ESTIMATING WHITE-TAILED DEER ABUNDANCE USING AERIAL QUADRAT SURVEYS

Brian S. Haroldson

SUMMARY OF FINDINGS

I estimated white-tailed deer (*Odocoileus virginianus)* abundance in select permit areas (PA) using quadrat surveys to recalibrate deer population models and evaluate the impact of deer season regulation changes on population size. With rare exception, precision of population estimates was similar among permit areas. However, because population estimates were not corrected for sightability, estimates represent minimum counts and are biased low. In 2009, I incorporated a sightability estimator to adjust estimates for animals missed during surveys. Sightability estimates were similar during 2009-2010. Additional sightability trials are needed to determine how sightability varies over space and time.

INTRODUCTION

Management goals for animal populations are frequently expressed in terms of population size (Lancia et al. 1994). Accurate estimates of animal abundance allow for documentation of population trends, provide the basis for setting harvest quotas (Miller et al. 1997), and permit assessment of population and habitat management programs (Storm et al. 1992).

The Minnesota Department of Natural Resources (MNDNR) uses simulation modeling to estimate and track changes in deer abundance and, subsequently, to develop harvest recommendations to keep deer populations within goal levels. In general, model inputs include estimates of initial population size and spatial/temporal estimates of survival and reproduction for various age and sex cohorts. Because simulated population estimates are subject to drift as model input errors accumulate over time, it is imperative to periodically recalibrate the starting population within these models with independent deer population estimates (Grund and Woolf 2004).

Minnesota's deer numbers are managed according to numeric population goals within 125 PAs. MNDNR recently revised deer population goals within each PA using a consensus-based, roundtable approach consisting of 15-20 citizens representing varied interest groups (e.g. deer hunters, farmers, foresters, environmental groups, etc.; Stout et al. 1996). Revised goals are used to guide deer-harvest recommendations. Currently, deer populations exceed management goals in many PAs. A conventional approach of increasing the bag limit within the established hunting season framework has failed to reduce deer densities. As a result, MNDNR began testing the effectiveness of 3 non-traditional harvest regulations to increase the harvest of antlerless deer and reduce overall population levels (Grund et al. 2005). Accurate estimates of deer abundance are needed to evaluate these regulations.

My objective in this investigation is to provide independent estimates of deer abundance in select PAs that are within 20% of the true mean with 90% confidence (Lancia et al. 1994). Abundance data will be used to recalibrate population models to improve population management and to evaluate impacts of deer season regulation changes on deer abundance.

METHODS

I estimated deer populations in selected PAs using a quadrat-based, aerial survey design. Quadrat surveys have been used to estimate populations of caribou (*Rangifer tarandus*; Siniff and Skoog 1964), moose (*Alces alces*; Evans et al. 1966), and mule deer (*O. heimonus*; Bartmann et al. 1986) in a variety of habitat types. Quadrats were selected using 1 of 3 sampling designs: (1) stratified random (StRS; Cochran 1977); (2) 2-dimensional (2-D) systematic (Cressie 1993, D'Orazio 2003); or (3) generalized random-tessellation stratified (GRTS; Stevens and Olsen 2004). I used a StRS sampling design in PAs where the local wildlife manager had prior knowledge about deer abundance and distribution. Quadrats were stratified into 2 abundance classes (low, high) based on relative deer densities. Occasionally, additional strata were constructed to encompass management boundaries (e.g., park boundaries). I used a 2-D systematic sampling design in other areas. Systematic designs are typically easier to implement and maximize spatial distribution of the sample. Beginning in 2008, I used the GRTS design to obtain spatially balanced stratified and random samples. This design improves the spatial distribution of StRS and permits replacement of sample quadrats that are lost due to navigation hazard or high human development. Previously, replacement quadrats were unavailable in systematic PAs because of the rigid, 2-D design.

