Monitoring Population Trends of White-tailed Deer in Minnesota - 2015

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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.

We utilized a stochastic population model to simulate annual variations in deer densities within individual DPAs. We defined ranges of values for fecundity 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.

METHODS

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. Based on harvest data from previous years (McInenly 2014), we estimated 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]).

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 harvested 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, which were within a range of values reported for Minnesota and Wisconsin (MNDNR unpublished data, Fuller 1990, McCaffery et al. 1998, DelGiudice et al. 2007, Dunbar 2007, Grund 2011, Wisconsin Department of Natural Resources 2014). Fecundity rates were partitioned by 2 age-classes of breeding females (i.e., yearlings <1.0 years old when bred and adults ≥1.0 years old when bred) and were allowed to vary by 3 eco-geographic zones (northeast, farmland-forest transition areas, southeast) that reflected relative differences in habitat quality. Fecundity rates were estimated to be lowest in the northeast (yearlings, mean = 0.06 [SD = 0.01]; adults, mean = 1.55 [SD = 0.03]), moderate in the farmland-forest transition zone (yearlings, mean = 0.10 [SD = 0.01]; adults, mean = 1.75 [SD = 0.03]), and greatest in the southeast (yearlings, mean = 0.15 [SD = 0.01]; adults, mean = 1.85 [SD = 0.03]). 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 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. Winters were considered mild when the WSI was <100 and severe winters had a WSI ≥180.

We used estimates of spring/summer survival of fawns, which spanned values reported in the primary literature for deer in Minnesota and populations in similar habitats (Huegel et al. 1985, Nelson and Mech 1986a, Nelson and Woolf 1987, Kunkel and Mech 1994, Van Deelen et al. 1997, Brinkman et al. 2004, Vreeland et al. 2004, Rohm et al. 2007, Hiller et al. 2008, Carstensen et al. 2009). 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 0.80 (SD = 0.03), 0.65 (SD = 0.03), and 0.45 (SD = 0.03) following mild (WSI <100), moderate (WSI ≥100 and <180), and severe winters (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 = 0.01, male = 0.98 [SD = 0.01]). 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 Survival

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 within DPAs.

We recognized that some deer were killed but not registered because hunters did not complete the registration process (Rupp et al. 2000), wounding loss occurred (i.e., deer was not recovered by the hunter and thus was not reported; Nixon et al. 2001), and deer were harvested illegally (Dusek et al. 1992). We first applied a mean multiplier of 1.05 (SD = 0.002) to the numerical harvest to account for non-registered deer. We then applied a mean multiplier of 1.05 (SD = 0.002) for wounding loss and 1.05 (SD = 0.002) for illegal harvest. The mean multiplier for combined harvest reporting errors was 1.13 (SD = 0.003).

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). 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).

For adult deer, we set mean winter survival at 0.95 during mild winters. For moderate to severe winters, the model used a linear equation to calculate survival as a function of winter severity (mean winter survival = $1 - [0.011 + 0.0015\ \text{WSI}]$). For fawns, we set the mean winter survival rate at 0.85 during mild winters. For fawn survival in moderate winters, the linear equation to calculate adult survival was used, however, an additional mortality rate of 0.05 was subtracted to simulate the parallel but lower survival of fawns versus adults (mean winter survival = $(1 - [0.011 + 0.0015\ \text{WSI}]) - 0.05$). For severe winters, the equation was adjusted to simulate increased mortality reported for fawns in field studies (mean winter survival = $1 - [0.0054\ \text{WSI} - 0.33]$). For extremely severe winters (WSI >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 $\approx$ 0.02.

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. 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 spring/summer survival of adult females $\leq$0.10 in conjunction with varying initial population densities.

We ran each model simulation for 6 years (2010-2015) with the final population estimate occurring pre-fawning for the spring following the most recent deer hunting season (i.e., spring 2015). All simulations were performed with the R programming language (ver. 3.1.2, R Core Team 2014). We used 1,000 Monte Carlo simulations (simulated draws from the stochastic distributions) 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). Since 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

Deer population goal-setting was conducted during 2015 in 40 deer permit areas through a public process. Of the 40 deer permit areas with new goals, 26 will be managed for deer densities higher than those established by the previous goals; 8 will be managed at similar densities to former goals; and 6 will be managed for densities below former goals. Management designations throughout the state for the 2014 deer season were conservative to intentionally reduce harvest of antlerless deer to offset deer mortality due to the harsh winter of 2013-14. The Statewide deer harvest of approximately 139,442 deer was the lowest observed since the mid-1980s with antlerless harvest 34% below the average for the previous 5 years. With more antlerless deer left on the landscape and mild winter conditions throughout much of the state, deer populations in most DPAs likely increased above 2014 levels following reproduction in 2015.

