DEPARTMENT OF
NATURAL RESOURCES

MONITORING POPULATION TRENDS OF WHITE-TAILED DEER IN MINNESOTA - 2018

Andrew Norton, Farmland Wildlife Populations and Research Group

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, the output from population modeling is considered 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 imposed stochasticity by independently drawing random samples from the Normal or Uniform distribution (i.e., Monte Carlo method) for all parameters. We specified means and standard deviations to represent ranges of values for initial population proportions, fecundity, harvest recovery rates, and survival by sex- and age-classes of deer based on primary literature and studies within Minnesota. For all proportion or rate parameters (e.g., survival), we used the inverse logit transformation $\left(p = \frac{e^{\alpha}}{1+e^{\alpha}}\right)$ to constrain random values between 0 and 1.

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 = 0.40 [SD = 0.02], adult males mean = 0.25 [SD = 0.02]). The remaining proportion (0.35) was allocated equally to young-of-year (YOY) males and females.

Within each annual cycle, we applied age-specific fecundity rates to females to estimate reproduction. All age- and sex-classes were subjected to spring/summer mortality, and the result was the pre-hunt fall population. Deer that died as a result of hunting were subtracted from the pre-hunt population. Winter mortality rates were estimated by age-class relative to the severity of winter, and were applied 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. In the following, we provide more detailed information about the selection of model parameters.

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). Fecundity rates were partitioned by 2 age-classes of breeding females (i.e., <1 year old [YOY] when bred and ≥1 years old [adult] when bred) and were allowed to vary by 3 eco-geographic zones (northeast, farmland and transition areas, southeast) that reflected relative differences in climate and habitat quality. Fecundity rates were estimated to be lowest in the northeast (YOYs, mean = 0.06 [SD = 0.003]; adults, mean = 1.55 [SD = 0.078]), moderate in the farmland and transition zone (YOYs, mean = 0.08 [SD = 0.004]; adults, mean = 1.70 [SD = 0.085]), and greatest in the southeast (YOYs, mean = 0.15 [SD = 0.007]; adults, mean = 1.85 [SD = 0.092]). The sex ratio of fawns at birth in most deer populations is approximately 50:50, but may vary annually (Ditchkoff 2011). We allowed the proportion of male fawns at birth to uniformly vary between 0.48-0.52.

Spring/Summer Survival

Survival rates of deer during winter 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 of spring/summer survival of fawns, from values reported in the primary literature for deer in Minnesota and populations in similar habitats (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). Fawn survival rates were adjusted to approximate the effects of winter severity on the condition of adult females during the previous winter. Mean spring/summer survival values for fawns 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 default 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 stochastically (female = 0.97 [SD = 0.004], male = 0.98 [SD = 0.003]). 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

In most DPAs in Minnesota, hunter harvest represents the greatest source of mortality for deer populations in 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 died during the hunting season because they were harvested illegally or not registered (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 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 $WSI \leq 25$. When $WSI > 25$, we used a linear equation to calculate survival as a function of winter severity (mean winter survival = $1 - [0.011 + 0.0015 \times WSI]$) based on previous research in Minnesota. For fawns, we set the mean winter survival rate at 0.85 when $WSI \leq 60$.When WSI was above 60 and less than 100, the linear equation to calculate adult survival was used. However, an additional mortality rate of 0.05 was subtracted to simulate parallel but lower survival of fawns versus adults (mean winter survival = $(1 - [0.011 + 0.0015 \times WSI]) - 0.05$). For more severe winters ($100 \leq WSI \leq 240$), the equation was adjusted to simulate increased mortality reported for fawns in field studies (mean winter survival = $1 - [0.0054 \times WSI - 0.33]$). When WSI exceeded 240, we set fawn survival at 0.033. We then allowed winter survival (for both fawns and adults) in any given model iteration to vary stochastically about the predicted mean using $SD \approx 0.012$. Winter survival relationships were parameterized 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 for the starting year of the simulation (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 and given assumptions about the harvest rate of adult males, the proportion of adult males in the pre-hunt population, and the proportion of adults in the pre-hunt population.