Within each PA, quadrats were delineated by Public Land Survey section boundaries and a 20% sample was selected for surveying. Sample size calculations indicated this sampling rate was needed to meet accuracy and precision objectives. I used OH-58 helicopters during most surveys and attempted to maintain a flight altitude of 60 m above ground level and an airspeed of 64-80 km/hr. A Cessna 182 airplane was used in 3 PAs dominated by intensive row-crop agriculture. To increase visibility, I completed surveys after leaf-drop and when snow cover measured at least 15 cm. A pilot and 2 observers searched for deer along transects spaced at 270-m intervals until they were confident all "available" deer were observed. When animals fled the helicopter, direction of movement was noted to avoid double counting. I used a real-time, moving-map software program (DNR Survey; MNDNR 2005), coupled to a global positioning system receiver and a tablet-style computer, to guide transect navigation and record deer locations, direction of movement, and aircraft flight paths directly to ArcView GIS (Environmental Systems Research Institute 1996) shapefiles. I estimated deer abundance from StRS surveys using PROC SURVEYMEANS (SAS 1999). I used the R programming language (RDCT 2009) and formulas developed by D'Orazio (2003) for 2-D systematic surveys and the R package SPSURVEY (ver. 2.0; RDCT 2009) for GRTS surveys. I evaluated precision using coefficient of variation (CV), defined as standard deviation of the population estimate divided by the population estimate, and relative error (RE), defined as the 90% confidence interval bound divided by the population estimate (Krebs 1999).

I conducted a pilot study in 2 PAs (240, 345) in 2009 to evaluate logistics of using double sampling (Eberhardt and Simmons 1987, Thompson 2002) to estimate sightability (*p*) of deer from the helicopter. I subjectively selected 10 sightability quadrats (sampling rate = 1.5–3.0%) within each PA where at least 20 deer had been previously observed to help ensure that animals would be available for the evaluation. Immediately after completing the operational survey on each sightability quadrat, a second more intensive survey was flown at reduced speed (48-64 km/hr) to identify animals that were missed (but assumed available) on the first survey (e.g., Gasaway et al. 1986). I used georeferenced deer locations, group size, and movement information from DNR Survey (MNDNR 2005) to "mark" deer (groups) observed in the operational survey and help estimate the number of "new" animals detected in the sightability survey. I defined *p* as number of "marked" deer / number of "marked" deer + number of "new" deer. I computed $\hat{p}$ for each PA using the arithmetic mean ($\bar{p}$) of quadrat-specific sightability estimates.

During 2010, I implemented double sampling (Eberhardt and Simmons 1987, Thompson 2002) on a subsample of quadrats in 3 permit areas (225, 227, 236) and St Croix State Park (SCSP) to estimate *p*. For each survey area, I sorted the random sample of survey quadrats (*n*) by percent woody cover and then selected a random systematic subsample of sightability quadrats (n_s = 7–26 quadrats/survey area; sampling rate = 3.7–11.3%) to help ensure a wide range of covariate values for evaluating the relationship between $\hat{p}$ and percent woody cover (at the quadrat scale). Flight protocol during the operational and sightability surveys was the same as described for 2009 surveys. I computed $\hat{p}$ and $\widehat{var}(\hat{p})$ for each survey area using a generalized linear model (glm function in the R stats package; R Development Core Team 2009) with a logit-link function and an events/trials response for each sightability quadrat where at least 1 deer was observed. Graphical analysis suggested a weak negative relationship between percent woody cover and $\widehat{p}$, but the effect was at least partly confounded with permit area effects. Therefore, I did not include percent woody cover in the logistic model. I used estimates of *p* from the logistic model to compute population estimates $\hat{\tau}$ adjusted for both sampling and sightability:

$$\hat{\tau} = \frac{N\bar{y}}{\hat{p}},$$

where *N* = total quadrats in the sampling universe and $\bar{y}$ = average deer count/quadrat in the operational survey (or stratified mean where applicable). With estimated sightability in the denominator, $\hat{\tau}$ is no longer unbiased for τ, although it may be approximately so (Thompson 2002:191). I used Tayor's theorem (Thompson 2002:191, eq. 9) to estimate $var(\hat{\tau})$, assuming *p* is uncorrelated with $\bar{y}$:

$$\widehat{var}(\hat{\tau}) \approx \frac{N^2}{\hat{p}^2}\left[var(\bar{y}) + \frac{\bar{y}^2}{\hat{p}^2}\widehat{var}(\hat{p})\right]$$

For stratified surveys, I applied the variance estimator to the population total (expanded for sampling; versus summing stratum-specific variance estimates) because when using a single parameter to correct for undetected animals, stratum-specific estimates of abundance will be positively correlated and summing stratum-specific variances will underestimate true uncertainty (Fieberg and Giudice 2008). For 4 permit areas (209, 210, 256, 257) where I did not conduct sightability surveys, I used a simple arithmetic mean ($\bar{p}$) and var($\bar{p}$) to adjust population estimates for estimated sightability.

