MONITORING POPULATION TRENDS OF WHITE-TAILED DEER IN MINNESOTA – 2019

Eric Michel, Farmland Wildlife Populations and Research Group

John H. Giudice, Wildlife Biometrics Unit

INTRODUCTION

Hunting is the primary method used to manage white-tailed deer (*Odocoileus virginianus*) populations in Minnesota. Minnesota Department of Natural Resources (MNDNR) sets hunting regulations annually to adjust deer harvest to meet management goals. MNDNR wildlife researchers conduct simulation modeling of deer populations within deer permit areas (DPAs) to understand historical deer herd dynamics, predict population sizes, and to explore the impacts of various hunting regulations on populations. To aid in decision-making, MNDNR Biologists consider output from population modeling along with deer harvest metrics, hunter success rates, surveys of hunter and landowner satisfaction with deer populations, and deer population goals set through a public process. This report summarizes the structure and parameters of the simulation model, and provides a description of recent trends in deer populations.

METHODS

We used a stochastic population model to simulate annual variations in deer densities within individual DPAs. We defined ranges of values for fecundity (number of offspring born per female) and survival by sex- and age-classes of deer based on values from the primary literature and data from studies within Minnesota. This report summarizes the structure and parameters of the simulation model, and provides a description of recent trends in deer populations.

Model Structure

We started each multi-year simulation in spring of the initial year before reproduction occurred (Figure 1). We specified an initial population density (see more about selection of initial population densities in Modeling Procedures section), and the model converted the initial population density into a total population size by multiplying the density by the total land area of the DPA. We set the proportion of adult deer by age- and sex-class in the initial population (adult females mean = 0.45 [SD = 0.02], adult males mean = 0.20 [SD = 0.02]). We allocated the remaining proportion (0.35) equally to young-of-year (YOY) males and females.

Within each annual cycle, we applied age-specific fecundity rates to females to estimate reproduction. We subjected all age- and sex-classes to spring/summer mortality, and the result was the pre-hunt fall population. We subtracted hunter-harvested deer from the pre-hunt population. We estimated winter mortality rates by age-class relative to winter severity, and we then applied winter mortality rates to the post-hunt population. The remaining population represented the starting population size for the next stage of the simulation. We assumed that the effects of immigration and emigration on a population within a DPA were equal. We provide more detailed information about model parameter selection in the following sections.

Reproduction

We used fecundity rates, from a range of values reported for Iowa, Minnesota, and Wisconsin (Iowa DNR unpublished data, Fuller 1990, McCaffery et al. 1998, DelGiudice et al. 2007, Dunbar 2007, Grund 2011, Storm 2014, Storm 2015, Dittrich 2016). We partitioned fecundity rates by 2 age-classes of breeding females (i.e., <1 year old [YOY] when bred and ≥1 years old [adult] when bred) and allowed rates to vary by 3 eco-geographic zones (northeast, farmland and transition areas, and southeast) that reflected relative differences in climate and habitat quality. We estimated fecundity rates to be lowest in the northeast (YOYs, mean = 0.06 [SD = 0.005]; adults, mean = 1.55 [SD = 0.001]), moderate in the farmland and transition zone (YOYs, mean = 0.07 [SD = 0.017]; adults, mean = 1.71 [SD = 0.022]), and greatest in the southeast (YOYs, mean = 0.13 [SD = 0.029]; adults, mean = 1.81 [SD = 0.055]). Sex ratio of fawns at birth in most deer populations is approximately 50:50, but may vary annually (Ditchkoff 2011). Therefore, we allowed the proportion of male fawns at birth to vary uniformly between 0.48-0.52.

Spring/Summer Survival

Winter survival rates of deer are dependent on the severity of winter conditions (Fuller 1990, DelGiudice et al. 2002). Likewise, the condition of breeding females following winter may directly influence survival of their newborn fawns (Verme 1977, Nixon et al. 1991, Carstensen et al. 2009). MNDNR calculates a winter severity index (WSI) in each DPA annually based on snow depth and minimum daily temperatures. WSI was calculated weekly by staff from Minnesota Information Technology Services at MNDNR. From 1 November through 31 May, 1 point was added to the WSI for each day with snow depths ≥15 in (38.1 cm). One point was also added to the WSI for each day when temperatures were ≤0^{0} F (-17.8^{0} C). Therefore, the WSI accumulated 0, 1, or 2 points each day in a DPA.