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 112 of 128 DPAs (Table 1). Recommendations from MNDNR research for the 2015 deer season were similar to 2014 to provide continuity in management designations wherever possible. Changes in management strategies were recommended to: 1) bring stabilization to deer populations that had reached appropriate levels by spring of 2015, or 2) to increase or decrease populations toward goals where necessary.

Farmland Zone

Most DPAs throughout the farmland region were recommended for Lottery designations with a low to moderate number of either-sex permits. Most deer populations have been stable for several years, and these DPAs generally have consistent hunter numbers with less hunting pressure than the farmland-forest transition zone and forest region. Antlerless harvest in the farmland is closely tied to the number of either-sex permits and a similar number of permits across years will maintain deer densities.

Farmland-Forest Transition Zone

Deer populations along the transition zone are highly productive. Most recommendations for the DPAs in the transition zone were for the Hunter Choice designation or Lottery with permit levels allowing ≥20% of hunters to receive an either-sex permit. Several areas were recommended for Managed where deer abundance is higher and agricultural depredation is a concern. Deer populations in DPAs 346 and 349 in extreme southeast Minnesota have been above goal levels for several years and agricultural complaints are common. These DPAs should be managed with an Intensive designation and an early season antlerless hunt to maximize the harvest of antlerless deer and to reduce deer densities in a reasonable timeframe.

Forest Zone

Deer herds in the forest zone were most impacted by the severe winter of 2013-14. In some DPAs, winter mortality of fawns would have exceeded 90% with substantial losses of adult deer. Several years of conservative management will allow deer numbers to rebound if winters continue to be mild. Recommendations for the majority of forest DPAs were for a low number of Lottery permits or Bucks-only designations. DPAs in the moose range have relatively low population goals to minimize the effects of deer abundance on moose. Also, with Bucks-only designations during 2014 in these areas, populations likely began to rebound. Given these factors, DPAs in the northeastern-most portion of the arrowhead were recommended for less conservative designations to maintain current deer densities.

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.

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.

MCINENLY, L. E. 2014. 2013 Minnesota deer harvest report. Pages 236-279 *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.

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.

R CORE TEAM. 2014. 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.

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.

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.

WISCONSIN DEPARTMENT OF NATURAL RESOURCES. 2014. County deer advisory council deer metrics, Adams County, fall 2014. Wisconsin Department of Natural Resources, Madison, Wisconsin, USA.

Table 1. Mean pre-fawn deer densities (deer/mi^2) derived from 5,000 population model simulations in Minnesota deer permit areas, 2010-2015.

		Pre-fawn deer density[a]					
Deer Permit Area	Land area (mi^2)	2010	2011	2012	2013	2014	2015
101	496	-	-	-	-	-	-
103	1820	4	4	4	4	3	3
105	740	13	12	13	13	10	10
108	1651	6	6	7	7	5	5
110	529	19	16	18	16	12	12
111	1438	3	3	3	3	2	3
114	116	-	-	-	-	-	-
117	927	-	-	-	-	-	-
118	1220	5	4	5	5	3	4
119	770	8	7	8	8	5	6
122	603	6	5	5	6	4	4
126	942	4	4	4	5	3	3
127	564	-	-	-	-	-	-
152	61	-	-	-	-	-	-
155	593	18	18	19	19	16	19
156	825	16	16	15	14	9	9
157	673	21	20	20	19	19	19
159	571	18	16	16	17	12	14
169	1124	13	12	13	12	8	9
171	701	12	12	13	13	10	11
172	687	21	21	22	23	18	21
173	584	10	10	10	10	7	8
176	1113	13	12	13	14	9	10
177	480	23	19	20	20	13	14
178	1280	16	13	12	12	7	8
179	862	20	18	18	17	11	10
180	977	10	9	8	8	5	5
181	708	18	15	13	14	8	9
182	267	-	-	-	-	-	-
183	663	14	15	16	18	12	13
184	1229	22	21	22	21	16	18
197	955	13	12	12	12	9	10
199	148	-	-	-	-	-	-
201	161	-	-	-	-	-	-
203	83	-	-	-	-	-	-
208	414	6	6	6	6	6	7
209	640	8	8	8	7	5	6