RESULTS AND DISCUSSION

I completed 4-8 surveys each winter (December-March, 2005-2010; Table 1). Stratified fixed-wing surveys were conducted in PAs 270 and 272. Based on long-term deer harvest metrics, population estimates in these areas were biased low. Several possibilities may explain this result: (1) deer were clustered in unsampled quadrats; (2) deer were wintering outside PA boundaries; (3) sightability was biased using fixed-wing aircraft; and/or (4) kill locations from hunter-killed deer were reported incorrectly. Land cover in these PAs was dominated by intensive row-crop agriculture. After crops were harvested each fall, deer habitat was limited to riparian areas, wetlands, abandoned farm groves, and undisturbed grasslands, including those enrolled in state and federal conservation programs. Although recreational feeding of deer could influence distribution, wildlife managers believed it was not a common practice in these PAs. Thus, I had no evidence to support non-traditional deer distribution in these units. I also had no reason to believe hunter registration errors had greater bias in these units than in other PAs. Although it was possible that deer occupied unsampled quadrats by chance, the use of optimal allocation to increase sampling effort in high strata quadrats because of expected higher deer densities should minimize this possibility. Furthermore, we surveyed 100% of the high-strata quadrats in PA 270, resulting in no unsampled quadrats. Sightability bias, however, is greater in fixed-wing aircraft than helicopters (LeResche and Rausch 1974, Kufeld et al. 1980, Ludwig 1981) and likely explained much of the bias I observed in these PAs. Consequently, beginning in 2007, all surveys have been conducted using a helicopter.

With the exception of PAs 270, 272, and 201, precision (CV, RE) of the population estimates was similar among PAs (Table 1). High precision in PA 270 was, in part, an artifact of sample design. Based on optimal allocation formulas, we selected and surveyed all high strata quadrats. Thus, because no sampling occurred within the high stratum (100% surveyed), sampling variance was calculated only from low strata quadrats. We observed few deer in these low strata quadrats, which resulted in low sampling variance and high precision of the population estimate. It is unlikely that this design (i.e., sampling 100% of high strata quadrats) will be feasible in all areas, especially if deer are more uniformly distributed throughout the landscape.

In contrast, survey precision in PAs 272 and 201 was poor. We observed few deer during either survey (*n*=144 and 56, respectively) and nearly all observations occurred within 1 or 2 quadrats. As a result, associated confidence intervals exceeded 60% of the population estimate (Table 1). Kufeld et al. (1980) described similar challenges with precision due to nonuniformity of mule deer distribution within strata in Colorado.

Prior to 2010, I did not correct population estimates for sightability. Thus, these estimates represent minimum counts and are biased low. Estimates of sightability in 2010 ranged from 0.652 (SE = 0.044) in SCSP to 0.780 (SE = 0.023) in PA 227 and averaged 0.728 (SE = 0.031), which are similar to sightability estimates in 2009 (0.80-0.82). Incorporating uncertainty in the detection process into the population estimates increased relative variance (CV[%]) by 0.4 to 1.6%, which was a reasonable tradeoff between decreased bias and increased variance – although costs associated with the sightability surveys are also important. However, I caution that my estimates of sightability are conditional on animals being available for detection ($p_i > 0$; *sensu* Johnson 2008). Unfortunately, like many other wildlife surveys, I have no estimates of availability or how it varies over space and time. My approach also assumes that sightability is constant across animals and quadrats. Heterogeneity in detection probabilities can lead to biased estimates of abundance, but the magnitude of the bias will depend on the degree of heterogeneity and the distribution of animal groups (counts) with respect to p_i. Common methods for correcting for heterogeneous detection probabilities include distance sampling, mark–recapture methods (with covariates), and logistic-regression sightability models (based on radio-marked animals). I did not have marked animals in my populations, and relatively high densities of deer in my survey areas would present serious logistical and statistical problems for distance-sampling and double-observer methods. Therefore, my double-sampling approach is a reasonable alternative to using unadjusted counts or applying more complicated methods whose assumptions are tenuous. Nevertheless, my "adjusted" population estimates must still be viewed as approximations to the truth.