We used estimates reported in the primary literature for deer in Minnesota and populations in similar habitats for fawn spring/summer survival (Wisconsin DNR unpublished data, Huegel et al. 1985, Nelson and Mech 1986a, Nelson and Woolf 1987, Kunkel and Mech 1994, Brinkman et al. 2004, Vreeland et al. 2004, Rohm et al. 2007, Hiller et al. 2008, Carstensen et al. 2009, Warbington et al. 2017). We adjusted fawn survival rates to estimate the effects of winter severity on the condition of adult females during the previous winter. Mean spring/summer fawn survival values were 0.70 (SD = 0.031), 0.55 (SD = 0.037), and 0.45 (SD = 0.037) when WSI<100, 100≤WSI<180, and WSI≥180, respectively.

Spring/summer survival rates reported in the primary literature for adult deer ≥1 year old were relatively high and similar for both sexes (DeYoung 2011). We used similar values for summer survival of adult deer from the population model previously used in Minnesota (Grund and Woolf 2004, Grund 2014) and allowed the values to vary randomly (female = 0.96 [SD = 0.011], male = 0.97 [SD = 0.015]). These estimates overlapped values reported in the literature for Minnesota and populations in similar habitats (Nelson and Mech 1986a, Fuller 1990, Van Deelen et al. 1997, Whitlaw et al. 1998, Brinkman et al. 2004, Grund and Woolf 2004, Grund 2011, Grovenburg et al. 2011).

Fall Harvest and Recovery Rates

Hunter harvest represents the greatest source of mortality for deer populations in most DPAs in Minnesota during the fall (Fuller 1990, DelGiudice et al. 2006, Grovenburg et al. 2011).

We obtained harvest data from the MNDNR Electronic Licensing System. Hunters were required to register deer within 48 hours after harvest, indicate in which DPA the deer was harvested, and classify the deer as adult male, adult female, fawn male, or fawn female. We pooled harvest data for the archery, firearms, and muzzleloader seasons, special hunts, and harvest reported by Native American Tribes within DPAs.

We recognized that some deer were not registered during the hunting season or they were harvested illegally (Dusek et al. 1992, Rupp et al. 2000), wounded and not recovered (Nixon et al. 2001), or died from other non-hunting causes (e.g., deer-vehicle-collision, Norton 2015). We applied a mean multiplier of 1.05 (SD = 0.002) to the numerical harvest to account for non-registered deer that died during the hunting season. Because we expect the true multiplier to be greater than 1.05, density estimates are conservative, but resulting population trends will likely be similar when different multipliers are used based on the modeling procedures.

Winter Survival

Winter severity, particularly snow depth, increases risk of deer mortality via starvation and predation, and fawns are more susceptible than adults (Nelson and Mech 1986b, DelGiudice et al. 2002, Norton 2015). We estimated winter survival rates relative to winter severity based on studies conducted in Minnesota (Nelson and Mech 1986a, DelGiudice et al. 2002, Brinkman et al. 2004, Grund and Woolf 2004, DelGiudice 2006, Grovenburg et al. 2011, Grund 2011). These studies reported survival rates similar to those observed in other deer populations in northern latitudes (Van Deelen et al. 1997, Whitlaw et al. 1998, DePerno et al. 2000, Dumont et al. 2000, Norton 2015).

For adult deer, we set mean winter survival at 0.95 when WSI≤25. When WSI>25, we used an equation to calculate survival to account for increased winter severity based on previous research in Minnesota. For fawns, we set the mean winter survival rate at 0.85 when WSI≤60.When WSI was above 60 and less than 100, we applied the same equation used to calculate adult survival. However, we subtracted an additional mortality rate of 0.05 to represent lower survival of fawns versus adults. For more severe winters (100≤WSI≤240), we adjusted the equation to represent increased mortality reported for fawns in field studies. When WSI exceeded 240, we set fawn survival at 0.033. We calculated winter survival relationships based on previous Minnesota research studies of radiocollared deer.

Modeling Procedures

To model each DPA, we tested several initial population densities including: 1) population estimates from field surveys when available (Haroldson 2014); 2) previous estimates from modeling (Grund 2014); or 3) a crude population estimate reconstructed from the reported harvest of adult males in the most recent deer season.

To determine the most appropriate initial population density, we examined the modeled population trends relative to: 1) population estimates from field surveys when available; 2) the trend in reported deer harvest; and 3) the relationship between estimated population densities and adult male harvest success. We incrementally increased and decreased the density and re-examined the modeled trend relative to the aforementioned indices to refine the initial population density. In some cases, we also adjusted other vital rates slightly in conjunction with varying initial population densities.

