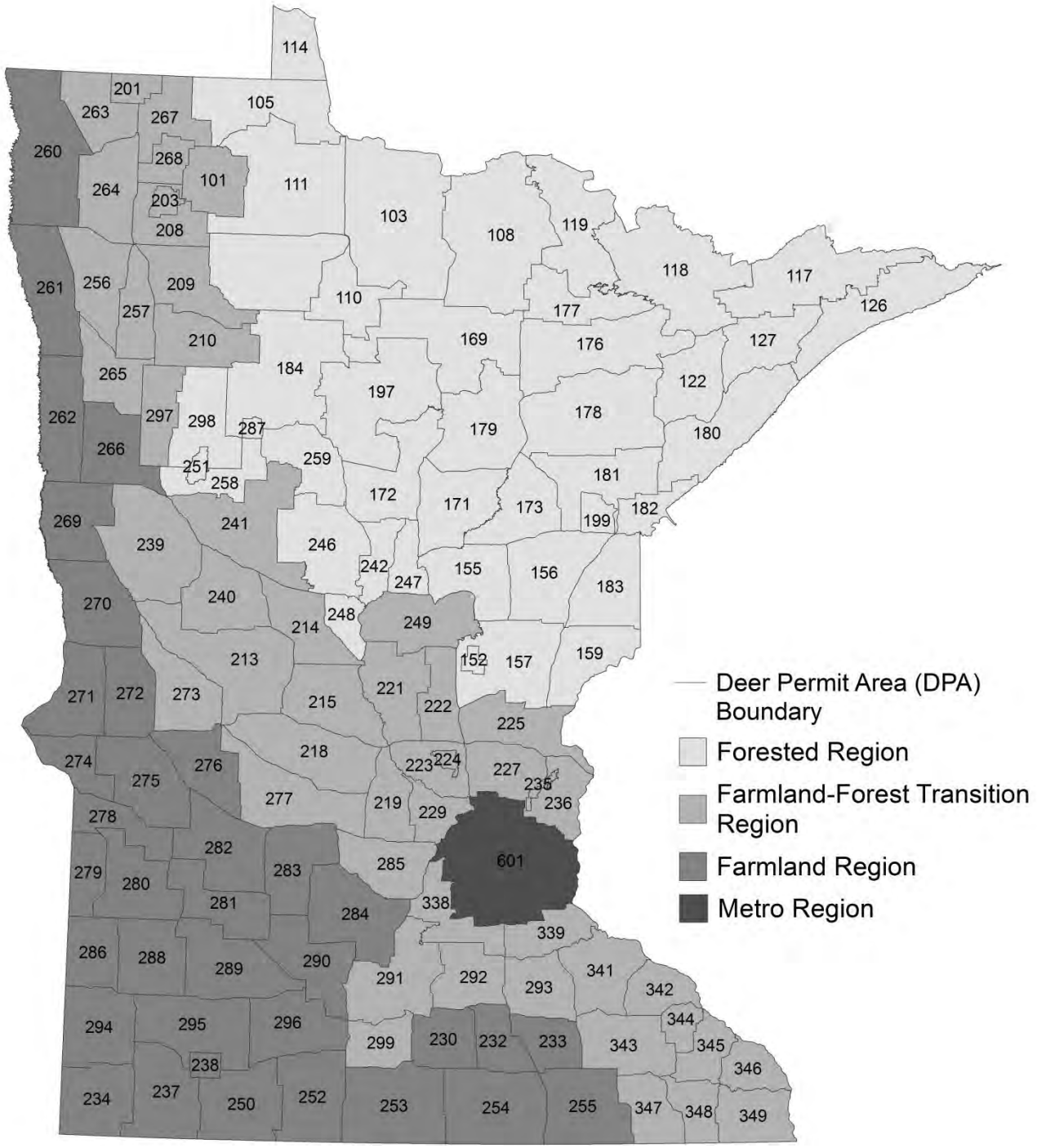
[1] *Minnesota Statutes* 2015, 84.941. Wildlife are renewable resources to be "conserved and enhanced through planned scientific management, protection, and utilization." *Minnesota Statutes* 2015, 97A.045, subd. 6, requires DNR to "collect, compile, publish, and disseminate statistics, bulletins, and information related to conservation."

[2] *Minnesota Statutes* 2015, 84.942. DNR must prepare wildlife management plans; coordinate its planning efforts with other public agencies; and make plans available to the public for input, review, and comment.

[3] *Minnesota Statutes* 2015, 97B.305; and *Minnesota Rules*, 6232.0200, subp. 4a, posted January 12, 2015.

[4] Minnesota's approach to DPAs is similar to that used in some states, such as Michigan or Maine. Some states' deer areas more closely align with county boundaries (such as Wisconsin), or are more similar in shape (Iowa).

Exhibit 2.1: Minnesota DNR Deer Permit Areas (DPAs) and Regions, 2015



NOTE: DNR is the Minnesota Department of Natural Resources.

SOURCE: Office of the Legislative Auditor, summary of Department of Natural Resources map data.

For purposes of managing hunting seasons, DNR defines hunting season dates and other variables according to hunting "zones" that are composed of blocks of DPAs.[5] The season length in each zone typically varies due to vulnerability of deer to sighting by hunters. For example, season length is longest in Minnesota's northern forested regions, and shortest in farmland regions. The DNR commissioner also may limit or close seasons in various areas, or establish controlled hunting zones and special seasons in designated areas.[6]

DEER MANAGEMENT PROCESSES

As we described in Chapter 1, DNR manages deer for many reasons, including for conservation purposes and to support recreational activities. Over the years, DNR has involved the public in deer management decisions related to hunting seasons and policy choices, and in administrative processes. For example, from 2007 through 2008, DNR worked with a committee of hunters and other stakeholders to simplify deer hunting regulations and make it easier for hunters to understand licensing options and seasons.[7] For hunters seeking to shoot older, larger antlered deer, DNR worked with hunters from 2009 through 2012 to scope and implement "antler point restrictions" in southeastern Minnesota.[8]

DNR's deer management activities include two core administrative processes (regulation and goal-setting) to compile, generate, and utilize information about the number and presence of deer around the state.

Beginning in 2012, DNR enhanced its administrative processes and resources to update deer population goals and manage deer.

Annual Deer Regulation Process

Deer management in Minnesota relies on hunting to reduce the number of deer toward preferred levels in local environments. Minnesota also supports hunting as a recreational activity. DNR's oversight of deer includes a process to set annual deer-related and hunting season regulations, described in Exhibit 2.2. As part of this process, DNR staff estimate the number of deer in DPAs, determine hunting season rules and restrictions, and designate

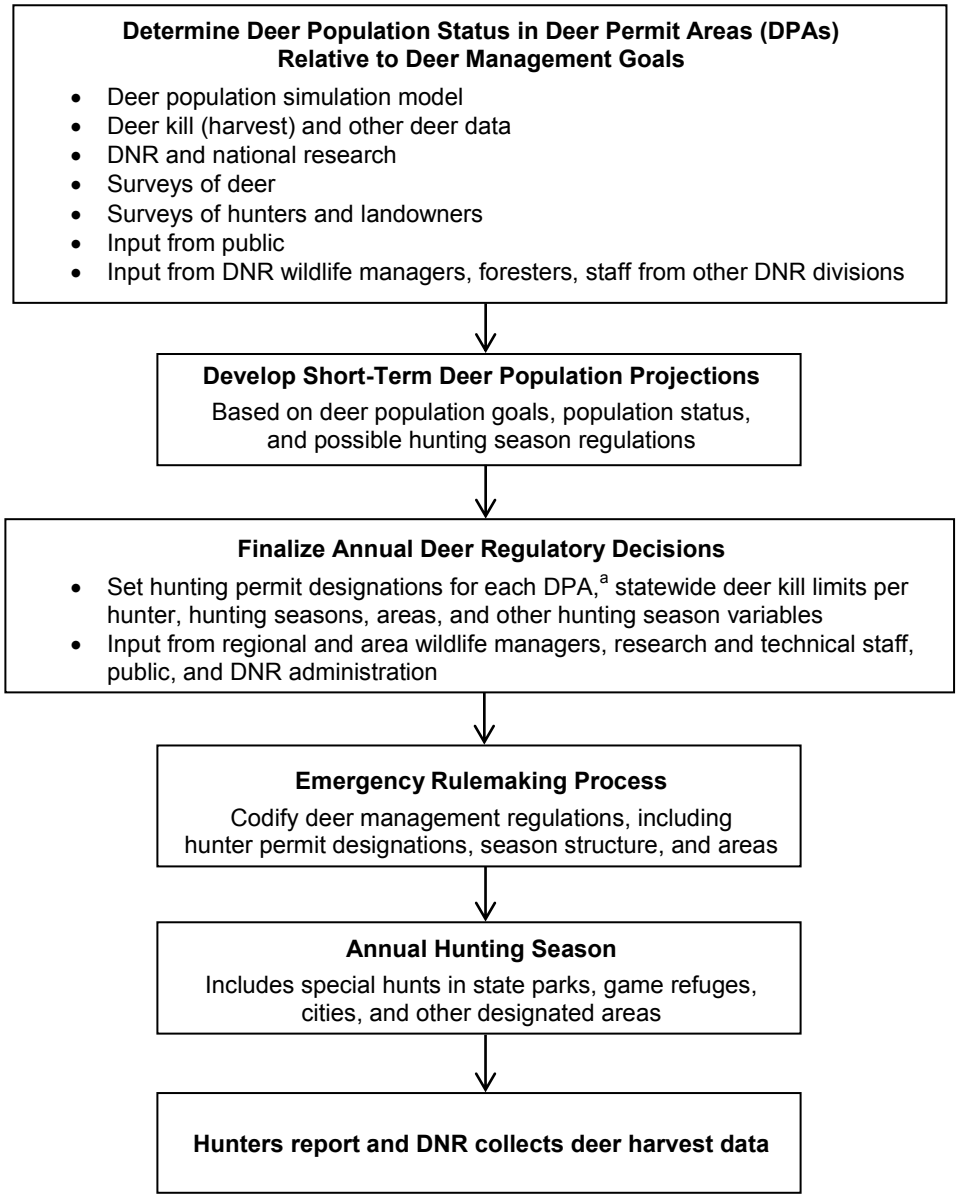
[5] Per *Minnesota Statutes* 2015, 97B.311(a), the DNR commissioner may, "by rule, prescribe restrictions and designate areas where deer may be taken, including hunter selection criteria for special hunts established under section 97A.401, subdivision 4. The commissioner may, by rule, prescribe the open seasons for deer within the following periods: (1) taking with firearms, other than muzzle-loading firearms, between November 1 and December 15; (2) taking with muzzle-loading firearms between September 1 and December 31; and (3) taking by archery between September 1 and December 31." *Minnesota Statutes* 2015, 97B.311(b), states that, "notwithstanding paragraph (a), the commissioner may establish special seasons within designated areas at any time of year."

[6] *Minnesota Statutes* 2015, 84.027, subd. 13; 97A.092; and 97A.401, subd. 4.

[7] For example, DNR condensed eight types of licenses down to two types of licenses, and consolidated deer seasons by eliminating a deer season zone with separate hunting dates.

[8] *Minnesota Rules*, 6232.0350, posted January 12, 2015.

Exhibit 2.2: DNR Annual Deer Management and Regulation Process, 2015



NOTE: DNR is the Minnesota Department of Natural Resources.

[a] DNR's seven primary deer permit area designations used in 2015 included: **Bucks Only** (hunter may kill only bucks with at least one antler three inches or longer); **Lottery** (lottery allocation of limited number of hunting permits for option to shoot antlerless deer; unsuccessful applicants may only shoot bucks); **Hunter Choice** (hunter may shoot either one buck or one doe); **Managed** (hunter may shoot one deer, either sex, then one antlerless deer [deer with antlers less than three inches long]); **Intensive** (hunter may shoot one deer, either sex, then four additional antlerless deer); **Youth Antlerless** (only individuals under age 18 may take antlerless deer through lottery; all other license holders may only take bucks); and **Unlimited Antlerless** (for DPA 601 covering most of the seven-county metropolitan area). DNR also may set hunting limits in designated areas—such as state parks, game refuges, or other areas—that differ from DPA-wide designations.

SOURCE: Office of the Legislative Auditor, summary of Department of Natural Resources documents.

hunting areas.[9] From year to year, DNR may adjust hunting seasons, areas, and other factors, based on current data.[10]

For these purposes, DNR recently changed its approach for estimating deer population sizes by using a more sophisticated deer population "model." As we describe in the next section, a deer population model is a statistical tool to keep track of changes in deer numbers—such as births and deaths—due to interactions with the environment. DNR uses modeling to help evaluate deer numbers and then estimate (simulate) future changes to deer population sizes, based on different management scenarios. Along with other information, DNR uses model results to inform its decisions about upcoming deer hunting seasons (including the number and types of deer that each hunter may kill overall and in each DPA), who may be eligible to shoot deer, the types of weapons that may be used, season dates, and other factors.

DNR formalizes its decisions about annual hunting seasons through an emergency rulemaking process, which codifies hunting regulations and permit designations for each DPA.[11] The rulemaking process also is used to designate and set guidelines for hunting in smaller areas within DPAs, such as state parks, wildlife areas, game refuges, and cities.

As noted in Exhibit 2.2, deer permit area designations specify the number and types of deer—buck or antlerless—that hunters may kill, and are used to manipulate the number of deer in each DPA. For example, to decrease deer numbers, the DNR may allow a hunter to kill up to five deer in a DPA designated for "intensive" hunting. In contrast, DNR may use a "bucks only" designation to restrict the type of deer that hunters may kill in a DPA to give the deer population an opportunity to reproduce and grow. We discuss DNR's use of these permit types further in Chapter 3.

Deer Population Goal-Setting Process

In 2012, DNR re-implemented a standardized public process to update deer population "goals" around the state. DNR had previously engaged hunters and others from calendar years 2005 to 2007 to identify local preferences and concerns about deer.[12] The outcome of that process was a deer population goal for each deer permit area. The purpose of the deer goals is to guide DNR decisions about changes to local deer populations, and to better align deer numbers with public preferences. Specifically, for annual deer hunting seasons, DNR decides which type of deer permit area designation for hunters (noted previously in Exhibit 2.2) should be used to help maintain populations within the goal for each DPA.

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[9] *Minnesota Statutes* 2015, 97A.475, subds. 2-3; and 97B.311; define the dates during which DNR can allow deer hunting, and the cost of deer hunting licenses.

[10] *Minnesota Statutes* 2015, 84.027, subd. 13. The commissioner may adopt rules to open or close seasons and areas, select hunters for areas, provide for tagging and registration of game, protect specific species, control wildlife diseases, control transportation of a wild animal, and adjust season variables based on current data. Emergency rulemaking is authorized for purposes of complying with this section and *Minnesota Statutes* 2015, 97A.045, including the need to adjust season variables on an annual basis based upon current biological and harvest data.

[11] *Minnesota Statutes* 2015, 84.027, subd. 13; and 97A.0455.

[12] DNR first implemented the goal-setting process in 2005 because Minnesota was experiencing historically high deer densities and DNR was facing challenges ensuring regeneration in Minnesota's forests due to deer feeding on young trees, in addition to societal interest in reducing deer densities.

The DNR goal-setting process is an opportunity for the DNR Division of Fish and Wildlife to engage with the public and afford citizens opportunities to share their ideas and concerns and inform DNR's decisions. Public feedback into deer management is important because individuals report very different reactions to the number of deer in their environment. For example, in response to online questions by DNR to collect public input regarding deer, individuals provided the following comments about deer populations:[13]

> "I think the deer population should be decreased to allow for better forest management, biodiversity, and an increase in public safety from reduced deer-auto collisions."
>
> "The deer population is down from the past but we had a lot of deer. Too many for the habitat. I had to hunt harder but that is good."
>
> "Do whatever you have to do to increase deer numbers….Most important is increasing deer population for entire state, but especially the area I frequent the most and have witnessed first hand the decline."
>
> "Increase the deer population by 100%, to 25 to 30 deer per square mile, whichever is larger."
>
> "DECREASE [deer population] by 50% at least. Too many deer. Unbelievable that any one would like an increase."

Capturing the wide range of individuals' preferences about deer requires a process to translate opinions into meaningful information that can be discussed, compared, and used for management purposes. DNR refined its goal-setting process between 2012 and 2015 to represent the diversity of perspectives related to deer management.[14] During this period, DNR administered three goal-setting processes for targeted groups of DPAs. Specifically, DNR updated deer goals for 22 deer permit areas in 2012, 9 deer permit areas in 2014, and 40 deer permit areas in 2015.

Exhibit 2.3 describes the DNR 2015 deer goal-setting process, including individuals' roles and activities. DNR used a public notification and nomination process to select 15 to 17 individuals to serve as members on one of five Deer Advisory Teams.[15] Each Deer Advisory Team acted, collectively, as a public representative for a designated group—"block"—of DPAs. For example, the 2015 Deer Advisory Team for the Superior Uplands Arrowhead Region discussed deer populations and proposed goals for five DPAs.

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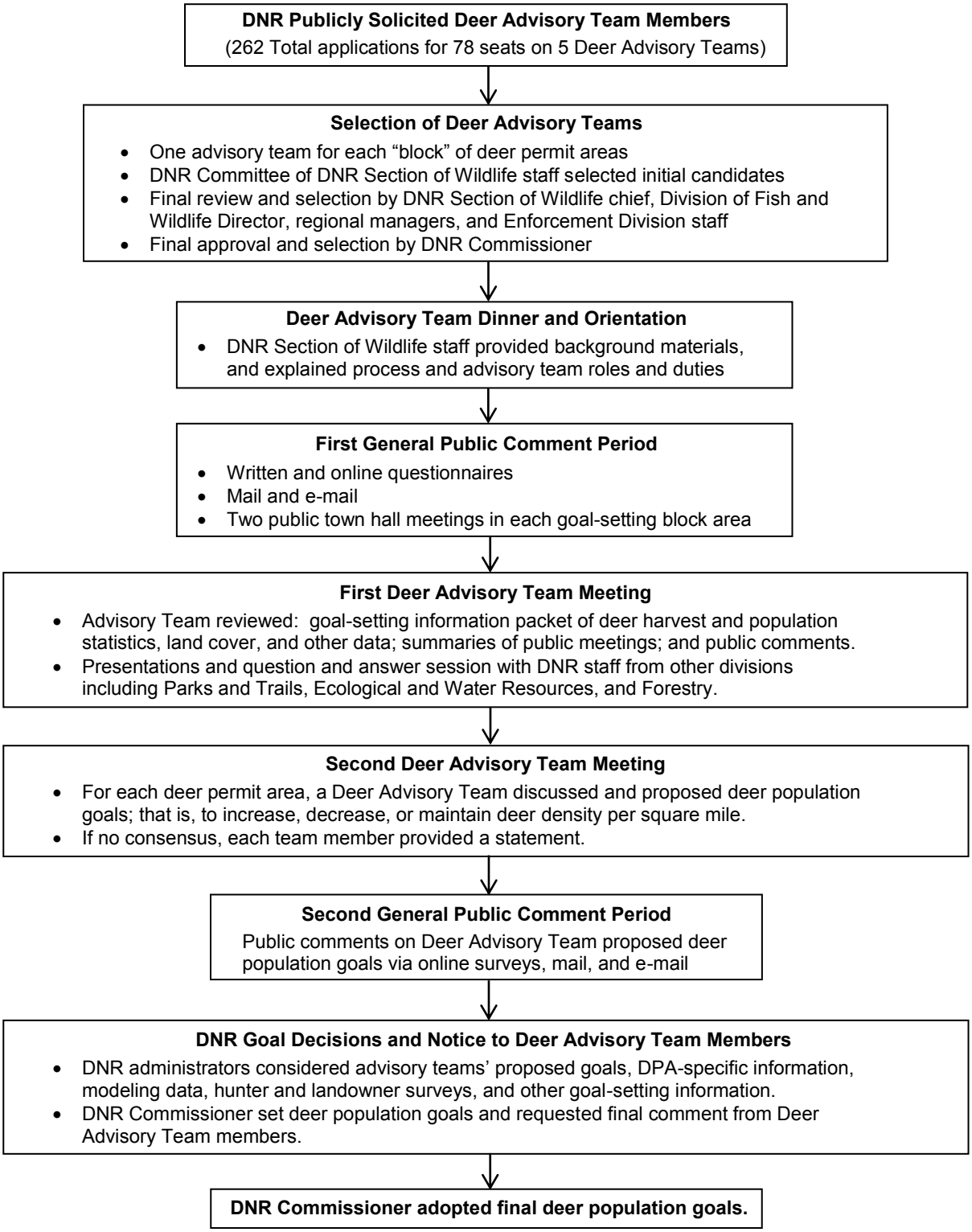
[13] Compiled from public responses to DNR online survey during 2015 goal-setting process.

[14] For more information about DNR's 2015 goal-setting process, see "2014-2015 Deer Population Goal Setting Summary and Evaluation" (Minnesota Department of Natural Resources, St. Paul, 2016).

[15] The 2015 Deer Advisory Teams consisted of individuals representing archery, firearm, and muzzleloader hunters; area residents and landowners; farmers; land managers; foresters; local business owners; and members of hunting and conservation organizations. The Minnesota Deer Hunters Association and the Nature Conservancy both had one authorized representative serving on each advisory team. American Indian Tribal representatives were included on three of the five teams.

Exhibit 2.3: DNR Periodic Deer Goal-Setting Process, 2015



NOTE: DNR is the Minnesota Department of Natural Resources.

SOURCE: Office of the Legislative Auditor, summary of Department of Natural Resources documents.

DNR staff facilitated the deer goal-setting processes for 2015.[16] DNR Section of Wildlife staff provided background information, commentary, and feedback to advisory team members. Staff from DNR Forestry, Parks and Trails, and other divisions also participated in the initial advisory team meetings by presenting information about the divisions relative to deer management, and by answering questions from advisory team members.

As we discuss later in this chapter, DNR staff compiled statistics and materials for advisory team members for their review and consideration. Following participation in public open house events and team meetings, each advisory team was asked to reach a consensus and propose to DNR Central Office staff deer population goals for the next three to five years.[17]

DNR designated the final deer population goal for each DPA after DNR staff considered: advisory team proposals; public comments; recommendations from research staff, regional and area wildlife managers, staff from other divisions, and American Indian tribal representatives; and historical hunter success rates, permit designations, and other data. For the 2015 deer goals, the DNR Central Office afforded advisory team members one more opportunity for review and comment before the DNR commissioner finalized the goals. As of 2015, DNR updated the goals for 69 DPAs (63 percent of all DPAs with goals) around the state. With some exceptions, the DNR's final goals generally aligned with Deer Advisory Team proposals; we discuss outcomes of the DNR goal-setting process to date in Chapter 3.

The DNR annual deer season regulation process and the deer goal-setting process both require information to make decisions. Some information is useful for statistical estimates, while other data represent opinion, such as responses to DNR surveys. In the next sections, we examine the scope and adequacy of certain information used by DNR for these two administrative processes.

ESTIMATING DEER POPULATIONS

Estimates of white-tailed deer population size are of interest to the public; however, the importance of knowing the size of the population is often overemphasized as the tool for deer management.[18] Rather, it is more important to know the relative abundance of deer over time compared with the carrying capacity of its environment. Federal and state wildlife agencies take different approaches in their methods, frequency, and resources devoted to this task, including the level of precision attached to their deer estimates.

Understanding how many deer may exist across the landscape is a challenging endeavor. In Minnesota, DNR last estimated there were about one million deer statewide in 2013, and

[16] DNR Fish and Wildlife Division Policy and Planning staff and Operations Services Division regional planners facilitated the meetings.

[17] The rule of decision was "consensus." Consensus was defined as an 80 percent supermajority of non-abstaining members indicating either "support" or "ok," with no more than two team members abstaining. As we discuss later in Chapter 3, teams achieved a consensus for 33 of 40 permit areas.

[18] Lowell K. Halls, ed., *White-Tailed Deer: Ecology and Management* (Washington, DC: Wildlife Management Institute, 1984), 206.

estimated deer population sizes varied greatly among deer permit areas.[19] Even through the use of extensive resources, a direct count of Minnesota's entire deer population would not be feasible and, thus, the use of indirect statistical measurement of deer is needed. For this purpose, DNR uses its deer population model to estimate deer numbers and trends at the DPA-level.

Deer population modeling requires unique expertise and understanding of statistics; however, the Department of Natural Resources' communications about its deer modeling were sometimes too technical and insufficient for goal-setting purposes.

In the following sections, we summarize information and findings regarding DNR's model and statistical methods using more general terms than used in DNR documentation about its modeling activities and results. Because DNR enlists individuals from the public to participate on Deer Advisory Teams and propose deer population goals based on DNR modeling data and other information, communications regarding the technical aspects of DNR's work should be clear and understandable for the average person. As we discuss later in this chapter, some members of Deer Advisory Teams found DNR's materials to be confusing and wanted more time and explanation to understand the information. To help readers understand DNR's modeling activities, we attempt to limit our use of technical jargon. However, we have included some of DNR's explanations in footnotes to provide additional detail and to illustrate the technical nature of their communication.

Purpose of Deer Population Modeling

Deer population modeling does not provide an exact number of deer, but it provides a tool to help DNR simulate deer population dynamics and estimate likely population *trends*.[20] In simple terms, modeling the likely changes in deer populations requires estimating the initial number of deer, their survival rates, likely deer added through births, and deer lost through death.[21] Statistical modeling also requires data and a process that accounts for other factors that may affect population changes, such as likely rate of deer deaths due to winter severity. Exhibit 2.4 describes terms related to deer population modeling.

The primary use of DNR's current model is to develop a biologically reasonable "range" of deer population estimates for the current year, given past deer harvest information and trends.[22] These deer estimates serve as the starting point for projecting what the deer population is likely to do under various regulatory decisions in the next year and over time. Specifically, DNR staff first estimate the likely range of number of deer per square

[19] Given the variability of estimates among deer permit areas, DNR discontinued producing an annual statewide deer population estimate in 2013. As explained by a DNR representative, DNR's model was designed to provide information at the DPA-level and not to produce a statewide estimate; as such, the accuracy of a statewide estimate was questionable at best.

[20] Estimates of deer populations are not an actual count, or census, of every deer within a DPA.

[21] Two other variables include the estimated number of deer moving into a DPA (immigration) and the estimated number of deer moving out of a DPA (emigration). In its modeling, DNR assumes these values to be equal.

[22] "Minnesota DNR Deer Management: Monitoring Deer Populations" (Minnesota Department of Natural Resources, St. Paul, 2015), 11.

Exhibit 2.4: Key Deer Population and Model Terms and Descriptions

Term	Description
Abundance	A measure of quantity or relative degree of plentifulness of deer. "Overabundance" of deer occurs when deer or deer presence: affects human life or well being, affects the fitness of the deer herd, reduces the esthetic value of deer, or causes dysfunctions in the ecosystem.
Aerial Survey	Use of aircraft to gather visual counts of deer on the ground and create estimates of deer population abundance and density.
Distance Survey	Method to gather visual counts of deer from the ground—such as from roads—and create estimates of deer population abundance and density.
Distribution	An arrangement of statistical data that shows the frequency of the occurrence of the values of a variable, often around an "average."
Antlerless	A deer without antlers, or antlers that are less than three inches long.
Buck	A male deer, defined as having at least one antler at least three inches long for hunting purposes; in some deer permit areas with antler point restrictions, a "legal buck" is defined as having at least one antler four inches long.
Wounding/Crippling Loss	Deer injured by hunters but not recovered and registered.
Deer Density	Number of deer per square mile (or other unit of area).
Doe	Female deer
Fawn	A young deer, typically one that is unweaned or less than one year old.
Harvest	Deer killed through regulation or management actions.
Index (Indices)	A number or statistical value used in a mathematical operation.
Mean/Average	A statistical value that is calculated by adding quantities together and then dividing the total by the number of quantities; the result is a value somewhere between the extremes among a set of values.
Model	Mathematical tool to help estimate and predict changes in deer populations.
Deterministic	Statistical Model that relies on specified values to create unique results but does not account for likely variation or "random" events and always performs the same way for a given set of conditions.
Stochastic	Statistical model that accounts for inherent variation—within populations and in response to environmental conditions—in its processes and model outputs (that is, the probability distributions or range of values). Purpose is to help predict what results might occur under different conditions.
Mortality	Number or percentage of deer deaths compared with total deer and typically defined as either (1) hunting-related, including reported and crippling loss; or (2) all other causes, including natural, illegal kills, and highway kills.
Poaching	Shooting, trapping, or taking of game outside of or in violation of regulated or approved actions.
Post-Hunt Population	Estimated deer population immediately following deer hunting season and prior to end of winter.
Pre-Fawn Population	Estimated deer population in Spring before fawns are born.
Rate	A quantity, amount, or degree of something measured per unit of something else; a fixed ratio between two things; for example, number of deer deaths relative to total deer herd.
Recalibrate	To adjust or standardize to measure precisely, especially to measure against a standard.
Recruitment	The number of deer added to population through births (fawns born in Spring that survive into Fall) and immigration into an area.
Reproduction	Deer births
Standard Deviation	A statistical measure used to describe the amount of dispersion or variation of a given set of values, typically relative to the mean/average value.
Ungulate	A hoofed typically herbivorous four-legged mammal.
Vital Rates	Statistical values representing changes in populations (increase or decrease) often based on births and deaths, and immigration and emigration within a defined area.

Source: Office of the Legislative Auditor, summary of deer management research and literature.

mile—referred to as "deer density"—in a DPA or region.[23] (DNR publishes density estimates that include a likely minimum, average, and maximum deer density in each DPA.)[24] DNR analyzes its initial deer density estimates against other factors to then forecast a one-year future deer density for each DPA and for each type of deer permit area designation (for example, "bucks only"). In 2015, DNR modeled deer densities for 112 of 128 DPAs; the remaining DPAs were either too small to produce reliable estimates, were under tribal jurisdiction, or experience too little hunting to provide sufficient data.[25]

Deer population modeling requires unique expertise and, for the DNR's model, knowledge of particular statistical computer programming language. To help us evaluate DNR's model, we contracted with Wildlife Management Institute, Inc., (WMI) to evaluate aspects of DNR's deer population modeling and deer survey methods, identify strengths and weaknesses, and recommend improvements.

In the next section, we summarize findings regarding DNR's model. The full report of WMI's work, including a complete list of findings and recommendations, is contained in Appendix A at the end of this report. We emphasize that from these findings we cannot conclude whether Minnesota's actual deer numbers are higher or lower than DNR's estimates.

Model Development

In Minnesota, hunting is a primary cause of deer deaths. Each deer hunter is required to report to DNR the location and other data about each deer the individual killed, and DNR relies on deer harvest data reported by hunters for monitoring and modeling deer populations.[26] The DNR deer model uses this harvest data and estimates of other vital statistics (for example, deer reproductive rates, and deer mortality rates due to non-hunting causes) to determine if a population is likely to be increasing, decreasing, or staying the same in a deer permit area. In short, the DNR population model is used to estimate the

---

[23] DNR staff describe this process as follows: "There are 2 modeling processes: retrospective (a type of population reconstruction based on reported harvest) and prospective (a forecasting piece based on expected harvest and vital rates given different regulatory packages, the historic distribution of WSIs [winter severity index] for a DPA or region, and historic data on hunter efficiencies under the various regulatory packages). The retrospective piece is ultimately used to estimate the current population size and trend given some starting point (year) and value (population size with some level of uncertainty). The prospective piece then takes the current estimated population size (with uncertainty based on [interquartile range]) and projects it forward 1 year for each regulatory package. This is done multiple times using stochastic algorithms to construct a distribution of possible outcomes."

[24] "Minnesota DNR Deer Management: Monitoring Deer Populations" (Minnesota Department of Natural Resources, St. Paul, 2015), 11-12. DNR staff also report that: "the stochastic model produces a distribution of possible abundance values (not just a min, max, and mean) given the reported annual harvest (the observation process) and assumptions about the starting population size, sex-age structure, vital rates, and underreporting (of harvest). In many cases the distribution of estimates approaches a normal distribution, which means that estimates closer to the mean are more likely to occur than estimates in the tails of the distribution. Thus, the mean (or median) and the interquartile range (IQR) are good statistics to describe the central location of the distribution and the most likely population values (given the model is true)."

[25] DNR also does not model the deer population in DPA 601 covering most of the seven-county metropolitan area. In some states, deer permit areas are much larger in size than Minnesota's deer permit areas. According to DNR staff, DNR must balance having enough data to model deer populations and hunter desire to know deer populations for smaller areas.

[26] *Minnesota Statutes* 2015, 97A.535, and *Minnesota Rules*, 6232.0400, posted January 2015, require deer hunters to register deer within 24 hours of the close of the season in which the deer was taken.

minimum number of deer that must be in the population to support the observed deer harvest over time.[27]

In recent years, DNR has modified its statistical models for estimating deer populations around the state. In 2014, DNR also changed its technical capacity and scientific modeling methods, in particular, to create estimates of a biologically reasonable range of deer density values and deer population trends in DPAs around the state. We reviewed the development, functionality, and data used for DNR's new model.

Aspects of DNR's deer population modeling in 2015 were commendable and aligned with accepted deer management practices.

Prior to 2012, DNR used two separate deer model processes—one for Minnesota's farmland region and one for its forested region. DNR combined these two models into a single statewide process in 2012. Between 2012 and 2014, DNR's model was a simple spreadsheet-based accounting model that functionally added (births) and subtracted (deaths) deer numbers for each DPA (a method used in many other states).[28] However, this type of model does not account for variation or uncertainty regarding deer population abundance and trends.[29] That is, DNR's previous accounting model did not entirely function in a way that more closely reflects possible dynamics of deer populations over time. Using this type of model, DNR modeling methods in some parts of the state relied on fixed values and did not incorporate a statistical range of values when estimating deer abundance. Thus, the DNR's modeling results led readers to infer more certainty in the department's estimates than could be expected.

During 2014, DNR upgraded from its spreadsheet accounting model to an R-based "stochastic" model to better estimate variation and uncertainty regarding deer population abundance and trends; this approach is more sophisticated than what is used in some other states.[30] Exhibit 2.5 describes DNR's 2015 stochastic deer population model and data. Very generally, the DNR generates estimates of the number of deer alive during successive periods of a twelve-month annual cycle. Many factors affect deer abundance, including deer birth rates, hunting, disease, predation, winter severity, availability of food, and other causes. The model cycle is divided into periods representing important biological events in a deer's life (for example, hunting season, winter, reproduction, and summer).[31]

Our technical review found that the current DNR population model used in 2015 was sound in its current form and an improvement over the DNR's previous deterministic model. DNR's current model uses state-of-the-art programming supported by values—or statistical indices—that are intended to simulate possible changes in deer population size and growth over time and to mimic the uncertainty in estimates of deer vital rates. DNR's rationale for shifting to a stochastic model was to increase transparency about the uncertainty in DNR estimates of population size and trends, and to frame discussions about deer estimates in a way that is

[27] "Minnesota DNR Deer Management: Monitoring Deer Populations" (St. Paul, 2015), 11.

[28] This type of model is referred to as a deterministic model.

[29] See also, "MN DNR Deer Modeling: Summary Information for Goal-Setting" (Minnesota Department of Natural Resources, St. Paul, 2015).

[30] Program R is open-sourced statistical software used by DNR to simulate population trends and dynamics.

[31] For a description of DNR 2015 deer modeling methods, see "Monitoring Population Trends of White-tailed Deer in Minnesota – 2015" (Minnesota Department of Natural Resources, St. Paul, 2015).