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

Because the initial population density is the primary parameter adjusted, similar population trends can be fit when the mean for parameters that are constant (with only random variation) among years (e.g., recovery rates, adult summer survival) is 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 most model simulations for 7 years (2012-2018) with the final population estimate occurring pre-fawning for the spring following the most recent deer hunting season (i.e., spring 2018). All simulations were performed with the R programming language (ver. 3.3.2, R Core Team 2017). We used 500 Monte Carlo simulations until the most reasonable set of starting parameters was determined, and 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 the parameters included in the model were derived from studies of deer in Minnesota or from studies in similar habitats and environmental conditions, uncertainty is inherent in modeling the dynamics of free-ranging deer populations. Our modeling allowed input parameters to vary stochastically to simulate uncertainty, and model outputs also 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 104 of 130 DPAs in Minnesota to estimate deer densities before reproduction during spring 2018 (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 nearly all DPAs increased through 2017. Management designations in 2017 were liberalized in most DPAs compared to prior years in attempts 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 2018 will be required again to effectively manage deer populations in DPAs with average and above average productivity.

With the exception of northeastern Minnesota, the extended 2017-2018 winter had little effect on deer mortality and deer densities continued to increase across much of the state despite more liberal antlerless regulations in 2017. In terms of management intensity, the 2018 designations afford more antlerless deer harvest opportunities to hunters in approximately one third of the DPAs versus the 2017 season. For most of the remaining DPAs, designations in 2018 were the same as 2017, and only a few DPA designations afforded less antlerless harvest opportunity.

Farmland Zone

Of the 36 farmland zone DPAs, 10 were within 10% of goal, 12 were at least 10% below goal, and 14 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 = 25) were under a Lottery designation. Five of the DPAs required Hunter Choice and 6 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 45 transition zone DPAs with goals, 8 were within 10% of goal, 2 were at least 10% below goal, and 35 were at least 10% above goal based on modeling or buck harvest trends. For the 2018 season designations, Lottery will be used for 5 of the DPAs, Hunter Choice for 10 DPAs, and Managed for 16 DPAs. In 17 DPAs, Intensive designations will be necessary to continue reducing deer densities toward goal level, 3 of which (DPA 346, 348 and 349) have additional antlerless seasons. In the metro area (DPA 601) and the chronic wasting disease management zone (DPA 603), 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, 16 were within 10% of goal, 9 were at least 10% below goal, and 19 were at least 10% above goal based on modeling or buck harvest trends. For 2018 season designations, Bucks-only will be used in 1 DPA, Lottery in 9 DPAs, Hunter Choice in 21 DPAs, Managed in 9 DPAs, and Intensive in 4 DPAs.

ABRIDGED DESCRIPTIONS OF DEER HUNTING SEASON DESIGNATIONS (MNDNR 2017)

Bucks-only Deer Areas – The bag limit is one legal buck total per year. Except residents of Minnesota State Veterans' Homes and hunters who are 84 or older, no antlerless deer may be harvested.

Lottery Deer Areas – The bag limit is one deer total per year. An either-sex permit is required to take an antlerless deer unless you have a youth deer license, are 84 or older or are a resident of a Minnesota State Veterans' Home.

Hunter Choice Deer Areas – The bag limit is one either-sex deer total per year.

Managed Deer Areas – The bag limit is two deer total per year, only one of which can be antlered.

Intensive Deer Areas – The bag limit is three deer total per year, only one of which can be antlered.

Unlimited Antlerless Deer Areas – There is no limit to the number of antlerless deer that may be taken.

Early or Late Antlerless Season – The bag limit is 5 additional antlerless deer during each season.

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Table 1. Estimated mean pre-fawn deer densities (deer/mi^2) derived from population model simulations in Minnesota deer permit areas, 2012-2018.