Because the initial population density is the primary parameter adjusted, similar population trends are fitted when the mean for parameters that are constant (with only random variation) among years (e.g., recovery rates, adult summer survival) are changed. However, the absolute density will shift similarly among years (e.g., all density estimates may be 20% greater if recovery rates are increased), because the modeler can adjust the initial density to fit the same trend. Importantly, the resulting density estimates are only unbiased when all input parameters are unbiased, but accurate trends can still be estimated even when mean values for parameters are biased.

We ran model simulations for 5 years (2014-2019) with the final population estimate occurring pre-fawning for the spring following the most recent deer hunting season (i.e., spring 2019). We performed all simulations with the R programming language (ver. 3.3.2, R Core Team 2017) and used 500 Monte Carlo simulations until we determined the most reasonable set of starting parameters. We then used 5,000 simulations for the final run.

It is not logistically or financially feasible to conduct field studies on deer populations across all DPAs with regularity to estimate model input parameters. Population modeling requires researchers to make assumptions about these data based on prior studies (Hansen 2011). Because model input data rely on broad generalizations about herd demographics and survival rates, models simulating deer populations in small geographic areas would not be realistic. Grund and Woolf (2004) demonstrated that modeling small deer herds increased variability in model estimates, thus decreasing the ability to consider model outputs in making management decisions. Therefore, we did not model populations in DPAs that were small in area or where harvest data were limited.

RESULTS

Deer Population Trends and Management Recommendations

Although we derived the model parameters from studies of deer in Minnesota or from studies from states that have similar habitats and environmental conditions, uncertainty is inherent in modeling wild deer populations. Our modeling allowed input parameters to vary randomly to represent uncertainty that occurs in wild populations, and model outputs included measures of uncertainty reflecting variation among model simulations. However, for ease of interpretation, we present mean pre-fawn deer densities in this document. We conducted simulation modeling in 105 of 130 DPAs in Minnesota to estimate deer densities before reproduction during spring 2019 (Table 1, Figure 2).

Following 3 deer seasons with relatively conservative management designations and 3 winters with mild conditions across most of the state, deer populations in most DPAs increased through 2019. Management designations in 2019 were consistent in most DPAs compared to 2018 in attempt to stabilize or reduce densities that had exceeded goals. However, some DPAs in the southwestern farmland and northeastern forest remained below goal, even with conservative hunting regulations, likely due to resource limitations. Because firearm hunting season conditions across some areas in the state were below average in 2018, antlerless harvest goals were not achieved, resulting in more deer after the hunting season than intended with hunting season regulations. Liberal antlerless seasons in 2019 will be required again to effectively manage deer populations in DPAs with average and above average productivity.

In terms of management intensity, the 2019 designations afford more antlerless deer harvest opportunities to hunters in about 17% of the DPAs versus the 2018 season. For most of the remaining DPAs, designations in 2019 were the same as 2018 and about 14% of DPA designations afforded less antlerless harvest opportunity.

Farmland Zone

Of the 36 farmland zone DPAs, 4 were within 10% of goal, 4 were at least 10% below goal, and 19 were at least 10% above goal based on modeling or buck harvest trends. Modeling deer densities in the farmland with harvest data continues to be a challenge, and relatively stable buck harvests the past 20 years suggests a stable population with limited potential for growth, likely a result of habitat constraints. We selected management designations to stabilize deer numbers with consistent regulations across years whenever possible. Most farmland DPAs (n = 24) were under a Lottery designation. Five of the DPAs required Hunter Choice and 7 were under Managed designations to stabilize or reduce deer numbers at appropriate levels.

Farmland-Forest Transition Zone

Deer populations in the farmland-forest transition zone are highly productive due to excellent habitat and generally milder winters as compared to the forest zone. Historical harvests and modeled population trends suggested that Lottery designations were not sufficient to stabilize deer numbers in most transition zone DPAs as evidenced by few DPAs with Lottery recommendations. Of the 50 transition zone DPAs with goals, 3 were within 10% of goal, 0 were at least 10% below goal, and 38 were at least 10% above goal based on modeling or buck harvest trends. For the 2019 season designations, Lottery will be used for 3 of the DPAs, Hunter Choice for 7 DPAs, and Managed for 14 DPAs. In 18 DPAs, Intensive designations will be necessary to continue reducing deer densities toward goal level, 1 of which (DPA 343) have additional antlerless seasons. In the metro area (DPA 701) and the chronic wasting disease management zone (DPAs 645, 646, 647, 648, 649, and 655), Unlimited Antlerless opportunity will be available during the legal hunting seasons.