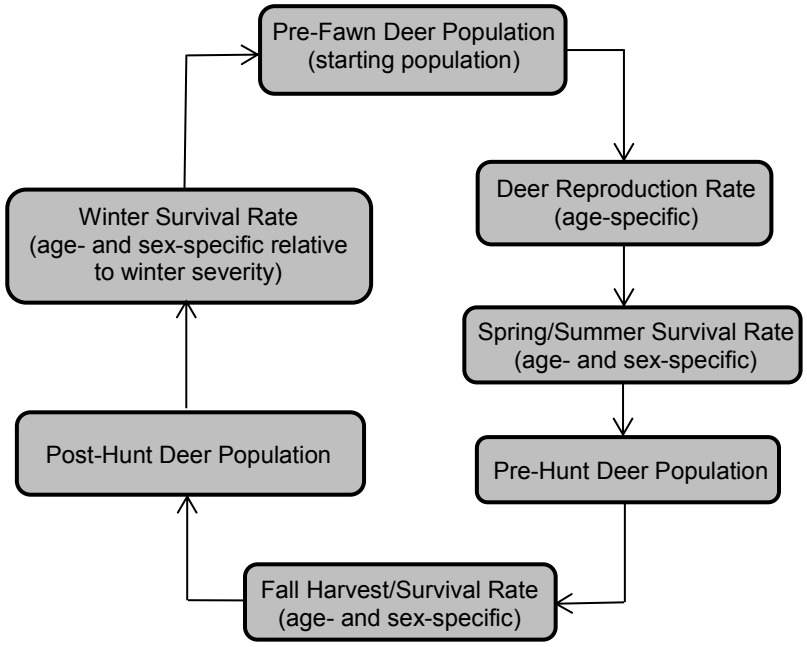
Exhibit 2.5: Structure of DNR's Model, Key Data, and Indices for Simulations of Deer Populations, 2015

DNR Modeling Data

- Total Deer Harvest, by Deer Age and Sex[a]
- Total Gun Hunters
- Total Harvest per Gun Hunter
- DPA Total Land Area
- Geographic Region
- Hunter Permit and Season Designation
- Population Goal

Model Indices

- Deer Reproduction Rate, by Deer Age
- Survival Rate, by Season, Age, and Sex
- Hunter Deer Registration Rate
- Crippling Loss Rate
- Illegal Harvest Rate
- Winter Severity Index



NOTE: DNR is the Minnesota Department of Natural Resources.

[a] Includes all license types (such as resident, non-resident, youth, all-season, and multi-zone buck) and weapons, including firearms, muzzleloader, and archery.

SOURCE: Office of the Legislative Auditor, summary of Department of Natural Resources model documentation. "Monitoring Population Trends of White-tailed Deer in Minnesota 2015" (Minnesota Department of Natural Resources, St. Paul, 2015).

supported by harvest data and knowledge about deer populations and how they are likely to vary geographically and over time.

As described in Exhibit 2.5, DNR in 2015 used historical summary data on deer reported harvested, by age and sex, number of reported hunters, geographic region, and other information to help model the number of deer in each DPA. DNR kept summary data about annual deer harvest and other information in an Excel-based spreadsheet, and used these data when running its statistical modeling code.

To help simulate likely changes in deer populations in each DPA, DNR used statistical indices and assumptions from deer research that DNR had conducted around the state.[32] The department also used indices from national research and literature, a practice that is routine for deer managers across the nation. Most of these indices were sufficient for basic modeling purposes and were appropriate for deer in northern climates. To account for regional variation in Minnesota's environment, DNR also sufficiently adjusted certain estimates of deer vital rates, both geographically and over time. For example, to account for deer survival in Minnesota's winter climates, DNR used an index to measure the impact

[32] DNR research cited for this report is referenced in Appendix A, page 50.

of winter severity on deer populations; this "winter severity index" used for 2015 compared favorably with similar measures used by wildlife agencies in other northern states.

DNR's statistical methods and data could be improved to better simulate dynamics of deer population growth and to fully utilize its new model.

Although DNR's modeling compared favorably with certain wildlife industry methods, some aspects fell short of expected practice. In particular, DNR was missing an important source of knowledge by not collecting and utilizing current age data from hunter-killed deer.[33] One other weakness of the new DNR model was that the value used for initial deer density had a potentially disproportionate impact on model output values. That is, the model had the potential to create unrealistic changes in deer population trends. To address this weakness, DNR modelers used professional judgement to adjust input values to the model, for example, changing the estimate of summer survival rates for adult females.[34] This shortcoming was due to limitations of the historical data used by DNR to initially develop its new stochastic model. The stochastic model is intended to better account for variation and uncertainty in population changes; however, because DNR prior to 2010 changed the boundaries of many deer permit areas, the limited historical data for DPAs meant DNR's methodology had the potential to produce unlikely results for some DPAs.

DNR also used a consistent, fixed range of values to estimate non-registered and illegal killing of deer (poaching) in all regions of the state.[35] DNR's model relies significantly on deer harvest data reported by hunters, but not all deer that are killed are reported, or may be reported to the incorrect deer permit area. DNR did not have adequate documentation to support the sufficiency of its methods used to estimate non-registered and illegal deer harvest (poaching); in particular, why the range of values it used would not vary over time or around the state. DNR staff assert they use this approach because (1) rates for non-registration and illegal harvest (poaching) are difficult to quantify, (2) the rates DNR uses generate reasonable model outputs with predictable outcomes, and (3) when compared with other modeling information (such as rates for non-hunting survival and values used for initial deer population size), rates regarding illegal harvest and non-registration have relatively little impact on model results.[36]

Modeling Practices and Data Storage

DNR's new deer model requires advanced statistical programming and data management skills. We reviewed DNR's methodology and processes for utilizing its deer data.

[33] In modeling deer populations, ratios of fawns-to-adults and yearlings-to-adults in the harvest provide important insight into non-harvest mortality, including winter mortality.

[34] More specifically, DNR modelers used professional judgement to adjust model inputs (and, thus, adjust model outputs), rather than through "feedback loops" within the model (e.g., harvest indices, permit success rates, etc.).

[35] Many deer die of non-hunter related causes, including starvation, predation, deer-vehicle crashes, disease, and other factors.

[36] Specifically, DNR staff report that: "sensitivity analyses performed with our model suggest that errors with these parameter inputs have little impact on model output relative to other model parameters (e.g., initial population size) that are assumed to be correct (e.g., non-hunting survival rate parameters)."

Our technical review found no logical errors in DNR's deer population modeling code; however, DNR's overall coding practices and data storage presented unneeded risks of user mistakes.

For calendar year and hunting season 2015, DNR's activities to estimate deer populations for each DPA was documented, and its statistical programming code for the deer model included no logical errors. However, the department's programming code for the deer model was overly complex, with unnecessary redundancy in formatting that required extensive user input. For example, modeling for each DPA required multiple user edits and manual entries throughout the code—an inefficient process that introduces the risk of user mistakes.

DNR currently does not have a central database or information system to house all deer population data needed for modeling. The DNR's use of spreadsheets was a less-than-ideal environment for DNR's deer data storage and updates. In particular, when compared with a database, spreadsheets have greater potential to compromise data integrity, consistency, and transparency.[37]

Data Validation

Estimating deer populations requires sound, reliable data. We tested the adequacy and completeness of DNR's modeling data. We also examined DNR's processes for validating the function of its model and its deer population estimates.

In recent years, DNR addressed data deficiencies in its deer model; however, more work is needed to improve deer population statistics and the goal-setting process.

Beginning in 2014, DNR reviewed and updated various aspects of its model and data management. These changes improved DNR's statistical methods but resulted in differences between new and historical deer statistics. In particular, DNR observed that it had in the past used total area (including water bodies, instead of land-only data) to produce deer density estimates in northern forested areas.[38] DNR also confirmed that its modeling methods prior to 2012 likely resulted in unintended overestimates—especially while populations were declining—and underestimates of deer densities in some northern forested DPAs.

One particular data challenge pertains to collecting consistent and complete information on the number of deer killed through special hunts held by local governments, parks, or game refuges. Administrators of special hunts may not always collect data from hunters on deer they killed, or hunters may instead report deer killed to the surrounding DPA (rather than to the special hunt area within the DPA). During 2015, research staff reviewed and, where missing, incorporated into the model deer harvest data from special hunts for years 2010-

[37] For example, every spreadsheet cell and its functionality is unique and may contain either a formula, an actual number, or text. From a user perspective, the increased functionality of a spreadsheet enhances its usefulness but can mean less standardization and greater risk of user mistakes.

[38] The department's 2015 published model output was correctly based on land-only data, and this change was noted in some reports.

2014. Although deer killed though special hunts may represent a small share of deer harvested statewide, special hunt harvests may account for a notable share of deer killed within some DPAs.[39] For special hunt areas that typically experience larger deer harvests, statistical reports and estimates for some DPAs may have been affected.[40]

DNR has improved the integrity of data it uses for its stochastic model; however, DNR did not sufficiently carry out some other activities considered best management practices when implementing a new model. For example, DNR did not take steps to fully validate new model outputs through comparison of data collected from independent observations and counts of deer in the environment. DNR could obtain comparison of model estimates through survey counts of deer from the road or from aerial surveys by helicopter, or other means. As mentioned previously, DNR was missing an important data source for modeling by not collecting and utilizing age data from hunter-killed deer in its model as an index to winter mortality and as a check on model results.

Typically, model verification may be done in a strategic way by having researchers focus their data collection and field surveys on a small sample of DPAs over a specific time period and comparing their findings to model outputs. Instead, DNR relied primarily on deer harvest data to validate its new forecasts of deer populations. Earlier we noted concerns about DNR's lack of documentation to support its use of certain fixed indices for unreported deer harvest by hunters around the state and over time. We discuss DNR's use of independent observations in the next section.

Surveys of Deer Populations

DNR collects information about Minnesota deer numbers from various means and sources, previously described in Exhibit 2.5. These efforts include aerial surveys of deer and surveys of hunters and landowners. We examined DNR's methodology and the scope of these surveys.

DNR's design and execution of recent aerial surveys were scientifically sound and met or exceeded industry standards; however, DNR's infrequent use of aerial or other deer population surveys limited their value for informing its deer modeling efforts.

From 2005 through 2014, DNR's execution of aerial surveys to assess deer presence improved and, in recent years, followed sound survey methods. DNR's use of aerial surveys has helped DNR develop deer estimates, but in a very limited way and for specific DPAs, only. DNR uses its resources and staff to conduct aerial surveys of other wildlife and, in recent years, focused these resources on researching the declines in Minnesota's moose populations. However, the department's limited use of its deer aerial surveys restricted the department's ability to use this tool to inform and help verify the accuracy of its deer model estimates.

DNR modeled deer estimates in 112 DPAs in 2015. DNR reported that from 2005 through 2014, it conducted 56 deer-specific aerial surveys in 41 DPAs around the state; 26 surveys

[39] According to DNR staff, the number of deer taken in some special hunt areas—such as the Camp Ripley special hunt—is large enough to make a difference in modeling for the surrounding DPA.

[40] DNR did not include data on deer harvested in Indian tribal areas in its model in recent years.

were carried out from 2010 through 2014. Many DPAs located in Minnesota's northern forested region are not amenable to aerial surveys due to sightability issues associated with deer located under tree cover. The usefulness of aerial surveys in DNR's modeling is further limited because seasonal movements of deer between the time of aerial surveys in winter and modeled deer estimates in fall and spring may produce discrepancies in estimates. Because of these factors, DNR told us it relies on aerial survey results for general comparison to model outputs only.

However, DNR does not conduct other types of observation surveys of deer—such as distance surveys from the road—specifically for modeling purposes. DNR does survey hunters and landowners to obtain their feedback on a range of issues, including their opinions and perceptions on recent changes in the size of deer populations in particular DPAs. The department conducts these surveys periodically as part of setting long-term population goals. DNR uses the survey results to compare against modeling results. We discuss these hunter and landowner surveys more in the next section.

INFORMATION FOR SETTING DEER POPULATION GOALS

Estimates of deer populations help individuals understand the current presence of deer, but they also should be considered in the context of longer-term goals. Goals are an endpoint for the desired direction in deer populations and are intended to balance local preferences and interests, wildlife conservation objectives, and the ability of the environment to support deer.

In this section we look at the information compiled and utilized by DNR to help obtain public feedback on deer population goals. That is, the number of deer that individuals prefer to see, and whether the number of deer are too few, too many, or about right.

Deer Population Goals

Deer are mobile and their numbers vary across Minnesota local environments, including public and private land. Gathering public input about deer population size and numbers requires administrative resources and actions to address societal expectations. As we described earlier, DNR re-implemented a standardized process in 2012 to update deer population goals that had been previously determined between 2005 and 2007. This administrative process involves setting population goals for a designated group of DPAs. Deer population "goals" are not defined in Minnesota statutes, nor is the time frame for revising goals. However, DNR has suggested that the goals for each DPA will be reevaluated every three to five years.

DNR's definition of deer population "goal" relies more on DNR statistical estimates of deer than other information, and is more complex than goals published in some other states.

As shown in Exhibit 2.6, DNR uses directional trends in deer density as the basis for determining a goal for each DPA. To calculate a goal, DNR first estimates the number of deer per square mile—or deer density—in a DPA. These estimates include a range of values within a published minimum, average, and maximum number of deer per square mile. Then DNR sets a trend goal for each DPA that represents a percentage increase,

percentage decrease, or no change in deer population size. The trend goal represents a directional change in the target deer density range over the next three to five years.

Exhibit 2.6: DNR Deer Population Goals, by Number of Deer Permit Areas, 2012, 2014, and 2015

Year Deer Population Goal Revised	Number of Deer Permit Areas (DPAs)	Revised Deer per Square Mile Population Goal	Minimum/Maximum Deer per Square Mile (psm) Among DPAs
2012 Goal Setting for DPAs located in Southwestern and Northern Minnesota			
	0	Decrease	
	7	Maintain Current Population	
	4	Increase 10%	
	11	Increase 25%	
Total DPAs	22		
			Minimum: 2-4 Deer psm Maximum: 14-19 Deer psm
2014 Goal Setting for DPAs located in Southeastern Minnesota			
	2	Decrease 50%	
	1	Decrease 10%	
	1	Maintain Current Population	
	1	Increase 10%	
	1	Increase 10-25%	
	2	Increase 25%	
	1	Increase 50%	
Total DPAs	9		
			Minimum: 9-11 Deer psm Maximum: 15-19 Deer psm
2015 Goal Setting for DPAs located in Northeastern, North-Central, and Eastern Minnesota			
	0	Decrease 50%	
	0	Decrease 25%	
	6	Maintain Current Population	
	21	Increase 25%	
	13	Increase 50%	
Total DPAs	40		
			Minimum: 3-5 Deer psm Maximum: 20-25 Deer psm

NOTE: DNR is the Minnesota Department of Natural Resources.

SOURCE: Office of the Legislative Auditor, summary of Department of Natural Resources deer population goal documents, 2012, 2014, and 2015.

For example, for DPA 169—located in the northern forested region of Minnesota—the 2014 density estimate was 7 to 13 deer per square mile. The 2015 advisory team proposal and the DNR designated goal for this DPA was a "50 percent increase" over the next three to five years, to 13 to 17 deer per square mile. The trend goal represents an average density for the *entire* DPA. Among the DPAs assigned a new goal in 2015, target deer densities ranged from 3 to 5 deer per square mile to 20 to 25 deer per square mile.

DNR deer density statistics are an important component for evaluating deer populations; however, wildlife agencies in some other states we looked at defined deer population goals

differently than Minnesota. These states' approaches were generally due to local preferences, goals, or objectives; statutory requirements; readily available data; ecological environments; resource limitations; or other reasons. In Michigan, for example, deer goals are framed more simply as "increase," "decrease," or "no change" without specifying a percentage. Currently, Michigan and Wisconsin generally revisit their goals every three years. On the other hand, Iowa still uses goals it set during the late 1990s.

Some states we looked at are changing their goals and objectives to assess habitat areas needed to support deer and to better reflect deer "impact" on the environment, such as deer-vehicle collisions or number of complaints by landowners. For example, Maine has used deer density goals that varied around the state, and today assesses deer impact in the environment or considers lack of food sources in northern areas affecting deer survival.

Information About Deer Populations

Minnesota statutes require DNR to compile and publish statistical information related to conservation; DNR uses deer density per square mile and statistical ranges—including estimates of minimum and maximum deer numbers—to describe deer populations and population goals. However, deer are not evenly distributed across the landscape within a DPA; as such, modeling deer populations is challenging and not an exact science.

DNR's information for goal-setting advisory teams included deer population trends, statistics, and ecological characteristics of deer permit areas; however, more information about local environments would be useful for determining goals and deer permit area designations.

To help Deer Advisory Team members consider and propose deer goals, DNR provided members with historical information about each DPA, including the number of deer killed and hunters, by types of deer and hunting licenses, and statistical estimates of current and forecasted deer densities. Additionally, DNR provided general education—not DPA-specific—materials and references to scientific literature about deer impact in the environment.[41] Exhibit 2.7 lists the information and materials provided to advisory team members. During our work, we learned that individuals interpreted DNR's statistics and goals in different ways, found the information confusing and difficult to understand, or thought DNR's method was overly complex and wanted a simpler approach. Others wanted more information about different aspects of deer management.

As we described in Chapter 1, wildlife management decisions should reflect an understanding of an area's environment and its ability to support deer. Since 2012, the information provided by DNR to deer advisory groups has increased and evolved to include such things as percentage of DPA land classified as private or public and percentage of land classified into select habitat categories, such as forest or agriculture. This information helps provide context about available deer habitat on public land, hunting opportunities, and potential for disagreement among residents' preferences. However, a more complete picture would include other, objective data, such as human population density in a region or, better yet, *trends* in human population density

[41] For example, DNR provided references to web-based information about Lyme disease and statewide deer-vehicle statistics. The Minnesota Department of Public Safety also compiles county-specific information about deer-vehicle crashes; however, DNR reported it did not use this information for goal-setting purposes because it could not verify the integrity of the reporting.

or changes in land use. Such information may not be available at the DPA level but can be compiled for a county or regional perspective. In recent years, DNR has not formally compiled and provided this information to advisory team members.

Exhibit 2.7: DNR Information for Deer Advisory Teams and Setting Deer Population Goals, 2015

Information and Resources

Deer Advisory Team Information Packet:

- General educational materials regarding: deer management and deer populations; biological, social, and reasonable carrying capacity; deer impact on the environment; deer disease; and bibliography references to national and DNR scientific research articles.
- Deer Permit Area descriptive data, including: DPA size; percentage DPA area, by habitat categories; historical summary information regarding number of hunters, deer harvest, hunter success rates, and hunter permit designations; and deer population model output.
- DNR Guide to Interpreting Results from Deer Population Modeling, and Deer Modeling Summary Information for Goal-Setting.
- DNR 2014 Deer Harvest Report (deer killed, hunter participation, hunter success rates, statewide and by DPA, special hunt areas, and weapon types).
- Commentary and feedback from DNR regional and area wildlife managers, and Forestry, Conservation Enforcement, Ecological and Water Resources, and Parks and Trails staff.
- Results of DNR surveys of hunters and landowners.
- Public comments from open town hall meetings, mail, e-mails, and results of written and online questionnaires.

NOTE: DNR is the Minnesota Department of Natural Resources.

SOURCE: Office of the Legislative Auditor, summary of Department of Natural Resources 2015 goal-setting documents.

DNR's surveys of hunters and landowners may not sufficiently capture the broad range of public opinions about deer.

DNR surveys hunters and landowners to obtain their feedback on a range of issues, such as hunter access to land, hunting experience, land use, and desired level of deer populations for a particular area. DNR recently conducted these surveys as part of its goal-setting process; however, DNR designs each survey to serve additional objectives, including research or feedback on legislative policy.

DNR is required to conduct annual hunter satisfaction surveys—generally, and not specifically regarding deer—and its approach to use one survey instrument to assess public attitudes on a range of issues may be efficient.[42] In our opinion, however, the responses to these surveys may not be aligned with DNR's intended objectives.

We reviewed DNR's surveys of hunters and landowners conducted in 2012, including the survey instrument and reported results. We found that some survey questions were poorly

[42] *Minnesota Statutes* 2015, 97B.063. DNR contracts with the University of Minnesota to administer hunter and landowner surveys.

constructed or did not represent some respondents' perspectives or experience. In particular, DNR's survey questions did not clearly address the range of respondents' interests concerning hunting allowed on private lands. DNR's survey questions to hunters and landowners about deer in their area also limited the options for desired changes in deer populations. For example, DNR did not ask whether deer populations should increase or decrease by *more than* 50 percent. To this concern, DNR staff stated that the department framed deer population questions and goals in the context of what can be accomplished and monitored during each goal-setting cycle (that is, changes in deer populations over the subsequent three to five years). Further, they said that offering increases in deer numbers beyond what is biologically possible (such as more than a 50 percent population increase) could be considered disingenuous and further exasperate conflicts over deer decisions.

DNR information provided to deer advisory teams for goal-setting purposes did not sufficiently address the overabundance and impact of deer in some local environments.

Setting goals requires information, which should include some science-based and biological data to inform discussions and decisions. This information might include the extent to which an area can support its deer population, or whether deer will excessively feed on plants and trees in an area and have a long-term undesirable impact on the environment. Deer overabundance in an area also can result in poor deer health, low reproduction, starvation, and death.

In general, DNR did not provide enough DPA-specific data about the impact of deer in the environment to advisory team members in 2012, 2014, and 2015. For example, DNR provided members with educational materials that contained bibliographic references to national and DNR scientific research about such issues as carrying capacity (discussed in Chapter 1), deer habitat, and the impact of deer feeding in forests.[43] However, DNR did not provide consistent, detailed data about the health of particular ecosystems in Minnesota—such as local DNR wildlife areas, state parks or game refuges that are also popular hunting areas—or private land suffering from overabundant deer populations foraging for food.

DISCUSSION AND RECOMMENDATIONS

Management decisions about deer should be informed by the best available science and data. As discussed throughout this chapter, the value of data depends on the integrity of reporting, underlying documentation, and whether the data are current or pertinent to a particular region of the state. We recommend DNR take the following actions to better understand the abundance of deer around Minnesota, factors affecting their abundance, and deer impact in their environment. (Appendix A contains a complete discussion of Wildlife Management Institute's recommendations.)

[43] The department did not provide members with the actual research articles.

RECOMMENDATIONS

The Department of Natural Resources should improve and validate its new deer population model and deer population statistical estimates. Specifically, DNR should:

- **Conduct field research to improve model data and indices used to estimate deer vital rates, hunter reporting of deer harvest, and illegal harvest around the state.**
- **Collect and utilize age data from hunter-killed deer as an index to winter mortality and to validate model results.**
- **Use independent observations—such as through aerial surveys—of deer populations to validate model results; and reassess the factors that limit DNR's use of aerial surveys for this purpose.**
- **Improve the department's database and record-keeping system used for deer population modeling.**
- **Modify statistical programming and code structure to improve workflow, reduce the risk of user mistakes, and better simulate a potential range of deer densities.**

Our technical review found that, overall, the DNR deer population model used in 2015 was sound in its current form. Many aspects of DNR's modeling were commendable and aligned with wildlife industry accepted practices. However, we found limitations in the scope, consistency, and adequacy of some data DNR used to develop deer population estimates. While DNR has conducted field research around the state to support its model indices, Minnesota has a range of ecological environments and climates, and research findings for a particular area are not necessarily reflective of experiences elsewhere around the state or over time.

Ideally, rather than rely so much on statistical model indices, a better approach would be to use more information from field data collection to better represent what is known about Minnesota's deer.[44] At a minimum, some of the shortcomings of the DNR model, data, and deer population estimates may be overcome by conducting more field research—such as collecting more data on deer age at harvest—to inform the department's vital rate estimates of deer births and deaths, and better reflect deer population dynamics.[45]

DNR's modeling and estimates of deer relies significantly on deer harvest reported by hunters. However, DNR did not provide sufficient documentation to support why

[44] Research has found that, increasingly, "integrated population models" (IPMs) are used for natural resource management because they synthesize various relevant data into a single analysis. IPMs provide a formal framework for combining different data sources, and they offer the potential to estimate additional parameters of interest. IPMs also require additional auxiliary data (or assumptions) and more sophisticated technical expertise. John R. Fieberg, Kyle W. Shertzer, Paul B. Conn, Karen V. Noyce, and David L. Garshelis, "Integrated Population Modeling of Black Bears in Minnesota: Implications for Monitoring and Management," *PLOS ONE* 5, no. 8 (August 2010): 1 and 7, http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0012114.

[45] This type of information is commonly collected on a periodic, regional, or ongoing basis by wildlife agencies.

unreported harvest rates and illegal killing of deer would not vary around the state or over time.[46] DNR's Enforcement Division recently improved its records management system to facilitate reporting by conservation officers of violations uncovered when enforcing hunting and wildlife laws, including illegal killing of deer. The extent to which DNR Section of Wildlife staff use historical data of deer-related offenses was not clear from our review. Further examination and documentation of these issues among local areas would help inform DNR's estimates and forecasts of deer populations. The department also should ensure the consistent collection of deer harvest data from special hunts held by local governments, state parks, game refuges, or other areas.

Currently, DNR does not have a strategic process to utilize aerial or other surveys —such as distance surveys from the road—or other independent observations and data as a check against its new model outputs.[47] The outcomes of these types of activities could improve model estimates for DPAs around the state, in particular, in northern forest regions where aerial surveys of deer are not as useful due to sightability issues with tree cover.

We recommend that DNR carry out additional research to collect deer data in order to improve its statistical reporting and validate its modeling, but we note that ongoing collection of data statewide and the logistics of certain types of field research can be prohibitively expensive.[48] Further, it is expensive to secure adequate sample sizes to estimate deer population vital rates across a single DPA, much less an entire state. Some research may need to be conducted on a regional basis to ensure scientifically valid sample sizes and results. However, targeted field research and data collection, particularly for areas in which deer modeling estimates and external data sources differ, could improve DNR's model. For example, DNR's efforts could focus on understanding more current deer survival rates in northern forested areas, where DNR's previous model overestimated deer populations and severe winters likely affected deer survival. Similar to Minnesota's experience, other states in northern regions experienced significant declines in deer numbers following recent severe winters. We discuss other recommendations to DNR regarding winter indices used among northern states in Appendix A of this report.

Our consultant's review of DNR statistical programming and model code revealed no logical errors, which was commendable given the complexity of the DNR model. However, DNR should revise its modeling practices to incorporate automated analysis using external data sets regarding trends, indices, and other data. DNR also should modify its code structure and data storage to improve workflow, help ensure data integrity, and reduce the risk of user mistakes. One solution would be to implement a central database to house all data, standardize user input, and control user interaction with the data.

These recommendations reflect a standard for deer population modeling that strives to balance statistical rigor and data integrity and to effectively support proactive deer management. DNR relies largely on staff expertise and judgment to assess model results and for *ad hoc* comparisons to other data. The use of modeler's professional judgment,

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[46] DNR representatives stated that poaching is generally a local problem, represents a very small share of total harvest, and does not affect deer populations, modeling, and related permit designations.

[47] One approach to help validate the DNR model would be to compile and use such data for a targeted number of DPAs over a specified time period.

[48] According to wildlife agency representatives with whom we spoke, some conduct deer research, but they are doing so on a strategic basis for particular issues or regional areas that are of concern to stakeholders. Other research they are conducting—such as assessing the impact of deer forage on state wildlife areas—requires long-term tracking and research, and the results will not be available for goal-setting teams for several years.

informed by other data, is a common practice in wildlife population modeling and should not be discarded as this helps align possible deer harvest scenarios with local interests and environments. However, without extensive documentation of modeler's inputs and decision rationale, it would be difficult to learn from successive iterations of the DNR's model.

Lastly, we cannot determine the extent to which enhanced collection and utilization of data would impact DNR's estimates of deer populations, that is, whether the estimates for any DPA could be higher or lower. Improvements to DNR's data collection and modeling may mean changes in DNR's published deer densities, and this should be expected.

RECOMMENDATION

For purposes of setting deer population goals and permit area designations for hunting, the Department of Natural Resources should compile and publish additional information about the characteristics of deer permit areas.

Underlying much of the conflict about deer presence is the availability of habitat for deer, the impact of deer on its surroundings, and the extent of hunting and recreational opportunities, particularly in public land areas. We think providing more information about human population density to the advisory groups, including regional population trends, would enhance understanding and discussion among stakeholders about social tolerance for deer in particular areas. For example, more information about changes in land use and development within DPAs will provide a better picture about changes in, or loss of, deer habitat on both private and public land. Such information could help facilitate discussion about resolving conflict among hunters and non-hunters, and private landowners. DNR provided very limited information about DPA characteristics to individuals involved in the recent deer goal-setting processes.

RECOMMENDATION

The Department of Natural Resources should consider enhancing its deer management surveys to obtain a broader range of opinions.

DNR currently surveys hunters and landowners as part of its goal-setting process. To reduce survey costs and gain efficiencies, DNR uses a single survey to serve multiple objectives, such as getting feedback on desired deer population goals, hunting experiences, and deer management policies. Saving costs is a valid objective as conducting and analyzing surveys can be resource and time intensive. Further, for the target survey population—hunters and private landowners around the state—the department does and should use both paper and online options for each survey.[49]

However, we think DNR should re-examine its survey instrument relative to the department's intended objective(s). We heard feedback from survey respondents that some questions were too limited or they were unclear whether some questions applied to them. We recommend that DNR revise survey definitions and wording to more directly capture

[49] *Minnesota Statutes* 2015, 97B.063, requires DNR to survey hunters using "established social science methods." DNR currently uses a "mixed mode" survey design that solicits responses from hunters and landowners via online and paper questionnaires. DNR may not achieve suitable survey response rates using online surveys only.

respondents' perspectives, and the department should pre-test these questions. For example, the department should either revise or add questions regarding hunters' and landowners' preferred level of deer presence, and perspectives about allowing hunting on private land.

DNR also should consider expanding its methods for collecting public opinion to obtain feedback about deer from motor-vehicle drivers, and information on the incidence and locations of vehicle crashes with deer. This population may include respondents that are neither landowners nor hunters. Public safety of individuals is one consideration that DNR may consider in its decisions about annual hunting seasons.

RECOMMENDATION

Within the limitations of data practices laws, the Department of Natural Resources should compile and utilize more specific information about deer presence and deer impact within local environments.

As we described in Chapter 1, DNR has a broad range of responsibilities that are directly and indirectly related to deer management, including habitat management, conservation enforcement, forestry, and management of other wildlife. These duties afford DNR opportunities to compile and publish—within the limits of data practices laws—more DPA-specific information. In particular, DNR should compile more deer-related information for the public land areas it manages.

For goal-setting purposes and working with advisory teams, DNR could better organize its data in a more consistent way that reflects local experience with deer. For example, counts and trends in complaints from private landowners about deer eating crops, and better data on deer-vehicle crashes, are typically provided to advisory groups in other states we examined.[50] Other information—such as disease in deer—may or may not be of notable concern, depending on the DPA. Some data may not be appropriate for modeling but can be used to understand other deer management issues, such as causes of vehicle collisions with deer in a particular area.[51]

We also see opportunities for DNR to better evaluate and incorporate into its management of deer information about deer-related issues handled by other DNR divisions.[52] As we discussed earlier, DNR should more strategically evaluate and compile data about deer-hunting violations encountered by DNR conservation officers in local areas where deer poaching and unreported harvest may be a problem. Such feedback could enhance understanding about deer harvest reporting, which will help with DNR goal-setting and setting deer permit area designations for DPAs.

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[50] Wisconsin provides advisory team members with reported deer-vehicle crashes per million miles of traffic driven and number of car-killed deer carcasses removed from roadways.

[51] For example, wildlife agencies in other states collect different data and use it in different ways. Iowa's wildlife agency collects deer road-kill data per estimated vehicle miles driven on highways to help estimate deer abundance. On the other hand, Maine's wildlife agency collects deer-vehicle collision data, but uses it as an indicator of public safety concerns and identifier of potential deer feeding issues in a region, for example.

[52] For example, to manage and hunt deer in state parks, DNR Division of Parks and Trails staff must document issues regarding overabundance, deer impact on the environment, and public safety.

DNR also should better document for goal-setting purposes the impact of deer populations on habitat in state wildlife areas, public parks, or forest areas that are also popular hunting areas. This information should include the state costs associated with mitigating deer foraging on food sources in forested areas, such as protecting tree seedlings. Understanding biological carrying capacity is an accepted concept for deer management, and the results of such research may result in setting goals and managing for either higher or lower deer numbers in a particular DPA.

This work should translate to improving the integrity and scope of information provided to Deer Advisory Team members, and for data used in DNR's deer population model. In making these recommendations, we note the challenges to using more data include understanding the data and their limitations. Publishing more data also can mean more variation in interpretation, or misinterpretation, of the information. And, as we discuss in the next chapter, providing more scientific and DPA-specific information may not assure the information will affect public opinions about deer population goals.

Chapter 3: Management Actions

The Department of Natural Resources' (DNR's) responsibilities related to deer management cover a broad range of activities.[1] In particular, DNR must ensure the species is conserved and enhanced, and prepare and make available wildlife management plans for public input, review, and comment.[2]

In this chapter, we discuss DNR's deer management goals and objectives, and the department's actions to directly manage deer around the state. We also describe recent results of public involvement in DNR's deer goal-setting process. We then make recommendations and discuss funding for DNR's management of deer in Minnesota. Although we did not evaluate the department's management of deer habitat and enforcement of wildlife laws, we briefly discuss these activities within the larger context of DNR oversight of deer.

MANAGEMENT GOALS AND OBJECTIVES

As we have discussed throughout this report, state statutes describe objectives for DNR related to managing wildlife and deer (shown previously in Exhibit 1.1). Generally, national research on deer management identifies two primary ways to manage deer and meet these objectives: (1) manage the number of deer through regulation and (2) manage deer habitat.[3] Our work focused on DNR processes to directly manage deer through regulation and hunting.

Sound wildlife management requires scientific planning with defined goals and objectives. The DNR Section of Wildlife manages wildlife populations, such as deer, by setting population goals. In the previous chapter, we described how DNR has used a standardized process to obtain public input for deer population goals around the state. DNR then considers these goals when setting annual hunting season regulations. However, these two processes do not define the full scope of DNR's deer-related work.

The Department of Natural Resources carries out many activities to directly and indirectly conserve and manage deer around the state; however, the department does not have a formal management plan that defines and prioritizes deer management resources, goals, and objectives.

[1] For example, DNR is required to: establish a statewide program to provide technical assistance to persons for the protection of agricultural crops from destruction by wild animals; prevent or control wildlife disease; prevent or reduce damage or injury by wildlife to people, property, agricultural crops, or other interests; and ensure recreational opportunities for hunters.

[2] *Minnesota Statutes* 2015, 84.941-84.942.

[3] Research has summarized that wildlife management in North America progressed through six stages that elevated ungulates [such as deer] from the status of unmanaged and overexploited to successfully managed and conserved: (1) the creation of laws and regulations; (2) appropriate predator control; (3) the creation of reservation land refuges; (4) artificial replenishment, mainly through reintroductions; (5) environmental controls (i.e., control of disease); and (6) habitat management. See Paul R. Krausman and Vernon C. Bleich, "Conservation and Management of Ungulates in North America," *International Journal of Environmental Studies* 70, no. 3 (June 2013): 376.

DNR carries out many activities around the state that directly or indirectly impact deer. For example, DNR feeds, or contracts with others to feed, deer experiencing shortage of food sources, particularly during severe winters.[4] From our interviews and review of DNR documents, we learned that individuals disagree on the value of feeding deer; some emphasize that deer may effectively disappear in some areas without supplemental feeding, while others expressed concern that centralized food sources facilitate the spread of diseases among deer. We do not question DNR's feeding of deer; however, it is unclear how decisions about feeding deer intersect with deer population goals.

DNR also has a wildlife damage program to help mitigate the impact of deer and other animals that are feeding on landowners' specialty crops or causing other damage. This program involves educating owners about fencing and other deer damage mitigation tips. Qualifying landowners who implement DNR recommendations but still experience problems also may receive limited funding to support these strategies. These actions reduce the need to shoot deer and help conserve the species. As a last resort, DNR may allow for specific hunting permits—referred to as depredation permits and shooter permits—for these landowners to resolve their issues with deer.[5] DNR handles requests for these two types of permits separately and outside of the annual deer hunting regulation process and the goal-setting process.