Deer Permit Area	Land area (mi^2)	Pre-fawn deer density[a]						
		2012	2013	2014	2015	2016	2017	2018
101	496	7	7	6	7	8	9	10
103	1,820	4	4	3	3	4	4	5
105	740	12	12	9	9	11	12	13
108	1,651	7	7	5	5	6	7	8
110	529	18	16	11	11	14	15	17
111	1,438	3	3	2	3	3	4	4
114	116	-	-	-	-	-	-	-
117	927	-	-	-	-	-	-	-
118	1,220	6	6	4	4	4	5	5
119	770	8	7	4	4	5	6	7
126	942	5	5	3	3	3	3	3
130	746	5	5	3	3	4	4	4
131	899	-	-	-	-	-	-	-
132	482	8	8	5	5	6	6	7
133	352	14	13	7	7	9	10	10
152	61	-	-	-	-	-	-	-
155	593	17	16	13	14	17	19	20
156	825	16	16	10	11	13	15	16
157	673	21	21	21	21	24	27	28
159	571	18	19	14	15	18	21	24
169	1,124	13	13	8	9	11	13	14
171	701	11	11	9	10	12	13	14
172	687	20	20	16	19	21	24	25
173	584	11	11	8	7	9	10	12
176	921	13	12	8	8	10	12	13
177	480	18	17	11	11	14	15	16
178	1,195	13	12	8	8	10	12	13
179	862	21	21	13	13	16	18	18
181	629	14	14	8	9	11	13	15
182	267	-	-	-	-	-	-	-
183	663	14	15	9	10	13	15	17
184	1,229	22	20	15	16	18	20	22
197	955	14	13	9	10	12	14	16
199	148	-	-	-	-	-	-	-
201	161	9	9	7	8	9	9	10
203	118	-	-	-	-	-	-	-
208	379	5	5	4	5	6	7	7

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

Deer Permit Area	Land area (mi^2)	Pre-fawn deer density[a]						
		2012	2013	2014	2015	2016	2017	2018
209	640	8	9	7	7	8	9	9
210	615	12	11	8	9	10	11	12
213	1,057	14	15	15	15	17	19	21
214	554	24	25	23	23	24	26	26
215	701	17	18	17	17	19	20	22
218	884	9	10	10	10	11	13	14
219	391	11	12	12	12	13	15	17
221	642	14	15	13	13	15	17	19
222	413	18	18	15	15	17	20	22
223	376	13	15	14	14	16	17	19
224	47	-	-	-	-	-	-	-
225	618	19	20	17	17	20	22	24
227	472	18	19	17	17	19	20	22
229	284	8	9	9	10	11	13	14
230	452	-	-	-	-	-	-	-
232	377	4	5	5	5	6	7	7
233	385	4	4	4	5	5	6	6
234	636	2	2	2	2	3	3	3
235	34	-	-	-	-	-	-	-
236	370	16	17	15	16	17	19	21
237	728	-	-	-	-	-	-	-
238	95	-	-	-	-	-	-	-
239	919	13	12	11	11	12	12	13
240	643	20	21	20	19	22	23	25
241	996	29	30	25	25	26	27	27
242	214	26	26	22	23	27	30	31
246	840	18	17	14	16	18	20	21
247	228	22	22	19	20	22	24	25
248	214	21	21	18	17	19	21	22
249	502	18	19	17	16	18	21	23
250	713	-	-	-	-	-	-	-
251	55	-	-	-	-	-	-	-
252	715	-	-	-	-	-	-	-
253	974	-	-	-	-	-	-	-
254	929	4	4	4	4	4	4	5
255	774	4	4	4	5	5	6	7
256	654	7	7	6	7	8	8	9
257	412	8	9	8	8	9	10	11
258	343	21	20	17	18	20	22	24
259	490	23	20	16	17	20	22	22

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

Deer Permit Area	Land area (mi^2)	Pre-fawn deer density[a]						
		2012	2013	2014	2015	2016	2017	2018
260	1,249	3	3	3	4	4	5	6
261	795	2	2	2	3	3	4	4
262	677	2	3	3	3	3	4	5
263	512	7	8	6	7	9	9	10
264	669	10	10	9	10	10	11	12
265	494	8	9	8	9	10	11	11
266	617	5	5	5	5	6	7	8
267	472	5	5	4	5	6	6	7
268	228	10	10	9	10	11	11	11
269	650	2	3	3	3	3	4	5
270	748	-	-	-	-	-	-	-
271	632	-	2	2	3	3	3	4
272	531	-	-	-	-	-	-	-
273	571	5	6	6	6	7	8	9
274	354	5	5	5	5	5	6	7
275	764	3	3	3	3	3	4	4
276	542	7	8	8	9	10	12	13
277	812	11	12	12	13	14	15	17
278	402	6	6	6	6	7	8	9
279	344	4	4	4	4	4	4	4
280	675	3	2	2	2	3	3	3
281	575	5	5	6	7	8	9	10
282	778	-	-	-	-	-	-	-
283	613	-	-	-	-	-	-	-
284	838	-	-	-	-	-	-	-
285	549	5	5	6	6	7	8	10
286	446	5	5	5	5	5	6	7
287	46	-	-	-	-	-	-	-
288	625	5	5	5	5	5	5	6
289	815	2	2	2	2	2	3	3
290	662	4	5	5	5	6	7	7
291	800	6	6	6	7	7	8	9
292	479	8	9	9	10	12	13	15
293	511	8	9	8	9	10	11	12
294	686	4	4	4	4	4	4	5
295	839	4	4	4	4	4	5	6
296	667	3	3	3	3	4	4	5
297	438	3	3	3	3	3	4	5
298	618	10	9	9	10	12	14	16
299	386	5	5	5	5	6	6	7