Forest Zone

Many deer populations in the forest zone with adequate habitat have recovered from the severe winter of 2013-14. Of the 44 forest zone DPAs, 8 were within 10% of goal, 13 were at least 10% below goal, and 15 were at least 10% above goal based on modeling or buck harvest trends. For 2019 season designations, Bucks-only will be used in 2 DPAs, Lottery in 14 DPAs, Hunter Choice in 19 DPAs, Managed in 5 DPAs, Intensive in 2 DPAs, and Unlimited Antlerless in 2 DPAs.

ABRIDGED DESCRIPTIONS OF DEER HUNTING SEASON DESIGNATIONS (MNDNR 2019)

Bucks-only. All hunters, including youth and archery hunters, are restricted to harvesting only legal bucks. No antlerless deer may be harvested; limited exceptions for hunters ≥84 years of age or persons in veterans homes. The bag limit is **one** deer.

Lottery. A hunter may apply for authorization to harvest one either-sex deer during either the firearm or muzzleloader season. Archery hunters can take a deer of either sex. Under this scenario, archers, youth, and disabled hunters can kill a deer of either-sex. The bag limit is **one** deer.

Hunter Choice. The initial license is either-sex and bonus permits cannot be used. There is no antlerless permit lottery application and all hunters potentially could harvest an antlerless deer, regardless of season. The bag limit is **one** deer.

Managed. The initial license is either-sex and a maximum of **two** deer (one buck) can be taken using any combination of licenses and permits.

Intensive. The initial license is either-sex and the maximum of **three** deer (one buck) can be taken using any combination of licenses and permits.

***Early Antlerless.** A hunter could harvest **five additional** deer in these permit areas during the early antlerless season (e.g. the annual limit in an intensive permit area with an early antlerless season would be eight deer).

LITERATURE CITED

Brinkman, T. J., J. A. Jenks, C. S. DePerno, B. S. Haroldson, and R. G. Osborn. 2004. Survival of white-tailed deer in an intensively farmed region of Minnesota. Wildlife Society Bulletin 32:1-7.

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. Journal of Wildlife Management 73:175-183.

DelGiudice, G. D., M. R. Riggs, P. Joly, and W. Pan. 2002. Winter severity, survival, and cause-specific mortality of female white-tailed deer in north-central Minnesota. Journal of Wildlife Management 66:698-717.

DelGiudice, G. D., J. Fieberg, M. R. Riggs, M. Carstensen Powell, and W. Pan. 2006. A long-term age-specific survival analysis of female white-tailed deer. Journal of Wildlife Management 70:1556-1568.

DelGiudice, G. D., M. S. Lenarz, and M. Carstensen Powell. 2007. Age-specific fertility and fecundity in northern free-ranging white-tailed deer: evidence for reproductive senescence? Journal of Mammalogy 88:427-435.

DePerno, C. S., J. A. Jenks, S. L. Griffin, and L. A. Rice. 2000. Female survival rates in a declining white-tailed deer population. Wildlife Society Bulletin 28:1030-1037.

DeYoung, C. A. 2011. Population dynamics. Pages 147-180 *in* D. G. Hewitt, editor. Biology and management of white-tailed deer. CRC, Boca Raton, Florida, USA.

Ditchkoff, S. S. 2011. Anatomy and physiology. Pages 43-73 *in* D. G. Hewitt, editor. Biology and management of white-tailed deer. CRC, Boca Raton, Florida, USA.

Dittrich, j. 2016. Deer Reproduction and nutritional condition in Wisconsin. Project W 160-P performance report. Bureau of Science Services, Wisconsin Department of Natural Resources, Madison, Wisconsin, USA. 8 pp.

Dumont, A., M. Crete, J. Ouellet, J. Huot, and J. Lamoureux. 2000. Population dynamics of northern white-tailed deer during mild winters: evidence of regulation by food competition. Canadian Journal of Zoology 78:764-776.

Dunbar, E. 2007. Fetus survey data of white-tailed deer in the farmland/transition zone of Minnesota-2007. Pages 29-34 in M. H. Dexter, editor. Status of wildlife populations, fall 2007. Division of Fish and Wildlife, Minnesota Department of Natural Resources, St. Paul, Minnesota. 302 pp.