Additional sightability trials are needed to determine how $\hat{p}$ varies over space and time. The relationship between $\hat{p}$ and visual obstruction (at the observation scale) will be examined to evaluate heterogeneity in sightability. Future analysis will also include *post-hoc* evaluation of habitat features present in quadrats containing deer. This will provide additional empirical data for use in quadrat stratification. In addition, the impact of winter feeding on deer distribution will be examined to determine if pre-survey stratification flights (Gasaway et al. 1986) are warranted.

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Table 1. Deer population and density estimates derived from aerial surveys in Minnesota, 2005-2010. Beginning in 2010, estimates were corrected for sightability.

Sampling design	Year	Permit area	Population estimate N	Population estimate 90% CI	CV (%)	Relative error (%)[a]	Density estimate ($deer/mi^2$) Mean	Density estimate ($deer/mi^2$) 90% CI	Model estimate ($deer/mi^2$)
Systematic	2005	252	2,999	2,034 – 3,969	19.5	32.2	2.9	2.0 – 3.8	2
		257	2,575	1,851 – 3,299	16.9	28.1	6.1	4.4 – 7.8	7
	2006	204	3,432	2,464 – 4,401	17.0	28.2	4.5	3.2 – 5.8	5
		209	6,205	5,033 – 7,383	11.4	18.9	9.3	7.6 – 11.1	5
		210	3,976	3,150 – 4,803	12.5	20.8	6.1	4.8 – 7.3	7
		256	4,670	3,441 – 5,899	15.9	26.3	6.8	5.0 – 8.6	5
		236	6,774	5,406 – 8,140	12.1	20.2	15.0	12.0 – 18.0	37
	2007	225	5,341	4,038 – 6,645	14.7	24.4	7.7	5.8 – 9.6	24
		227	5,101	4,245 – 5,960	10.1	16.8	9.7	8.1 – 11.3	13
		346	7,896	5,736 – 10,062	16.4	27.4	21.6	15.7 – 27.6	31
	2008	266	3,853	2,733 – 4,977	17.5	29.1	5.9	4.2 – 7.6	n/a[b]
Stratified	2005	206	2,486	1,921 – 3,051	13.7	22.5	5.3	4.1 – 6.5	5
		270	631	599 – 663	3.0	5.0	0.8	0.8 – 0.9	5
		342	3,322	2,726 – 3,918	10.8	17.7	8.9	7.3 –10.4	10
	2006	201	274	100 – 449	37.6	61.9	1.5	0.6 – 2.5	6
		269	1,740	1,301 – 2,180	15.2	25.1	2.6	1.9 – 3.2	3
		272	472	179 – 764	37.4	61.5	0.9	0.3 – 1.4	5
		SCSP[c]	765	587 – 944	14.2	23.4	12.3	9.5 – 15.2	n/a[c]
	2007	343	6,982	5,957 – 8,006	8.9	14.6	10.0	8.6 – 11.5	29
		344	4,116	3,375 – 4,857	10.7	17.7	19.4	15.9 – 22.9	49
		347	5,482	4,472 – 6,492	11.1	18.2	12.6	10.3 – 14.9	13
		349	10,103	8,573 – 11,633	9.1	15.0	20.2	17.1 – 23.2	35
	2008	262	2,065	1,692 – 2,437	10.9	17.9	2.9	2.4 – 3.4	n/a[b]
		271	1,019	848 – 1,189	10.1	16.6	1.6	1.3 – 1.8	8
		SCSP[c]	1,271	989 – 1,554	13.5	22.2	20.5	16.0 – 25.1	n/a[c]
	2010	SCSP[c]	1,686	1,253 – 2,120	15.6	25.7	27.2	20.2 – 34.2	n/a[c]
GRTS[d]	2008	265	4,575	3,766 – 5,384	10.7	17.7	9.2	7.5 – 10.8	n/a[b]
	2009	240	11,041	9,799 – 13,003	8.5	14.1	16.7	14.4 – 19.1	28
		261	1,721	1,450 – 1,992	9.6	15.7	2.2	1.8 – 2.5	4
		345	4,247	3,678 – 4,806	8.0	13.2	12.8	11.1 – 14.5	21
		348	5,717	4,953 – 6,480	8.1	13.4	17.8	15.4 – 20.1	13
	2010	209	6,180	4,923 – 7,438	12.4	20.4	9.6	7.6 – 11.5	7
		210	4,083	3,106 – 5,061	14.6	24.0	6.4	4.8 – 7.9	10
		225	10,271	8,853 – 11,690	8.4	13.8	15.9	13.7 – 18.1	13
		227	9,318	7,810 – 10,827	9.8	16.2	19.4	16.2 – 22.5	18
		236	7,787	6,487 – 9,088	10.2	16.7	19.3	16.1 – 22.5	19
		256	3,076	2,174 – 3,979	17.8	29.4	4.8	3.4 – 6.2	3
		257	2,810	2,089 – 3,532	15.6	25.7	6.7	4.9 – 8.4	6