Staff activities from other DNR divisions indirectly affect deer and their presence. The DNR Forestry Division takes steps to mitigate deer damage to trees and facilitate reforestation, such as placing small "caps" on young tree seedlings to prevent irreversible damage from deer feeding. DNR also must acquire and improve land for food and cover for wildlife, and DNR forestry staff consider deer habitat needs and impact when planning forest regeneration. DNR conservation officers help protect deer by educating hunters and the public, and by enforcing wildlife laws. All of these activities are important components of deer management, but they require DNR staff and funding resources that are under the control of DNR divisions other than the DNR Section of Wildlife.

Minnesota statutes require DNR to develop wildlife management plans but do not require a plan exclusive to white-tailed deer. The DNR Division of Fish and Wildlife has publicly stated strategic objectives and performance measures related to deer, for example, to maintain deer populations within goal ranges in at least 75 percent of the state's 130 deer permit areas. DNR very briefly mentions deer in its 2005-2015 wildlife action plan developed as a condition of receiving grant funds through the U.S. Fish and Wildlife Service. Other DNR divisions also have used performance goals that indirectly relate to deer management.[6] These actions do not formalize DNR's broad range of deer-related responsibilities into defined deer management objectives, nor do they align these goals with other deer objectives.

Despite the lack of a formal written plan, DNR has in recent years carried out actions to address the broad range of concerns about the number and presence of deer in Minnesota. In the next section, we discuss outcomes of the DNR's deer goal-setting process and DNR's management decisions regarding the number and types of hunting permits for hunting across the state. We also examine how DNR integrates public feedback into final deer population goals.

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[4] *Minnesota Statutes* 2015, 97A.075, subd. 1; and 97A.135.

[5] *Minnesota Statutes* 2015, 97A.401, subd. 5.

[6] For example, the DNR Enforcement Division had a 2012 goal to maintain fiscal year 2011 enforcement hours spent on game enforcement.

Results of Goal-Setting Process

In Chapter 2, we described DNR's 2015 process for setting deer population goals, as well as information provided by DNR to Deer Advisory Team members. One key aspect of the 2015 process was that DNR sought to expand the range of public interests represented on teams, including hunters, farmers, foresters, and others.[7] This work included a process to solicit and review individuals' nominations to participate on one of five Deer Advisory Teams.

Public Interests

We interviewed some individuals who participated in the Deer Advisory Team process to gain insight into their experience. We also reviewed results from DNR follow-up surveys of advisory team members who participated in setting deer goals.

Deer Advisory Team members reported mixed opinions regarding the composition of advisory teams and representation of public interests.

DNR surveyed 2015 Deer Advisory Team members regarding their experience participating in the goal-setting process. Among their responses, members stated:

> "[There was] a diverse group of committee members."
>
> "Group size, and selection process of volunteers [worked well]."
>
> "The diversity of hunter interests was good."
>
> "Expand representation on each team to include the following interests: public health, tourism, public safety, grouse hunting, birding, and agriculture."
>
> "[Need a] broader spectrum of panel members. Appeared tilted toward forestry interests."
>
> "Need more opportunity to hear from vegetative management specialists like forestry and people in the nursery trade."
>
> "I feel you need more representation from hunting/landowners groups."

Members' experiences interacting with other team members also varied considerably. Some members valued the experience and thought it useful to bring the community together to discuss this topic. On the other hand, some questioned whether their opinions and DNR's goal-setting information were considered by other members. Some suggested DNR should have played a stronger role in guiding discussions and explaining DNR's information.

[7] The 2015 Deer Advisory Teams consisted of individuals representing archery, firearm, and muzzleloader hunters; area residents and landowners; farmers; land managers; foresters; local business owners; and members of hunting and conservation organizations. The Minnesota Deer Hunters Association and the Nature Conservancy both had one authorized representative serving on each advisory team. American Indian tribal representatives were included on three of the five teams.

In Chapter 2, we described how DNR staff provided advisory team members with statistical data and basic ecological characteristics about each deer permit area (DPA). DNR also provided general education—not DPA-specific—materials and references to scientific literature about deer impact in the environment.[8] Although we learned of complaints about the lack of DPA-specific data, we also learned of comments suggesting that more information from DNR would not have swayed some individuals' preferences when voting on proposed goals.

DNR Final Deer Population Goals

Between 2012 and 2015, the majority of revised deer population goals approved by DNR were to increase deer numbers in DPAs. As shown previously in Exhibit 2.6, 54 of 71 DPAs were assigned trend goals to increase deer populations, 14 were assigned goals to maintain the current populations, and 3 were assigned goals to decrease deer numbers. In 2015, the DNR commissioner determined the final goal for each of the 40 DPAs reviewed, after DNR administration reviewed recommendations from advisory teams, area managers, and the general public, and collected comments from other DNR divisions. Area managers are most familiar with deer populations in their region, and they were expected to make sure that the number and types of deer hunting permits aligned with stated deer population goals. For the goals set in 2015, the DNR commissioner afforded advisory team members one additional opportunity for review and comment before finalizing the goals.

Of the 40 deer permit areas reviewed during 2015, DNR adopted 88 percent of the deer goals recommended by Deer Advisory Teams; however, some members disagreed with the goals proposed by their team.

To frame goal-setting decisions, DNR requested Deer Advisory Team members to indicate whether deer populations should (1) stay the same, (2) increase by either 25 percent or 50 percent, or (3) decrease by either 25 percent or 50 percent. DNR offered these choices as realistic deer population goals that could be achieved over the subsequent three to five years.

Among the 40 DPAs that received updated goals in 2015, proposals from the five designated Deer Advisory Teams were that deer populations should stay the same in 5 DPAs and increase in 28 DPAs, shown in Exhibit 3.1.[9] A consensus—that is, agreement among 80 percent of members on a team—was reached for 33 DPAs, and DNR adopted the proposed goal for 29 of these 33 DPAs. However, there was not a consensus among members for seven DPAs, requiring DNR to set these final goals based on a review of goal-setting information. Among Deer Advisory Team members who disagreed with their team proposals, some wanted fewer deer. On the other hand, among 13 DPAs, some members wanted an increase in deer numbers that exceeded 50 percent over the next three to five years.[10]

[8] Deer Advisory Team members also were expected to consider public feedback through open houses, online postings, and surveys of hunters and landowners.

[9] Among the nine DPAs in Southeastern Minnesota assigned revised goals in 2014, DNR adopted the proposed advisory team goal for eight DPAs. Among the 22 DPAs assigned revised goals in 2012, DNR set goals comparable to Deer Advisory Team recommendations for 17 of 22 DPAs (that is, DNR goals were within about 5 percentage points of team proposed goals).

[10] Among the 13 DPAs, the number of members wanting deer densities to increase by more than 50 percent (beyond the limit set by DNR) ranged from 1 to 6.

Exhibit 3.1: Summary Results of DNR Deer Goal-Setting Process, 2015

Deer Advisory Team Proposed Goal	Number of Deer Permit Areas (DPAs)	Number of DPAs DNR Adopted Deer Advisory Team Goal	Number of DPAs DNR Set Goal Different than Deer Advisory Team Proposed Goal	DNR-Set Goal Different than Deer Advisory Team Goal
No change	5	5	0	Not applicable
25% increase	12	12	0	Not applicable
50% increase	16	12	4	25% Increase
No consensus[a]	7	Not applicable	1	No change
			5	25% increase
			1	50% increase
Total	**40**	**29**	**11**	

NOTE: DNR is the Minnesota Department of Natural Resources.

[a] Each advisory team was required to reach a consensus—agreement among at least 80 percent of members—to propose a goal to DNR for each DPA. If team members did not reach a consensus, individual team members were expected to submit a statement regarding a proposed goal.

SOURCE: Office of the Legislative Auditor, summary of Department of Natural Resources documents.

One example of a regional area for which there was disagreement among advisory team members over deer goals was in Northeastern Minnesota. Some team members had concerns about declining moose populations due to deer and moose sharing habitat in some DPAs. Team members noted that increasing deer numbers to improve hunting opportunities in the regions would negatively affect moose populations. DNR has since proposed realigning DPA boundaries to better reflect management priorities and hunting opportunities inside and outside of moose range. Future deer goals for areas designated as moose habitat would be determined separately from DPAs outside of designated moose environments.

Even among hunters serving on a Deer Advisory Team, individuals' recommendations for population goals varied due to preferences in deer type or for annual hunting opportunities.[11] Minnesota rules designate specific DPAs in Southeastern Minnesota as under an "antler point restriction" to afford hunters the opportunity to take older, larger antlered deer during hunting season.[12] Some hunters wanted to afford deer several years to mature. On the other hand, other hunters were more interested in consistent annual recreational opportunities and did not want antler point restrictions.

In 2015, deer population densities and deer goals for DPAs varied greatly around the state.

As of early 2015, DNR's estimated deer densities among DPAs ranged from 24 to 38 deer per square mile in DPA 346 in Southeastern Minnesota, to 1 to 2 deer per square mile in

[11] Other hunters with whom we spoke also had differing hunting preferences.

[12] Under "antler point restrictions," hunters may only take male deer that have at least one antler with at least four antler points. *Minnesota Rules*, 6232.0350, posted January 12, 2015.

several DPAs in West central Minnesota.[13] As of 2015, the designated deer densities—or DNR goal populations—ranged from 20 to 25 deer per square mile in DPAs 249 and 258 (located in the Northwest and East central parts of the state) to 2 to 3 deer per square mile in some DPAs around the state.

Due to a desire for increased hunting opportunities, some 2015 Deer Advisory Teams advocated for historically higher deer densities in some areas, for example, 18 to 24 deer per square mile in DPA 183. Among the 40 DPAs assigned new deer density goals in 2015, 26 DPAs will be managed for higher deer densities and 6 will be managed for lower deer densities, when compared with previous density goals set between 2006 and 2008.[14] Eight DPAs will be managed for deer densities comparable to previous goals.

In addition to factors outside of the DNR control—such as winter severity—progress toward these deer population goals depends on other considerations, such as the types of deer permit area designations used by DNR for hunting, hunter participation and success, and statutory requirements regarding special areas and special permits. We discuss these in more detail in the next section.

MANAGEMENT DESIGNATIONS

Deer management in Minnesota relies on hunting to move deer populations toward preferred levels in local environments. State statutes and DNR rules define season dates, length of season, type of weapon, hunter age, and other variables.[15] DNR is responsible for setting annual seasons, special hunt areas, and hunting permits.[16] DNR's deer population modeling is intended to help the department determine the types of permit area designations needed to move deer numbers toward population goals. Specifically, after estimating deer numbers and setting a deer density goal for each DPA, DNR compares deer population estimates against historical hunting activity—such as number of licenses purchased and number of deer reported killed—deer trends, and other factors. DNR then designates for each DPA and special hunt area the allowable number and types of deer a hunter may kill each year, using either archery or firearms permits.

Deer Permit Area Designations

The types of DNR permit area designations have changed over the years. For example, the official "managed" designation (hunter may shoot one deer of either sex, then one additional antlerless deer) was first implemented in 2003. During 2007 and 2008, DNR worked with a committee of hunters and others on a "deer simplification project" to streamline and improve hunting experiences and regulations in Minnesota. Based on the

[13] "DeerModel_Data18Apr2015" (computer file, Department of Natural Resources, St. Paul, 2015).

[14] Minnesota Department of Natural Resources, *Monitoring Population Trends of White-Tailed Deer in Minnesota – 2015* (St. Paul, January 2015), 4.

[15] For example, *Minnesota Statutes* 2015, 84.027, subd. 13; and 97B.311; and *Minnesota Rules*, 6232.0200 to 6232.2560, posted October 2013 and January 2015.

[16] As we discussed in Chapter 1, the DNR commissioner "may protect a species of wild animal in addition to the protection provided by the game and fish laws, by further limiting or closing seasons or areas of the state, or by reducing limits in areas of the state, if the commissioner determines the action is necessary to prevent unnecessary depletion or extinction, or to promote the propagation and reproduction of the animal." *Minnesota Statutes* 2015, 97A.045, subd. 2; 97A.091; and 97A.401, subd. 4.

committee recommendations, DNR consolidated and changed boundaries for certain DPAs and condensed deer season areas, among other changes. Later, in 2011, DNR reintroduced "hunter choice" as a permit designation. Hunter choice is intended to help stabilize deer populations through more consistent regulation that allows hunters to shoot one deer of either sex, rather than using "lottery" or "managed" permits.

Exhibit 3.2 describes the current deer permit area designations allowed by DNR rules, including: intensive, managed, hunter choice, youth only antlerless, bucks only, or lottery for a predetermined number of antlerless permits. As determined by DNR, "bonus" permits are used in combination with a hunter's license under these designations to take additional deer. DNR also may allow for higher deer limits in designated areas *within* a DPA.

Exhibit 3.2: Types of Deer Permit Area Designations and Other Permit Types, 2015

Type of Permit Designation	Description
Bucks Only	Hunter may kill only bucks with at least one antler three inches or longer.
Youth Only Antlerless	Only youth under age 18 may take antlerless deer through lottery. All other license holders may only take bucks.
Lottery	Hunter may kill one deer in deer permit area. DNR allocates by lottery a limited number of permits that allow hunters the option to kill an antlerless deer (that is, deer with no antlers or antlers less than three inches long). Unsuccessful applicants may only shoot bucks.
Hunter Choice	Hunter may shoot either one buck or one doe.
Managed	Hunter may shoot one deer, either sex, then one additional antlerless deer.
Intensive	Hunter may shoot one deer, either sex, then four additional antlerless deer.
No Limit Antlerless	Hunter may kill one deer, either sex, then may take unlimited number of antlerless deer (used in deer permit area 601, covering majority of seven-county metro area).
Antler Point Restriction	Hunter may only take deer with at least four antler points on at least one antler.
Other Types of Deer Hunting Permits	
Bonus	A bonus permit allows the hunter to shoot one antlerless deer, in addition to the one deer allowed for initial deer license. Bonus permits are used in combination with licenses and as allowed under deer permit regulations.
Earn a Buck	Hunter must shoot one antlerless deer before taking one buck.
Free Landowner	Landowners may apply and receive one free license to kill an antlerless deer in deer permit areas designated by DNR.
Depredation Permit	DNR may grant an eligible landowner a designated number of permits to address deer feeding on crops or landscaping. Permit must be used during hunting season.
Shooter/Removal Permit	DNR may grant a government entity or an eligible landowner up to ten permits to address problems with deer presence, such as deer eating crops or landscaping, or public safety issues at airports, for example. Permit may be used outside of regular hunting season.

SOURCE: Office of the Legislative Auditor, summary of Department of Natural Resources documents.

Beginning in 2011, DNR has used more conservative deer permit area designations intended to increase hunting opportunities, when compared with 2006 and 2010 hunting seasons.

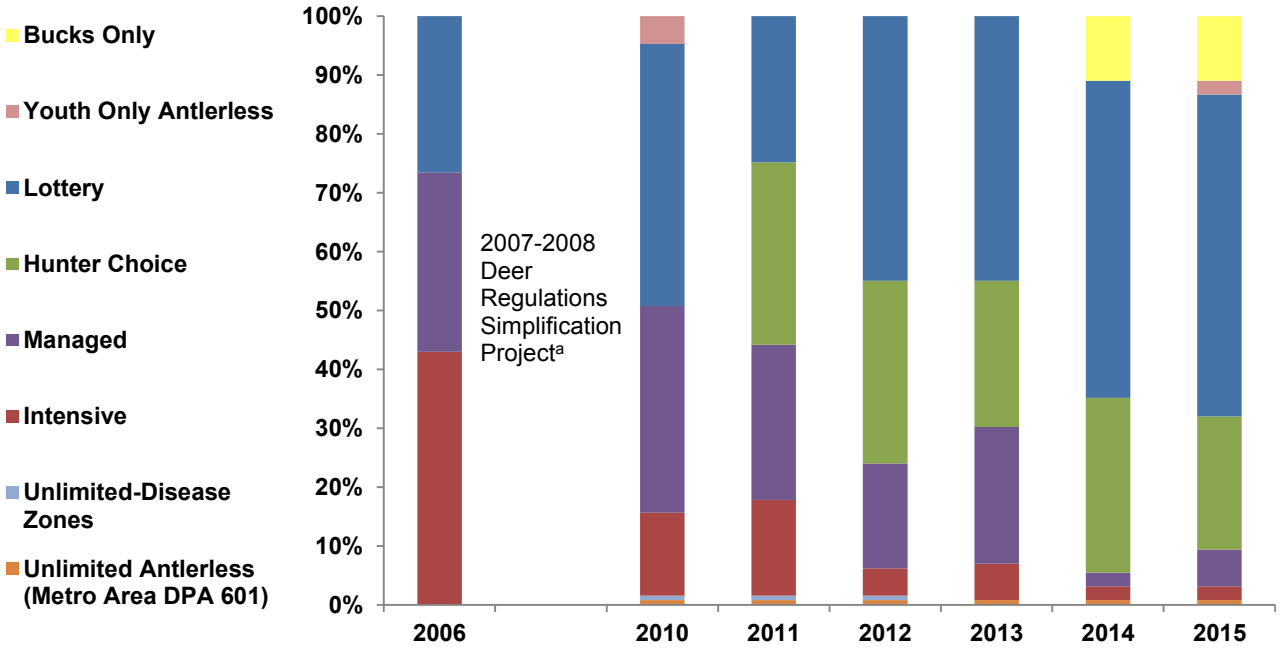
Beginning in 2011, DNR generally has taken a more conservative approach to preserve, protect, and propagate deer. As shown in Exhibit 3.3, DNR has reduced its use of permit area designations that allow hunters to shoot more than one deer, when compared with hunting seasons in 2006 and 2010. For example, DNR designated 73 percent of DPAs as "intensive" or "managed" in 2006, compared with 29 percent of DPAs in 2013. Further, among DPAs designated for lottery, the median number of allowed antlerless permits was 400 in 2006, 500 in 2010, and 250 in 2012.[17] According to DNR staff, DNR's more frequent use of certain permit area designations—such as hunter choice, rather than managed—was intended to restrict the number of deer killed by hunters and also allow the population to increase.

DNR also may allow for additional hunting opportunities that are not reflected by the annual DPA-wide hunter permit designation. Exhibit 3.3 shows that the number of DPAs designated by DNR for early hunting prior to regular firearm season (referred to as "early antlerless") decreased from eight in 2006 and ten in 2010, to zero and two in subsequent years. As one approach to help manage deer at specific locations within DPAs during hunting season, DNR may allow eligible landowners to obtain one free additional license to shoot one antlerless deer. Exhibit 3.3 shows that one free landowner license was available to eligible landowners in 90 DPAs in 2006, 62 DPAs in 2010, 71 DPAs in 2013, and 40 DPAs in 2015.

The overall trend in DNR's use of permit designations generally aligned with the objectives to increase deer populations and improve hunting opportunities in a majority of DPAs assigned updated goals set in 2012, 2014, and 2015 (shown previously in Exhibits 2.6 and 3.1). We note, however, a precise comparison of goals and DNR deer permit area designations for any particular year is difficult. As we discussed previously in Chapter 2, deer goals are intended to represent a target deer density over the next three to five years, and annual deer management decisions for each hunting season involves some judgement. For example, DNR may use a permit designation to ensure consistent designations among neighboring DPAs and to reduce complexity in season regulations for hunters. From our review of DNR documentation for some DPAs, it is unclear whether annual permit designations were based on deer modeling results, desire for consistent designations, or other objectives for areas within DPAs. We discuss DNR management strategies for these special areas in the next section.

[17] Reducing the number of antlerless permits decreases the number of female deer that may be killed, thereby allowing deer populations to reproduce and increase.

Exhibit 3.3: Percentage of Deer Permit Areas (DPAs), by Type of Permit Designation, 2006, and 2010-2015



	2006	2010	2011	2012	2013	2014	2015
Median Number Antlerless Permits Allowed: Lottery DPAs	400	500	375	250	350	300	300
Number DPAs: Early Antlerless	8	10	0	0	2	2	2
Number DPAs: Free Landowner License	90	62	54	69	71	43	40
Total Statewide Limit per Hunter[b]	5	5	5	5	5	5	5

NOTES: The Department of Natural Resources' (DNR's) seven primary deer permit area designations used during this period included: **Bucks Only** (hunter may kill only bucks with at least one antler three inches or longer); **Lottery** (lottery allocation of limited number of hunting permits for option to shoot antlerless deer; unsuccessful applicants may only shoot bucks); **Hunter Choice** (hunter may shoot either one buck or one doe); **Managed** (hunter may shoot one deer, either sex, then one additional antlerless deer); **Intensive** (hunter may shoot one deer, either sex, then four additional antlerless deer); **Youth Antlerless** (only individuals under age 18 may take antlerless deer through lottery; all other license holders may only take bucks); and **Unlimited Antlerless** (for DPA 601 encompassing most of the seven-county metropolitan area). As a method to directly control disease in deer populations, DNR creates separate **Unlimited-Disease Zones**, which allow for unlimited taking of deer. DNR also may set hunting limits in designated areas—such as state parks, game refuges, or other areas—that differ from DPA-wide designations. As one approach to help manage deer at specific locations within DPAs during the hunting season, DNR may allow an eligible landowner in designated DPAs to obtain a **Free Landowner License**.

[a] From 2007 through 2008, the Department of Natural Resources (DNR) worked with a committee of hunters and other stakeholders to simplify deer hunting regulations and make it easier for hunters to understand licensing options and seasons. Based on the committee recommendations, DNR consolidated and changed boundaries for certain DPAs and condensed deer season areas, among other changes. Later, in 2011, DNR reintroduced "hunter choice" as a permit designation.

[b] Exceptions to statewide hunter limits apply for deer taken in: "unlimited" areas, including disease zones and metro area 601; certain DPAs designated for "**Early Antlerless**" season in some years; and eligible landowners who obtain one free additional permit.

SOURCE: Office of the Legislative Auditor, analysis of Department of Natural Resources deer season regulations and documents.

Management for Special Areas

The DPA deer population goals, deer densities, and permit area designations reflect DPA-wide management strategies. Deer population goals are determined at the DPA-level, generally, because it is too costly and resource intensive to produce reliable estimates of deer densities in smaller areas. (DNR currently does not model density estimates for about ten DPAs for this reason.) Further, because deer roam across the landscape, deer density goals apply to the entire DPA—as an average—and are not specific to any particular tract of public or private land.

However, DNR must manage smaller, designated areas *within* DPAs—such as state parks or game refuges—according to objectives defined in state statutes. As a tool to address localized concerns, state statutes also authorize DNR to issue special hunting permits to individual landowners and local government entities experiencing negative impacts from deer.[18] These types of permits also afford hunters an additional hunting opportunity beyond the general deer permit area.

DNR's goal-setting process does not sufficiently address DNR's statutory obligations for managing deer in some smaller areas.

For example, DNR must preserve and balance plant and wildlife in state parks, and criteria regarding deer abundance and hunting are prescribed in state statutes.[19] Some areas, such as state wildlife management areas, explicitly serve broader purposes, including managing lands for public hunting.[20] DNR may and does establish, or allow for, hunting within these designated areas, and these hunts are typically held within the regular hunting season.[21] DNR may designate certain areas for "special hunts" for a number of reasons allowed for in statute that diverge from the DPA-wide regulations, for example, to provide a controlled hunting environment for disabled individuals or to mentor youth. For safety reasons regarding hunting in smaller areas, DNR may limit the number of eligible hunters but increase the total deer limit in order to sufficiently address the impact of deer.

Many, but not all, of these designated areas are public land, while some game refuges are owned by nonpublic entities. Other recreational areas are governed by special districts or cities, and these entities coordinate with DNR to resolve deer issues and hold special hunts.

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[18] *Minnesota Statutes* 2015, 97A.401, subds. 1, 4, and 5.

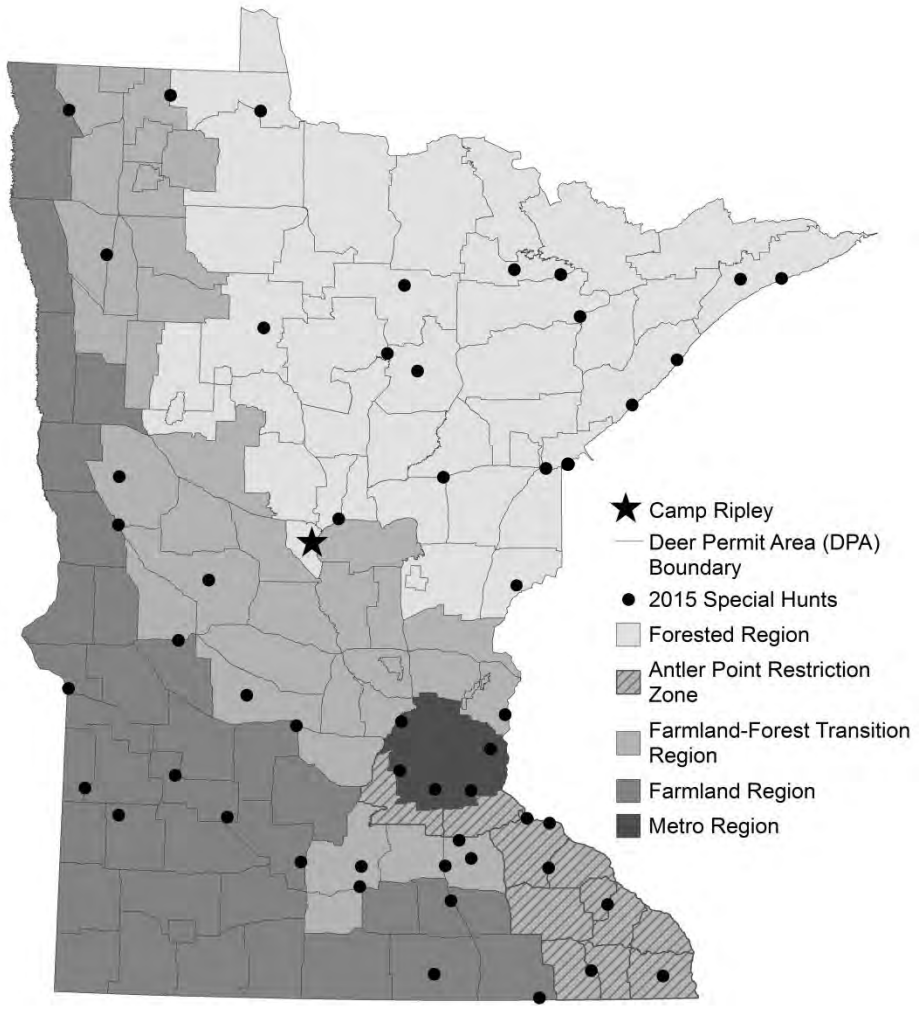
[19] *Minnesota Statutes* 2015, 86A.05; and 97A.091, subd. 2(a). "The commissioner may allow hunting of a protected wild animal species within any portion of a state game refuge, including a state park. Hunting may be allowed under this paragraph only if the commissioner finds: (1) the population of the species exceeds the refuge's carrying capacity; (2) the species is causing substantial damage to agricultural or forest crops in the vicinity; (3) the species or other protected wild animals are threatened by the species population; or (4) a harvestable surplus of the species exists."

[20] *Minnesota Statutes* 2015, 86A.05, subd. 8. Further, "use of hunting shall be consistent with the limitations of the resource, including the need to preserve an adequate brood stock and prevent long-term habitat injury or excessive wildlife population reduction or increase."

[21] *Minnesota Statutes* 2015, 97A.401, subd. 4. DNR may issue special permits, "with or without a fee, to take a wild animal from game refuges, wildlife management areas, state parks, controlled hunting zones, and other areas of the state that the commissioner may open for the taking of a wild animal during a special season or subject to special restrictions. … Local units of government may charge an administrative fee in connection with special hunts under their jurisdiction. Fees to be collected shall be based upon the estimated cost of conducting the special season or administering the special restrictions."

As we described earlier, Minnesota statutes give municipalities control over the discharge of firearms within city limits, thereby restricting the DNR's ability to control deer during firearms season.[22] Exhibit 3.4 shows a sample of areas designated for special hunts in 2015. Some of these types of special hunts occur outside of regular hunting season. Most often, requests for these special hunts are either handled by DNR area wildlife managers, or approved by DNR but administered by the owner of the game refuge or local officials. One DNR representative said that deer permit area designations and special hunts do not always reduce deer overabundance, and some entities eventually hire sharpshooters to resolve issues.

Exhibit 3.4: Map of DNR-Published Special Hunts, 2015



NOTES: DNR is the Minnesota Department of Natural Resources. Special hunts include deer hunting opportunities for firearm, muzzleloader, and archery hunters in special permit areas designated by DNR. The map does not include special hunting opportunities for youth and individuals with disabilities. The antler point restriction zone represents deer permit areas with restriction on the taking of bucks; hunters may only shoot deer with at least four antler points on at least one antler.

SOURCES: Department of Natural Resources, *2015 Minnesota Hunting and Trapping Regulations Handbook* (St. Paul, 2015), 85-86, 88, and 91-92; and Department of Natural Resources, *Monitoring Population Trends of White-Tailed Deer in Minnesota—2015* (St. Paul, 2015) 28.

[22] *Minnesota Statutes* 2015, 471.633.

To further address localized concerns regarding deer presence, DNR uses two types of special permits—referred to as depredation permits and shooter permits—described previously in Exhibit 3.2. Under these permits, landowners may shoot deer or may allow other hunters to shoot deer on their land and, depending partly on the deer permit area designation, each hunter may be allowed to shoot more than one deer. Before approving these special permits, DNR may require landowners to first take several actions to mitigate deer impact, such as installing fencing and moving storage of feed, where feasible.

We reviewed DNR's documents and processes for determining the number and types of permits designated for special hunt areas and for granting special permits to landowners to resolve problems with deer. The DNR Section of Wildlife has a process in place for documenting and reviewing the requests for hunting in state parks, state game refuges, and wildlife and other local areas; this information is reported to the DNR Central Office. Hunts in state parks, for example, are administered by staff in the DNR Parks and Trails Division. We also reviewed materials provided by DNR to Deer Advisory Team members regarding the goal-setting process.

We found that the objectives and hunting requirements for individual hunts in these smaller areas do not necessarily align with the precise deer density and goals proposed by Deer Advisory Teams and set by DNR. In particular, DNR permit designations for these smaller areas did not always align with the designations for the surrounding DPA set to drive deer densities towards the three- to five-year deer goal. For 2015, DNR Central Office set guidelines intended to align permit decisions for special hunt areas—such as state parks—with DPA-wide limits. However, some hunter harvest limits in special areas were higher than the surrounding DPA limit and others were not.[23]

From our review of DNR documents and reported harvest of deer killed through special hunts, we did not find evidence that DNR was granting excessive permits when approving local solutions to manage deer on private land, at airports, or for municipalities. However, as we discussed earlier in this report, special hunt deer harvest statistics may be underreported because some hunters may not correctly register deer to the special hunt designation, but instead register deer killed to the broader deer permit area.

Noting these issues with registration of harvested deer, for hunting seasons 2012 through 2015, DNR reported that the department issued a total of 1,278 depredation permits (compared with more than 605,000 total licenses and permits issued for the 2015 hunting season).[24] Hunters reported to DNR that 413 deer were killed under these permits. For landowners and entities experiencing deer issues outside of the hunting season, DNR reported that it issued a total of 689 "shooter" permits between 2009 and 2014.[25] Each shooter permit allows for shooting up to ten deer; and the reported harvest under these permits totaled 1,996 deer. DNR also designated 40 deer permit areas eligible for qualifying landowners to apply for a free landowner license to shoot one antlerless deer in

[23] For example, the City of Granite Falls' 2015 special hunt allowed ten hunter permits and one deer per hunter, but the surrounding DPAs were designated Lottery (one deer). The St. Croix State Park special hunt allowed 350 permits to eligible hunters and two deer per hunter, and DNR designated DPA 159 as Lottery.

[24] According to DNR staff, hunters seeking to shoot deer under a depredation permit may obtain up to five permits per hunter per year if in a Managed DPA, two permits per year if in a Hunter Choice DPA, or one permit per year if in a Lottery or Bucks Only DPA.

[25] DNR reported it issued a total of 73 shooter permits to government entities and the University of Minnesota; 29 shooter permits to airports; and 587 shooter permits to private agriculture during this five-year period.

2015. The registered harvest through these landowner permits totaled 1,404, compared with 159,343 total deer registered in 2015.[26]

However, some Deer Advisory Team members and other individuals disagreed with DNR's allocation of permits for special hunt areas, or DNR's use of permits to resolve private landowner problems with deer presence. They also questioned DNR's rationale and documentation supporting the number and types of permits used in special hunt areas, including the allowance of bonus permits. Specifically, they asserted DNR was allowing too many deer to be killed in these public and private areas, thereby reducing deer populations—and hunting opportunities—below the goals advocated by Deer Advisory Teams. These individuals likely assumed that the DNR goals for deer densities within a DPA represented the required deer population levels for *all* areas, including all private and public land.[27]

We reviewed DNR documentation for setting the types and number of permits in special hunt areas (such as state parks), and we think that information provided to Deer Advisory Team members about statutory obligations and exceptions for these smaller areas was insufficient. The lack of information contributed to resentment and complaints about DNR's processes and, overall, the department's allowance of hunting in special areas; most notably, the Camp Ripley area.[28] Specifically, hunters said that this area did not afford suitable hunting opportunities and success due to liberal DNR hunting policies and overhunting. On the other hand, DNR staff emphasize that Camp Ripley is managed as a game refuge and is subject to specific management requirements.[29]

DEER MANAGEMENT OUTCOMES

Our work focused on specific issues presented for this evaluation. Broadly, deer hunters voiced dissatisfaction with the number of deer seen and taken during hunting seasons in recent years. Hunters said that they observed generally fewer deer on the landscape, statewide; however, deer presence appeared notably lower in northern deer permit areas when compared with deer populations a decade ago. DNR reports support this observation; in particular, no modeled DPA in the DNR's forested zone had trends that suggested an increasing deer population from 2009 through 2014.[30] Further, DNR identified ten of the most notable DPAs that had declining modeled and harvest trends during this period in the forested zone, while trends in modeled deer densities and harvests were relatively stable in most southern forest zone DPAs.[31]

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[26] According to DNR licensing data, 41,147 free landowner permits were issued over a ten-year period, between 2005 and 2014. The number of deer reported killed using these landowner permits totaled 13,105 during this ten-year period, or an average of 1,311 deer annually.

[27] The deer population goal is related to the *average* deer density in a DPA as deer are mobile and their travel patterns change.

[28] DNR deer population goal for DPA 248 that has Camp Ripley within its area was set in 2015.

[29] *Minnesota Rules*, 6230.0400, subp, 3, posted October 3, 2013, define Camp Ripley as a state game refuge, subject to different management restrictions than areas surrounding Camp Ripley; that is, deer hunts in these areas are intended to manage deer populations and not necessarily to provide recreational hunting opportunities. See *Minnesota Statutes* 2015, 97A.085; and 97A.091, subd. 2.

[30] Minnesota Department of Natural Resources, *Monitoring Population Trends of White-Tailed Deer in Minnesota 2014* (St. Paul 2014) 21.

[31] *Ibid*. The ten DPAs were: 110, 111, 122, 126, 177, 178, 180, 181, 197, and 298.

In response to questions about DNR deer management decisions, DNR staff explained that the lower deer populations were partly due to (1) unexpected back-to-back severe winters during 2013-2014 that greatly diminished deer survival rates, (2) more conservative deer population goals for some areas due to concerns about forest regeneration, and (3) deer population goals set during the public goal-setting processes in 2005-2007 that were intended to reduce deer populations in many DPAs. As we noted in Chapter 2, the DNR's modeling methods likely overestimated deer densities in Minnesota's forested regions prior to 2012. These factors likely affected deer population estimates and progress toward goals.

Evaluating certain aspects of deer management is challenging because the collection and availability of some types of data—such as the impact of deer feeding on forest and plant species and local costs related to agricultural crop loss—has not been well documented in Minnesota in recent years. In Chapter 2, we recommended DNR conduct field research and collect deer-related data that would improve its model data and help validate model outputs. However, we did examine information that represents certain outcomes of deer management; this includes deer harvest and hunter success rates and deer-vehicle collisions. We consider data regarding these issues to also have limitations, which we discuss in the following sections.