Dusek, G. L., A. K. Wood, and S. T. Stewart. 1992. Spatial and temporal patterns of mortality among female white-tailed deer. Journal of Wildlife Management 56:645-650.

Fuller, T. K. 1990. Dynamics of a declining white-tailed deer population in north-central Minnesota. Wildlife Monographs 110.

Grovenburg, T. W., 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. American Midland Naturalist 165:426-435.

Grund, M. D., and A. Woolf. 2004. Development and evaluation of an accounting model for estimating deer population sizes. Ecological Modelling 180:345-357.

Grund, M. D. 2011. Survival analysis and computer simulations of lethal and contraceptive management strategies for urban deer. Human-Wildlife Interactions 5:23-31.

Grund, M. D. 2014. Monitoring population trends of white-tailed deer in Minnesota-2014. Pages 18-28 *in* M. H. Dexter, editor. Status of wildlife populations, fall 2014. Unpublished report. Division of Fish and Wildlife, Minnesota Department of Natural Resources, St. Paul, Minnesota. 328 pp.

Hansen, L. 2011. Extensive management. Pages 409-452 *in* D. G. Hewitt, editor. Biology and management of white-tailed deer. CRC, Boca Raton, Florida, USA.

Haroldson, B. S. 2014. 2014 white-tailed deer surveys. Pages 29-34 *in* M. H. Dexter, editor. Status of wildlife populations, fall 2014. Unpublished report. Division of Fish and Wildlife, Minnesota Department of Natural Resources, St. Paul, Minnesota. 328 pp.

Huegel, C. N., R. B. Dahlgren, and H. L. Gladfelter. 1985. Mortality of white-tailed deer fawns in south-central Iowa. Journal of Wildlife Management 49:377-380.

Hiller, T. L., H. Campa, S. Winterstein, and B. A. Rudolph. 2008. Survival and space use of fawn white-tailed deer in southern Michigan. American Midland Naturalist 159:403-412.

Kunkel, K. E., and L. D. Mech. 1994. Wolf and bear predation on white-tailed deer fawns in northeastern Minnesota. Canadian Journal of Zoology 72:1557-1565.

McCaffery, K. R., J. E. Ashbrenner, and R. E. Rolley. 1998. Deer reproduction in Wisconsin. Transactions of the Wisconsin Academy of Sciences, Art, and Letters 86:249-261.

Nelson, M. E., and L. D. Mech. 1986a. Mortality of white-tailed deer in northeastern Minnesota. Journal of Wildlife Management 50:691-698.

Nelson, M. E., and L. D. Mech. 1986b. Relationship between snow depth and gray wolf predation on white-tailed deer. Journal of Wildlife Management 50:471-474.

Nelson, T. A., and A. Woolf. 1987. Mortality of white-tailed deer fawns in southern

Illinois. Journal of Wildlife Management 51:326-329.

Nixon, C. M., L. P. Hansen, P. A. Brewer, and J. E. Chelsvig. 1991. Ecology of white-tailed deer in an intensively farmed region of Illinois. Wildlife Monographs 118.

Nixon, C. M., L. P. Hansen, P. A. Brewer, J. E. Chelsvig, T. L. Esker, D. Etter, J. B. Sullivan, R. G. Koerkenmeier, and P. C. Mankin. 2001. Survival of white-tailed deer in intensively farmed areas of Illinois. Canadian Journal of Zoology 79:581-588.

Norton, A. S. 2015. Integration of harvest and time-to-event data used to estimate demographic parameters for white-tailed deer. Dissertation, University of Wisconsin – Madison, Madison, Wisconsin, USA.

R Core Team. 2015. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <http://www.R-project.org/>.

Rohm, J. H., C. K. Nielson, and A. Woolf. 2007. Survival of white-tailed deer fawns in southern Illinois. Journal of Wildlife Management 71:851-860.

Rupp, S. P., W. B. Ballard, and M. C. Wallace. 2000. A nationwide evaluation of deer hunter harvest survey techniques. Wildlife Society Bulletin 28:570-578.

Storm, D. 2014. Deer Reproduction and nutritional condition in Wisconsin. Project W 160-P performance report. Bureau of Science Services, Wisconsin Department of Natural Resources, Madison, Wisconsin, USA. 6 pp.

Storm, D. 2015. Deer Reproduction and nutritional condition in Wisconsin. Project W 160-P performance report. Bureau of Science Services, Wisconsin Department of Natural Resources, Madison, Wisconsin, USA. 6 pp.