[a]Relative precision of population estimate. Calculate as 90% CI bound/N.
[b]Permit area boundaries were recently modified. No model estimate is available.
[c]St Croix State Park. No model estimate is available.
[d]Generalized Random-Tessellation Stratified sample design.

NEST SITE SELECTION AND NESTING ECOLOGY OF GIANT CANADA GEESE IN CENTRAL TENNESSEE[1]

Jason S. Carbaugh, Daniel L. Combs, and Eric M. Dunton

ABSTRACT

Little information is available on giant Canada goose (*Branta canadensis maxima*) nest site selection on isolated nesting ponds. We monitored 46 island and 72 shoreline nests in the Upper Cumberland (UC) region of central Tennessee during 2002 and 2003. We measured 6 habitat variables at nesting ponds and randomly selected non-nesting ponds, and we used logistic regression to determine which measured habitat variables were important in nest site selection. Presence of an island was the most important variable but was excluded from the final analysis because of quasi-separation (i.e., geese nested on all known islands in the study area). Geese that nested on shorelines generally selected larger ponds which may have offered a larger foraging base and more escape options from predators. Nest success rates were similar for island and shoreline nests. Management actions in the UC region and similar areas should be concentrated on ponds with islands because of higher goose nesting densities and ease in finding nests.

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CONSERVATION RESERVE PROGRAM GRASSLANDS AND RING-NECKED PHEASANT ABUNDANCE IN MINNESOTA

James F. Drake, Richard O. Kimmel, J. David Smith, and Gary Oehlert

ABSTRACT

Ring-necked pheasant (Phasianus colchicus) abundance was measured on 15 study areas using roadside counts during the summers of 1990-1994 to examine possible relationships to permanent grasslands and 9 other cover types. The majority of permanent grasslands was enrolled in the Conservation Reserve Program (CRP) and likely would have been actively used for agriculture if not for the CRP. Roads were divided into 300 m segments and the proportion of each cover type was determined within 200 m and 800 m of each segment. A non-parametric procedure was used to determine the most significant predictors of number of pheasants observed on each road segment during roadside surveys. Year, study area, and proportion of cover type were used as predictor variables. Proportion of permanent grassland cover was the most significant predictor in every model examined. Numbers of pheasants, predominantly broods, were approximately 10 times higher in samples that had >30% grassland compared to samples with 10%. There was no statistically significant increase in number of pheasants as grassland increased from 30 to 100%. Year-to-year variation and differences among study areas were the second most significant factors in predicting the number of pheasants observed. Small grains and pasture were also positively correlated to pheasant numbers. If CRP grassland had not been available, pheasant abundance would have been significantly lower in the study areas.