Deer Harvest and Hunter Success

In Minnesota, the two largest factors affecting deer numbers are hunting, followed by winter severity.[32] The Minnesota Constitution affords residents hunting opportunities as prescribed by law. The DNR commissioner also must make special provisions for the management of wildlife to ensure recreational opportunities for hunters.[33] State statutes do not prescribe particular levels of hunting in locations around the state, however.

Deer hunting opportunities vary significantly around the state; however, deficiencies in reporting of deer harvest and aspects of DNR modeling impede evaluating deer population management and progress towards deer goals.

Among the individuals we interviewed during our evaluation, some said that hunter perception of "success" is shaped by individual hunting experience. They noted that some hunters consider the very high deer numbers and kill rate in the mid-2000s as the norm; other individuals with whom we spoke said that this type of experience does not represent hunting experience in Minnesota, historically. One measure of hunters' experiences is "hunter success" rate. Hunter success rates represent the number of deer killed by the number of licensed hunters.[34] DNR annually compiles information about the numbers of licensed hunters, by type of weapon, and number of deer killed, statewide and by DPA and special hunts. We evaluated DNR data, deer population estimates, and hunter-reported harvest rates and, overall, deer hunting opportunities and success varied greatly around Minnesota.

[32] As we discussed in Chapter 1, winter severity also increases the risk of deer deaths by wolves.

[33] *Minnesota Statutes* 2015, 97A.045, subd. 1.

[34] For example, if three of six hunters each shoot one deer, hunter success rate is 50 percent.

Deer Densities and Deer Harvest Rates

Minnesota has a wide range of urban, rural, and forested environments. As of early 2015, DNR's deer density estimates around the state also varied, from an estimated 1 to 2 deer per square mile in some DPAs to 24 to 38 deer per square mile in one DPA.[35] The number of deer killed in 2014 also varied, from 6,737 deer killed in DPA 241 in the Northwestern part of the state to 29 deer in DPA 117 in northern Minnesota. In 2014, reported hunter success rates ranged from 70 percent in DPA 346 in Southeastern Minnesota to 10 percent in DPA 127 in Northeastern Minnesota.

According to DNR harvest data, the total number of deer reported killed each year also has varied significantly over the past decade. As shown in Exhibit 3.5, 270,778 deer were killed in 2006, compared with 139,442 in 2014 (the lowest in recent decades). Hunter success rates ranged from 33 percent of hunters reporting killing at least one deer in 2006, compared with 26 percent in 2014. About 10 percent of hunters reported killing more than one deer in 2006, compared with less than 1 percent in 2014. Lower total harvest in 2014 and 2015 (159,343 deer registered with DNR in 2015) may be partly due to the more restricted permit designations for DPAs in 2014 compared with 2006. As shown previously in Exhibit 3.3, DNR has reduced its use of intensive and managed designations in recent years.

Factors Affecting Evaluation of Progress Toward Deer Goals

DNR's objective for establishing deer goals is to guide management decisions about deer densities around the state. DNR relies on hunting to help move overabundant deer populations toward goals. We identified issues we think impede successful measurement of recent deer management outcomes, recreational hunting opportunities, and progress towards deer goals; these include insufficient deer modeling historical data, hunting policies and enforcement of hunting laws, and DNR's use of bonus permits for special hunt areas.

In Chapter 2, we identified shortcomings of DNR modeling data, including (1) DNR's model prior to 2012 overestimated or underestimated deer populations in forested regions; (2) DNR needed better collection of data regarding deer age at harvest and overwinter survival; and (3) DNR needed better validation of outputs from its new deer population model. We also discussed inconsistent reporting of deer harvest through special hunts, and we noted the lack of documentation supporting DNR's use of fixed estimates to account for nonregistration of deer and deer killed in violation of state laws and hunting regulations around the state.

Throughout our evaluation, we learned about concerns of hunters and others regarding illegal deer killing, unreported deer harvest, and insufficient enforcement of laws regarding both hunting violations and protection of deer. Hunters are required by law to register deer killed with the department, and DNR provides for phone, in-person, or online reporting by hunters. Minnesota does not mandate hunters to report whether they did *not* kill a deer as a requirement for purchasing future deer licenses. Nevertheless, deer that are killed by hunters but not reported to DNR affect conservation efforts and opportunities for successful hunting by others. Further, DNR's modeling relies heavily on deer harvest reported by hunters, and the lack of reporting may impact DNR modeling estimates, at least for some parts of the state.[36] Regarding these issues, DNR staff said that illegal harvest represents a very small share of total statewide harvest, and that poaching is a localized issue.

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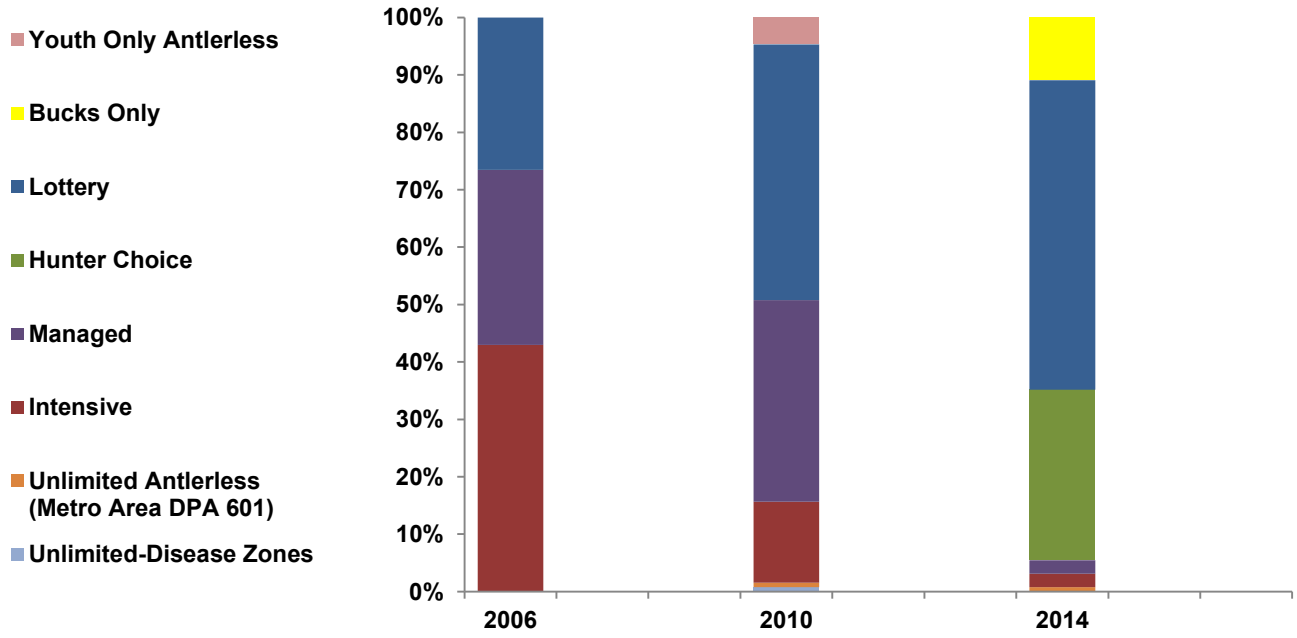
[35] "DeerModel_Data18Apr2015" (computer file, Minnesota Department of Natural Resources, St. Paul, 2015).

[36] Hunter success rates also would be affected if deer killed are reported to the incorrect DPA.

Exhibit 3.5: Percentage of Deer Permit Areas (DPAs), by Type of Permit Designation and Hunter-Reported Success Rates, 2006, 2010, and 2014



	2006	2010	2014
Number of Deer Reported Killed	270,778	207,313	139,442
Median Number Antlerless Permits Allowed Among Lottery DPAs	400	500	300
Number of Hunters	482,135	495,728	499,332

Hunter Success Rates
Percentage of Hunters Reporting Taking:

0 Deer	57.3%	63.6%	73.1%
1 Deer	32.7	31.4	26.1
2 Deer	7.8	4.3	0.6
3 or more deer	2.2	0.7	0.2

NOTES: The Department of Natural Resources' (DNR's) seven primary deer permit area designations used during this period were: **Bucks Only** (hunter may kill only bucks with at least one antler three inches or longer); **Lottery** (lottery allocation of limited number of hunting permits for option to shoot antlerless deer; unsuccessful applicants may only shoot bucks); **Hunter Choice** (hunter may shoot either one buck or one doe); **Managed** (hunter may shoot one deer, either sex, then one additional antlerless deer); **Intensive** (hunter may shoot one deer, either sex, then four additional antlerless deer); **Youth Antlerless** (only hunters under age 18 may take antlerless deer through lottery; all other hunters may only take bucks); and **Unlimited Antlerless** (for DPA 601 encompassing most of the seven-county metropolitan area). As a method to control disease in deer populations, DNR creates separate **Unlimited-Disease Zones**, which allow for unlimited taking of deer. DNR also may set hunting limits in designated areas—such as state parks, game refuges, or other areas—that differ from DPA-wide designations.

SOURCE: Office of the Legislative Auditor, analysis of Department of Natural Resources hunter license and deer registration data, deer regulations 2006, 2010, and 2014, and other documentation.

Minnesota also allows the practice of deer hunter "cross-tagging," which impacts "hunter success" rates. Cross-tagging allows individuals hunting together in a group—referred to as "party hunting"—to use each others' deer permit tags.[37] In essence, a killed deer may be tagged by someone who did not shoot the deer. While this practice does not affect the total number of deer killed or the total number of permits purchased, hunter success rates do not necessarily represent each hunter's actual "success."[38] We heard from individuals who objected to the state's allowance of cross-tagging—particularly when deer populations are relatively low—as this affects other hunters' opportunities to take a deer. They observed that sometimes a single individual in a hunting party accounts for a disproportionately large share of deer killed.

We also heard from individuals who expressed concern about DNR's allowance of bonus permits for hunters, including for areas designated for special hunts or for free landowner licenses that differed from DPA-wide permit designations. From our review of DNR documentation, we found that DNR's limits on bonus permits generally declined in recent years in some, but not all, areas. Because state statutes impose a range of responsibilities that affect DNR's management of deer, we also found it difficult to assess how DNR's use of bonus permits, or special hunt administrators' requests for bonus permits, aligned with overall DPA-wide deer population goals or decisions about DPA designations.

DNR staff also described shortcomings in the collection and reporting of deer killed through special hunts. DNR in the past year reviewed its modeling data for completeness to better understand total harvest of all deer killed within a deer permit area, including deer taken through special hunts.

Lastly, we note that the total number of deer killed in a particular DPA can be affected by many factors, including low deer numbers, severe winter weather that restricts deer movement, the number of hunters in a particular DPA, and DNR's actual deer permit area designations. (That is, a lottery for 100 permits or bucks-only designation may be intended to reduce the number of deer killed [and to grow the population] in a DPA; this restriction would be reflected in hunter-reported harvest.)[39] These factors impact hunter success rates.

Deer-Vehicle Crashes

Deer-vehicle crashes can result in serious injuries, and sometimes death. However, accurate, complete data on the number, severity, and outcomes of deer-vehicle crashes in Minnesota is not available; this includes counts of individuals injured and deer deaths. Deer-vehicle crashes involving severe injuries are typically reported to the Minnesota Department of Public Safety; however, many other incidents likely are not reported to state

[37] *Minnesota Statutes* 97B.301, subd. 3. A "party" is defined as any group of two or more licensed deer hunters who are all afield, hunting together at the same time, AND all using firearms (including muzzleloaders) or all using archery. The intent of the party hunting regulation is to prevent parties from shooting more deer than the available number of tags. DNR party hunting regulation requires that all hunters who intend to tag deer for each other be hunting together, in the field, at the time the deer are taken. Party members who are not afield hunting with the individual who takes a deer at the time it is taken may not legally cross tag that deer. Hunters may not lend licenses to or borrow licenses from other hunters.

[38] For example, if one hunter killed five deer for the group and they cross-tagged deer, hunter success rates would reflect that five hunters each killed one deer.

[39] A lottery limit of 100 permits may be relatively high in some DPAs when compared with historical lottery limits.

or local authorities.[40] Many states monitor deer-vehicle crash rates out of public safety concerns but also use the data to identify possible deer feeding concerns. For example, perhaps deer are crossing a busy road to feed on stored food or corn provided by private landowners. In these cases, the deer-vehicle crash rate in a particular area does not necessarily mean that there are more or fewer deer than elsewhere.

DNR's deer management designations to control deer in deer permit areas are restricted by local cities' authority to regulate the discharge of firearms. Deer permit area boundaries also do not necessarily align with either city or county boundaries. Thus, DNR deer population goals and decisions about types of hunter permits may or may not be directly related to reported deer-vehicle collision rates in some parts of the state, particularly in areas with high human population density. Rather, local decisions about deer hunting within city limits play a role, too.

Noting these caveats to deer-vehicle crash data, we examined county-specific data of incidents statewide. Based on data reported to the Minnesota Department of Public Safety (DPS), total reported deer-vehicle crashes statewide decreased 54 percent between 2005 and 2014, from 4,176 to 1,912.[41] Among 76 counties for which there were fewer crashes reported following this ten-year period, 8 counties accounted for 33 percent of the decrease; nearly all of these counties are located in a metropolitan statistical area.[42] State hunting regulations may or may not have affected deer populations in these areas. In particular, four counties—Anoka, Hennepin, Ramsey, and Washington—are partially or entirely located within DPA 601. DNR first designated this area as "unlimited antlerless" in 2007 to ensure that DNR hunting designations were not a barrier to municipalities who had an interest in lowering suburban and urban deer populations. However, reports of deer-vehicle crashes for seven other counties did not decrease, or decreased very little, following this ten-year period, including reports for Carver, Dakota, and Stearns counties.[43] These three counties include highly populated areas that are partially or entirely outside of the DNR's metro area Deer Permit Area 601 that allows for unlimited antlerless deer hunting.

Despite deficiencies in deer-vehicle crash data, reducing deer-vehicle crashes as a management objective is worthwhile. In our view, localized deer solutions to reduce injuries from deer-vehicle crashes should be articulated within a larger framework of a DNR deer management plan.

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[40] The DNR Farmland Wildlife Populations and Research Group tracks certain reports and incidents regarding deer-vehicle collisions. Reporting occurs through two methods: (1) salvage permits filed when people take a deer carcass from an incident for personal use, and (2) deer-vehicle collisions reported by state and transportation districts when a carcass is removed from the road. DNR reported it receives fewer than 5,000 reports of deer-vehicle collisions each year, yet published estimates by a national insurance entity exceed 40,000 annually in Minnesota. DNR staff also reported that for multiple counties, they have not received a single report of a deer-vehicle crash; however, it is likely deer-vehicle collisions have occurred in these counties.

[41] According to DNR staff, lower DPS deer-vehicle crash numbers in recent years are due to lower reporting.

[42] These counties were Anoka, Blue Earth, Douglas, Hennepin, Isanti, Ramsey, Sherburne, and Washington. A metropolitan statistical area (MSA) is a geographical region with a relatively high population density at its core and close economic ties throughout the area. MSAs are designated by the federal government and used by the Census Bureau for statistical purposes.

[43] These seven counties were: Brown, Carver, Dakota, Itasca, Koochiching, Stearns, and Swift.

DISCUSSION AND RECOMMENDATIONS

RECOMMENDATION

The Department of Natural Resources should develop a deer management plan that includes:

- **Clearly defined short-term and long-term goals and objectives that address the broad range of DNR's deer-related responsibilities.**
- **Strategies to improve and maintain adequate deer hunting and wildlife viewing opportunities in targeted areas around the state. This may require a separate goal-setting process for some areas within DPAs.**

DNR is required to preserve, protect, and propagate desirable species of wild animals. Most people want to see at least one or some deer in the environment, perhaps on private land, in public parks and recreational areas, or both. Public perceptions about the appropriate size of deer populations vary greatly, as we learned from advisory team member comments and individuals with whom we spoke. Deer management activities also can bring about outcomes that impact one or many public interests. For example, maintaining a smaller deer population to lessen the spread of disease from deer to another species, or to reduce deer-vehicle crashes, also reduces recreational opportunities for hunters and wildlife viewers.

Given the broad and often mixed views about deer, a formal written plan to manage deer would provide a tool to more clearly articulate the many variables, activities, and legal responsibilities related to deer oversight. DNR has two main administrative processes—the annual hunting regulatory process and periodic deer goal-setting process—that are more visible to the public. However, DNR carries out other, localized deer management actions, some of which involve cities and private landowners. For example, DNR has implemented a hunter "walk-in access program" in Southwestern Minnesota to facilitate hunter access to deer residing on private land in that area.[44] DNR's Section of Wildlife handles most deer management responsibilities, but work by other DNR divisions involves deer, too. A single written plan would synthesize all DNR deer-related activities into one document that articulates DNR's purpose and objectives for conserving and managing deer.

In our opinion, both the public and DNR would benefit from a deer management plan that clearly defined both long-term needs and shorter-term goals. With input from both the public and staff from across DNR divisions, a plan would help describe how DNR prioritizes deer goals relative to other DNR activities—such as immediate needs to mitigate deer impact in forests or long-term reforestation plans that might improve deer habitat and tree cover—or other species, such as moose and elk. A written plan also would more clearly identify for regional and area wildlife staff DNR's priorities and long-term actions, either within their region or elsewhere in the state. From the public perspective, a written plan with goals will define expectations and help others assess DNR's progress toward such goals.

[44] *Minnesota Statutes* 2015, 97A.126. DNR staff report that this program and related hunter participation and deer harvest do not have a measurable impact on deer population modeling.

Minnesota is a relatively large state, with a range of climates and ecological environments, varying deer habitats on public and private land, and diverse public interests.[45] As we described in Chapter 1, changes in human population density and changes in land use also add pressure on natural resources, result in loss of natural deer habitat, and create disputes between agricultural and other private landowners who want fewer deer because of deer feeding and hunters citing lost hunting opportunities. Loss of high-quality natural habitat affects recovery of deer populations; at the same time, agricultural and specialty crops are a food source for deer. A deer management plan would help synthesize the range of actions needed to manage deer around the state, help document and prioritize local issues, and address conflicts between landowners and hunters. It could also lay out strategies to improve deer hunting and recreational opportunities in targeted public areas around the state. Because of the diverse ecological differences in land and variation in hunting pressure and preferences, this may require a separate goal-setting process for some areas within DPAs. DNR also should more clearly document within a deer plan how its use of deer permit area designations, special hunts, and permits approved to address local concerns are intended to align with DPA-wide deer population goals.

In Chapter 2, we identified additional information about deer to help understand their presence around the state. This information includes further researching the presence of deer relative to other factors. A management plan could clearly lay out strategies and actions to improve DNR's modeling data, including collecting age data from hunter-killed deer and assessing nonregistration and illegal killing of deer. Additional DNR research should be coordinated with goal-setting activities for DPAs to provide a more comprehensive picture of deer presence. Ideally, a plan will help define goals for deer other than just deer density goals; specifically, whether there should be more deer, or whether the goal is for a smaller but better balanced herd (that is, ratio of buck and doe). It also should reflect the balance between the desire for hunting and viewing deer with the need to reduce the negative impacts from deer.

RECOMMENDATION

The Department of Natural Resources should clarify the role of Deer Advisory Teams in setting deer population goals in state parks, game refuges, and other special areas.

White-tailed deer roam across Minnesota's environment, and their travel patterns change over time. DNR's deer goal-setting process is one approach the department uses to involve the public in considering deer numbers around the state. However, DNR's range of deer management activities impact overall deer densities within DPAs. Local government's authority over the discharge of firearms within city limits also restricts DNR's management options and Deer Advisory Teams' proposals for deer populations. Because other statutory obligations affect DNR's management of deer, DNR should clarify for Deer Advisory Teams and members of the public the limitations of deer goals. Perhaps more involvement in the goal-setting process by local government representatives in areas experiencing higher conflict related to deer would provide insight into these issues.

[45] In total square miles, Minnesota is the 12th largest state in the nation and is over 400 miles long from north to south and 350 miles east to west. Minnesota also has four distinct ecological provinces and a wide range of climates.

State statutes provide DNR with tools to address localized concerns regarding deer presence, including the authority to issue special permits to local governments, airports, nonpublic game refuges, and private landowners. DNR also must manage public state parks, game refuges, and other areas according to specific objectives in law, such as to serve recreational purposes. These processes allow DNR to more directly manage local concerns and interests regarding wildlife, rather than imposing DPA-wide policy or changing deer density goals. However, we heard greatly conflicting opinions about DNR's authority and actions to carry out these policies. Some individuals said DNR was excessively resistant to granting special permits to kill deer, while others felt DNR was too liberal in granting special permits and questioned DNR's documentation of its processes. We heard support from hunters who advocated that DNR use more micro-level—rather than DPA-wide—solutions to local problems, but we also heard from hunters who questioned DNR's use of localized solutions.

DNR took steps in 2015 to improve the recording of deer harvest occurring through special hunts for purposes of modeling deer population densities. We think DNR should better integrate information about special permits and the frequency in which they are approved into its goal-setting process and overall deer management objectives. Again, such information could help facilitate discussions about deer goals, perhaps mitigate conflict among landowners and hunters, and address concerns about public safety regarding deer-vehicle collisions.

RECOMMENDATION

The Department of Natural Resources should continue updating deer population goals around the state, including deer permit area goals set during 2012.

DNR reimplemented its public goal-setting process in 2012 to help proactively manage changes in deer populations and public expectations regarding deer. Although not part of a formal, written plan, DNR has publicly stated that addressing societal expectations and concerns about deer influence their management decisions. However, in Chapter 2 we noted concerns about DNR's modeling of deer and the need for more research and data to inform goal-setting decisions. DNR should integrate its goal-setting processes with improved efforts to collect data. These actions should target areas of particular concern within DPAs, and focus deer research efforts in a strategic way to improve deer management outcomes. We also recommend that DNR clearly articulate the timing and schedule for revisiting population goals around the state within its formal deer management plan, including identifying the results of goal-setting and factors that may impede DNR progress towards goals.

FUNDING

In this section, we describe funding sources for the Division of Fish and Wildlife, including state appropriations, federal funds, and fees. We discuss the role of user fees, specifically deer hunting licenses, and how they have changed over time; we also examine DNR's spending related to deer population management. Finally, we discuss the Division of Fish and Wildlife's funding structure and state costs for managing Minnesota's deer.

Revenue

Wildlife-related activities—including deer management—are primarily funded with user fees, federal grants, and lottery payments.[46] These monies, including hunting license fees paid to DNR, are deposited into the state's Game and Fish Fund and distributed to DNR through appropriations and required funding to dedicated accounts.

Direct Appropriations

The majority of activities carried out by the Division of Fish and Wildlife are funded through legislative appropriations.[47] These appropriations are typically determined each biennium as part of the Legislature's budget-setting process and are funded in part with DNR revenues from a wide array of sources, including hunting and fishing license fees, federal grants, restitution payments, land leases, timber sales, application fees, and fines. The Division of Fish and Wildlife's appropriation is distributed among DNR's Wildlife Management, Fisheries Management, Licensing, and Outreach sections.

Fiscal year 2015 direct appropriations to the Division of Fish and Wildlife totaled about $62.8 million, nearly all of which came from the Game and Fish Fund, as described in Exhibit 3.6.[48] The Game and Fish Fund receives revenues from license fees and fines related to hunting and fishing, for example. These appropriations to the division fluctuated between fiscal years 2008 and 2015, averaging $61.5 million per fiscal year. During this eight-year period, the largest share of these monies came from the Game and Fish Fund, with much smaller appropriations from two other sources—the Natural Resources Fund and the General Fund. The appropriations to the division from the General Fund decreased during this period, from $3.5 million in fiscal year 2008 to $199,000 in fiscal year 2013, before finally being phased out in fiscal year 2014. The Legislature increased overall appropriations to the Division of Fish and Wildlife for fiscal years 2016 and 2017, totaling about $71.2 and $71.7 million, respectively.

Deer Hunting License Revenue

DNR's operations are also funded through user fees imposed on individuals seeking to hunt deer. With some exceptions, hunters are required to purchase a license to hunt. The Minnesota Legislature establishes the cost of hunting licenses, which varies by hunter age and residency status.[49] The cost of adult deer hunting licenses has increased gradually over time for both residents and nonresidents. The price of an adult deer hunting license for a Minnesota resident increased from $22 in 1990 to $30 by 2015; most recently, the price of an adult resident license fee was increased in 2012, from $26 to $30.[50]

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[46] Lottery-related revenue comes from in lieu of sales tax receipts on the sale of state lottery tickets. Half of 72.43 percent of total in lieu of sales tax receipts are deposited into the Game and Fish Fund to be used for activities that improve, enhance, or protect fish and wildlife resources.

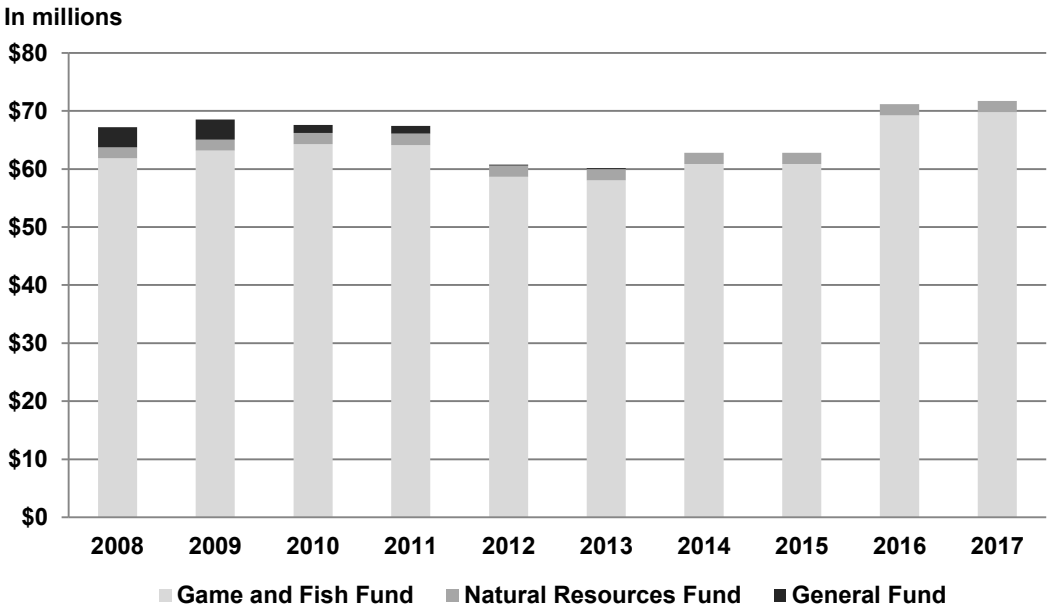
[47] A direct appropriation is an authorization to spend a specific amount of money for a limited period of time. The Legislature makes direct appropriations in session laws; direct appropriations are not codified in statute.

[48] In fiscal year 2015, 3 percent of the direct appropriation to the Division of Fish and Wildlife came from the Natural Resources Fund. *Laws of Minnesota* 2013, chapter 114, art. 3, sec. 4, subd. 6.

[49] *Minnesota Statutes* 2015, 97A.015, subd. 12; and 97A.475. A resident must maintain legal residence in Minnesota for at least 60 consecutive days before purchasing a license. A nonresident under age 21 whose parent is a Minnesota resident is also considered a resident.

[50] *Laws of Minnesota* 2012, chapter 277, art. 2, sec. 16, subd. 2.

Exhibit 3.6: Appropriations by Fund, Division of Fish and Wildlife, Fiscal Years 2008-2017



NOTES: Appropriations reflect session laws. The Game and Fish Fund receives revenues from license fees and fines related to hunting and fishing, which are spent for related purposes. Included within the Game and Fish Fund is the Heritage Enhancement account, which receives payments in lieu of sales tax on lottery tickets. The Natural Resources Fund receives revenue from fees, donations, and taxes from fuel used in recreational vehicles, which are used to fund management of related natural resource programs. The General Fund is the largest fund in the state treasury and receives revenue from most major taxes. Most money in the General Fund is not earmarked for specific purposes.

SOURCE: Office of the Legislative Auditor, review of appropriation laws.

Revenue generated from deer hunting licenses and permits was somewhat consistent between fiscal years 2012 and 2015.

Revenue from deer hunting licenses and permits averaged $19.1 million annually during this four-year period. In fiscal year 2015, DNR recorded about $18.6 million from deer hunting license and permit sales. Over the past 15 years, the annual number of individuals who obtained a deer hunting license ranged from a low of 464,000 in 2002 to nearly 516,000 in 2012.[51]

Revenue from deer hunting licenses is handled in two ways. Minnesota statutes require that DNR direct a share of this revenue into statutory accounts for deer and other wildlife management activities and to support DNR's electronic licensing system. As we discuss in the following section, $3.3 million of a total $18.6 million in hunter license fees was

[51] Beginning in 2000, DNR improved its information technology system to better track hunter participation, by individual hunter and license purchased. As we discussed earlier in this chapter, DNR deer season management regulations—such as number of lottery allotments—also can affect hunter participation and, thus, license revenue. When compared with Minnesota's overall population, the share of individuals purchasing a deer license was about the same in 2014 and 2015 (9.2 percent) as in 2000 (9 percent).

deposited into dedicated accounts in 2015. The remaining deer license revenue that is not allocated for these purposes ($15.3 million in 2015) must be deposited into the Game and Fish Fund and reallocated to DNR as part of the Legislature's appropriation processes.

By law, DNR revenue from deer hunting licenses is not used solely for deer population management activities.

Minnesota statutes place restrictions on the ways in which DNR can use revenue from hunting licenses—specifically that DNR must use deer hunting license revenue for game, fish, and related activities—but it does not restrict the use of these monies to exclusively benefit deer.[52] Thus, DNR uses revenue from deer hunting licenses and permits to fund a wide array of DNR activities, such as wild animal surveys and the protection and enhancement of wildlife management areas (WMAs).

Dedicated Accounts and Receipts

The Division of Fish and Wildlife receives revenue through accounts specifically intended to support wildlife management. In particular, Minnesota statutes require DNR to direct a share of revenue from deer hunting licenses into accounts supporting deer, bear, and wolf management activities.[53]

By law, DNR must direct a portion of revenue from deer hunting licenses into accounts dedicated to deer management and related purposes.

Funded largely by hunting licenses, money from these deer-related accounts must be used for specific purposes, as outlined in Exhibit 3.7.[54] In fiscal year 2015, DNR directed approximately 18 percent of revenue from deer hunting licenses and permits to these dedicated deer-related accounts and the department-wide electronic licensing system. Specifically, we estimated $2.3 million—or 12 percent of revenue from deer hunting licenses and permits—was directed into the dedicated deer-related accounts in fiscal year 2015.[55] The total dollar amount per deer hunting license credited to each account has not increased since each account's inception.

State law also requires DNR to recover costs involved in providing an electronic licensing system by collecting a fee from each electronic license sold.[56] Nearly $1 million—or 5 percent of total revenue from deer hunting licenses and permits sold in fiscal year 2015—was collected for the purpose of maintaining DNR's electronic licensing system.

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[52] *Minnesota Statutes* 2015, 97A.057, subd. 2.

[53] In addition to annual deer hunting licenses, revenue for statutory appropriations is also collected from "lifetime" deer hunting licenses and "super sports" licenses. An individual who purchases a lifetime license pays a higher, one-time license fee for the authorization to hunt deer each year, according to annual regulations. A super sports license allows an individual to fish and hunt small game and deer under the authorization of one license.

[54] *Minnesota Statutes* 2015, 97A.075, subd. 1.

[55] Accounts include: Deer Management Account (DNR refers to this account as the Deer Habitat Improvement account), Deer and Bear Management, Emergency Deer Feeding and Wild Cervidae Health Management, and Wolf Management and Monitoring. *Minnesota Statutes* 2015, 97A.075, subds. 1 and 7; and 97A.485, subd. 7.

[56] *Minnesota Statutes* 2015, 84.027, subd. 15(a)(5); and 97A.485, subd. 7.

Exhibit 3.7: Deer Management-Related Statutory Accounts and Appropriations, Fiscal Year 2015

	Account Use	Revenue Source	Funds Credited per Deer Hunting License Sold	Estimated Revenues from Deer Hunting Licenses[a]
Deer Management Account (also known as Deer Habitat Improvement Account)	Deer habitat improvement or deer management programs	Deer hunting and super sports licenses[b]	$2.00	$1,190,385
Deer and Bear Management Account	Deer and bear management programs, including a computerized licensing system	Deer and bear hunting and super sports licenses[b]	1.00	537,788
Emergency Deer Feeding and Wild Cervidae Health Management Account[c]	Emergency deer feeding and wild cervidae health management	Deer hunting and super sports licenses	0.50	297,596
Wolf Management and Monitoring Account	Wolf management, research, damage control, enforcement, and education	Wolf hunting licenses and applications, deer hunting, and super sports licenses[b]	0.50	297,596
Commissioner's License Issuing Fee[d]	DNR electronic licensing system operation	Sales made through the electronic licensing system		969,966

[a] Total revenues include those generated from deer hunting licenses only. Additional account revenues—such as those from bear and wolf hunting licenses—are not included.

[b] In addition to annual deer hunting licenses and permits, a credit per lifetime deer hunting license is collected annually from the lifetime fish and wildlife trust fund.

[c] A cervidae is an animal that is a member of the family Cervidae, which includes—but is not limited to—white-tailed deer, mule deer, red deer, elk, moose, caribou, reindeer, and muntjac. *Minnesota Statutes* 2015, 35.153, subd. 2.

[d] Statutes do not stipulate the dollar amount to be collected but specify that the DNR commissioner "shall establish the commissioner's fee in a manner that neither significantly overrecovers nor underrecovers costs involved in providing the electronic licensing system." *Minnesota Statutes* 2015, 84.027, subd. 15(a)(5).

SOURCES: *Minnesota Statutes* 2015, 97A.075, subds. 1 and 7; 97A.485, subd. 7; and 84.027, subd. 15(a)(5).

Federal Funding

As mentioned above, the Division of Fish and Wildlife also receives federal funding for wildlife management activities. The Federal Aid in Wildlife Restoration Act provides states with financial and technical assistance to conduct hunter education programs and for projects that benefit wildlife resources.[57]

Some DNR deer population management activities qualify for reimbursement through Federal Aid in Wildlife Restoration Act grants.

Also referred to as the Pittman-Robertson Act, the Federal Aid in Wildlife Restoration Act provides financial reimbursement to states for certain wildlife restoration and hunter education activities. Funded through an excise tax on firearms, ammunition, and archery equipment, states are eligible for reimbursement of up to 75 percent of expenses for

[57] *Federal Aid in Wildlife Restoration Act of 1937, 16 U.S. Code*, sec. 669 (2015).

qualifying activities.[58] Activities eligible for reimbursement are listed in Exhibit 3.8. DNR deer population management expenditures eligible for federal reimbursement over the last four fiscal years included salaries, travel expenses, equipment repair, and more.

Through the Act, the U.S. Fish and Wildlife Service made available to DNR about $24.9 million in grants in fiscal year 2015, $15.3 million (61 percent) of which was acquired by DNR as reimbursement for wildlife management activities.[59] Total grant dollars available to DNR through the Act have more than tripled over the last ten fiscal years due to increasing purchases of guns and related equipment nationally. However, DNR reports that federal grants from the Act are expected to peak in 2016 and decline thereafter.

Exhibit 3.8: Activities Eligible for Reimbursement through the Federal Aid in Wildlife Restoration Act

- Wildlife population surveys and inventories
- Habitat acquisition, management, and improvement
- Introduction of wildlife into suitable habitat to help stabilize species populations
- Improvements to public access and facilities for the use and enjoyment of wildlife resources
- Wildlife management area operation and maintenance
- Land acquisition through fee title, lease, or agreement for wildlife conservation and public hunting purposes
- Research conducted on wildlife and activities to monitor wildlife status
- Hunter education and safety programs and facilities development and improvement
- Shooting or archery range development and management

NOTE: There are four Federal Aid in Wildlife Restoration Act grant programs authorized by Congress: Wildlife Restoration, Multistate Conservation, North American Wetlands Conservation Program, and Firearm and Bow Hunter Education and Safety.