Van Deelen, T. R., H. Campa, J. B. Haufler, and P. D. Thompson. 1997. Mortality patterns of white-tailed deer in Michigan's upper Peninsula. Journal of Wildlife Management 61:903-910.

Verme, L. J. 1977. Assessment of natal mortality in upper Michigan deer. Journal of Wildlife Management 41:700-708.

Vreeland, J. K., D. R. Diefenbach, and B. D. Wallingford. 2004. Survival rates, mortality rates, and habitats of Pennsylvania white-tailed deer fawns. Wildlife Society Bulletin 32:542-553.

Warbington, W. H., T. R. Van Deelen, A. S. Norton, J. L. Stenglein, D. J. Storm, and K. J. Martin. 2017. Cause-specific neonatal mortality of white-tailed deer in Wisconsin, USA. Journal of Wildlife Management 81:824-833.

Whitlaw, H. A., W. B. Ballard, D. L. Sabine, S. J. Young, R. A. Jenkins, and G. J.

Forbes. 1998. Survival and cause-specific mortality rates of adult white-tailed deer in New Brunswick. Journal of Wildlife Management 62:1335-134.

Table 1. Estimated mean pre-fawn deer densities (deer/mi^2) derived from population model simulations in Minnesota deer permit areas, 2014-2019.

		Pre-fawn deer density[a]					
Deer Permit Area	Land area (mi^2)	2014	2015	2016	2017	2018	2019
101	496	8	9	11	12	14	15
103	1820	3	3	4	4	5	5
105	740	10	11	13	14	16	15
108	1655	5	5	7	7	8	8
110	529	11	12	14	15	16	16
111	1438	2	2	3	3	3	3
114	123	-	-	-	-	-	-
117	936	-	-	-	-	-	-
118	1239	4	4	4	4	4	4
119	782	5	5	6	7	7	7
126	942	3	3	3	3	3	3
130	746	3	3	4	4	4	4
131	899	-	-	-	-	-	-
132	482	4	5	5	6	7	6
133	352	7	8	9	10	10	9
152	60	-	-	-	-	-	-
155	594	15	17	20	23	25	25
156	819	10	12	13	15	16	17
157	888	20	20	22	25	19	19
159	571	12	13	15	17	19	21
169	1124	8	9	11	12	13	13
171	701	10	11	13	15	16	16
172	692	19	21	24	27	28	28
173	584	8	9	10	12	13	13
176	921	7	8	9	10	10	10
177	491	11	12	14	15	14	13
178	1195	8	9	11	13	14	14
179	857	12	13	15	16	16	15
181	629	9	10	12	14	15	16
182	278	-	-	-	-	-	-
183	664	11	12	15	18	20	21
184	1229	16	17	19	21	22	20
197	957	9	10	12	13	15	15
199	153	-	-	-	-	-	-
201	161	9	10	12	13	15	16
203	118	-	-	-	-	-	-
208	378	4	5	6	7	8	8

[a]"-" indicates deer permit area was not modeled

		Pre-fawn deer density[a]					
Deer Permit Area	Land area (mi^2)	2014	2015	2016	2017	2018	2019
209	639	7	8	9	10	10	10
210	615	8	8	9	10	10	9
213	1059	15	16	18	20	22	23
214	553	25	27	29	32	34	35
215	701	18	20	21	23	25	26
218	884	10	11	13	14	16	18
219	392	12	13	14	16	18	21
221	643	13	14	16	19	22	23
222	413	15	16	18	21	23	25
223	377	14	15	17	18	20	21
224	46	-	-	-	-	-	-
225	618	17	18	20	22	24	25
227	471	18	20	22	25	28	30
229	285	9	10	12	14	15	17
230	454	-	-	-	-	-	-
232	377	5	6	7	7	9	10
233	384	5	6	6	7	8	9
234	636	2	3	3	3	4	4
235	35	-	-	-	-	-	-
236	368	16	18	20	22	26	29
237	728	-	-	-	-	-	-
238	95	-	-	-	-	-	-
239	928	12	13	13	14	15	15
240	643	20	22	24	27	29	29
241	997	26	27	28	29	30	27
242	213	20	22	25	28	29	27
246	838	16	17	20	22	23	23
247	229	17	19	20	21	21	19
248	216	15	16	17	18	18	17
249	502	16	17	19	21	23	24
250	712	-	-	-	-	-	-
251	55	-	-	-	-	-	-
252	716	-	-	-	-	-	-
253	974	-	-	-	-	-	-
254	930	4	4	4	4	5	5
255	774	5	5	6	7	8	9
256	654	7	7	8	9	10	9
257	412	8	9	10	11	12	12
258	343	18	19	22	24	26	25
259	490	17	19	21	22	22	21