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ECOLOGY, HUNTING SEASONS, AND MANAGEMENT OF GRAY AND FOX SQUIRRELS IN MINNESOTA

Emily J. Dunbar, Richard O. Kimmel, and Eric M. Walberg

SUMMARY OF FINDINGS

We conducted a pilot study to identify potential problems for squirrel hunters and to explore if squirrel-hunting opportunities could be enhanced by harvest regulation changes or management activities. We surveyed Minnesota squirrel hunters to provide an understanding of how hunting opportunities could be improved and to determine if perception of squirrel hunting problems differed among hunter groups. We also surveyed personnel from state and provincial wildlife agencies in the U.S. and Canada to provide information on squirrel season management in other jurisdictions. Finally, a literature review and summary was completed to gain a better understanding of the management and ecology of gray and fox squirrels.

Results of the hunter survey suggest most Minnesota squirrel hunters spent $\leq$ 7 days hunting and harvested <10 squirrels during the 2008 squirrel-hunting season. In general, hunters have not changed hunting areas in the past 5 years. The most frequently cited obstacle for squirrel hunters was private land access. Most hunters do not believe hunting regulations or squirrel habitat management need to change, but many stated that the Minnesota Department of Natural Resources (MNDNR) could improve their hunting experience by providing additional public hunting land and improving access to public land. There were numerical differences among metro Hmong hunters and non-Hmong hunters regarding number of years hunting squirrels, types of properties being hunted, obstacles faced by hunter groups in gaining access to hunting land, squirrel population trends, and which regulations changes, if any, should take place to change squirrel population trends.

The survey of other wildlife agencies in the U.S. and Canada suggest that, although squirrel hunting season structure varies from state to state, Minnesota's season length and bag/possession limits are similar to most other states/provinces. Most agencies do not have declining squirrel populations, but feel that the resource, due to declining hunter participation, is underutilized.

Indications from this pilot study would suggest that future discussions on squirrels in Minnesota should consider: 1) providing increased hunter access to land for squirrel hunting; 2) managing for higher squirrel populations and hunter harvest through habitat improvement and hunting season management; and/or 3) conducting additional surveys with larger sample sizes to examine the numerical differences observed in this pilot study in more detail and determine if they should be taken into account in future management decisions.

INTRODUCTION

Gray and fox squirrel (*Sciurus carolinensis* and *S. niger*) hunting provides recreational opportunities for an estimated 26,000 hunters annually in Minnesota (Dexter 2008). The reported harvest for gray and fox squirrels has declined by 50% in the past 2 decades. The number of hunters has also declined significantly, from an estimated 39,000 gray squirrel hunters in 1985 to 26,000 hunters in 2008. MNDNR recognizes that hunter participation has declined and wants to encourage greater participation by outreach efforts directed at various groups, including those who "experience language or cultural barriers" (Minnesota Department of Natural Resources 2009). One such cultural community is the Hmong, an ethnic group from Southeast Asia. Hmong hunters have expressed concern about perceived low populations of squirrels on public hunting land near population centers (Tim Bremicker, personal communication).

MNDNR initiated this pilot study to determine if squirrel-hunting opportunities could potentially benefit from harvest regulation changes and/or management activities and to determine which changes could increase the huntable squirrel population on public land.

OBJECTIVES

1. Survey a sample of non-Hmong and Hmong Minnesota squirrel hunters to determine if perception of squirrel hunting problems differed between the hunter groups and to provide an indication of how hunting opportunities could be improved;
2. Survey other state/provincial wildlife agencies to gain knowledge about their squirrel hunting seasons and management programs; and
3. Conduct a literature review and summary to gain a better understanding of the management and ecology of gray and fox squirrels.

METHODS

A survey of Minnesota squirrel hunters was conducted April-May 2009. We collected names and addresses of hunters who indicated they had harvested squirrels on small game hunter surveys from 2005-2008. We sampled 400 hunters; 200 hunters were selected from the metro region and 200 hunters were selected from greater Minnesota. Hunters from the 'metro' area were those hunters with mailing addresses from the 7 county area (Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington) surrounding Minneapolis and St. Paul, MN. Statewide non-metro hunters had addresses outside of the metro counties previously indicated. Note that these designations do not necessarily indicate where those surveyed hunted, but where they received mail. One hundred metro hunters were assumed Hmong hunters and 100 hunters were assumed non-Hmong hunters based on surname. Hmong names were selected by choosing hunters with traditional Hmong clan surnames provided by the Southeast Asian Community Liaison. Non-Hmong hunters were those hunters whose last name did not match the list of Hmong traditional clan surnames. The sample size gathered from the 2005-2008 small game hunter survey did not meet the desired sample size for the metro Hmong hunter group, so additional names and addresses of Hmong hunters were included from the 2008-2009 small game hunter survey. The survey instrument (Appendix 1) consisted of questions relating to harvest, counties and land ownership of properties hunted, hunter experiences, hunter access, hunter perception of squirrel populations, and suggestions for improving squirrel hunting experiences. Responses were entered into Microsoft Access and converted to percentages.