SOURCE: U.S. Fish and Wildlife Service, *Pittman-Robertson Wildlife Restoration, FY 2013 Budget Justifications and Performance Information Fiscal Year 2013* (Washington, DC, 2012), WR-1 – WR-12.

Other State Funding

In 1988 and 2008, Minnesota voters supported constitutional amendments creating two natural resources-based funds: the Environment and Natural Resources Trust Fund and the Outdoor Heritage Fund. Funded by proceeds from the Minnesota State Lottery and a sales tax increase, respectively, these funds were established for the purpose of protecting, conserving, preserving, and enhancing habitat and natural resources.[60] The funds support

[58] The Federal Aid in Wildlife Restoration Act calls for an 11 percent excise tax on all long guns, ammunition, and archery equipment, and a 10 percent tax on all pistols, handguns, and revolvers. The federal government determines state apportionments based on the state's land mass and number of paid hunting license holders.

[59] In fiscal year 2015, DNR claimed nearly 100 percent of total available Federal Aid in Wildlife Restoration Act dollars. Federal apportionment dollars not spent on wildlife management activities were used for other eligible expenses, such as hunter education.

[60] Revenue for the Environment and Natural Resources Trust Fund is generated from a combination of contributions and investment income. Forty percent of net proceeds from the Minnesota State Lottery are deposited into the Fund annually; the remaining proceeds come from private donations and other sources. Legacy Amendment funds—including revenue for the Outdoor Heritage Fund—come from a sales tax increase of three-eighths of 1 percent through 2034. The Outdoor Heritage Fund receives 33 percent of the revenue generated by the sales tax increase.

projects administered by a wide variety of grantees, including DNR and nongovernmental groups, such as the Minnesota Deer Hunters Association.

Historically, projects supported by money from either fund have largely targeted biological research and habitat acquisition or restoration that produce benefits at the ecosystem-level, not projects that benefit one animal or plant species alone. While most projects may not be deer-specific, the deer population benefits along with other species. For example, a fiscal year 2013 grant to Crow Wing County from the Outdoor Heritage Fund helped to protect nearly 2,000 acres of wetland and forest habitat that is home to a wide variety of birds and waterfowl; reptiles and amphibians; and mammals, such as deer and fox.

Over the last four fiscal years, the Legislature appropriated about $118.3 million from the Environment and Natural Resources Trust Fund; and almost $387 million was awarded from the Outdoor Heritage Fund. During that time period, DNR received approximately $164.3 million in grants from the two funds combined, primarily for research and habitat-based projects.[61]

Expenditures

There are many costs associated with deer population management, including hunting season management, habitat management, population modeling and research, deer damage management, facility development and improvement, and others. Because many wildlife population management activities serve multiple purposes and provide benefits to deer as well as other species, DNR tracks the majority of its expenditures by activity type, not by species.

To better understand DNR deer population management expenditures, we analyzed (1) expenses coded to deer-specific activities, (2) select other deer population management expenses not coded to deer-specific activities but related to deer population management, and (3) spending from deer-related dedicated accounts.[62] Total estimated deer management expenditures also include shared administrative and departmental service costs.[63]

We estimated that DNR spent approximately $2.8 million on activities related or specific to deer population management in fiscal year 2015.

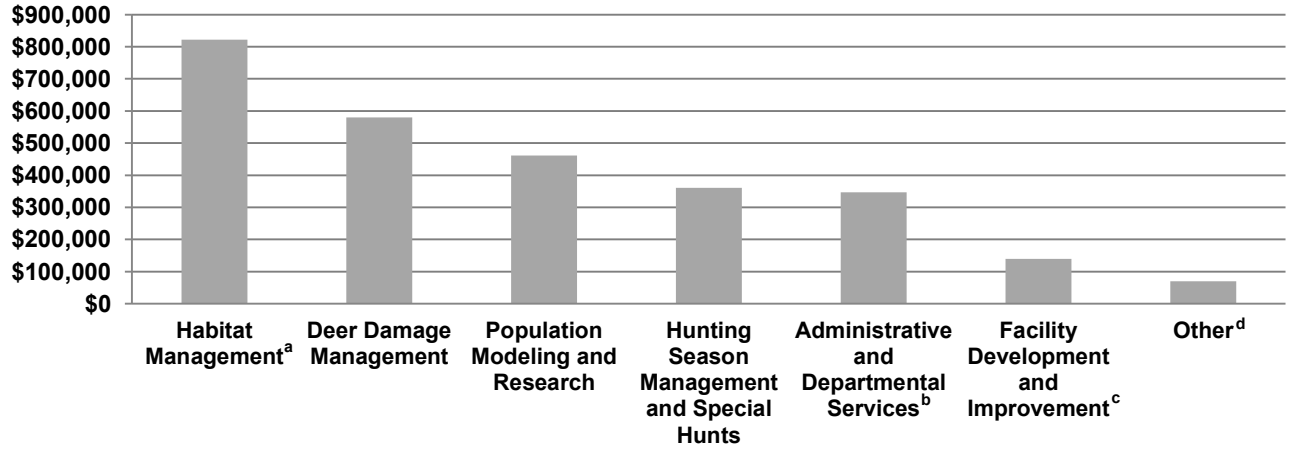
[61] Total includes pass-through funding—such as appropriations for the Conservation Partners Legacy Grant Program—and only includes Outdoor Heritage Fund and Environment and Natural Trust Fund grants in which DNR is the sole grant recipient. From fiscal year 2012 to fiscal year 2015, the Legislature appropriated for collaborative projects an additional $14.7 million from the Outdoor Heritage Fund to be shared between DNR and other grant recipients.

[62] DNR codes only a limited number of expense categories—primarily those related to population modeling and research—specifically to deer. DNR uses other expense categories for expenditures relating to multiple species, including deer. At our request, DNR provided estimates of total deer-related expenditures in the following categories: nuisance animal technical guidance, depredation management, season management, special hunts, animal disease management, winter food development, statistical consultation, literature review, informal wildlife surveys, and formal wild bird and mammal surveys. Deer-related dedicated accounts include the Deer Habitat Improvement, Deer and Bear Management, Emergency Deer Feeding, and Wild Cervidae Health Management accounts.

[63] Administrative and departmental service costs include the division's expenses for computer and technology support; shared services, such as human and management resources, facilities, and financial management; and leadership, including the Commissioner's Office and regional operations.

Estimated DNR spending on activities related to deer population management in fiscal year 2015 was relatively small—about 15 percent—when compared with total revenue from deer hunting license and permit sales. However, estimated deer management expenditures in fiscal year 2015 exceeded the total revenue from deer hunting licenses and permits allocated to dedicated accounts benefitting deer, previously shown in Exhibit 3.7. As shown in Exhibit 3.9, habitat-related activities accounted for the largest amount ($822,000) of total estimated deer management expenditures in fiscal year 2015, followed by deer damage management ($580,000). Habitat-related activities include—but are not limited to—brushland burns and forest stand improvement, while deer damage management activities include efforts to provide technical guidance to private landowners on how to manage nuisance deer and DNR on-site activities in solving nuisance animal problems or property damage.

Exhibit 3.9: Total Deer Population Management Expenditures by Activity Type, Fiscal Year 2015



[a] "Habitat Management" expenditures shown here include activities funded by deer-related dedicated accounts and DNR estimates of deer-related expenditures for winter food development and cooperative farming. Other habitat-related activities that may benefit deer are not included.

[b] "Administrative and Departmental Services" costs include the division's expenses for computer and technology support from the information technology agency for Minnesota's executive branch (MN.IT); shared services, such as human and management resources, facilities, and financial management; and leadership, including the Commissioner's Office and regional operations.

[c] "Facility Development and Improvement" expenditures shown here include activities funded by deer-related dedicated accounts only. It does not include DNR facility-related activities that may also benefit deer paid for with nondedicated funds.

[d] "Other" includes expenditures related to public outreach and technical guidance, among other things.

SOURCE: Office of the Legislative Auditor, analysis of Minnesota Department of Natural Resources Division of Fish and Wildlife data and estimates of deer-related expenditures.

The $2.8 million spent in fiscal year 2015 is an estimate of *minimum* DNR expenditures on deer population management; it is likely that total agency deer population management expenditures exceeded $2.8 million in fiscal year 2015. Because DNR generally identifies expenditures by activity type and does not attribute costs to a particular species, this estimate does not include spending from several expense categories that may indirectly

benefit deer or deer population management.[64] For example, the estimate does not include expenditures related to land acquisition. DNR might acquire land for a wildlife management area, which increases available habitat for all animals, including deer. Determining which expenditures from these expense categories pertain to deer specifically is problematic; thus, OLA excluded these data from our analysis.

While the majority of DNR expenditures pertaining to deer management are not tracked by species, DNR identifies a limited number of expense types—primarily those related to deer population modeling and research—that are specific to deer.[65]

DNR expenditures specific to deer population modeling and research more than tripled over the last four fiscal years.

Deer population modeling and research expenditures grew from about $109,000 in fiscal year 2012 to approximately $385,000 in fiscal year 2015 and totaled about $1 million over the four-year period. From fiscal year 2012 to fiscal year 2015, deer population model recalibration and deer damage research accounted for the greatest percentage of deer population modeling and research expenses—36 and 20 percent, respectively.[66]

Financial Oversight

Three citizen "oversight committees" provide oversight of Game and Fish Fund activities.[67] As outlined in law, committee members are responsible for reviewing game and fish annual reports, work plans, and budgets; proposing policy and revenue changes; and making recommendations to the Legislature and the commissioner for improvements in the management and use of Game and Fish Fund monies. The Wildlife Oversight Committee specifically reviews "wildlife funding and expenditures, including activities related to…deer and big game management."[68]

[64] OLA's estimate does not include expenditures such as habitat management, facility development or improvement, electronic licensing system maintenance, public assistance and information provision, DNR's Walk-In Access and Venison Donation programs, or land acquisition, unless the activity was funded through one of the Game and Fish Fund dedicated accounts supporting deer management. Estimates also do not include activities indirectly benefitting deer funded through the Wolf Management and Monitoring Account or deer-related Division of Enforcement expenditures.

[65] Expense categories specific to deer include deer population modeling, deer population model recalibration, deer damage research, deer hunter surveys, alternative deer management research, deer thermal cover research, and research on deer killed by vehicles.

[66] Deer population model recalibration includes DNR efforts related to conducting field surveys and estimating abundance of deer to recalibrate deer population models. Deer damage research includes activities related to a DNR study examining agricultural crop damage caused by white-tailed deer and an evaluation of the effectiveness of localized deer management techniques for reducing deer depredation. DNR also reported investing $308,000 on surveys conducted or scheduled to be conducted during fiscal years 2015 through 2017.

[67] The three committees include the Fisheries Oversight Committee, Wildlife Oversight Committee, and Budgetary Oversight Committee. The DNR commissioner appoints members to each committee, striving to include a wide array of stakeholder perspectives.

[68] *Minnesota Statutes* 2015, 97A.055, subd. 4b(b)(2).

Funding Deer Management

DNR receives monies from a variety of sources that may be used for purposes that directly or indirectly impact deer.

It is difficult to obtain a complete picture of state costs for managing Minnesota's deer.

While DNR receives federal and state funding for deer and wildlife purposes, there are limits on how those monies can be used. As a result, DNR must use funding from other sources to fulfill all of its responsibilities related to deer population management.

DNR is limited in the ways in which it can use federal grant funding from the Federal Aid in Wildlife Restoration Act. Certain activities that protect wildlife or provide important information to the public—such as wildlife law enforcement or wildlife-related public relations—are ineligible for funding. The agency is likewise limited in its use of revenue from hunting and fishing licenses, as statutes requires DNR to spend those dollars on game, fish, and related activities only.

DNR relies heavily on user fees—specifically deer hunting and fishing licenses—to pay for many wildlife needs. This funding approach creates service expectations for those customers; that is, by paying for a deer hunting license, deer hunters expect that DNR will maintain a deer population that meets hunter desires.

However, other stakeholders benefit from deer and deer population management, such as wildlife watchers or photographers. As we described earlier, funding from other sources indirectly support deer habitat management and deer environments, such as state parks, wildlife areas, game refuges, or forests. We also noted earlier that other DNR divisions use resources to conserve deer and manage deer presence, such as deer impact on forests. DNR staff point out that the Division of Fish and Wildlife does not pay for protection of tree seedlings from deer, for example. These divisions are supported by other types of funding and user fees, for example, fees to access state parks and sales tax for funding the Outdoor Heritage Fund. Similar to hunters' expectations for hunting licenses, these fees and costs also create service expectations by the public.

Tracing the direct costs and benefits of all monies spent on conserving and managing deer is not possible and would require considerable time and resources to develop an estimate. However, a written deer management plan that fully addresses the broad range of interests and investments that affect deer presence would help lay out for the public the extensive work required for deer oversight, and the range of management activities provided by DNR. It would also help prioritize spending on deer management based on public feedback to DNR's deer management plan.

List of Recommendations

- The Department of Natural Resources should improve and validate its new deer population model and deer population statistical estimates. Specifically, DNR should:
    - Conduct field research to improve model data and indices used to estimate deer vital rates, hunter reporting of deer harvest, and illegal harvest around the state.
    - Collect and utilize age data from hunter-killed deer as an index to winter mortality and to validate model results.
    - Use independent observations—such as through aerial surveys—of deer populations to validate model results; and reassess the factors that limit DNR's use of aerial surveys for this purpose.
    - Improve DNR's database and record keeping system used for deer population modeling.
    - Modify statistical programming and code structure to improve workflow, reduce the risk of user mistakes, and better simulate a potential range of deer densities. (p. 40)
- For purposes of setting deer population goals and permit area designations for hunting, the Department of Natural Resources should compile and publish additional information about the characteristics of deer permit areas. (p. 42)
- The Department of Natural Resources should consider enhancing its deer management surveys to obtain a broader range of opinions. (p.42)
- Within the limitations of data practices laws, the Department of Natural Resources should compile and utilize more specific information about deer presence and deer impact within local environments. (p. 43)
- The Department of Natural Resources should develop a deer management plan that includes:
    - Clearly defined short-term and long-term goals and objectives that address the broad range of DNR's deer-related responsibilities.
    - Strategies to improve and maintain adequate deer hunting and wildlife viewing opportunities in targeted areas around the state. This may require a separate goal-setting process for some areas within DPAs. (p. 63)
- The Department of Natural Resources should clarify the role of Deer Advisory Teams in setting deer population goals in state parks, game refuges, and other special areas. (p. 64)
- The Department of Natural Resources should continue updating deer population goals around the state, including deer permit area goals set during 2012. (p. 65)

Wildlife Management Institute, Inc.

Technical Review of Department of Natural Resources' Deer Population Modeling and Survey Methods

APPENDIX A

In September 2015, the Office of the Legislative Auditor entered into a technical services contract with Wildlife Management Institute, Inc., to assist with various aspects of our evaluation of the Department of Natural Resources' management of Minnesota's deer populations. The reason for these services was to provide a technical review of the statistical model currently used by the Department of Natural Resources for estimating and forecasting deer populations, and of DNR's methods for surveying deer. The final report by Wildlife Management is attached herein as Appendix A of our report.

Technical Review of Department of Natural Resources' Deer Population Modeling and Survey Methods

SWIFT Contract Number: 100434

Final Report - 2/25/2016
Revised - 5/12/16

Wildlife Management Institute, Inc.
2016

EXECUTIVE SUMMARY

The Wildlife Management Institute (WMI) contracted with the Minnesota (MN) Office of Legislative Auditor (OLA) on September 14, 2015 to conduct a technical review of the MN Department of Natural Resources' (DNR) deer population model and its use of aerial deer surveys. The time period for our analysis was the years of the 2012-2015 deer hunting seasons. WMI met with DNR and OLA staff; reviewed and analyzed numerous documents provided by DNR and OLA; consulted with experts; reviewed scientific literature; analyzed model form, function, inputs and outputs; and communicated with DNR and OLA throughout the review period. WMI contracted with 3 individuals with population modeling expertise (2 from the University of Montana and 1 from the University of Vermont) to assist in this review.

Numerous state fish and wildlife agencies conduct deer population modeling to assist in monitoring deer population abundance and to inform deer harvest management strategies. There is no single industry standard for deer population modeling and no single population model that has been adopted by all state agencies. Further, population modeling is used as an index of deer population abundance and population trends, not as an exact census of deer population numbers. Population modeling also provides deer managers with a mathematical tool to simulate population response to different harvest strategies.

Data used as inputs to deer population models also vary from state to state. Data collected and collection methods vary as well. Currently states use a number of different approaches to population modeling: integrated population models, sex-age-kill models, accounting models, and the use of expert judgment to manage deer populations.

Given that no one standardized model is in use across the country and in order to address the OLA's "industry standard" reference, WMI developed a gold standard population model to compare against the current DNR model. The gold standard model strives to balance statistical rigor, management utility and data integrity. The model reflects a desire to inform proactive deer population management.

The model in use for the 2012-2014 was a deterministic accounting model using user-defined values within the model with no amount or measure of uncertainty. This model was operated in Excel spreadsheets. In 2015, DNR adopted a stochastic accounting model as a population simulation model. The current model was based in R statistical computing language. Stochastic models set parameter values within the model for initial conditions then they incorporate uncertainty by selecting random values within a statistical distribution surrounding user-defined input parameters. As such, they mimic the uncertainty in population vital rate estimates, population size, and growth.

WMI found that the earlier Excel spreadsheet model was well documented and we could replicate DNR model outputs. WMI did note some deficiencies in the use of the deterministic accounting model and the use of Excel as a computer program for modeling. The current use of the stochastic simulation model based in R statistical language was an enhancement of DNR's modeling sophistication.

WMI found that the model was sensitive to initial population size (an estimate provided by the user). Changes in the initial population size were not informed by feedback loops within the model (e.g. harvest indices, permit success rates, etc.) rather they were adjusted by the user's expert judgment, informed by survey, trend, and/or indices data. The use of expert judgment, informed by other indices, although not ideal, is a common practice in population modeling. The model was also sensitive to the Winter Severity Index (WSI). Changes in WSI values from 0.8 to 1.2 resulted in density estimates that ranged from 8 to 6 deer per square mile and population growth rates from 1.07 to 1.02, respectively.

The DNR parameter estimates were based on values published in scientific literature and were appropriate to deer management in northern climates. WMI found that DNR has conducted substantial research through the years, in Minnesota, to help advise parameter estimates. Indices used by DNR (e.g., harvest trends, adult male harvest, etc.) were used extensively across the U.S. and may provide adequate information to achieve deer population management; however, they do not include estimates of uncertainty associated with point estimates.

Further, the lack of adequate age and sex data of harvested deer complicated attempts to verify model inputs and outputs. WMI found that population vital rates were informed by previous published literature and varied geographically and annually according to WSI. Harvest registration parameters and illegal harvest parameters were also held constant and WMI could find no evidence to support their estimates. The DNR population model was sensitive to initial population estimates and WSI. The current population model did not appear to incorporate current data (with the exception of registered harvest) nor did it contain automated "feedback loops" to inform the population projections. Rather, model input was largely dependent on expert judgment informed by existing data and indices found in modelers' reports and notes for each DPA. Without extensive documentation of model inputs and decision rationale, WMI believes it would be difficult to learn from successive iterations of the model in an adaptive management context.

WMI found that DNR's design and execution of aerial surveys, sample sizes and survey techniques were scientifically sound and met or exceeded accepted standards. The methods used to select quadrants became more sophisticated over the analysis period due to increased experience, development of statistical methodology, and data recording software. The use of quadrat sampling, based on Public Land Survey Sections, was a valid and efficient sample design. The protocol used to conduct aerial surveys ensured collection of accurate data and facilitated rapid analysis of results.

Aerial surveys in MN were limited due to 3 major factors. First, ground snow cover was necessary for sightability. DNR did not conduct aerial surveys unless adequate snow cover was available. Second, aerial surveys were of limited value in the northern Forest Zone due to vegetative cover that impaired sightability. Third, availability of DNR aircraft, pilots, and observers limited the time periods when surveys could be conducted. DNR prioritized aerial surveys for moose over deer surveys, which further narrowed the window for aerial deer surveys.

These limitations affected the use of aerial surveys as a basis to inform the population modeling effort. Inadequate geographic and temporal survey data constrained the use of these data to inform and validate the population model. Further, WMI found that seasonal movements of deer between the time of aerial surveys in winter and model estimates in fall and spring may produce discrepancies between model estimates and aerial survey estimates of population density.

WMI recommended DNR reassess the factors that limit use of aerial surveys for model validation. Chief among, these within the control of DNR, is the allocation of resources to aerial surveys. The number of surveys flown in any given year would need to be increased significantly to fulfill the recommendation of Grund and Wolff (2004) to recalibrate the population model every few years. DNR should also continue to explore means to overcome the problems created by the timing of aerial surveys in winter, when deer distribution may differ from that in the fall or spring when populations are modeled. Finally, ongoing climate change may further impact aerial surveys by reducing the frequency of adequate snowpack. DNR should consider the impacts of climate change when addressing the issue of survey timing.

DNR employed a WSI to account for the impacts of snow depth and days of snow cover on overwinter survival of deer. Although not exactly the same, DNR's WSI methodology and metric was similar to other northern states and southern Canadian provinces. Winter severity rate estimates and impact on deer populations were also similar to states and provinces within the region.

WMI suggested that DNR consider collaborating with adjacent states to combine their efforts with respect to defining a consistent measure of WSI and determining the impact of such rates on overwinter survival. WMI also suggests that DNR consider the collection of sex and age data from hunter-killed deer to examine fawn:adult ratios as an assessment of WSI impact.

In conclusion, WMI found that the DNR deer population model was sound in its current form and an improvement over the previous deterministic, spreadsheet based model. However, we recommend improvements in design, data storage, and use. The data used to inform model parameter values were based on scientific literature and appropriate for northern climate deer populations. WMI could replicate most of the DNR's model outputs but not all. We expected this and attributed the difference to the stochastic nature of the model and input parameters

that were modified but unknown to WMI during our initial analysis. These input parameters were documented in modelers' notes and reports that WMI received subsequent to our analysis.

WMI questions the validity of certain parameters that were consistently applied across all sex and age classes across the entire state; specifically, we could not find documentation of the rate estimates for non-registration of deer harvested nor illegal harvest. In addition, we question the constant use of these rates from year to year without any apparent measure or validation of the assumption that these rates do not vary. This shortcoming may be overcome by conducting additional research to inform both rates and their measures of uncertainty. WMI understands that the expense and logistics of this type of research may be prohibitive.

WMI recognizes that DNR adopted the new deer population model in 2015. The sophistication of this model exceeds their previous population model. Development of the model is a work in process. Although we identified numerous concerns about the model, WMI believes that DNR understands these concerns and the fact that the model must evolve through time. DNR will have to assess its ability to provide the necessary resources to operate and maintain the more complex model with the statistical rigor necessary to conduct stochastic modeling.

WMI cautions DNR to evaluate the model's effectiveness in managing populations and harvest strategies as the model evolves in its sophistication. In addition, DNR should provide the public with an explanation of the current use of the model, its current weaknesses, plans for improvement, and its role in establishing hunting season structure and permit allocations. Although no population model is perfect, the use of population modeling in a disciplined approach, can inform deer managers about population dynamics and the impacts of mortality that drive or impede population growth.

DNR staff were honest and forthcoming during our face-to-face interviews and contacts during the review process. Requested information was provided in a timely manner. WMI believes that DNR staff are capable of and committed to improving the integrity of the population model and has made measurable strides to accomplish that goal. WMI recognizes limitations inherent in the modeling of deer populations across the state of Minnesota and in the resources necessary to improve data collection and analysis. WMI recommends numerous strategic actions that should be considered by DNR as they continue to develop their population modeling effort.

TABLE OF CONTENTS

INTRODUCTION

Founded in 1911, the Wildlife Management Institute (WMI) is a private, nonprofit, scientific and educational organization, dedicated to the conservation, enhancement and professional management of North America's wildlife and other natural resources. Since that time WMI has been involved in national, regional, and state wildlife conservation efforts, projects, programs, and policy development. WMI has conducted more than 70 program and project reviews for state and federal agencies. We administer and host the North American Wildlife and Natural Resources Conference, the largest conference for state, federal, and conservation organization leadership in North America. WMI currently provides the following services for the professional wildlife community: science and management review and assistance, program review and policy development, wildlife information and education, project coordination and administration, and service to the profession and our partners. WMI is a science-based, independent, nonpartisan, and non-membership organization. As such, we provide objective evaluation, conclusions, and recommendations to our clients.

WMI understands that effective management of big game populations is a critical factor in the success of state fish and wildlife agencies. Big game species are a public trust resource in the United States, and the people of each state hold state government accountable for the management of their resources.

WMI understands that effective management depends on successful integration of biological and social elements. The biological elements must be accurately measured, monitored, and analyzed using scientifically sound techniques. The social elements must provide meaningful ways for people to gain knowledge about big game resources and participate in decision-making. Citizens have a range of values from naturalistic to utilitarian. For these reasons and others, big game management systems must consist of processes that are well defined, transparent, and understood by both the managers and the constituents they serve. The North American Model of Wildlife Conservation, built on such principles as managing wildlife as a public trust, using science as the basis for decision- making, providing all citizens a voice in the process, allocation of wildlife harvest by law - not the market or privilege - and equal opportunity for all citizens to participate in hunting is the overarching framework by which state agencies seek to meld the biological and social elements to achieve desired outcomes.

In August 2015, WMI submitted a response to the July 2015 Minnesota (MN) Office of Legislative Auditor's (OLA) Informal Solicitation for: *Qualified Contractors to Provide Technical Review of Deer Population Modeling and Survey Methods*. In September, The OLA notified WMI that our proposal was selected and the Professional and Technical Services Contract (SWIFT Number 100434) was signed on September 14, 2015.

WMI staff met with OLA staff and conducted interviews with DNR staff on October 15, 2015. Prior to our meeting, DNR provided WMI numerous documents and computer files describing the deer population model design, model operation, data integrity, and survey methods. In addition, DNR provided scientific articles that related to model parameter estimates. WMI found that DNR staff were knowledgeable and very helpful during the entire evaluation process.

WMI collaborated with two independent consultants from the University of Montana and one independent consultant from the University of Vermont to conduct the technical review of the population model's design, functionality, and sensitivity. These consultants have extensive experience with population modeling and access to the R and S-Plus computer software programs that were used by the DNR.

METHODOLOGY

Evaluation of the design of DNR's deer population model

WMI reviewed DNR's deer population model and critiqued model form, scope, area of analysis and assumptions. We requested DNR to provide the computer code, computer programs and any written documentation of the deer population model along with an example data set. We examined model form and structure and compared and contrasted that with the state-of-the-art in deer population modeling. We examined assumptions for biological realism, practical application and mathematical tractability. We paid particular attention to how sampling and process uncertainty were included in the model, how they were separated for inference and applied in forecasting.

Test of functionality and sensitivity of the deer population model

WMI reviewed historical and current programming for DNR population models. We tested the functionality of the current deer population model in terms of needs of DNR for deer management. We examined how data enter the model and what outputs were produced including measures of sampling and process uncertainty. We developed and applied a simulated test data set to examine internal model functionality. We compared the deer population model functionality and user experience with other modern deer population models.

WMI collected model inputs and re-ran the population model for randomized subset of the Deer Permit Areas for the years of 2012-2015. We evaluated inputs based on research results and timeliness and those based on empirical computation. We conducted a sensitivity analysis to identify and measure the input variables that have a disproportionate impact on model output values. In addition, we compared model outputs to DNR published values.

Data used in deer population models

WMI reviewed the integrity of data used in MN's deer population models. This task required direct access to data used in the population models in an electronic form. We reviewed data sources included in the deer population model and compared that to model requirements as well as requirements for alternative modeling techniques. We examined data storage and retrieval methods focusing on reliability of storage, ease of access, and quality control. We compared and contrasted the deer model data to state-of- the-art methods for storage, transfer and quality control.

Review of deer population survey protocol

WMI reviewed protocols for deer population surveys in MN. We requested documentation from DNR describing deer sampling protocols, analysis

techniques and data processing. We interviewed DNR personnel involved in the design and implementation of deer surveys in-person and by telephone to obtain a better understanding of how deer surveys were conducted in Minnesota. We examined the sampling design and considered how standard statistical sampling principles were considered and applied. We reviewed ways that statistical sampling techniques were applied to deer surveys to reduce bias and improve efficiency. We considered assumptions made in survey design and how those assumptions influenced population estimates. We reviewed statistical analysis procedures to ensure that they aligned with the sampling design and provided efficient estimates.

Review of winter severity index (WSI)

During the course of the model review, OLA requested that WMI evaluate the use of the WSI as a model input. WMI reviewed the literature and conducted telephone interviews with selected state fish and wildlife agencies and Canadian provincial government officials.

FINDINGS AND CONCLUSIONS

Task 1A. Evaluate the design of DNR's deer population model for deer hunting seasons 2012-2015 relative to wildlife management industry practices and expected methodology for Minnesota (a northern U.S. climate).

BACKGROUND AND DEFINITION OF A GOLD STANDARD MODEL

Deer population modeling methods vary widely among state wildlife management agencies. There is no single standard method employed to compare against for this review. Data collected by different agencies varies. Deer population densities vary and deer management objectives vary across states and management units. Currently, states use integrated population models (Johnson et al. 2010, White and Lubow 2000), sex-age-kill models (Millspaugh et al. 2009), accounting models, and expert judgment among other methods to manage deer populations. Therefore, defining a single best modeling method is complicated. To provide a point of comparison, we define a gold standard method incorporating the best statistical methods currently available and strong application to wildlife management.

Our gold standard for ungulate population dynamics modeling strives to balance statistical rigor, management utility and data integrity. Population models should include sufficient biological realism to adequately represent biological processes at the population level without requiring too many parameters resulting in little predictive power (model parsimony is preferable to overfitting). Stated another way, models that perform robustly with fewer parameters are superior to those that require numerous parameters. Arguably the goal of population management is to proactively manipulate populations in a manner that maintains populations within objectives. Several methods of estimating the state of a population rely on linear trends, ignore autocorrelation in the time-series, provide purely historic reconstructions or fail to provide meaningful predictions in the face of uncertainty. The gold standard we chose reflects a desire to proactively manage populations.

Bayesian Integrated Population Models (IPM, also referred to as state-space models) represent the state-of-the-art in population modeling (Schaub and Abadi 2011, Johnson et al. 2010). IPMs combine a biological process model with an observation model for each data source. The biological process model provides a mathematical description of the demographic processes of a population such as survival and recruitment. For example, survival of adult deer could be described by a binomial distribution with population size of adult deer as the number of trials and survival probability as the success rate. The observation model provides a statistical description of the data. For example, estimation of survival from radio-collared animals could be described by a binomial process with the number of collared animals as the number of trials and the number of deer that survive as the outcome. IPMs allow multiple sources of data to be combined into a single population model

including all sources of uncertainty. The IPM separates components of variation into process and sampling uncertainty while explicitly modeling autocorrelation in the time-series. Process uncertainty includes variation in demographic parameters such as survival and recruitment due to variation in the environment and chance events (e.g. whether a newborn animal is male or female or the realized number of animals that die in a given year). In addition, these methods are not simulation based and consequently are less subject to confirmatory workflows.

Features a population model should include:

1. A statistical model that allows for uncertainty in both observation and process.
    a. Observed input is assumed to include sampling uncertainty.
    b. Biological process is assumed to include structural uncertainty or accounts for it by way of multiple models.
2. Model should be fit with a statistically rigorous optimization method.
    a. Markov chain Monte Carlo (MCMC) – MCMC performs numerical integration across a complex and potentially high dimensional surface. It is well suited for fitting Bayesian models. MCMC is currently the best option available for fitting complex population models (Brooks et al. 2004).
    b. Kalman filtering – acceptable, but difficult to implement in general (Besbeas et al. 2002) and in typical form requires biologically unrealistic assumptions that cannot be overcome with the quantity of data typically available to managing agencies
    c. Expectation-Maximization (EM) algorithm – acceptable, but difficult to implement in general (Lange 1998)
3. Model should allow for prediction.
    a. Process uncertainty is carried into the prediction.
    b. Observation uncertainty withheld from predictions.
    c. Future conditions can be modified to evaluate outcome of scenarios in the face of uncertainty.
4. Model should allow for incorporation of previous knowledge derived from scientific inquiry.
    a. Given logistical and financial realities models should incorporate previous knowledge in a rigorous manner that eases data requirements. Prior knowledge can be included in Bayesian analyses through the use of prior distributions. In the case of deer demography, large amounts of scientific literature can guide the shape of a prior distribution for survival and recruitment.
5. Model should be implemented in a way that minimizes the potential for user error.
    a. Options should be selected from lists.
    b. Data should be pulled directly from a centralized database.

c. Code changes should be tracked.
d. User requirements to directly modify code should be minimized.

6. Data should be available to use in the model in real time.
    a. Data should be immediately entered into a central database from which the population model accesses.
    b. Data should be collected and analyzed in a timely manner so that they are available for the next license setting process.
    c. Data entry protocols should be designed to maximize data integrity.

MODEL EVALUATION

Forestland Model used until 2014

The spring population estimate for 2007 appeared to be the starting population and was a single source estimate (not calculated by the model). These initial population densities were derived from population estimates from field surveys (when available), trends in reported deer harvest, and/or the relationship between estimated population densities and adult male harvest (D'Angelo and Giudice 2015). Although the above DNR indices have been used extensively across the nation, these indices are not necessarily accurate and do not include an estimate of uncertainty surrounding the mean estimate.

To further adjust the initial population density, DNR incrementally increased or decreased the initial density estimate. These results were compared to the indices noted above. In addition, the spring/summer adult female survival rates of some DPAs were modified and results were compared with the aforementioned indices (D'Angelo and Giudice 2015). The use of professional judgment and reliance on indices may be adequate to manage deer populations within acceptable population ranges.

The 2007 spring population estimate was the initial starting population for the DNR model calculations. The spring population was broken into adult males, adult females, yearling males and yearling females. The 2007 sex- and age-composition was fixed. The model calculated all other years' composition. All age classes were summed to derive a spring total population. WMI could not ascertain how the 2007 starting population was broken into sex and age classes or how the model's sex and age composition was verified from year to year. WMI was told that DNR does not collect age data on harvested deer that would allow examination of the harvest sex ratio as an index to the population's sex ratio.

The first step of the model was to estimate the number of fawns borne to the spring population. A fetus-per-adult female estimate was multiplied by the number of adult females to calculate the number of fawns borne to adult females. Similarly, the

number of fawns born to fawn females was estimated as the product of the number of spring yearling females and a fetus-per-fawn female estimate. Each fawn population estimate was multiplied by a fawn sex-ratio estimate to divide the fawn population into male fawn and female fawn populations. The number of spring fawns was added to the spring total population to derive a post-fawn total population (D'Angelo and Giudice 2015).

As an example, in DPA #298, estimates for the number of fetuses-per-female was 0.17 fetuses-per-fawn female and 1.51 fetuses-per-adult female. The fawn sex ratio estimate was expressed as 50:50 males:females. The rates did not vary among the years of 2007-2014. WMI understands the origin of the estimated rate was from published literature (Table 1). However, WMI found no support for the assumption that rates did not vary through time.

Table 1. Documentation of survival and reproductive rate estimates provided by DNR.