[a]”-“ indicates deer permit area was not modeled

		Pre-fawn deer density[a]					
Deer Permit Area	Land area (mi^2)	2014	2015	2016	2017	2018	2019
260	1248	3	4	5	6	7	7
261	793	3	4	4	5	7	7
262	677	3	3	4	4	5	5
263	512	8	9	11	12	14	14
264	669	12	13	16	17	19	19
265	494	9	10	11	12	14	13
266	617	5	6	6	7	9	9
267	472	4	5	5	6	6	5
268	228	9	9	10	11	10	10
269	650	3	3	4	4	5	5
270	736	3	3	3	4	5	5
271	632	3	3	3	3	4	4
272	532	-	-	-	-	-	-
273	572	6	6	7	8	9	10
274	355	6	6	6	7	8	9
275	764	4	4	4	5	5	6
276	542	9	10	11	13	15	16
277	812	12	13	14	15	16	18
278	402	6	6	7	8	9	10
279	344	4	4	4	5	5	5
280	674	3	3	3	3	3	3
281	575	7	7	8	10	12	13
282	778	-	-	-	-	-	-
283	613	4	4	4	4	4	4
284	840	-	-	-	-	-	-
285	546	5	5	6	7	8	9
286	447	5	5	6	7	8	9
287	47	-	-	-	-	-	-
288	624	5	5	5	6	6	6
289	816	2	2	3	3	3	4
290	661	5	6	6	7	8	8
291	799	6	6	7	8	9	10
292	480	9	10	11	12	14	16
293	511	8	9	10	10	11	12
294	687	4	4	4	5	5	6
295	839	4	5	5	6	7	8
296	665	3	4	4	4	5	6
297	438	3	3	3	4	5	5
298	618	9	10	12	15	17	17
299	387	5	6	6	6	7	8

[a]"-" indicates deer permit area was not modeled

		Pre-fawn deer density[a]					
Deer Permit Area	Land area (mi^2)	2014	2015	2016	2017	2018	2019
338	454	6	7	8	9	11	13
339	394	6	7	8	10	11	13
341	611	14	16	17	20	22	24
342	350	14	16	18	20	22	25
343	662	13	14	14	15	17	17
344	190	19	19	18	19	21	22
345	326	13	14	15	17	18	19
346	319	28	28	27	28	29	28
347	272	-	-	-	-	-	-
348	122	-	-	-	-	-	-
349	492	26	27	27	29	31	33
601	1632	-	-	-	-	-	-

[a]"-" indicates deer permit area was not modeled

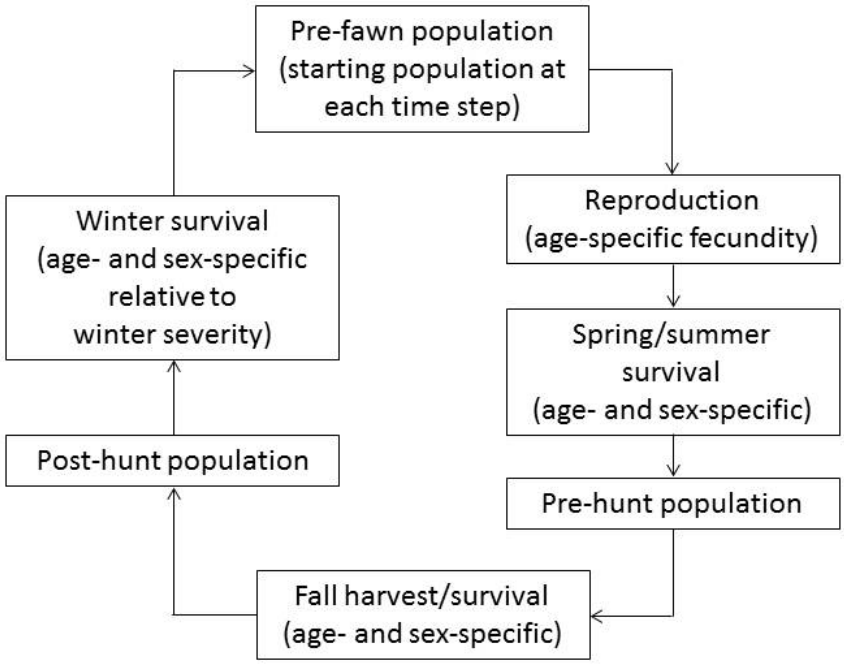

Figure 1. Model structure for simulations of white-tailed deer populations in Minnesota.