A survey of state/provincial wildlife agencies was conducted during April-May 2009. An email survey was sent to 47 state wildlife agencies (Alaska, Hawaii, and Minnesota were excluded) and 4 Canadian provincial wildlife agencies (Quebec, Ontario, Manitoba, and Saskatchewan). The survey instrument (Appendix 2) consisted of questions relating to season opening/closing dates, bag and possession limits, management, research, population estimation, and issues concerning squirrel hunting.

A list of manuscripts relating to the ecology, management, and hunting mortality of gray and fox squirrels was compiled and selected manuscripts summarized.

RESULTS

Hunter Survey

Surveys were mailed on 10 April 2009 with a second mailing to non-respondents on 1 May 2009. The overall response rate was 80% for 2 mailings. Non-response bias was not evaluated due to the high response rate. Overall, a majority (58%) of the respondents indicated that they had hunted squirrels during the last hunting season (2008). A higher percentage of metro Hmong respondents (73%) hunted squirrels in 2008 as compared to metro non-Hmong and statewide non-Hmong hunters (55% and 52%). Metro non-Hmong hunters (hereafter referred to as MNH hunters) hunted squirrels in 33 of the state's 87 counties (Table 1). The 3 most often hunted areas were Washington (19%), Anoka (15%), and Pine (13%) counties (Table 1). Metro Hmong hunters (hereafter referred to as MH hunters) hunted squirrels in 26 of the state's 87 counties (Table 1). The 3 most often hunted areas were Winona (37%), Anoka (13%), and Houston (13%) counties (Table 1). Statewide non-Hmong hunters (hereafter referred to as SNH hunters) hunted squirrels in 49 of the state's 87 counties (Table 1). The 3 most often hunted areas were Morrison (7%), Stearns (7%), and Wright (6%) counties (Table 1).

Roughly half of squirrel hunters harvested between 1 - 5 squirrels during the last hunting season (46%; Table 2). Forty-eight percent of MNH and MH hunters harvested between 1 - 5 squirrels, while 43% of SNH hunters harvested the same amount (Table 2). Overall, about 1/3 of the hunters harvested between 6 and 10 squirrels (27%; Table 2). Thirty-three percent of SNH hunters harvested between 6 and 10 squirrels, while 17% and 28% of MNH and MH hunters harvested squirrels at this same level (Table 2). The 3 hunter groups spent a similar amount of time hunting squirrels, with most squirrel hunters (70%) reporting spending 7 days or less hunting squirrels (Table 3). Over half (53% and 63%) of MNH and SNH hunters have hunted squirrels for at least 21 years, while over half (58%) of the MH hunters have hunted for 10 years or less (Table 4). Most MH hunters hunted exclusively on public land (98%), while only 17% and 5% of MNH and SNH hunted exclusively on public land (Table 5).

Hunters were also asked if they had hunted new properties in the past 5 years. Approximately half (49%) of hunters indicated hunting the same properties, while other half hunted new properties in addition to traditional properties (Table 6). Few hunters have switched to different properties in the past 5 years (Table 6). MH hunters were the only group where some hunters had completely switched to new properties, with 9% of MH hunters indicating that they were hunting on different properties in the past 5 years (Table 6).