Author Study years and Habitat	Estimates		
	Season	Survival Rate	95% CI
Grovenburg, et al. 2011	annual	0.76	0.70-0.80
2000-2007	summer	0.97	0.96-0.98
Grassland habitat	fall	0.80	0.76-0.83
	winter	0.97	0.96-0.98
	Season	Survival Rate	
Fuller 1990	annual >1 F	0.69	
1981-1986	annual >1 M	0.46	
Forest habitat	fawns	0.60-0.89	
	Season	Survival Rate	
Grund 2011	summer	0.93-0.95	
1996-1999		0.84-1.00	
Urban/no hunting	winter	0.72-0.95	
Females only			
	Season	Survival Rate	
Brinkman, et al. 2004	annual	0.77	
2001-2002	Jan 01-Aug 02	0.75	
Farmland habitat	neonate summer	0.84	
	Age	Survival Rate	
Carstensen, et al. 2009	neonate 12 wks.	0.47	
2000-2001			

Forest habitat			
	Season	Survival Rate	
Grund & Woolf 2004	summer	0.96-1.00	
1996-2000		0.76-0.96	
Farm-forest transition			
Females only			
Reproduction Rate Estimates			
	Age	Production	95% CI
Grund 2011	fawn	0.28/doe	0.22-0.34
1996-1999		1.65/doe	1.52-1.76
Urban/no hunting			
Females only			
	Age	Production	
DelGiudice, et al. 2007	yearling	1.3 fetuses/doe	
1991-2002	adult	1.8 fetuses/doe	
Forest habitat			
	Age	Production	
Fuller 1990	all females	1.3 fawns/doe	
1981-1986			
Forest habitat			

The second step of the model was to estimate the pre-hunt population of adult males, adult females, fawn males and fawn females. The pre-hunt adult male population was calculated by adding the number of spring adult males and spring yearling males, then multiplying that total by a spring-to-pre-hunt adult male survival estimate. Similarly, the pre-hunt adult female population was calculated by adding the number of spring adult females and spring yearling females, then multiplying that total by a spring-to-pre-hunt adult female survival estimate. The pre-hunt fawn male population was the product of the number of spring fawn males and a pre-hunt fawn male survival estimate. And finally, the pre-hunt fawn female population was the product of the number of spring fawn females and a pre-hunt fawn female survival estimate. The various pre-hunt population estimates were summed to derive a pre-hunt total population (D'Angelo and Giudice 2015).

In DPA #298, estimates for pre-hunt survival were 0.98 for adult males, 0.97 for adult females, 0.76 for fawn males, and 0.76 for fawn females. The rates did not vary from 2007-2014. WMI understands that the origin of the pre-hunt survival rate was from published literature (Table WW). However, WMI questioned that these rates remain constant over time and geographic area.

The third step of the model displayed fall harvest for adult males, adult females, fawn males and fawn females. For each sex/age class, a total (corrected) harvest for firearms and bows was divided by a registration rate statistic to derive total harvest.

In DPA #298, the registration rate was 0.95 for all years. In MN, successful deer hunters must register their harvest at a Walk-In Big Game Registration Station, through an Interactive Voice Response telephone system, or through the Internet using the DNR's website. Although registration is legally mandatory, experience has shown that not all successful hunters register their deer. WMI could not find evidence of the origin or verification of the registration rate value nor that the rate does not vary over time.

The fourth step of the model calculated post-hunt population size for adult males, adult females, male fawns and female fawns. The calculation was configured as an if-then equation:

> *If -- the Pre-hunt pop (for each sex/age class) minus harvest minus crippling loss minus poaching is greater than zero…*
>
> *Then -- Post-hunt Population is equal to that answer,*
>
> *Otherwise -- Post-hunt Population is zero.*

Crippling loss was calculated as the product of post-hunt population size (for each sex/age class) and a crippling rate (for each sex/age class). Poaching loss was calculated as the product of post-hunt population size (for each sex/age class) and an illegal harvest rate (for each sex/age class). Both rates were expressed as the proportion of the registered harvest (D'Angelo and Giudice 2015).

In DPA #298, the crippling rate was 0.1 for adult males and 0.05 for adult females and male and female fawns. Illegal harvest rates were 0.05 for all sex/age classes. Rates did not change over time. WMI was unaware of evidence that the estimated rates are accurate.

The fifth step of the model transformed the post-hunt population for year (t) to a spring population for year (t+1). The transformation relied upon an estimate of overwinter survival, which itself relied upon a winter severity index (WSI) statistic. Adult female overwinter survival was calculated via a formula involving WSI:

For DPA #298, the calculation was:

> *Adult Female Overwinter Survival = 1 – ((WSI * 0.0015) + 0.011)*

Adult male overwinter survival for DPA #298 was set at 0.05 higher than adult female overwinter survival. Male fawn overwinter survival was estimated with an if/then calculation:

If -- WSI is less than 100…

Then – male fawn overwinter survival is equal to 0.84,

*Otherwise – male fawn overwinter survival is 1 – ((WSI * 0.0054) - 0.38)*

Female fawn overwinter survival was calculated as equal to male fawn overwinter survival.

Spring population size for each sex/age class was therefore estimated as the product of post-hunt population size and overwinter survival rate.

Farmland Model used until 2014

The Farmland Model is identical to the Forestland model except Overwinter Survival is set to a constant and was not reliant upon a WSI. In DPA #349, overwinter survival was set at 0.94, 0.95 and 0.85 respectively for adult males, adult females and fawns. Rates did not vary over time (1993-2015).

Excel model for 2012-2014

We examined the Excel model for years 2012-2014. This model represented a deterministic accounting model. We examined the formulae in the Excel spreadsheet. We selected a DPA and checked each formula cell-by-cell for any errors. There did not appear to be any errors in the spreadsheet.

Stochastic model in R initiated in 2015

DNR updated their deer population models to a stochastic accounting model in 2015. This model was implemented in the statistical computing language R (R Development Core Team 2015, www.r-project.org). R is a state-of-the-art statistical development program that is widely used by scientists across many disciplines including wildlife biology and management. Implementing the models in R rather than Excel represents a forward thinking update for MN DNR.

The stochastic accounting model was a simulation model. Parameter values were set within the model for initial conditions, then large numbers of random values were selected from the distributions specified by user-defined parameters. The model was then incremented across years to determine how the deer population changed across time. Finally, values for the deer population such as population size and growth rate were summarized across all of the simulated replicates. By generating a large number of random values from the specified distributions, one can examine the range of variation that may be possible in the deer population.

The simulation models used harvest data in the model (StochasticModule_v8e.R, lines 388-395), but it did not statistically fit the model to data or account for observation error in the harvest estimates. Population estimates were not included in the model at this time. In fact, their inclusion was difficult in a simulation context because the model was not directly fit to data. Beyond setting initial conditions, there was nothing in the simulation process that used the population estimates to guide the population trajectory. This allowed the population model to diverge from observed deer population trends without correction. Typically, abundance estimates were relegated to ad hoc validation procedures such as visual comparisons of population estimates to simulation runs that ignored uncertainty in the estimates.

DNR abundance estimates relied only on the mean of the abundance estimate. Estimates of abundance, like other estimated quantities, include both a point estimate of the value and a measure of uncertainty (e.g. SE). MN DNR chose to ignore measures of uncertainty associated with abundance estimates in favor of a fixed value (0.05). The chosen fixed quantity suggested that abundance estimates were more certain than they actually were and more optimistic than what is routinely achieved by abundance monitoring programs in other states. Instead of assuming a fixed value, an intuitive way of including abundance estimates as the initial state of the population would be to parameterize a normal distribution using the mean of the abundance estimates as the mean of the distribution and the standard error of the estimate as the standard deviation of the distribution. This approach would use all of the information derived from field data collection and honestly represent what is known about the state of the population.

DNR employed numerous indices and relationships among indices to make inferences with respect to relative population size and growth (Grund e-mail to Williams dated 2/19/16). These indices included: actual reported harvest of antlered and antlerless deer, estimated harvest rate, and projected harvest for the upcoming deer season. DNR used these indices and relationships to simulate harvests and to inform their decisions about appropriate harvest strategies (i.e., bucks-only, lottery deer, hunter choice, managed, and intensive management) for each DPA.

WMI recognizes that DNR adopted the new deer population model in 2015. Development of the model is a work in process. Although we identified numerous concerns about the model, WMI believes that DNR understands these concerns and the fact that the model must evolve through time. WMI cautions DNR to assess the model's effectiveness in managing populations and harvest strategies until the model has evolved in its sophistication. In addition, DNR should provide the public with an explanation of the current use of the model, its current weaknesses, plans for improvement, and its role in establishing hunting season structure and permit allocations. Although no population model is perfect, the use of population modeling in a disciplined approach, can inform deer managers about population dynamics and the impacts of mortality that drive or impede population growth.

Further, population modeling provides deer managers with a tool to simulate the impact of different harvest strategies.

Data Storage

Data used in the MN DNR deer models were provided to us in an Excel spreadsheet named "DeerModel_Data_18Apr2015.xlsx". The file contains 5 tables with information on the updates, harvest data, harvest metadata, DPA goals, and winter severity.

The 2015 deer model data spreadsheet was well documented. The Updates Log provided notes, dates and user names for all updates to the spreadsheet. Those data were useful to document how and why data may change through time. The MetaData_Harv table provided a definition for all fields in the harvest data table. Metadata are crucial for long-term consistency and understanding of the information.

Model data were stored in the HarvData and WSI tables. These tables provided clear information about harvest and winter severity by DPA and year. The data was accessed through references to individual cells in the spreadsheet.

Data storage in Excel has limitations. Excel files exist individually on a computer. This could result in DNR staff using multiple copies of the file stored on multiple computers. Individual copies can be updated without all copies being updated leading to inconsistent data among users. Therefore, different users may see different data. In addition, data queries can be difficult, inefficient and unreliable in Excel because fields are defined by column names rather than a database structure that relies on rigorous data indices. Therefore, changes in column or row structures can change the data in unintended ways. Finally, Excel has restrictions on the number of records that can be included in a spreadsheet. While the DNR deer data do not currently approach those limits, changes in data volume could cause limits to be reached.

Task 1B. Test the functionality and sensitivity of DNR's model and outputs (population estimates and forecasts) relative to model-simulated harvest strategies and goals for Minnesota's deer management areas.

Model Testing

We selected a random subset of Deer Permit Areas (DPA) from both Farmland and Forest habitat types. In addition, we tested 6 DPAs based on a request from OLA. We randomly selected units Farmland DPAs 208, 277, 209, 276, 281, 269 and Forest DPAs 176, 197, 171, 122, 177, 172. In addition, OLA requested that we evaluate DPAs 157, 183, 222, 237, 285, and 341.

For each DPA tested, we reviewed the output file provided by MN DNR (file names: "D-101.1.4.2.12 DPAXXX_2010_2015_mgr.pdf" where XXX is the 3-digit code for the DPA). We obtained the initial deer density from the report (input variable "dpsm.t0" on page 1) and crosschecked that value with the median line on the red box plot on page 3 to be sure that the value of dpsm.t0 was not rounded to an integer for display. We then set the input values in the R script ("MN_DeerModel_SeasonSetting2015_v2c.R") to run the model. Specifically, we updated the following lines of code in the R script:

Line 23: updated the working directory to match our computers
Line 25: updated the output path to match our computers
Line 27: updated the source path to match our computers
Line 47: updated path for the DeerModel_data_18Apr2015.xlsx file
Line 49: updated path for the AntlerlessHarvestIntensity_Data_03-16-15.xlsx
Line 51: updated path for the Aerial deer survey results 2005-2014.xlsx
Line 293: set the DPA
Line 306: update "dpsm.t0.mod" for the DPA being tested
Line 327: update "dpsm.t0.input" for the DPA being tested
Line 406: Increased the number of simulation replicates "m" to 5000.

After setting initial values for each DPA in the R script code, we ran the script in R. We then compared the median pre-birth density (dpsm) estimates for 2015 and estimated annual rate of change in the output file generated by the R script (page 4 of "DPAXXX_2010_2015_mgr.pdf") to those in the files provided by MN DNR ("D-101.1.4.2.12 DPAXXX_2010_2015_mgr.pdf"). In our comparison, we considered the fact that this is a stochastic simulation and therefore the results may not match exactly due to random variation in the stochastic process.

We were able to exactly reproduce the results for 11 DPAs (Table 2). The results for one DPA differed by a small amount (8%). The remaining DPAs differed substantially (25-50% absolute difference in 2015 median deer population size). The 11 replicated results demonstrate that the model performed as expected when all of the input parameters match between the simulation runs performed by DNR

and our runs. The results that do not match suggest there was a difference in input parameters. DPAs selected at random and those selected for purposive evaluation by OLA showed the same rate of differences in output (4/12 for random selection and 2/6 for purposive selection). Based on the randomly selected DPAs, we estimate that the rate of differences of 0.33 (SE = 0.14). DNR (Grund e-mail to Williams dated 2/19/16) provided an explanation for the mismatches. Input parameters (summer survival rates and density estimates) were modified in the MN DNR model runs due to model sensitivity to inputs. WMI was unaware of those modifications at the time of our initial analysis.

Table 2. MN DNR stochastic deer model test for 18 DPAs. DNR reported results based on modeler-adjusted inputs (e.g., Summer Survival Adult Female (SSAF) = 0.80-0.93) and modeler reports. WMI results using published indices, R code, and DNR manager reports (e.g., mean SSAF = 0.97).

	MN DNR		WMI		Resulting % Difference Reported Due to DNR Modeler Input Values/ Adjustments/Corrections	
DPA	Pre-birth Density	Growth Rate	Pre-birth Density	Growth Rate	Pre-birth Density	Growth Rate
122	4	0.90	4	0.90	0.0	0.00
157*	19	0.92	19	0.92	0.0	0.00
171	11	0.97	14	1.01	-27.3	-4.12
172	21	0.99	21	0.99	0.0	0.00
176	10	0.94	10	0.94	0.0	0.00
177	14	0.90	14	0.90	0.0	0.00
183*	13	0.97	12	0.96	7.7	1.03
197	10	0.93	10	0.93	0.0	0.00
208	7	1.04	7	1.04	0.0	0.00
209	6	0.91	6	0.91	0.0	0.00
222*	15	0.97	15	0.97	0.0	0.00
237*	3	1.01	4	1.18	-33.3	-16.83
269	4	1.05	5	1.12	-25.0	-6.67
276	11	1.06	15	1.14	-36.4	-7.55
277	22	1.13	22	1.13	0.0	0.00
281	9	1.08	12	1.16	-33.3	-7.41
285*	6	1.05	9	1.15	-50.0	-9.52
341*	12	0.97	12	0.97	0.0	0.00

*DPAs selected by OLA

Testing for syntactical and logical errors

We used a 3-observer mark-recapture approach to check for coding errors. For this approach, each observer independently examined the model code. Observers record the location and nature of each error encountered. We compared to develop capture histories for each error (how many errors were discovered by 1, 2, or 3 observers).
No errors were detected by any of the 3 observers. We therefore estimated that there are zero syntactical and logical errors in the R code in files "MN_DeerModel_SeasonSetting2015_v2c.R" and "StochasticModule_v8e.R".

Coding Best Practices

While the DNR deer models did not contain any identified errors, the coding style could lead to errors and unintended results in the future. The issues can be separated into categories of formatting, object scoping and redundancy.

Format

The R code in files "MN_DeerModel_SeasonSetting2015_v2c.R" and "StochasticModule_v8e.R" is formatted in a way that makes it difficult to understand and operate. For example, the variable "ind" is redefined 20 times in the "MN_DeerModel_SeasonSetting2015_v2c.R" without comments identifying the change in usage or a change in scope. The input variable for initial deer density is defined with a different variable name "dpsm.t0.input" (MN_DeerModel_SeasonSetting2015_v2c.R line 327) than is presented in the output "dpsm.t0" (D-101.1.4.2.12 DPAXXX_2010_2015_mgr.pdf page 1).

User input in the DNR deer model is imbedded directly into the R code and spread throughout the model (lines 23, 25, 27, 47, 49, 51, 293, 294, 295, 298, 299, 306, 327, and 406 in MN_DeerModel_SeasonSetting2015_v2c.R). When user input is spread throughout the code it increases the chance for user error and makes it more difficult for other users to implement the analysis.

In a number of places within the code, year or DPA specific information is hard-coded into the model rather than supplied through input variables (lines 86-100 in MN_DeerModel_SeasonSetting2015_v2c.R). When specific information about years or DPAs is hard-coded, it is difficult to adjust that information and particularly difficult for a new user to understand where or how to adjust the information if needed.

Some of the model inputs that vary by DPA are automatically looked up in Excel tables (e.g. WSI), but two inputs (DPA number and starting density, 'dpsm.t0.input') must be entered manually for each DPA. Requiring a user to enter a critical value manually for each of the approximately 121 DPAs that must be modeled opens the modeling process up to human input error. For these inputs, error could result from entering an incorrect value for initial density, or failing to change the value between successive runs of the model. A better practice would be to consolidate all inputs in

the Excel spreadsheet or a centralized database and program the model to iterate over the 121 DPAs or some specified subset of DPAs.

The code in "StochasticModule_v8e.R" and "MN_DeerModel_SeasonSetting2015_v2c.R" inconsistently begins at the left page margin rather than following standard code indenting conventions for each code block. Beginning all lines of code at the left margin makes it difficult to interpret the code and understand where code blocks such as for loops and if statements begin and end. If some places the code is indented properly, in other places it is not. Examples of good coding style practices can be found at https://google.github.io/styleguide/Rguide.xml and http://adv-r.had.co.nz/Style.html.

Object Scoping

Almost all objects in the DNR deer model are stored in the global environment in R. Functions written in the "StochasticModule_v8e.R" such as *mcsim* (lines 317-563 in "StochasticModule_v8e.R") and *output.mod* (lines 574-980 in "StochasticModule_v8e.R") operate on global variables rather than local variables passed as arguments to the functions. Operations on global variables are at risk of unintended results when global variables are accessed or changed in other parts of the code. This practice of using global objects within sub-environments is beyond a violation of best practice and considered a coding error by the review team despite the syntactic correctness.

Redundancy

Redundant variable declarations exist in the DNR deer population model code. Lines 331-343 in MN_DeerModel_SeasonSetting2015_v2c.R and lines 22-34 in StochasticModule_v8e.R both define the same variables. While the code operates correctly as written, if the values assigned in the variables are changed in one location and not the other, unintended results may be produced. Redundancy is one of the most commons ways to inject errors in code.

Sensitivity Analysis

Sensitivity of a parameter in a population model is the resulting change in model output (Mills 2012). We tested the sensitivity of the MN stochastic deer model by varying two key input variables, initial deer density and the winter severity effect on adult survival. We then compared the resulting 2015 deer density and population growth rate. We chose DPA 208 as the reference DPA for the sensitivity analysis. Given the fixed structure of the model, results will be qualitatively similar regardless of the DPA selected for the analysis.

We varied initial density and the winter severity effect independently while holding all other parameters constant. DNR provided an initial density for DPA 208 of 6

deer per square mile. We varied density from 4-8 deer per square mile in increments of 1 deer per square mile. The R code in StochasticModule_v8e.R line 225 defines the winter severity effect as -0.0015. We scaled that value by a multiplicative change of 0.8-1.2 by increments of 0.1 (a range of 20% increase and decrease).

Variation in initial density resulted in variation in both 2015 population size and growth rate (Table 2). A decrease in initial density from 6 to 5 deer per square mile resulted in a change from a growing (4% per year) to a declining (-7% per year) deer population. Changes in initial deer density caused changes in population growth rate because harvest was included in the model at the observed rate that did not change as a function of population size. The DNR population model was sensitive to the initial population size estimate. This was a weakness in the DNR model. The stochastic model was not fit to population size data therefore any change in the initial population size could not be corrected within the model run process. Rather, DNR relied on expert judgment that was informed by various indices. The high sensitivity to initial density suggested that population estimates were very valuable data points and that a model fit to data such as an IPM will perform more reliably than a simulation model.

These critiques are not unique to MN DNR's application of simulation modeling, but address larger issues with simulation modeling as a management tool. A useful extension to the current approach would be to implement rigorous validation procedures that measure the differences between model outputs and field data not considered by the model. However, such a validation procedure will quickly become onerous and the astute modeler will realize that the model structure is approaching that of an IPM. At a minimum WMI recommends the implementation of validation procedures that utilize abundance estimates to quantify deviations in simulation runs from field based estimates of abundance. This step would fall short of our gold standard, but would allow expensive abundance estimates collected after 2007 (i.e. the first year of simulation) to inform the modeler as to which parameter values are most likely.

Variation in the magnitude of the winter severity effect also caused changes in population size and growth rate (Table 3). Population growth rate remained above 1.0 across the range of magnitude of values considered. WSI influenced variation in adult survival which was often the most sensitive parameter in population models of long-lived species. A 20% reduction in the WSI factor increased population growth from 4% to 7%. This suggested that the WSI parameterization should be carefully considered and should include uncertainty in the parameter values when included in a population model.

Table 3. Sensitivity analysis results for the MN DNR stochastic deer population model implemented in R. Analysis was performed using DPA 208 as a reference DPA. Initial deer density and winter severity effect were varied while all other parameters were held constant. We examined changes in 2015 deer density and population growth rate.

Parameter	Value	Deer density in 2015	Population Growth Rate
Initial Density	4	3	0.92
	5	4	0.99
	6*	7	1.04
	7	9	1.07
	8	11	1.09
WSI factor	0.8	8	1.07
	0.9	7	1.06
	1*	7	1.04
	1.1	6	1.02
	1.2	6	1.02

* Value used in MN DNR population model for DPA 208

Discussion and Recommendations

DNR updated their deer population model during the evaluation period of this review. The update switched the model from a simple Excel-based deterministic accounting model to an R-based stochastic accounting model. The model update represented a substantial move forward in modeling sophistication; therefore the bulk of this discussion will focus on the new model form.

In 2015, DNR expanded their deer population model to allow for stochastic dynamics through a simulation model in R. This change allowed biologists to consider the range of variation in deer population dynamics that may be possible given a set of input parameter values. This provides a more realistic representation of the level of uncertainty biologists have in the systems they manage.

DNR deer population model data, including modelers' notes and reports, are currently stored in Excel spreadsheets. The spreadsheet was saved to a central agency computer, which provided back-up storage to prevent data loss. Unfortunately, Excel spreadsheets impart many limitations and challenges for data storage. Spreadsheets lack data integrity because every cell is unique and inconsistency becomes likely. Values displayed in a spreadsheet may not represent the underlying data (e.g. a number stored as a character or a formula). Spreadsheets lack the ability to scale well. Excel has storage limits that constrain

the amount of data and performance declines as the amount of data increases. Finally, collaboration is difficult using spreadsheets. It is difficult to maintain version control and a "master" spreadsheet as the number of users increases.

Data storage and sharing could be improved by building a central database to house deer population data. Database structure enforces consistency within a field (column). All rows in a specific column must have the same data type. Databases allow consistent and efficient merging of data across different tables. Agency employees can access a database to obtain past data and store newly collected data. The database could allow different levels of access (e.g. read versus edit) to different employees depending on their job duties. A central database allows real time, coordinated access to agency data without the risk of different people using different copies of the data. (More information on the advantages of databases over spreadsheets is available at http://schoolofdata.org/2013/11/07/sql-databases-vs-excel/.)

The current DNR deer population model is scripted in R with user inputs coded directly in the model. The user inputs were scattered throughout the code making interpretation difficult. It would be advantageous to place all user inputs at the head of the code with clear comments describing what values need to be adjusted. An even better solution for standardized user input is to have a user interface with drop-down menus connected to a central database. A user interface could prevent unintended entries in the model.

We found no syntactical or logical errors in the R code. This is highly commendable given the complex nature of the code. To reduce the chance of future errors, we recommend that coding best practices be more strictly followed. When possible move scripts into functions that clearly define specific programming tasks. Pass arguments to functions rather than use global variables. Consistently indent code blocks for clear interpretation of the code. Finally, use of code versioning software (e.g. Git, Subversion) would make changes explicit, record scenarios and provide a record of all changes to the code base. Code development and maintenance is challenging, but the long-term benefits in interpretation are worth the effort.

Model testing demonstrated repeatability of results for 11 of 18 DPAs. The fact that we were able to exactly replicate models runs for a substantial number of DPAs suggests that the model code was performing as expected. For DPAs runs that differed between our runs and those performed by DNR, we suggest that there were differences in input parameters. DNR provided explanation for the differences. To increase repeatability of model results, input values should be stored more clearly. All input variables should be displayed in the output reports to level of precision used in the input. For example, initial density is displayed as an integer, but sometimes input as a decimal value, implying a level of precision not actually attained. In addition, it may be useful to have a comment field in the output file to note any DPA specific changes that may have been made for that unit based on expert opinion or other reason. Finally, revising the R code to improve object

scoping, variable redundancy and data connections will help prevent unintended values from entering the model.

The stochastic accounting simulation model contained some of the features of a gold standard model, but was missing other features. Table 4 highlights each main point and contrast IPMs with the simulation model.

Table 4. Evaluation of the MN DNR population model relative to an IPM gold standard.

Gold Standard Attribute	DNR Model Evaluation	Recommendation
Allows for uncertainty in observation -- variation caused by the inability to know an exact parameter value.	Incorporated process uncertainty in the form of a stochastic distribution on demographic parameters. The uncertainty was an arbitrarily defined parameter, typically based on published values. All model parameters were assigned and assumed to be fixed. This ignored uncertainty inherent in model parameters.	Some parameters could be estimated from data rather than sourced from literature.
Allows for uncertainty in process -- variation caused by sampling uncertainty.	The simulation model did not include observation uncertainty.	Sampling uncertainty can be estimated by non-parametric bootstrapping or an alternative method.
Model fit with a statistically rigorous optimization method.	Input parameter values were based on surveys or literature values. The model is then run with those parameter values and adjusted based on professional judgment and external data sets (indices and trends).	Update growth and harvest rates with values from trends observed in the data.
Model data-driven with documented, transparent link between inputs and outputs.	DNR simulation models used data inefficiently because data were not brought directly into the model to inform the simulation, they were only available for ad hoc comparison. DNR simulation models risked providing confirmatory results where the user could adjust the model inputs to achieve expected results without a penalty for model fit.	Use data to fit a statistical model robust to input sensitivity.
Model allows for prediction.	Process uncertainty was carried into the DNR model predictions.	Changes in harvest or survival rate could be included in predictions of future population size to evaluate effects potential management actions on deer populations.
Model allow for incorporation of previous knowledge derived from scientific inquiry.	All DNR model parameters were based on published values or expert judgment.	
Model implemented in a way that minimizes the potential for user error.	R code for the DNR deer model was complex and required multiple user changes throughout the code.	Improvements could be made to the DNR workflow by centralizing user input values or adding an interface to control user interaction with model.
Data available to use in the model in real time.	DNR data were stored in an Excel spreadsheet leading to potential data storage and data input issues described above. DNR data were not available in real time, but only as the spreadsheet was updated and loaded to the central server.	Developing a central DNR database to house deer data would improve this workflow.

Task 1C. Audit the integrity of data collected by DNR and used for modeling.

The evaluation of the integrity of data used in the model must be viewed in the context of the model structure and the difficulty in acquiring accurate and precise estimates for model input data. The description of the model provided in the Model Evaluation section (see above) is based on the deterministic spreadsheet model of the population dynamics within each Deer Permit Area (DPA) (D'Angelo and Giudice 2015).

The adoption of the new stochastic population model using Program R in 2015 incorporates the same parameters (Table 5) and process; however, the 2015 model introduced variability (based on a normal distribution) into input parameters (Cornicelli memo to Williams dated 10/8/15). This inclusion better mimics nature's variability and provides a range of potential population estimates given the uncertainty associated with the estimation of population vital rates.

Table 5. Parameter estimates used in the MN DNR population model.

Reproduction Rates

	Forest – NE	Farm-Forest Transition	Farm - SE
yearlings	0.06	0.10	0.15
adults	1.55	1.75	1.85

Spring/Summer Survival Rates

	WSI<100	100<WSI<180	WSI>180
fawns	0.80	0.65	0.45
adult males	0.98		
adult females	0.97		

Fall Harvest & Survival Rates

	All DPAs
male fawn	reported harvest*1.05 non-reg*1.05 loss*1.05 illegal
female fawn	reported harvest*1.05 non-reg*1.05 loss*1.05 illegal
adult male	reported harvest*1.05 non-reg*1.05 loss*1.05 illegal
adult female	reported harvest*1.05 non-reg*1.05 loss*1.05 illegal

Winter Survival Rates

	WSI<100	100<WSI<180	WSI>180	WSI>240
fawns	0.85	1-(0.011+0.00150*WSI)-0.05	1-(0.0054*WSI-0.33)	0.033
adults	0.95	1-(0.011+0.00150*WSI)		

"non-reg" = non-registered deer harvest rate

The Forestland and Farmland Population Models were accounting models and included data for 2007-2014. The models displayed population composition and size for spring, pre-hunt and post-hunt. The models also displayed harvest. The only distinction between the Forestland and Farmland Models was the use of the winter severity index.

DISCUSSION AND RECOMMENDATIONS

The estimation of white-tailed deer population vital rates (reproduction and mortality rates) is extremely difficult. These rates vary temporally and geographically. In addition, it is expensive to secure adequate sample sizes to estimate a rate across a DPA, much less the entire state of Minnesota. Therefore, it is routine for deer managers throughout the nation to rely on published literature and other indices to estimate these rates. DNR has conducted a number of research projects through time and geography that form the basis of their estimated rates.

WMI's review of the majority of these published rates indicated that they were sufficient to provide model parameters. However, WMI does question the validity of the consistent estimates, across space, for non-registration of deer harvested nor illegal harvest. WMI could find no evidence of their validity. In addition, we question the constant use of these parameters from year to year without any apparent measure or validation that the assumption is appropriate. This shortcoming may be overcome by conducting additional field research to inform both rate estimates and their measures of uncertainty. WMI recognizes that the expense and logistics of this type of research may be prohibitive. The winter severity index evaluation is found later in this document.

Task 1D. Through document review and interviews, evaluate recent DNR methods for surveying Minnesota deer populations, including distance and aerial survey design and execution, sample size, and survey techniques. Identify any deficiencies.

The OLA tasked WMI with evaluating recent DNR methods for surveying deer populations, including distance and aerial survey design and execution, sample size, and survey techniques. In particular, WMI was charged with identifying any deficiencies in the survey methodology.

WMI addressed this task by requesting and reviewing documentation from the DNR that summarized the methods used and results obtained through distance and aerial sampling of deer populations. WMI also interviewed DNR staff in person on October 15, 2015 and requested additional information in writing as a follow-up to the interviews. WMI evaluated the design and execution of surveys, sample sizes, and survey techniques used by DNR in relation to standards for similar surveys of deer and other ungulate populations in similar habitats found in peer-reviewed publications. WMI's analysis also relied on team members' experience conducting aerial surveys.

DNR informed WMI that distance sampling is being evaluated for possible future use, but at present distance sampling plays no part in deer management (Cornicelli memo to Williams dated 10/8/15; D'Angelo memo to Williams dated 10/27/15). Because DNR has not yet established or applied a defined methodology for distance sampling, there is nothing for WMI to evaluate in relation to design, execution, sample size, or techniques for distance sampling.

DNR provided WMI with copies of the Annual Summaries of Research Findings published between 2005 and 2010 and Annual Status of Wildlife Populations reports published in 2013 and 2014. These reports summarized methods and results for aerial surveys conducted between 2004 and 2014. From these reports, WMI determined that DNR conducted aerial deer surveys in the Farmland and Farmland – Forest Transition Zones each year from 2004 through 2011, as well as 2013 and 2014 (Haroldson et al 2005; Haroldson and Giudice 2006, Haroldson 2008, 2009; Dexter 2013, 2014). No aerial surveys were conducted in 2012 or 2015 due to inadequate snow cover (Cornicelli memo to Williams dated 10/8/15). DNR reported that aerial surveys were not conducted in the Forest Zone due to low sightability of deer in that zone (L. Cornicelli, pers. comm. during interview).

DNR informed WMI that the primary purpose for conducting aerial deer surveys was to periodically recalibrate the starting population values used in the deer population model as recommended by Grund and Woolf (2004). Haroldson (2009) stated aerial surveys were also intended to provide a means to assess the effectiveness of three non-traditional harvest regulation packages for reducing deer numbers. However, DNR clarified that this statement only applied to a limited

number of surveys, conducted to provide density estimates used to evaluate harvest efficiency (DNR memo to V. Bombach dated 2/17/2016).

Throughout the analysis period, DNR's aerial survey methodology was based on quadrat sampling, using Public Land Survey sections as the basic sample unit (quadrat). Each year during late-summer or fall, a prioritized list of Deer Permit Areas (DPAs) was developed for sampling by the Farmland Wildlife Populations and Research Group based on consultation with field personnel regarding the need to validate population model outputs, other research needs, preferences of area and regional staff, and availability of funding (D'Angelo memo to Williams dated 10/27/16; L. Cornicelli, Pers. Comm. during interview). Surveys were scheduled to progress from the highest priority DPA identified in the fall down the list. However, which DPAs were actually surveyed in a given year was a function of survey conditions, available aircraft and other factors discussed below (L. Cornicelli, Pers. Comm. during interview). The number of DPAs surveyed averaged 4.75/yr. and ranged from zero to nine (Cornicelli memo to Williams dated 10/8/15).

DNR used simple random sampling, stratified random sampling, 2-dimensional systematic sampling, or generalized random tessellation stratified procedures (GRTS; Stevens and Olsen, 2004) to draw sample quadrats within each DPA selected for surveying (Haroldson 2009, Dexter 2013, 2014). The method used to select quadrats for sampling with a given DPA depended on habitat characteristics and prior knowledge of deer distribution and abundance, and was intended to reduce variance of the resulting estimate (Haroldson 2009). The methods used to select quadrats within a DPA became more sophisticated over the analysis period in response to increased experience of DNR staff, development of improved statistical methodology, and the availability of enhanced, open-source computer software (e.g. R programming).

The minimum sample size used throughout the analysis period was 20% of the quadrats within a DPA. Haroldson and Guidice (2006) reported this sample size was based on the desire to generate population estimates within 20% of the true population size with 90% confidence. In some DPAs, sample size was increased by including all quadrats within a state park or all quadrats in the "high density" stratum, either of which would be expected to increase the accuracy of the final estimate.

Aerial surveys were conducted using line transects. Flight lines were spaced approximately 270 m apart and pilots attempted to maintain an average altitude of 60 m above ground level and airspeed of 64 – 80 km/hr. In 2004 - 2006, three of fifteen DPAs were surveyed using fixed-wing aircraft and twelve were surveyed with DNR-owned OH-58 helicopters. Based on increased visibility and the capacity to operate safely at lower airspeeds using helicopters, all surveys conducted after 2006 were flown with the OH-58 platform (Haroldson 2009).

Each survey crew consisted of a pilot and two observers, one seated beside the pilot and the other behind the pilot. Each observer was responsible for detecting deer on one side of the aircraft. The pilot varied survey intensity based on snow cover and deer density and assisted with detection of animals as a secondary responsibility to maintaining altitude, airspeed and heading and safely operating the aircraft (Haroldson 2009). DNR reported that experienced personnel trained less-experienced observers and that individual sorties were limited in duration to avoid bias due to missed observations (L. Cornicelli, Pers. Comm. during interview). DNR reported using a real-time, moving map software program developed by and for DNR (MN DNRSurvey; Wright et al. 2011), coupled to a global positioning system receiver and a convertible tablet computer, to guide transect navigation and record observations of deer and aircraft flight paths directly into ArcGIS (Environmental Systems Research Institute, Redlands, CA) shapefiles (Haroldson 2009). Data collected for each observation included the number of deer seen, their direction of movement relative to the person making the observation and the date and time recorded to the second (Grund memo to Erickson-Eastwood dated 5/15/14). This system minimized the risk of data transcription errors and allowed more rapid and accurate analysis of survey results.

Aerial surveys were conducted during mid- to late-winter after leaf-drop from deciduous vegetation and when complete snow cover was $\geq$ 15 cm to maximize observability of deer (Haroldson et al 2005). DNR reported that it typically takes two to three days to survey all the selected quadrats within a selected DPA (D'Angelo email to Smith dated 12/22/15). Completing the surveys within that timeframe minimized bias associated with movement of deer between quadrats during the survey period. Movement between quadrats was also likely to be minimal due to the small size of Minnesota deer winter home ranges, < 1mi^2 (Rongstad and Tester 1969).

DNR staff cited the requirement for complete snow cover during interviews as a major limiting factor for conducting aerial surveys. Two other factors were identified that limit DNR's ability to conduct aerial deer surveys.