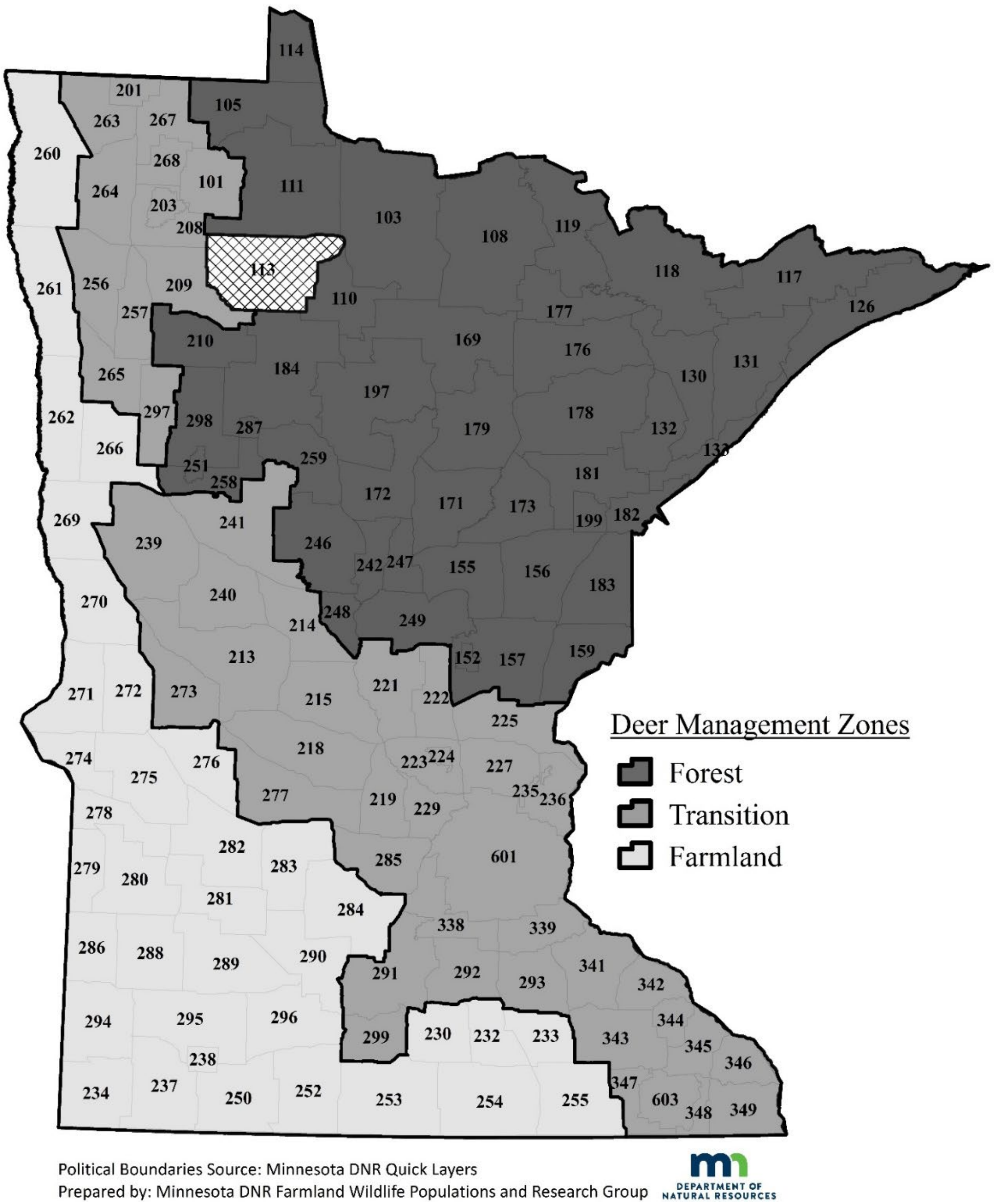

Figure 2. Deer permit areas (DPAs) in Minnesota and deer management zones used to describe deer population and harvest trends, 2018. DPAs were assigned to forest, transition, or farmland zones based on historical land cover and current woody cover. Generally, forested DPAs were composed of ≥60% woody cover, transition DPAs were composed of 6%-50% woody cover, and farmland DPAs were composed of ≤5% woody cover.