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

Deer Permit Area	Land area (mi^2)	Pre-fawn deer density[a]						
		2012	2013	2014	2015	2016	2017	2018
338	454	5	5	6	6	7	8	10
339	394	6	6	6	7	7	8	10
341	612	13	13	13	14	14	15	16
342	349	14	14	14	15	15	16	17
343	663	13	13	13	13	13	13	14
344	190	19	19	18	17	16	16	17
345	323	12	13	13	14	14	15	16
346	318	27	29	30	29	28	28	29
347	434	-	-	-	-	-	-	-
348	332	-	-	-	-	-	-	-
349	490	23	25	26	27	26	27	28
601	1,625	-	-	-	-	-	-	-
603	364	-	-	-	-	-	-	-

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

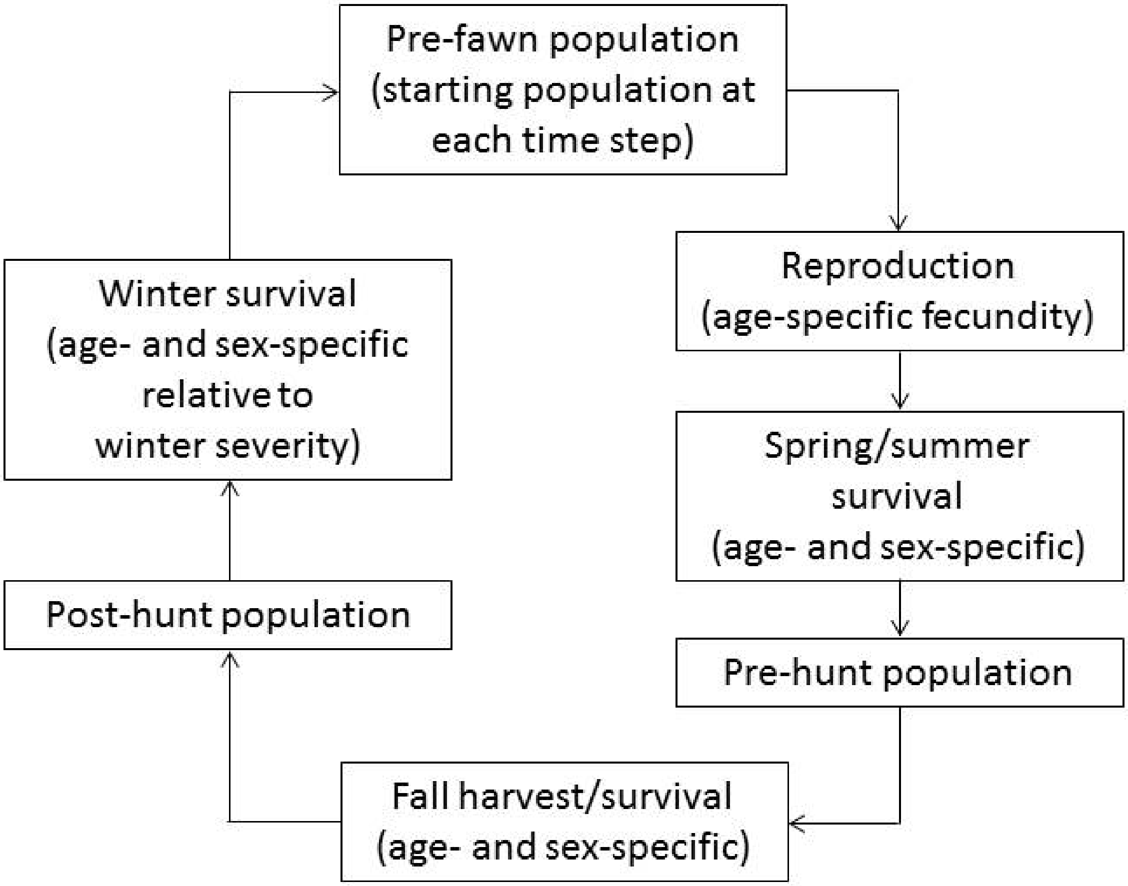
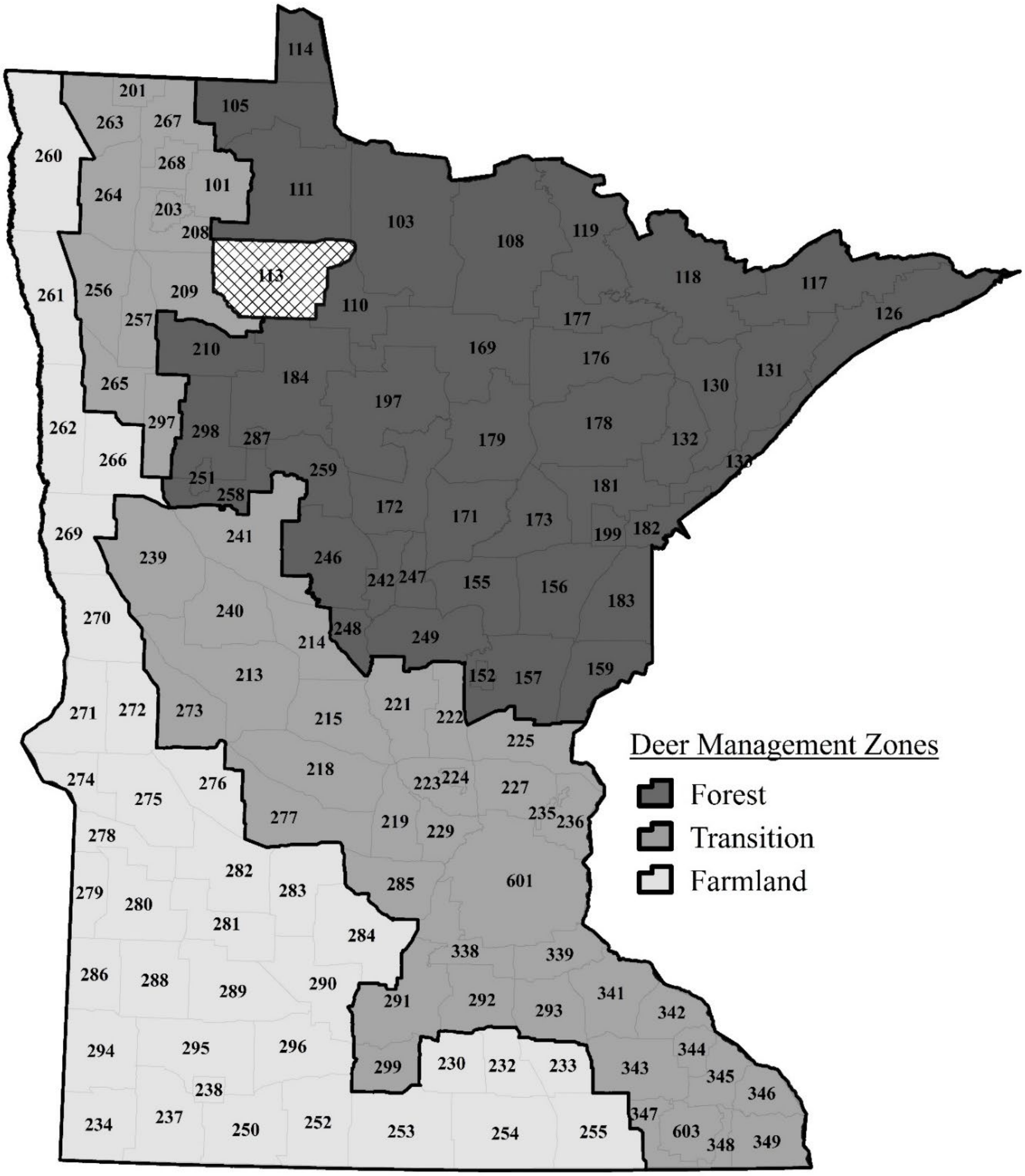


Figure 1. Model structure for simulations of white-tailed deer populations in Minnesota.



Political Boundaries Source: Minnesota DNR Quick Layers
Prepared by: Minnesota DNR Farmland Wildlife Populations and Research Group

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.