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

Deer Permit Area	Land area (mi^2)	Pre-fawn deer density[a]					
		2010	2011	2012	2013	2014	2015
210	615	14	12	11	10	7	7
213	1057	15	14	15	16	18	21
214	554	23	24	26	28	26	27
215	701	15	16	17	19	18	18
218	884	9	10	10	11	11	13
219	391	12	13	13	15	15	17
221	642	14	14	15	16	14	14
222	413	17	17	17	17	14	15
223	376	12	13	14	16	16	17
224	47	-	-	-	-	-	-
225	618	17	16	17	18	14	14
227	472	17	17	17	18	15	16
229	284	7	8	8	10	10	12
230	452	4	4	4	4	4	4
232	377	6	5	5	6	5	6
233	385	5	5	5	5	5	5
234	636	2	3	3	3	3	3
235	34	-	-	-	-	-	-
236	370	17	16	17	17	16	17
237	728	2	2	3	2	2	3
238	95	-	-	-	-	-	-
239	919	13	12	12	12	11	13
240	643	20	19	20	21	20	20
241	996	28	28	28	30	24	25
242	214	24	23	22	20	15	14
246	840	16	16	17	17	15	17
247	228	20	20	21	22	19	20
248	214	20	20	20	20	17	16
249	502	18	16	17	18	16	16
250	713	4	4	4	5	6	7
251	55	-	-	-	-	-	-
252	715	4	4	4	5	6	7
253	974	3	3	4	4	4	5
254	929	4	4	5	5	5	5
255	774	4	4	4	5	5	5
256	654	6	6	6	6	6	6
257	412	8	7	8	8	7	8
258	343	21	20	22	22	19	22
259	490	25	24	24	23	18	21
260	1249	2	2	2	3	2	3

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

		Pre-fawn deer density[a]					
Deer Permit Area	Land area (mi^2)	2010	2011	2012	2013	2014	2015
261	795	2	2	3	3	4	4
262	677	2	2	2	3	3	3
263	512	8	7	8	9	8	9
264	669	10	10	11	13	12	14
265	494	8	8	8	9	9	10
266	617	5	4	4	5	5	6
267	472	4	4	4	4	3	4
268	228	11	10	11	12	11	13
269	650	3	3	3	3	3	4
270	748	2	2	2	2	2	3
271	632	3	3	3	3	4	5
272	531	3	3	3	4	4	6
273	571	6	6	6	7	8	10
274	354	5	5	5	6	8	9
275	764	4	3	3	4	4	5
276	542	8	8	8	9	9	11
277	812	12	12	13	16	18	22
278	402	6	6	6	7	8	11
279	344	4	4	4	5	6	7
280	675	2	2	2	3	3	4
281	575	6	6	6	7	8	9
282	778	2	2	2	2	3	4
283	613	4	4	4	5	6	7
284	838	3	3	3	4	4	5
285	549	5	5	5	6	6	6
286	446	5	5	5	5	5	5
287	46	-	-	-	-	-	-
288	625	6	6	6	6	6	6
289	815	2	2	2	3	3	3
290	662	6	5	5	6	6	7
291	800	6	6	7	7	8	9
292	479	8	8	9	11	12	15
293	511	8	8	8	8	7	7
294	686	3	3	4	4	4	5
295	839	4	4	4	5	5	6
296	667	4	4	4	5	6	7
297	438	3	3	3	3	3	3
298	618	10	9	10	10	9	12
299	386	5	5	5	6	6	6
338	454	5	6	6	6	6	6

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

Deer Permit Area	Land area (mi^2)	Pre-fawn deer density[a]					
		2010	2011	2012	2013	2014	2015
339	394	6	6	6	7	7	7
341	612	13	13	12	12	11	12
342	349	16	16	15	14	12	11
343	663	12	12	12	12	12	11
344	190	-	-	-	-	-	-
345	323	11	11	12	12	12	12
346	318	26	28	28	28	26	22
347	434	8	9	10	10	9	9
348	332	16	16	16	15	14	14
349	490	22	24	23	23	22	20
601	1625	-	-	-	-	-	-

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

Figure 1. Model structure for simulations of white-tailed deer populations in Minnesota, 2015.