Aerial surveys required significant investments of staff time and operational funding. Although other factors have had a greater effect on limiting overall survey effort in recent years (L. Cornicelli, Pers. Comm. during interview), available resources could affect DNR's ability to conduct sufficient surveys to meet management needs in the future.

A more significant limiting factor was availability of DNR aircraft and pilots. DNR's priority use of the OH-58 helicopters during winter was moose surveys (L. Cornicelli, Pers. Comm. during interview). These aircraft and pilots were not available to fly deer surveys until moose surveys are completed and necessary maintenance and mandatory pilot rest periods were completed. As a result, deer surveys could only be conducted during the relatively narrow window after moose

surveys are finished and before the snow melts. Climate change may reduce this timeframe further in years ahead.

From 2005 - 2008, DNR reported they used SAS Proc SURVEYMEANS (SAS 1999) to estimate deer numbers from data collected in DPAs surveyed using stratified random sampling and formulas from D'Orazio (2003) for DPAs surveyed using systematic sampling (Haroldson 2009). Beginning in 2009, DNR added R programming language, including R package SPSURVEY (ver. 2.0; RDCT 2009) for DPAs where GRTS was used to select sample quadrats (Haroldson 2009). DNR reported they evaluated precision of their population estimates by estimating coefficient of variation (CV) defined as standard error of the population estimate divided by the estimate, and relative error (RE), defined as the 90% confidence interval divided by the population estimate (Haroldson 2009).

DNR was aware that observers do not detect all deer within a quadrat during an aerial survey (Lancia 1994) and initiated efforts to correct for "missed" deer in 2009 as recommended by Steinhorst and Samuel (1989). Following procedures outlined by Eberhardt and Simmons (1987), and Thompson (2002) DNR used double sampling of a subset of quadrats within two of four DPAs surveyed in 2009 and three of seven DPAs surveyed in 2010 to evaluate their ability to estimate a "sightability correction factor" (Gasaway et al. 1986) that could be applied to the results of a standard survey to generate a more accurate estimate of deer numbers and density (Haroldson 2009).

Immediately after completing the operational survey of a selected quadrat, a re-survey was conducted at a reduced speed of 48-64 km/hr. Observers used information recorded from the operational survey in DNR Survey to distinguish between deer observed on the first survey and those observed on the second. Deer observed on the first survey were treated as "marked" deer and deer seen only on the second survey were considered "new" deer. The probability of sighting any deer in the quadrat was estimated as the number of "marked deer" divided by the number of "marked deer" plus the number of "new" deer. The estimated probability of sighting any deer within the DPA was assumed to be the mean of the probabilities for the double-sampled quadrats.

In 2010, DNR estimated sightability in three of seven DPAs surveyed using the same flight protocol, but with a more advanced statistical approach that allowed computation of the variance in the probability of sighting as recommended by Fieberg and Giudice (2008). Nevertheless, Haroldson (2009) acknowledged that estimates derived using the SCF remain "approximations of the truth" and stated that additional sightability trials would be needed to determine how the probability of sighting deer varies over space and time.

Based on results from 2009 and 2010, MN DNR began conducting sightability correction surveys on 4% of the quadrats in each DPA surveyed and applying the resulting correction factor to population estimates for all surveys conducted from

2011 – 2015 (Dexter 2013; D'Angelo email to Smith dated 12/11/2015). This change in estimation makes estimates for these years more accurate, but makes comparison of estimates from surveys prior to 2010 impossible.

DISCUSSION AND RECOMMENDATIONS

DNR's decision to use quadrat sampling for aerial surveys was scientifically sound. Quadrat sampling is commonly used for estimating wildlife populations and recognized by the profession as a standard practice (Krebs 1999, Lohr 2010). Importantly, quadrat sampling allows generation of estimates of population size (or density) with associated measures of precision, both of which are important for making management decisions.

DNR's decision to limit aerial surveys to the Farmland and the Farmland-Forest Transition Zones due to low sightability in the Forest Zone was logical. Overcoming sightability limits in forested habitats would significantly increase the cost of aerial surveys in the Forest Zone. In neighboring Wisconsin, which also contains extensive forested habitat, aerial surveys are limited to their Chronic Wasting Disease (CWD) monitoring area (Rolley emails to Smith dated 12/11/2015). Wisconsin conducted helicopter surveys in two study areas in December 2013 and January 2014, applying a protocol similar to that employed by MN DNR (Rolley 2014; http://MN DNR.wi.gov/topic/wildlifehabitat/population.html, accessed 12/11, 2015), but without any SCF. Wisconsin has used fixed-wing surveys over the entire CWD monitoring area to monitor trend, but these surveys only provide an index to population size, not a statistically bounded estimate (Rolley 2014; Rolley email to Smith dated 12/11/2015). Another nearby state, Michigan, does not conduct any aerial surveys for deer (Lederle email to Smith dated 12/13/2015).

DNR's use of Public Land Survey Sections (1 mi^2) as the sample unit for quadrat sampling was a valid and efficient approach. A square mile is large enough to be representative of the habitat within a given stratum within a DPA, while also small enough to be completely surveyed (and resurveyed if used for the SCF calculation) within a short enough time period to minimize observer fatigue or significant movement of deer within, into, or out of the sample unit all of which would compromise results. Bias due to deer movements between quadrats was also minimal because deer winter home ranges in Minnesota average less than one square mile, (Rongstad and Tester 1969). Use of GPS tracking systems in the aircraft and the tablet computer ensured that the flight lines and observations fall within a selected quadrat.

Stratification of quadrats into high and low density strata, use of GRTS (Stevens and Olsen, 2004) to optimize sample distribution when appropriate, and using a minimum sample size of 20% of the quadrats in a DPA are appropriate and effective techniques to improve the precision of estimates (Lohr 2010). The relative errors of results reported by DNR for aerial surveys improved over time, from a mean of 26.9

in 2011 (MN DNR unpub. "Aerial deer survey results 2001-2014" provided to Williams 2015) to 17.0 in 2014(Dexter 2014). Nevertheless, the size of the confidence intervals surrounding the density estimates limits their utility in relation to the stated purposes for conducting aerial surveys, as discussed further, below.

The protocol DNR reported for conducting surveys was consistent with standard practices for aerial surveys of deer and other ungulates (Lancia et al 1994, Unsworth et al 1994). The spacing, elevation, and airspeed of flight lines; use of multiple observers; training of observers; and use of real-time data logging linked to GPS tracking software met or exceeded standards for surveys of this type.

DNR's development of SCFs in 2009–10 and application of SCFs to all estimates beginning in 2011 was an important improvement over earlier years in relation to MN DNR's stated purpose of conducting aerial surveys to recalibrate population model inputs. DNR's approach to development and application of SCF complied with recommendations by Pollock and Kendall (1987) and Fieberg and Giudice (2008). Results from surveys that were not corrected for sightability could be used to monitor trends in population, but without the SCF, results could not be used to estimate density for purposes of recalibrating the deer population model.

The non-random process used to select which DPAs to survey in a given year allowed DNR to focus effort on those DPAs where there was the greatest need to recalibrate the model or address other management questions. However, the limited number of DPAs surveyed in any given year (mean = 4.75) precluded DNR's ability to meet the recommendation in Grund and Woolf (2004) to recalibrate the model for a given population (i.e. DPA) "every few years." DNR would need to substantially increase the number of surveys conducted annually to meet that recommendation.

DNR's priority use of aircraft and pilots for moose surveys, combined with the effects of climate change on the depth and duration of snowpack, limit DNR's ability to increase the number of DPAs surveyed each year. Even without these constraints, available staff and operating resources may preclude DNR from increasing deer survey efforts substantially.

WMI found that, overall, DNR's design and execution of aerial surveys, sample sizes and survey techniques met or exceeded accepted standards. The use of quadrat sampling, based on Public Land Survey Sections, was a valid and efficient sample design. The protocol used to conduct aerial surveys ensures collection of accurate data and facilitates rapid analysis of results. Calculation of SCFs allowed DNR to estimate actual deer density, which was necessary to fulfill one of the stated purposes for conducting aerial surveys, recalibration of the population model inputs.

Although the survey methods and execution are sound, WMI found a number of problems with use of the results for model validation. As discussed above, the

limited number of surveys DNR can conduct each year constrains use of aerial surveys to recalibrate the population model. WMI also found that aerial surveys occurred in the winter between model estimates of post hunt population density and spring population density. The timing of aerial surveys means that the population of deer sampled within a DPA is not necessarily, or even likely to be, the same as the population being modeled due to seasonal movements of deer. The asynchrony between timing of surveys and model density estimates may explain why WMI found that aerial survey population density estimates did not fall within the range between fall and spring modeled population densities in 4 of 6 DPAs surveyed (Table 6). DNR staff indicated they are aware of this problem and are exploring options, including distance sampling, to better align the timing of direct estimates of population density and model predictions of density.

Table 6. Deer population density (deer/mi^2) estimates derived from aerial surveys in Minnesota in 2014 (Dexter 2014) compared to model estimates pre- and post-aerial surveys.

Permit	Aerial Survey Density Estimate		Population Model Density Estimate	
Area	Mean	90% CI	2013 Post- Hunt	2014 Spring
221	7	6-9	14.6	13.0
222	15	13-18	17.2	15.2
239	10	8-12	10.8	9.8
342	10	8-12	14.8	13.4
346	35	30-41	33.0	29.9
349	30	26-33	30.1	27.3

Finally, although the surveys were relatively precise, the 90% confidence intervals surrounding density estimates reported in Dexter (2014) were as large as 11 deer/mi^2. Given the sensitivity of the population model to initial density input, this range limited the value of aerial survey results for use as either initial density input values or as a check on model outputs. Nevertheless, DNR staff informed WMI they believe the surveys provide useful information to the modeler (DNR memo to V. Bombach dated 2/17/2016). Consistent or significant differences between aerial survey and population model results serve as an indicator that DNR needs to reassess the validity of survey results to reflect density of the modeled DPA populations due to seasonal re-distribution of deer or due to differences between model parameters and actual demographic patterns within the population. Thus, rather than being viewed as a direct measure of model accuracy, aerial survey results constitute one additional source of information that managers can use in making professional judgements about deep population status and trend.

WMI expressed our concern to DNR staff about the relationship between model estimates and aerial estimates. In response, DNR provided the following graph (Figure 1) based on aerial surveys conducted between 2010 and 2014 on 25 different DPAs (Grund e-mail to Williams dated 2/23/16). WMI could not reconcile

all values between the model spreadsheets provided to WMI and DNR annual reports.

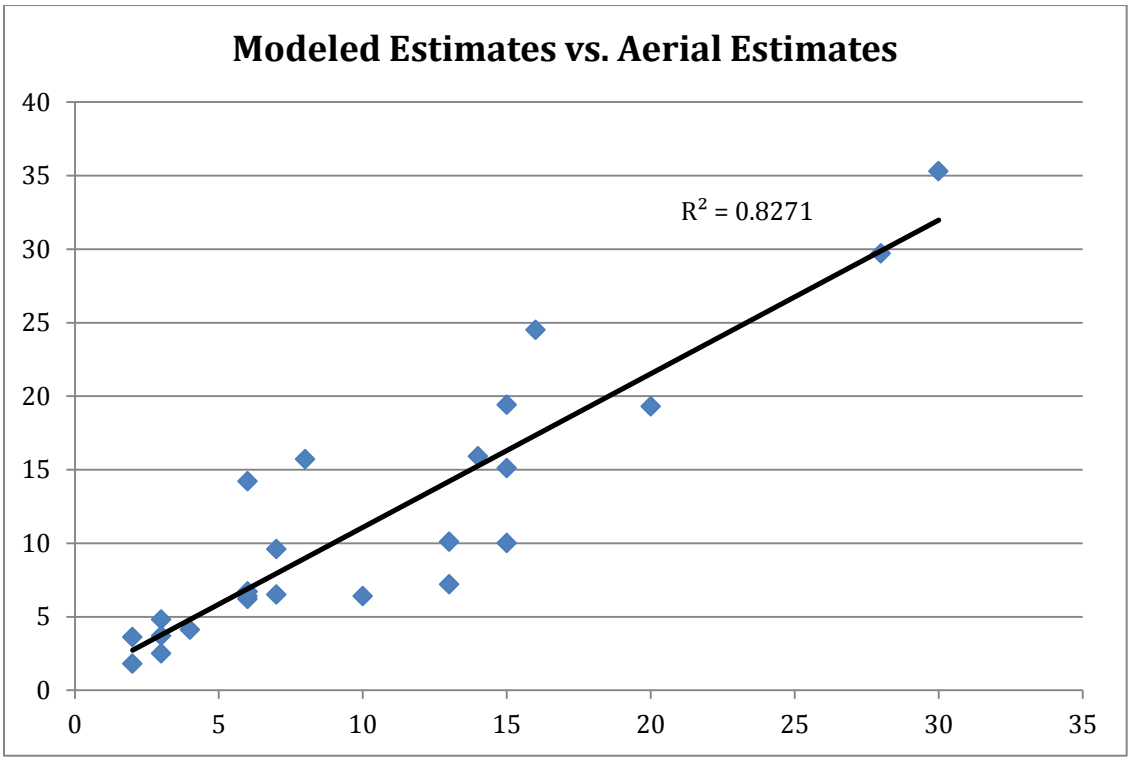


Figure 1. DNR population model estimates, as reported in annual reports, correlated to aerial estimates provided by DNR for 25 DPAs between the years of 2010 and 2014.

Although aerial surveys were not conducted in the Forestland Zone, WMI was aware that DNR modified the denominator (square mile) used in estimating deer density per square mile in the Forestland Zone some years ago. This change was made to exclude water body surface areas. WMI concurs with the modification. However, based on discussions with DNR staff, this change was not communicated adequately to some stakeholders leading them to question the validity of DNR population density estimates. Based on our experience evaluating deer management processes elsewhere, it is common for fish and wildlife agencies to be criticized for reporting different estimates from one year to another, even through there may be valid justification for such changes. WMI recommends DNR do a better job of informing stakeholders of the rationale and justification for changes to published data. In making this recommendation, we note that, despite the best attempts by state agencies to communicate decisions to the public, it is not unusual that there are stakeholders who question such decisions and seek more information.

Winter Severity Index

Winter weather conditions – snow depth, snow compaction, minimum temperature and wind chill -- have been shown to exert a significant effect on dynamics of deer populations in northern states and southern provinces.

White-tailed deer increase body fat reserves in late summer and fall, and then essentially live off those reserves until spring green-up in March or April. Mean percent body fat rose from 9.1 to 24.9 percent from September to December, and then declined through February in New Hampshire deer studied by Worden and Pekins (1995). In the same study, mean metabolizable energy intake declined 54% by February.

To slow the use of fat reserves, deer concentrate in areas with reduced snow depth and stable temperatures. Winter ranges are frequently coniferous, with thick, overlapping overstories and understories (Dumont et al. 1998), but steep south-facing hardwood slopes also may be used (Dickinson 1976). The primary purpose of winter range is to lessen the energetic demand of withstanding low temperatures and traveling through deep snow. Deer densities on winter range often are 10 times greater than summer range (Broadfoot et al. 1996) as deer concentrate in these topographically or vegetatively unique areas.

Mautz's (1978) analogy of deer sledding on a bushy hillside provides an appropriate description of the interaction between winter severity, winter food availability, and northern deer survival. Winter browse supplies slow the descent to mortality, but if the winter is severe enough, or if fall fat levels are inadequate, deer will not survive because fat reserves are depleted. (Mautz 1978).

The most immediate and apparent impact of the winter environment is the increase in mortality of deer due to starvation. Mortality associated with winter severity may be additionally correlated with changes in deer vulnerability to predation due to winter environmental conditions.

For those deer that survive the winter environment, malnourishment can exact a less apparent, but as significant, impact to the population by lowering reproduction through absorption of embryos and increasing neonatal mortality in the subsequent spring, and lowering conception rates and litter size in the subsequent fall breeding season.

A Quebec white-tailed deer population decreased by 71% in 8 years, with winter mortality rates exceeding 40% for the population in some years (Potvin et al. 1981). Most of the mortality was concentrated in fawn or adult female age/sex categories. Potvin et al. (1981) suggested that the extreme mortality rates resulted from high winter severity rather than from over-population.

Mech et al. (1987) found that 36-51% of the variation in fawn:doe ratios was explained by the summation of snow accumulation over the 3 previous winters. Mech et al. (1987) believed that fecundity and fawn survival in any 1 year reflected accumulated effects of winter severity, either directly through fawn mortality or indirectly through the diminishment of physical condition of adult females. (See also Messier 1995 and McRoberts et al. 1995).

Winter severity was 1 of 3 factors explaining white-tailed deer population growth in Nova Scotia (Patterson and Power 2002). The authors believed that the effects of winter severity on over-winter survival may be cumulative over 2 consecutive winters. During the late 1980's, density dependence and winter severity effects both contributed to substantial declines in deer populations (Patterson and Power 2002).

The Wildlife Management Institute (Williamson 2003) conducted an assessment of deer management strategies to assess whether agencies can effectively monitor population dynamics through metrics commonly available to agency biologists. Sixteen jurisdictions in northeastern U.S. and southeastern Canada provided data for 546 deer management units under their control. Data were collected 1990-2000 and represented typical harvest and check station data collected by wildlife management agencies. Fawn frequency was negatively correlated with a snow depth index (SDI) suggesting that winter severity influences the production of spring fawns, and hence the ratio of fawns to adult does in the fall harvest (Figure 2).

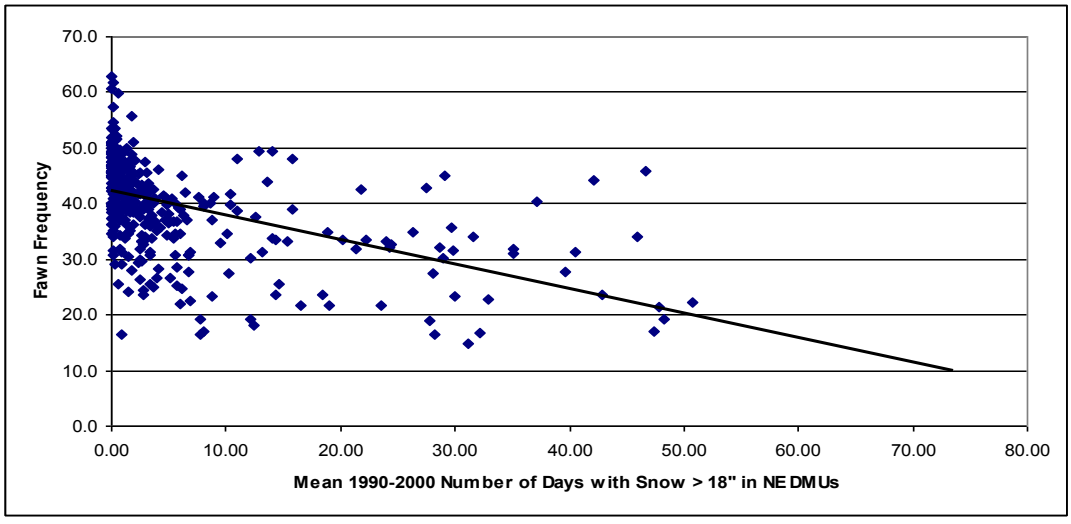


Figure 2: Relationship between the frequency of fawn age classes in the harvest and the number of days with snow >18" in northeastern deer management units (Williamson 2003).

Buck harvest density was negatively correlated with SDI values and both variation in buck harvest density and variation in yearling buck frequency were positively correlated with winter severity. If buck harvest density is considered as an index to population size, this correlation illustrates the effect of winter severity on the total population mortality rate.

Winter Severity Indices (WSI) were created to allow managers to objectively evaluate the likelihood of winter effects on population size. Early researchers attempted to mimic the metabolic cost of a deer enduring winter by the use of a chillometer (Verme 1968). The chillometer is essentially a modified pressure cooker and the chill index is the amount of energy required to keep a constant volume of water sealed in the chillometer at a constant temperature. WSI's also utilized snow depth as a variable reflecting the energetic cost of walking and the degree to which food supplies are inaccessible. Some indices transform snow depth to sinking depth through the use of a compaction gauge.

USE OF WSI

State wildlife management agencies in northern climates have developed and employ a variety of ways to measure winter severity.

New Hampshire uses NOAA weather station data collected from around the state to construct a WSI (K. Gustafson, NH Fish and Game Department, personal communication, 12/11/2015). The WSI combines 1) the number of days between December 1 and April 30 with snow depth greater than 18 inches and 2) the number of days between December 1 and April 30 where minimum daily temperature is $<0^{o}$ F. The WSI then assigns a 0, 1 or 2 "score" for each day in the reporting period, producing a WSI potentially ranging between 0 and 302.

Vermont uses the same WSI as NH with measurements taken daily at stations around the state (currently 37 stations) between December 1 and April 30 (Nick Fortin, Vermont Fish and Wildlife Department, personal communication, December 14 2015). VT has demonstrated that WSI is negatively correlated with fawn:doe ratios sampled from road-killed females (Figures 3 & 4)(VTFW 2009).

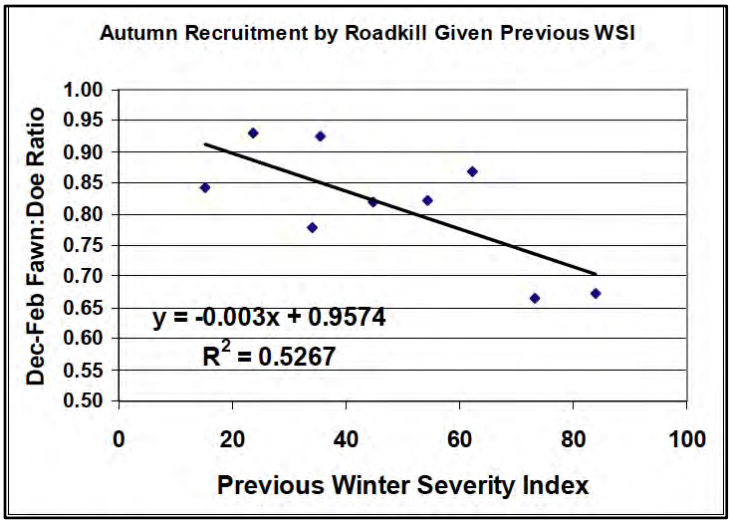


Figure 3: Change in state-wide post-hunt fawn: doe ratio collected from road killed females during the months of December-February following winters of varying severity in VT, 2000-2008 (VTFW 2009)

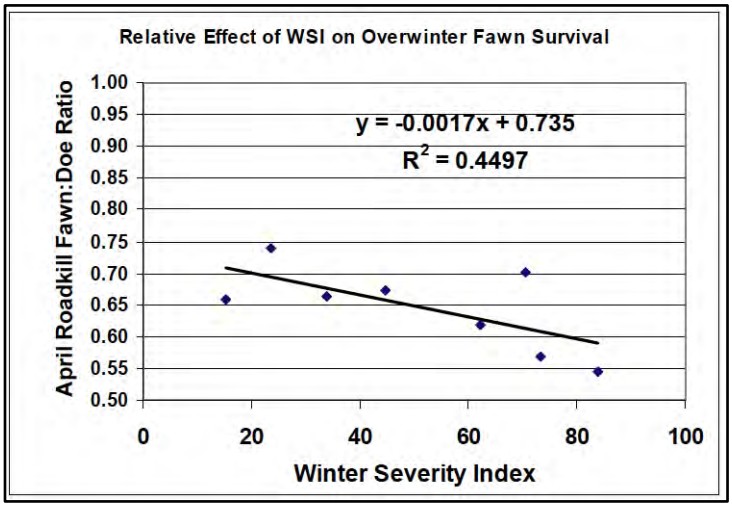


Figure 4: Change in state-wide post-hunt fawn: doe ratio collected from road killed females in the month of April following winters of varying severity in VT, 2000-2008 (VTFW 2009)

Wisconsin also uses a WSI identical to NH and VT with data collected at 35 locations across northern Wisconsin (WIDNR 1998). Agency biologists believe that a WSI below 50 is mild, 50-80 is moderate, and over 80 is severe. High WSI values are believed to result in decreases in overall winter survival, decreases in fawn survival the subsequent spring and decreases in adult buck harvest the following fall and are useful for season and quota setting (WIDNR 1998). Between 1964 and 1972, 5 of 8

winters were judged severe and northern deer herds declined by more than 50% (WIDNR 1998). Mild winters in the 1980's allowed deer populations to rebound. The 1995 and 1996 winters were severe (WSI of 127 and 116) and populations declined by >35% (WIDNR 1998).

Maine Department of Inland Fisheries and Wildlife biologists collect weather data at 26 winter severity stations between early December and late April (MDIFW 2011). Data collected include snow depth, deer sinking depth and snow profile characteristics within the shelter portion of deer wintering areas. Temperature data is also collected from statewide stations between December and April. Agency biologists believe annual winter losses can range from 10% in a moderate winter to 30% or higher in a severe winter (MDIFW 2011). WSI values are used to calculate a winter mortality rate = $2.29e^{0.0222WSi}$ (MDIFW 2007). Because the calculation may underestimate actual winter loss rates at ends of the severity spectrum, managers transform mortality rates by a comparison to historical rates (MDIFW 2007).

New Brunswick measures total snow depth measurements from 37 stations distributed across the province between January 1 and April 30 (Joe Kennedy, New Brunswick Ministry of Natural Resources, personal communication, December 18, 2015). The WSI is the cumulative average snow depth. Winter mortality was calculated from 1990 – 2001 using the algorithm [winter mortality rate = $0.36e^{0.04WSi}$]. After 2002, the Province adopted Maine's formula for calculating winter mortality with WSI values adjusted to correspond with Maine's.

Michigan DNR began tracking winter severity through a standardized index in 1964 that combined air chill and sinking depth (MIDNR 2009). A chillometer was employed to estimate the metabolic cost of a deer enduring winter. The index also utilized snow hazard effects. MI DNR responded to the challenges associated with intensive data collection procedures by adopting an automated system for calculating a revised version of the WSI (MIDNR 2009). The new WSI uses National Climatic Data Center measurements collected hourly at automated weather stations distributed throughout the state. The index employs temperature, wind speed and precipitation data, averaged on a weekly basis, between November 1 and April 30. The agency acknowledges that one index does not sufficiently model the complex interactions between winter weather and patterns of over-winter mortality, fawn production and deer physical condition. The agency does believe that the index is useful to identify management responses to potential effects of winter weather (MI DNR 2009).

Ontario has had a winter severity index since 1952 but the Ontario Ministry of Natural Resources research division is in the beginning stages of reviewing the index and investigating whether or not there may be more accurate methods of estimating winter severity as it pertains to deer (specifically fawn) mortality (Kevin Middel, Ontario Ministry of Natural Resources, personal communication 12/15/2015). The province currently runs and maintains a network of snow depth monitoring courses for the purpose of estimating winter severity, which is

incorporated into population models and is used in the process of quota setting. Each course is approximately 180m long and consists of 10 stations where snow depth is measured weekly and the average depth calculated. There are approximately 50-60 courses run each year across the province. Historically, the agency used an index called the Ontario Winter Severity Index (OWSI), which is a combination of snow depth, heat loss (via a chillometer device) and snow penetration depth. More recently, the agency adopted a simpler Snow Depth Index (SDI) as a means of assessing winter severity (OMNR 1997). SDI is simply the cumulative average weekly depth by course. SDI is then used to estimate winter severity both mid-winter and at the end of the winter. Agency researchers believe natal mortality of fawns is between 0-20% in mild winters (SDI of <590; OWSI <100) and >40% in severe winters (SDI >760; OWSI >125) (Figure 5) (OMNR 1997).

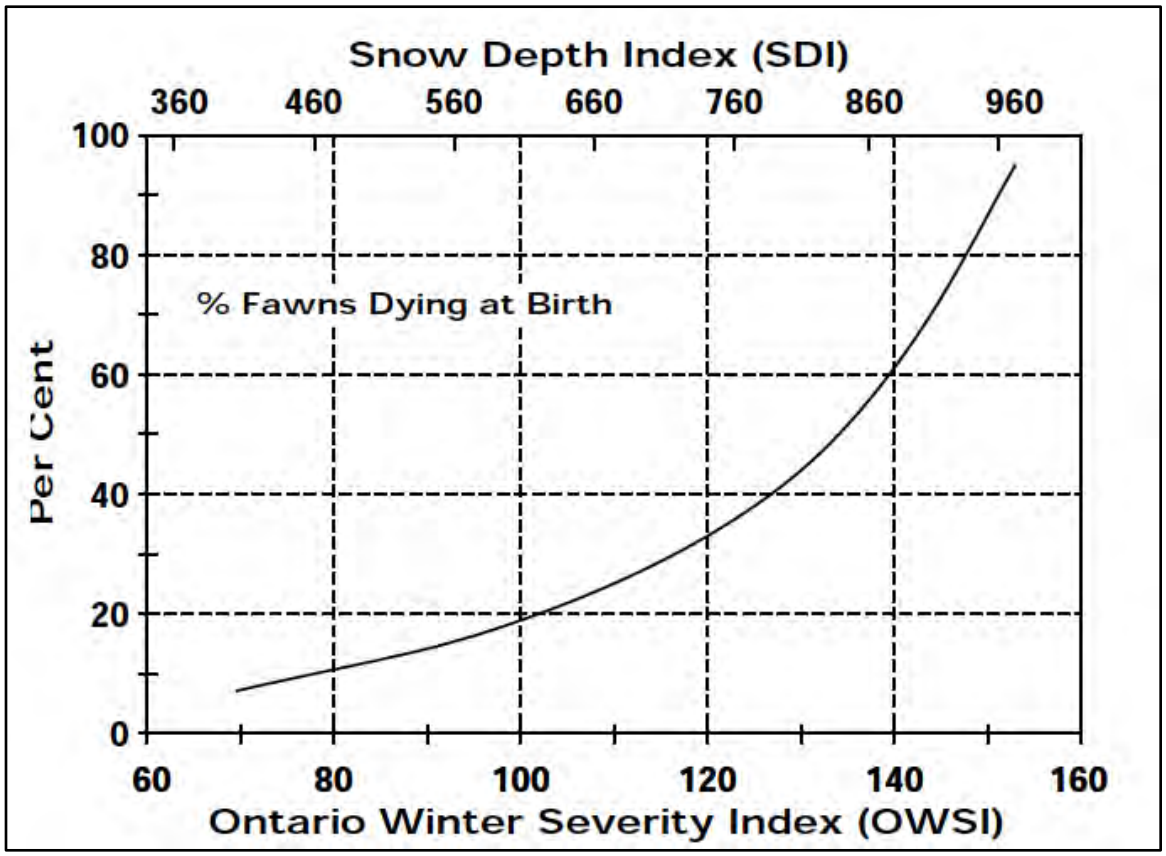


Figure 5: Relationship between winter severity and natal mortality in Ontario (OMNR 1997).

Quebec maintains 30 snow stations located in the hunting zones of the province. During each winter snow accumulation is measured every two weeks and sinking depth is estimated. There is no specific WSI but agency biologists are beginning a project in 2016 to evaluate the utility of a WSI (Francois Lebel, Quebec Ministère des Forêts, de la Faune et des Parcs, personal communication, December 14 2015).

MINNESOTA USE OF WSI

DNR employed a WSI that is similar in some respects, and different in others, to WSI's described herein (D'Angelo and Giudice 2015). Similarities include: the DNR WSI scored a day with a 0, 1 or 2 and scores were assigned based on snow depth and minimum daily temperature with the temperature threshold set at 0^{o} F. One difference between MN and other jurisdictions was that the MN WSI ranges from November 1 through May 31, therefore adding an additional 30 days to accumulate WSI points. The potential range, therefore, of the annual WSI was a score between 0 and 424. WSI values <100 are considered mild and >180 severe. The second difference was that snow depth scores were based on a threshold of 15 inches, instead of the more commonly used 18 inches of snow depth.

The DNR WSI influenced several population model parameters. Fawn spring/summer survival rates were set at 0.80, 0.65 and 0.45 for mild, moderate and severe preceding winters, respectively (D'Angelo and Giudice 2015). Each population rate input had a standard deviation of 3%.

Winter survival rates were based on published literature from MN or locales with environment similar to MN and may be found in D'Angelo and Giudice (2015). Survival of adult deer was set at 0.95 in mild winters (D'Angelo and Giudice 2015). Adult survival in moderate and severe winters was calculated as (mean winter survival = 1-[0.022+0.0015 WSI]). Fawn survival was set at 0.85 in mild winters (D'Angelo and Giudice 2015). In moderate winters, the same calculation as with adult survival was used except the outcome was reduced by 0.05. Fawn survival in severe winters was calculated as 1-(0.0054 WSI – 0.33). For extremely severe winters (WSI > 240), fawn survival is set at 0.033. All survival rates were allowed to vary in the model iterations based on a standard deviation of 0.02 (Figure 6).

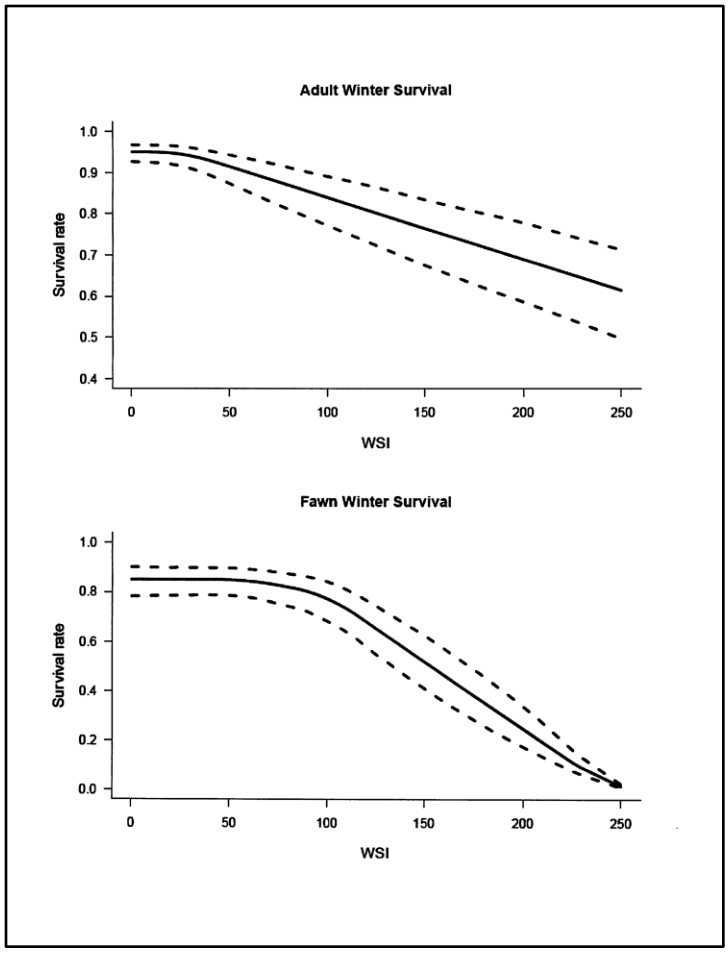


Figure 6: Relationship between winter severity and fawn and adult survival in Minnesota (D'Angelo and Giudice 2015)

DISCUSSION AND RECOMMENDATIONS

While some winter severity indices employed by jurisdictions are complex aggregations of temperature, snow depth and sinking depth, the simple measure of the duration of snow cover can allow evaluation of winter severity (Williamson 2003). No jurisdiction has explained the significance of treating snow cover equal to minimum temperature. A simplified WSI applied equally across the northern deer range, would facilitate learning and adaptive management among agencies. This effort would, for the first time, allow agencies to share data and continuously document and learn from winter weather effects across the region.

DNR should lead a discussion among northern jurisdictions to adopt one measure of winter severity and inform management systems about varying levels of winter mortality. This discussion should include implementing a survival monitoring program and subsequent population and survival modeling to test hypotheses about the impact of WSI across the entire state and Great Lakes region.

The MN deer model appropriately included winter severity effects from current and previous winters. MN DNR based calculations estimating survival rates in varying winters on published literature. Those rates appear to closely track rates employed by other management agencies (Table 7). While there is the continuous need to further document vital rates, WMI found the model calculations of survival impacts from winter severity to be scientifically based and reasonable for the estimation of deer population dynamics in winter.

Table 7: Summary of survival rates for fawns and adults as influenced by winter severity (Williamson 2003).

		Source of WSI Information					
Rate	Severity	MN	ONT	ME/ NB	VT	VT #2	WMI
WSI	mild winter	80			20	20	
	moderate	140			50	50	
	severe	200			100	100	
Fawn Survival	mild winter	85%			70%	90%	
	moderate	82%			65%	81%	
	severe	25%			57%	66%	
Adult Winter Survival	mild winter	95%		95%			
	moderate	77%		85%			
	severe	68%		70%			
Fawn Spring/Summer Survival	mild winter	80%	80%				
	moderate	65%	70%				66%
	severe	45%	>60%				44%

WMI did find that the agency was missing an important source of knowledge by not collecting age data from hunter-killed deer. Ratios of fawns-to-adults and yearlings-to-adults in the harvest provide important insight into non-harvest mortality, including winter mortality. Harvest age ratio data would provide an important check on model outputs. DNR should evaluate the collection and incorporation of deer age data into the population model as an index to winter mortality and as a check on model outputs.

The DNR WSI is unique in the span of time that data are collected. It is commonly noted that winter mortality is influenced by: 1) how early deer are forced to

concentrate in deeryards, 2) whether deer can leave deer yards in mid-winter to access food supplies, and 3) how late deer are confined to deeryards in the spring. The MN index was appropriately designed to detect early movement to deeryards in November and potentially significant mortality events associated with late winter severity in May.

The DNR WSI was also unique in that depth of snow that triggers a WSI point. Williamson (2003) documented that the statistic of days of snow cover >10 inches performed better than days of snow cover >18 inches as a winter severity index, although both were fairly evenly correlated. The DNR measure of 15 inches may also be better suited than the more traditional 18 inches. However, WMI notes that snow cover of <15 inches in November, December, April and May will have impacts to deer populations that will not be detected if the snow depth threshold is set too high (Williamson 2003).

COMPILATION OF RECOMMENDATIONS

MODEL DESIGN AND FUNCTION

- Data storage and sharing would be improved by building a central database to house deer population data.
- It would be advantageous to place all user inputs at the head of the code with clear comments describing what values need to be adjusted. An even better solution for standardized user input is to have a user interface with drop-down menus connected to a central database.
- All input variables should be displayed in the output reports to level of precision used in the input. For example, initial density is displayed as an integer, but sometimes input as a decimal value, implying a level of precision not attained.
- The DNR deer model only incorporates process uncertainty in the form of a stochastic distribution on demographic parameters. The uncertainty is an arbitrarily defined parameter that could be estimated from data.
- Observation uncertainty should be considered in the model. The simulation model does not include variation caused by sampling uncertainty.
- The DNR population model was sensitive to the initial population size estimate. This was a weakness in the DNR model. The stochastic model was not fit to population size data therefore any change in the initial population size could not be corrected within the model run process. The high sensitivity to initial density suggested that population estimates were very valuable data points and that a model fit to data such as an IPM will perform more reliably than a simulation model.
- Simulation models use data inefficiently because data are not brought directly into the model to inform the simulation, they are only available for ad hoc comparison. Future model enhancements could include automated analysis and incorporation of existing index and trend information.
- R code for the deer model is complex and requires multiple user changes throughout the code. Improvements could be made to the workflow by centralizing user input values or adding an interface to control user interaction with model.
- Developing a central database to house deer data would improve this workflow.

DATA INTEGRITY

- Additional research would improve vital rate estimates and provide a measure of uncertainty for population vital rates such as fall harvest and survival rates. These rates vary geographically and temporally.
- The non-registration of harvested deer rate and illegal harvest rate should be documented through research.

AERIAL SURVEYS

- DNR should reassess the factors that limit use of aerial surveys for model validation. Chief among these within the control of DNR is the allocation of resources to aerial surveys. The number of surveys flown in any given year would need to be increased significantly to fulfill the recommendation of Grund and Wolff (2004) to recalibrate the population model every few years. DNR should also continue to explore means to overcome the problems created by the timing of aerial surveys in winter, when deer distribution may differ from that in the fall or spring when populations are modeled. Finally, ongoing climate change may further impact aerial surveys by reducing the frequency of adequate snowpack. DNR should consider the impacts of climate change when addressing the issue of survey timing.

WINTER SEVERITY INDEX

- DNR should lead a discussion among northern jurisdictions to adopt one measure of winter severity and inform management systems about varying levels of winter mortality. This discussion should include implementing a survival monitoring program and subsequent population and survival modeling to test hypotheses about the impact of WSI.
- DNR should evaluate the practicality of collection and incorporation of statewide deer age data into the population model as an index to winter mortality and as a check on model outputs.

LITERATURE CITED

Besbeas, P., S. N. Freeman, B. J. T. Morgan, and E. A. Catchpole. 2002. Integrating mark-recapture-recovery and census data to estimate animal abundance and demographic parameters. Biometrics 58:540–547.

Brinkman, T.J., J.J. Jenks, C.S. DePerno, B.S.Haroldson, and R.S. Osborn. 2004. Survival of White-tailed Deer in an Intensively Farmed Region of Minnesota. Wildl. Soc. Bull. 32:1-7.

Broadfoot, J. D., D. R. Voigt and T. J. Bellhouse. 1996. White-tailed deer, Odocoileus virginianus, summer dispersion areas in Ontario. Canadian Field Naturalist 110: 298-302.

Brooks, S. P., R. King, and B. J. T. Morgan. 2004. A Bayesian approach to combining animal abundance and demographic data. Animal Biodiversity and Conservation 27: 515–529.

Carstensen, M., G.D. DelGiudice, B.A. Sampson, and D.W. Kuehn. 2009. Survival, Birth Characteristics, and Cause-Specific Mortality of White-tailed Deer Neonates. J. Wildl. Manage.73:175-183.

Cochran, W. G. 1977. Sampling techniques, 3rd edition. John Wiley and Sons, New York, NY.

D'Angelo, G. J. and J. H. Giudice. 2015. Monitoring Population Trends of White-tailed Deer in Minnesota – 2015. Minnesota Department of Natural Resources.

DelGiudice, G.D., M.S. Lenarz, and M.C. Powell. 2007. Age-Specific Fertility and Fecundity in Northern Free-Ranging White-tailed Deer: Evidence for Reproductive Senescence?. J. Mammal. 88:427-435.

Dexter, M.H., editor. 2013. Status of wildlife populations, fall 2013. Unpub. Rep., Division of Fish and Wildlife, MN Dept. Nat. Res., St. Paul, MN. 338 pp.

Dexter, M.H., editor. 2014. Status of wildlife populations, fall 2014. Unpub. Rep., Division of Fish and Wildlife, MN Dept. Nat. Res., St. Paul, MN. 328 pp.

Dickinson, N.R. 1976. Observation on steep-slope deer wintering areas in New York and Vermont. N.Y. Fish and Game J. 23: 170-174.

D'Orazio, M. 2003. Estimating the variance of the sample mean in two-dimensional systematic sampling. Jour. Agricultural, Biological, and Environmental Statistics 8:280-295.

Dumont, A., J-P Ouellet, M. Crete and J. Huot. 1998. Characteristics of forest populations as seen in the white-tailed deer in winter at the northern limit of its distribution area. Canadian Journal of Zoology 76: 1024-1036.

Eberhardt, L.L., and M.A. Simmons. 1987. Calibrating population indices by double sampling. J. Wildl. Manage. 51:665-675.

Fieberg, J. and J. Giudice. 2008. Variance of Stratified Survey Estimators with Probability of Detection Adjustments. J. Wildl. Manage. 72(3):837-844.

Fuller, T.K. 1990. Dynamics of a Declining White-tailed Deer Population in North-Central Minnesota. Wildl.Monogr. 110:1-37.

Gasaway, W.C., S.D. Dubois, D.J. Reed, and S.J Harbo. 1986. Estimating moose population parameters from aerial surveys. Biol. Papers, Univ. of Alaska, No. 22, Fairbanks.

Grovenburg, T.W., C.C. Swanson, C.N. Jacques, C.S. Deperno, R.W. Klaver, and J.A. Jenks. 2011. Female White-tailed Deer Survival Across Ecoregions in Minnesota and South Dakota. A,. Midl. Nat. 165:426-438.

Grund, M.D. and A. Woolf. 2004. Development and evaluation of an accounting model for estimating deer population sizes. Ecol. Modelling. 180:345-357.

Grund, M.D. 2011. Survival analysis and computer simulations of lethal and contraceptive management strategies for urban deer. Human-Wildl. Interactions. 5:23-31.

Haroldson, B.S., R.G. Osborn, and J.H. Giudice. 2005. Estimating white-tailed deer abundance using aerial quadrat surveys. Pp 128 – 131. In: Summaries of Wildlife Research Findings 2005.P.J. Wingate, R. O. Kimmel, J.S. Lawrence, and M.S. Lenarz, eds. MN Dept. Nat. Res., St. Paul, MN

Haroldson, B.S. and J.H. Giudice. 2006. Estimating white-tailed deer abundance using aerial quadrat surveys. Pp 96 – 100. In: Summaries of Wildlife Research Findings 2006.M.W. DonCarlos, R. O. Kimmel, J.S. Lawrence, and M.S. Lenarz, eds. MN Dept. Nat. Res., St. Paul, MN

Haroldson, B.S. 2008. Estimating white-tailed deer abundance using aerial quadrat surveys. Pp 1 – 7. In: Summaries of Wildlife Research Findings 2008. J.S. Lawrence, R. O. Kimmel, and M.S. Lenarz, eds. MN Dept. Nat. Res., St. Paul, MN

Haroldson, B.S. 2009. Estimating white-tailed deer abundance using aerial quadrat surveys. In: Summaries of Wildlife Research Findings. J.S. Lawrence, R. O. Kimmel, and M.S. Lenarz, eds. MN Dept. Nat. Res., St. Paul, MN

Johnson, H. E., L. S. Mills, T. R. Stephenson, and J. D. Wehausen, .2010. Population-specific vital rate contributions influence management of an endangered ungulate. Ecological Applications 20: 1753–1765.

Kellie, K.A. and R.A. DeLong. 2006. Geospatial survey operations manual. Alaska Department of Fish and Game. Fairbanks, Alaska, USA. 63 PP.

Krebs, C.J. (1999). Ecological Methodology. Addison-Welsey Educational Publishing, Inc. Menlo Park, CA.

Lancia, R.A., W.L. Kendall, K.H. Pollock, and J.D. Nichols. 1994. Estimating the number of animals in wildlife populations. Pages 215-253 in T.A. Bookout, ed. Research and management techniques for wildlife and habitats. Fifth Ed. The Wildlife Society. Bethesda, MD.

Lange, K. 1998. Numerical analysis for statisticians. Springer-Verlag, New York, NY.

Lohr, S. L. 2010. Sampling: design and analysis, 2nd edition. Brooks/Cole, Boston, MA.

Maine Department of Inland Fisheries and Wildlife (MDIFW). 2011. Maine's Game Plan for Deer: A Plan to Increase Maine's Northern, Eastern and Western Deer Herd. http://www.maine.gov/ifw/hunting_trapping/pdfs/WTD%20Plan_4Mar2011_FINAL.pdf.

Maine Department of Inland Fisheries and Wildlife (MDIFW). 2007. White-tailed Deer Population Management System and Database. https://www1.maine.gov/ifw/pdfs/species_planning/mammals/whitetaileddeer/managementsystem2007.pdf

Mautz, William W. 1978. Sledding on a bushy hillside: the fat cycle in deer. Wildlife Society Bulletin 6: 88-90.

McClintock, B. T., G. C. White, K. P. Burnham, and M. A. Pryde. 2009. A generalized mixed effects model of abundance for mark-resight data when sampling is without replacement. Pages 271-289 in Thomson, D. L., E. G. Cooch, and M. J. Conroy. Modeling demographic processes in marked populations. Environmental and Ecological Statistics Volume 3. Springer-Verlag, New York, NY.

McRoberts, R. E., L. D. Mech, and R. O. Peterson. 1995. The cumulative effect of consecutive winters' snow depth on moose and deer populations: a defense. Journal of Animal Ecology 64: 131-135.

Mech, L. D., R. E. McRoberts and R. O. Peterson. 1987. Relationship of deer and moose populations to previous winters' snow. Journal of Animal Ecology 56: 615-27.

Messier, F. 1995. Is there evidence for a cumulative effect of snow on moose and deer populations? Journal of Animal Ecology 64: 136-140.

Michigan Department of Natural Resources (MIDNR). 2009. A Review of Deer Management in Michigan. Lansing, MI. https://www.michigan.gov/documents/dnre/WLD_Deer_Mgmt_Plan_Appendix_D-A_Review_of_Deer_Management_in_Michigan_310657_7.pdf

Mills, L. S. 2012. Conservation of wildlife populations: demography, genetics and management. John Wiley and Sons.

Millspaugh, J. J., J. R. Skalski, R. L. Townsend, D. R. Diefenbach, M. S. Boyce, L. P. Hansen, and K. Kammermeyer. 2009. An evaluation of Sex-Age-Kill (SAK) model performance. Journal of Wildlife Management 73: 442-451.

Ontario Ministry of Natural Resources (OMNR). 1997. The Snow Network for Ontario Wildlife: The Why, When, What and How of Winter Severity Assessment in Ontario. http://www.firearmssafetycourse.ca/Hunting/snow-network-for-ontario-wildlife.pdf

Patterson, B. R. and V. A. Power. 2002. Contributions of forage competition, harvest, and climate fluctuation to changes in population growth of northern white-tailed deer. Oecologia 130: 62-71.

Pollock, K.H. and W.L. Kendall. 1987. Visibility bias in aerial surveys: a review of estimation procedures. J. Wildl. Manage. 51:502-510.

Potvin, F., J. Huot, and F. Duchesneau. 1981. Deer mortality in the Pohenegamook Wintering area, quebec. Canadian Field Naturalist 95: 80-84.

R Development Core Team (RDCT), 2009. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org. April 2010.

Rolley, R. 2014. Relationships of deer ecology, disease ecology, and hunter behavior to manage chronic wasting disease (CWD) in Wisconsin. Unpubl. Prog. Rept. Proj. W-160-P. Wis. Dept. Nat. Res. Madison, WI.

Rongstad, O.J. and J.R. Tester. 1969. Movements and Habitat Use of White-Tailed Deer in Minnesota. J. Wildl. Manage. 33(2):366-379.

SAS Institute. 1999. SAS OnlineDoc, version 8. SAS Institute, Cary, North Carolina, USA. http://v8doc.sas.com/sashtml/. April 2006

Schaub, M., and F. Abadi. 2011. Integrated population models: a novel analysis framework for deeper insights into population dynamics. Journal of Ornithology 152: 227–237.

Stevens, D.L., Jr. and A.R. Olsen. 2004 Spatially balanced sampling of natural resources. Jour. of the Amer. Statistical Assn. 99:262-278.

Thompson, S.K. 2002. Sampling. Second Edition. John Wiley & Sons, New York, NY, USA.

Unsworth, J. W., L. Kuck, E. O. Garton. 1990. Elk sightability model validation at the National Bison Range. Wildlife Society Bulletin 18: 113–115.

Unsworth, J.W., F.A. Leban, D.J. Leptich, E.O. Garton and P. Zager. 1994. Aerial Survey: User's Manual with Practical Tips for designing and conducting aerial big game surveys. 2nd ed. Idaho Dept. Fish Game, Boise, ID. 84pp.

Ver Hoef, J. M. 2002. Sampling and geostatistics for spatial data. Ecoscience 9(2):152-161.

Ver Hoef, J. M. 2008. Spatial methods for plot-based sampling of wildlife populations. Environ. Ecol. Stat. 15:3–13.

Verme, L. J. 1968. An index of winter weather severity for northern deer. J. Wildl. Manage. 32:566-574.

Vermont Fish and Wildlife Department (VTFW). 2009. Appendix B. Explaining the Density-Dependent Winter-Effects Doe-Accounting Model and Harvest Recommendations. http://s3.amazonaws.com/zanran_storage/www.vtfishandwildlife.com/ContentPages/401360334.pdf

Walsh, D. P., H. Campa III, D. E. Beyer Jr, and S. R. WInterstein. 2011. Measurement error and survey design in sightability model development. Journal of Wildlife Management 1228–1235.

Williamson, S. J. 2003. White-tailed Deer Harvest Management and Goal Setting in the Northeast. The Wildlife Management Institute. Washington DC. 164 pages

Wisconsin Department of Natural Resources (WIDNR). 1998. Wisconsin's Deer Management Program: The Issues Involved in Decision Making. 2nd Edition. http://dnr.wi.gov/topic/wildlifehabitat/documents/deerbook.pdf

Worden, K. A. and P. J. Pekins. 1995. Seasonal change in feed intake, body composition, and metabolic rate of white-tailed deer. Canadian Journal of Zoology 73: 452-457.

Wright, R.G., B.S. Haroldson, and C. Pouliot. 2011. DNRSurvey-moving map software for aerial surveys. Pages 271-275 in G. DelGiudice, M.Grund, L. Lawrence, and M. Lenarz, eds. Summaries of Wildlife Research Findings, 2010. Division of Fish and Wildlife, MN Dept. Nat. Res., St. Paul, MN

APPENDIX A. Exhibit A - Statement of Work

EXHIBIT A

Statement of Work

Technical Review of Department of Natural Resources' Deer Population Modeling and Survey Methods

Project Summary

The State of Minnesota (State), acting through its Office of the Legislative Auditor (OLA), has contracted with the Wildlife Management Institute (Contractor) to provide technical assistance to OLA for its evaluation of the Minnesota Department of Natural Resources' (DNR) deer population management activities.[1] OLA was directed by the 2015 Legislative Audit Commission to conduct this program evaluation pursuant to *Minnesota Statutes* 2014, 3.971. The Contractor's work will be part of a broader initiative by OLA to evaluate DNR processes for establishing Minnesota's deer population goals and harvest management strategies.

Objectives

The objectives of the Contractor's work are to provide technical review services, guidance, and recommendations to OLA in the task areas identified below. The Contractor will:

1. Determine whether DNR:
    a. Follows wildlife industry accepted practices for surveying and calculating white-tailed deer populations;
    b. Uses scientifically valid statistical model(s), assumptions, and industry-accepted methods for projecting deer population estimates; and
    c. Compiles and uses sufficient data to ensure reasonably accurate deer population estimates.
2. Determine the extent to which DNR modeling accurately simulates and predicts deer population dynamics.
3. Verify the accuracy of certain DNR public reports relative to model outputs and source data.
4. Identify deficiencies and make recommendations for improvements related to Objectives 1-3.

Scope of Work

For purposes of this Contract, the Contractor will execute the Tasks and Deliverables to help address the research questions described in Exhibit C, Evaluation Issue 2. The Contractor's scope of work includes the deer population models, data, goals, documentation, and reports used and/or prepared by DNR for deer hunting seasons 2012-2015.[2]

Contractor's Duties

The Contractor will execute the following tasks and deliverables under the authority of and in accordance with this Contract, SWIFT Contract Number 100434. OLA

[1] See Exhibit C, OLA project description for the evaluation *Deer Population Management*.

[2] Key references include, but are not limited to, *Minnesota Statutes*, ch. 97A and 97B; and *Minnesota Rules*, ch. 6232 (various subparts).

action items are noted in italics. The Contractor's employees and subcontractors approved by OLA to work under this Contract are:

- Steven Williams, Wildlife Management Institute (WMI) Project Manager
- Scot Williamson, WMI Vice President
- Christian Smith, WMI Staff
- Paul Lukacs, WMI Consultant
- Joshua Nowack, WMI Consultant
- Jon Katz, WMI Consultant

The tasks and deliverables below may be modified during the course of this Contract, but such changes would occur only in accordance with this Contract, Term 7.2. In executing these tasks, the Contractor will conduct some on-site fieldwork as pre-approved by OLA. As requested by OLA, the Contractor also will provide technical clarification to OLA employees regarding the Contractor's potential findings and recommendations. The Contractor will update the State's Project Manager regarding any information that DNR classifies as "not public."

WMI Task	**Description and Deliverables**	**Due Dates**
1	Hold initial project meeting with OLA and DNR representatives.	WMI Lead: Steven Williams Week of 10-5-2015
1A	Evaluate the design of DNR's deer population model for deer hunting seasons 2012-2015 relative to wildlife management industry practices and expected methodology for Minnesota (a northern U.S. climate). This task includes, but is not limited to, critiquing the following aspects of the DNR model(s): • Functional form and specifications, • Scope and timeliness of data used, • Area units of analysis, and • Sources and range of assumptions. Identify any deficiencies, strengths, and weaknesses.	WMI Lead: Steven Williams Start: 9-14-2015 Finish: 2-12-2016
	OLA provide WMI with documentation received to date from DNR regarding DNR models, model code, example data sets, and assumptions used for deer hunting seasons 2012-2015.	Week of 9-14-15
	i. Identify accepted wildlife management standards pertaining to deer population modeling, including model functional form and specifications, scope and timeliness of data used, area units of analysis, and data. Provide OLA with such standards to be used by WMI to complete Task 1A.	Week of 10-5-2015
	ii. Review and analyze documentation provided to date. Request additional documentation from DNR as needed.	Ongoing through 2-12-2016
	iii. Complete initial evaluation of DNR model design.	Due: 1-1-2016
	iv. Interview DNR staff regarding outstanding questions and verification of findings.	Ongoing through 2-12-2016

	v. Develop draft findings and recommendations. Provide written draft document to OLA for review and comments.	1-22-2016
	vi. OLA and Contractor conference via phone to discuss draft document. OLA return draft with comments to Contractor.	1-29-2016
	vii. Prepare and submit to OLA a written two-page executive summary, final full report, and a sourced final report and workpapers.	2-12-2016
1B	Test the functionality and sensitivity of DNR's model and outputs (population estimates and forecasts) relative to model-simulated harvest strategies and goals for Minnesota's deer management areas. Task 1B includes evaluating whether the model functions as designed, reviewing historical and current programming, and verifying outputs against a sample of published documents. Identify any deficiencies, strengths, and weaknesses.	WMI Lead: Steven Williams Start: 9-14-2015 Finish: 2-12-2016
	OLA to provide previously obtained scripted analysis, code, and other supporting documentation of assumptions, methods, and practices used by DNR.	Week of 9-14-2015
	OLA to provide additional samples of published documents and information for testing.	10-16-2015
	i. Develop test plan and identify accepted criteria and threshold for variance (materiality). Provide OLA with copy of test plan.	Week of 10-5-2015
	ii. Request from DNR input data used for models 2012-2015 and corresponding output.	Week of 10-5-2015
	iii. Complete initial testing of model and verification of outputs against published documents.	1-1-2016
	iv. Interview DNR staff regarding outstanding question and verification of findings.	Ongoing through 2-12-2016
	v. Develop draft findings and recommendations. Provide written draft document to OLA for review and comments.	1-22-2016
	vi. OLA and Contractor conference via phone to discuss draft document. OLA return draft with comments to Contractor.	1-29-2016
	vii. Prepare and submit to OLA a written two-page executive summary, final full report, and a sourced final report and workpapers.	2-12-2016
1C	Audit the integrity of data collected by DNR and used for modeling. Task 1C includes: • Testing the reliability, completeness, validity, and suitability of harvest and other data used for years 2012-2015. • DNR practices for compiling or testing the data. Identify any deficiencies, strengths, and weaknesses.	WMI Lead: Steven Williams Start: 9-14-2015 Finish: 2-12-2016
	i. Develop test plan and identify accepted criteria and threshold for variance (materiality). Provide OLA with copy of test plan.	Week of 10-5-2015
	ii. Request from DNR datasets and information on data sources, storage, and quality control for datasets used for deer population	10-2-2015

	modeling, for deer hunting seasons 2012-2015.	
	iii. Complete initial evaluation of integrity of data used for deer population modeling and DNR's quality assurance protocols for the data it uses.	1-1-2016
	iv. Interview DNR staff regarding outstanding questions and verification of findings.	Ongoing through 2-12-2016
	v. Develop draft findings and recommendations. Provide written draft document to OLA for review and comments	1-22-2016
	vi. OLA and Contractor conference via phone to discuss draft document. OLA return draft with comments to Contractor.	1-29-2016
	vii. Prepare and submit to OLA a written two-page executive summary, final full report, and a sourced final report and workpapers.	2-12-2016
1D	Through document review and interviews, evaluate recent DNR methods for surveying Minnesota deer populations, including distance and aerial survey design and execution, sample size, and survey techniques. Identify any deficiencies.	WMI Lead: Steven Williams Start: 9-14-2015 Finish: 2-12-2016
	OLA provide Contractor with documentation received to date regarding source documentation for survey data used in DNR models for hunting seasons 2012-2015.	Week of 9-14-15
	i. Identify accepted wildlife management and scientific standards for conducting distance, aerial, and other types of surveys (if used by DNR) of white-tailed deer in northern U.S. climates, including survey design, sample size, and execution. Provide OLA with standards to be used by WMI to complete Task 1D.	Week of 10-5-2015
	ii. Review and analyze documentation provided to date. Request from DNR additional information on its survey methods and protocols as needed.	Ongoing through 2-12-2016
	iii. Complete initial assessment of DNR survey design, methodology, and practices.	1-1-2016
	iv. Interview DNR staff regarding outstanding questions and verification of findings.	Ongoing through 2-12-2016
	v. Develop draft findings and recommendations. Provide written draft document to OLA for review and comments.	1-22-2016
	vi. OLA and Contractor conference via phone to discuss draft document. OLA return draft with comments to Contractor.	1-29-2016
	vii. Prepare and submit to OLA a written two-page executive summary, final full report, and a sourced final report and workpapers.	2-12-2016
2	Respond throughout the duration of the project to OLA employees' questions of a technical nature related to the scope and tasks of this Statement of Work, within a specified time period agreed to between	WMI Lead: Steven Williams

	OLA and the Contractor, but no more than seven business days. The Contractor will provide written responses to OLA questions via e-mails or other written communication (or, as a last resort, telephone calls).	Start: 9-11-2015 Finish: 5-15-2016 Approx. Hours: 20
3	Provide professional testimony regarding findings and recommendations resulting from work conducted on behalf of OLA.	WMI Lead: Steven Williams Start: 2-12-2016 Finish: 5-15-2016 Approx. Hours: 20
4	Submit biweekly status reports to the State's Project Manager that are updates of progress and descriptions of activities under this work plan. Progress should be documented by using a copy of this work plan and adding a successive entry below the pertinent task, including the date completed and any problems encountered in executing these tasks.	WMI Lead: Steve Williams Start: 9-25-2015 Finish: 2-12-2016

APPENDIX B. Biographies of Review Participants

Steven Williams. Ph.D. - WMI President - Project Manager

Dr. Steven Williams is the President of the Wildlife Management Institute (WMI). As President of WMI, Steve serves on the Board of Directors of the National Fish and Wildlife Foundation, American Wildlife Conservation Partners, Wildlife and Hunting Heritage Conservation Council (a federal advisory committee to the Secretaries of Interior and Agriculture), Council to Advance Hunting and Shooting Sports, and Chair of the National Conservation Leadership Institute. He is a professional member of the Boone and Crockett Club and The Wildlife Society.

Prior to joining WMI, Steve served as Director of the U. S. Fish and Wildlife, the Kansas Governor's Cabinet Secretary of the Department of Wildlife and Parks, Deputy Executive Director of the Pennsylvania Game Commission, and Assistant Director for Wildlife and Deer Project Leader of the Massachusetts Division of Fisheries and Wildlife. He received his B.S. and Ph.D. Degrees from The Pennsylvania State University and a M.S. Degree from the University of North Dakota.

Scot Williamson – WMI Vice President and Northeast Field Representative

Scot Williamson is Vice President of the Wildlife Management Institute. Scot has been with WMI since 1994 and has assisted Northeastern states and conservation groups on a number of wildlife and land management initiatives. The WMI publication, "Feeding Wildlife, Just Say No!" was authored by Scot and received the Wildlife Society Conservation Education Award in 2003. Scot's current duties include coordination of multi-state habitat conservation initiatives dedicated to conservation and restoration of shrubland-dependent wildlife, and advancement of landscape level science collaboratives (Landscape Conservation Cooperatives).

Prior to joining WMI, Scot was Big Game Director for Texas Parks and Wildlife Department and White-tailed Deer Project Leader for NH Fish and Game Department. Scot received a MS in Wildlife Science from the University of Vermont and a Bachelor of Science in Forestry from the Pennsylvania State University.

Christian Smith, CWB - WMI Western Field Representative

Chris Smith is the Western Field Representative for the Wildlife Management Institute. Chris has over 34 years experience in planning, management, research, supervision and administration of resource conservation programs throughout Alaska and Montana. He has extensive involvement with the Association of Fish and Wildlife Agencies, Western Association of Fish and Wildlife Agencies and inter-agency teams. Chris has specialized training and

experience in wildlife policy and law, public involvement, conflict resolution, personnel management, and strategic planning.

Prior to joining WMI, Chris served as Deputy Director for the Montana Department of Fish, Wildlife, and Parks for 11years. Prior to working in Montana, Chris worked for the Alaska Department of Fish and Game. In his 23 years working for Alaska, he rose from Fisheries Technician to Assistant Director of the Division of Wildlife Conservation. Chris holds a B.S. Degree in Wildlife Management from the University of Alaska and a M.S. Degree in Wildlife Biology from the University of British Columbia.

Paul Lukacs. Ph.D. - WMI Consultant

Dr. Paul M. Lukacs is Associate Professor of Quantitative Wildlife Ecology in the Wildlife Biology Program, Department of Ecosystem and Conservation Sciences at the University of Montana. Dr. Lukacs' research interests include developing and expanding statistical tools available to ecologists and applying those tools to understanding questions in population dynamics. Dr. Lukacs is particularly interested in predictive accuracy of population dynamics models. He has been actively involved in software development throughout his graduate school and professional career. Dr. Lukacs generated more than $1.4M in research funding in the past 4 years. He authored 48 peer-reviewed journal articles and book chapters. Dr. Lukacs' research is widely cited (>1000 citations, h-index = 17) and applied in wildlife conservation.

Paul holds Ph.D. and M.S. Degrees in Fishery and Wildlife Biology from Colorado State University and a B.S. Degree in Wildlife Biology with High Honors from the University of Montana.

Joshua Nowak, Ph.D. - WMI Consultant

Dr. J. Joshua Nowak is a Research Scientist in the Wildlife Biology Program, Department of Ecosystem and Conservation Sciences at the University of Montana. Dr. Nowak's research focuses on the application of quantitative tools to applied wildlife problems. Dr. Nowak has worked closely with several state agencies on a variety of species bringing a unique blend of interpersonal, statistical, and computing skills to difficult problems. The success of one of these efforts led to Dr. Nowak being personally recognized by Montana's Governor, Steve Bullock. Recently, Dr. Nowak was invited to help write management plans for mountain lions in Montana and deer in South Dakota. On campus, Dr. Nowak recently earned special recognition for the help he has given to graduate students. The graduate student community created an award bearing his name and named him the first recipient. Prior to his involvement in wildlife research, Dr. Nowak served 5 years as an Explosive Ordnance Disposal

technician in the United States Navy. Dr. Nowak was trained to supervise and perform tasks associated with finding, disarming and disposing of explosive hazards both manufactured and improvised. During this time, Dr. Nowak held a top-secret security clearance and worked closely with the United States Secret Service and Special Forces Units both foreign and domestic. Dr. Nowak also taught courses on explosive hazards for the FBI, ATF and multiple military units. Dr. Nowak received meritorious advancement, was recognized as an honor graduate from multiple military schools, and was decorated for his involvement in combat operations during Operation Enduring Freedom.

Joshua earned Ph.D. and M.S. Degrees in Forest Science from Laval University, Quebec, QC and a B.S. Degree in Wildlife Biology with High Honors from the University of Montana.

Jon Katz. Ph.D. -WMI Consultant

Dr. Jon Katz is a postdoctoral researcher in the Rubenstein School of Environment and Natural Resources at the University of Vermont Dr. Katz currently writes software to facilitate game population estimation from harvest numbers in R and is simultaneously creating a web-interface for non-R users. Past work includes creating custom tools to produce data-driven internal and public-relations reports, developing methods for automated detection of bird songs in digital recordings, and designing/building custom databases for small businesses.

Dr. Katz has 5 years of experience working with R and is co-author of an R package for automatic detection of sounds in digital recordings. He holds a PhD in Natural Resources from the University of Vermont.

Minnesota Department of Natural Resources
500 Lafayette Road Saint Paul, Minnesota 55155-4037
Office of the Commissioner
651-259-5555

May 19, 2016

Mr. James Nobles, Legislative Auditor
Office of the Legislative Auditor
Room 140 Centennial Office Building
685 Cedar Street
St. Paul, Minnesota 55155-1603

RE: OLA Program Evaluation Report on Deer Population Management

Dear Auditor Nobles:

Thank you for the opportunity to review and respond to the Office of Legislative Auditor's (OLA) findings and recommendations resulting from the recent program evaluation of the Department of Natural Resources (DNR) Deer Population Management Program. Deer and deer hunting are important to many Minnesotans, and sound management of the deer herd is a very high priority for DNR. We appreciate and value the independent review conducted by the OLA.

The evaluation identified a number of the complexities and challenges of managing Minnesota's deer population. To better address these complexities and challenges, the DNR agrees that a formal deer management plan would help to define, clarify, and prioritize deer management goals, objectives, and resources. The DNR is currently working on developing a process to complete a comprehensive deer management plan, and we will work to involve hunters and other stakeholders and include a broad array of public opinions to inform the plan as recommended by the OLA.

Another key component of the evaluation is the assessment of the DNR's current deer population model. We appreciate the OLA finding that DNR's model is sound and effective at generating trend estimates that allow for determining management prescriptions to meet established goals. We have already incorporated some of the more technical aspects of the evaluation recommendations as they relate to overall model improvement, such as improving how the user inputs data in order to reduce the chance of input errors.

DNR's responses to the recommendations addressed in the report are as follows:

Recommendation: The Department of Natural Resources should improve and validate its new deer population model and deer population statistical estimates.

DNR Response: The DNR concurs with this recommendation. However, it is important to note that this evaluation also states that the importance of knowing the precise size of the deer population is often overemphasized, and we believe that any additional research and model validation efforts should be limited to what is necessary for deer managers to effectively model and manage deer populations.

Recommendation: For purposes of setting deer population goals and permit area designations for hunting, the Department of Natural Resources should compile and publish additional information about the characteristics of deer permit areas.

DNR Response: The DNR concurs with this recommendation.

Recommendation: The Department of Natural Resources should consider enhancing its deer management surveys to obtain a broader range of opinions.

DNR Response: The DNR concurs with this recommendation.

Recommendation: Within the limitations of data practices laws, the Department of Natural Resources should compile and utilize more specific information about deer presence and deer impact within local environments.

DNR Response: The DNR concurs with this recommendation.

Recommendation: DNR should develop a deer management plan that includes clearly defined short- and long-term goals, and objective that address the broad range of DNR's deer-related responsibilities, and strategies to improve and maintain adequate deer hunting and wildlife viewing opportunities in targeted areas around the state.

DNR Response: The DNR concurs with this recommendation.

Recommendation: Department of Natural Resources should clarify the role of Deer Advisory Teams in setting deer-population goals in state parks, game refuges, and other special areas.

DNR Response: The DNR concurs with this recommendation; however, we note that the desire for more local information by Advisory Teams will likely always outweigh the DNR's ability to collect meaningful localized data to reflect the scale at which most people hunt or observe deer.

Recommendation: The Department of Natural Resources should continue updating deer population goals around the state, including deer permit area goals set during 2012.

DNR Response: The DNR concurs with this recommendation.

Thank you again for your work on this evaluation and for the opportunity to respond. Deer management is challenging work, made more complex by a diverse landscape and a diverse set of public opinions. These findings and recommendations will help us improve our future work.

Sincerely,

Tom Landwehr
Commissioner

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