Hunters were asked whether they encountered obstacles to gain access to hunting land. Sixty-two percent of MNH hunters reported obstacles, 78% of MH hunters reported obstacles, and 46% of SNH hunters reported obstacles (Table 7). Private land access was the most frequently cited obstacle for all groups (62%). While private land access was the most frequently cited obstacle for both MNH (64%) and SNH (71%) hunters, it was not the most frequently cited obstacle for MH hunters (50%; Table 7). The most frequently cited obstacles for MH hunters (64%) were how to find additional public hunting land and not comfortable asking for permission to access private land (Table 7). Many hunters (40%) reported 2 different types of obstacles, while 3% reported 5 or more different types of obstacles (Table 8). The highest percentage of MNH (50%) and SNH (43%) reported 2 different types of obstacles, but the highest percentage of MH hunters (31%) reported 3 different types of obstacles (Table 8).

Regarding squirrel population trends in areas used by hunters, 51% of the hunters surveyed reported that squirrel populations have remained stable over the past 5 years (Table 9). Few hunters (13%) felt that squirrel populations were increasing (Table 9). More MH hunters (65%) felt the populations had declined than MNH and SNH hunters (37% and 19%; Table 9).

Hunters were also asked about changes to hunting regulations and habitat management based on their perception of squirrel populations in the areas where they hunt. Most hunters (62%) recommended no changes (n=103; Table 10). MH hunters recommended no change to regulations less often (35%) than MNH (68%) and SNH (74%) hunters (Table 10). Hunters that indicated that changes were needed cited habitat management more frequently (n=56) than hunting regulation changes (n=34; Table 10).

The final question asked hunters what the DNR could implement to improve their squirrel hunting experience. Most respondents reported additional public hunting land and improved access to hunting land would improve their hunting experience (Table 11).

Agency Survey

Surveys were emailed on 27 April 2009 with a second emailing to non-respondents on 15 May 2009. The overall response rate was 86% for 2 emailings. Eighty-two percent of wildlife officials that responded to the survey indicated that their state/province does have a fox and/or gray squirrel-hunting season (n = 38). Squirrel seasons varied widely among the different agencies. Two agencies reported year-round squirrel-hunting seasons (Manitoba and

Washington); while 7 other agencies (Arkansas, Connecticut, Kentucky, Louisiana, Pennsylvania, Tennessee, Wyoming) reported split seasons. Split seasons refer to the states/provinces that provide multiple hunting seasons throughout the year (for example, having a spring and fall squirrel hunting season). Agencies that reported using different hunting zones include Massachusetts, Mississippi, New York, Oregon, and Texas. Pennsylvania and West Virginia have youth hunts before the regular season.

Opening and closing dates varied widely. Agencies that did not have a split season or different hunting zones responded that opening dates occurred during the months of May (n = 1), June (n = 1), August (n = 4), September (n = 9), October (n = 2), and November (n = 1) and closing dates occurred during December (n = 3), January (n = 6), and February (n = 8), and March (n = 1). States that had a fall and spring season had opening dates in August (n = 1), September (n = 2), October (n = 1) for the fall season and opening dates in January (n = 1) and May (n = 3) for the spring season. Closing dates for states that have a fall and spring season are December (n = 1), February (n = 3), March (n = 1), May (n = 1), and June (n = 2), respectively. States that have hunting zones generally have different start dates, but have the same end date (Massachusetts, Mississippi, and New York). Connecticut and Pennsylvania each have 3 regular seasons that vary in length and occur in the fall and winter months (September to February). Length of squirrel-hunting seasons differs from 75 days to 365 days (average = 172).

Bag and possession limits for squirrel harvest varies. Most states (n = 21) reported a single bag limit (range = 4-12, average = 7) and possession limit (range = 4-40, average = 15). Some states (n = 9) reported a single bag (range = 5-10, average = 6) with no possession limit. State-specific bag and possession limits include:

- having different limits for gray and fox squirrels;
- having different limits for different parts of the state;
- having different limits for different seasons;
- having no limits; and
- intending to raise limits.

Most shooting hours are 1/2 hr before sunrise to 1/2 hr after sunset (n = 21), or 1/2 hr before sunrise until sunset (n = 7), although 4 states/provinces have no restrictions.

Wildlife officials were asked if they specifically manage for fox and/or gray squirrels. Maryland was the only state that monitored population trends and harvest to establish seasons and bag limits. Other states/provinces manage for squirrels indirectly by managing forest habitat (n = 8). None of the states responded that they estimate squirrel populations, although 3 states (Illinois, Maryland, and Michigan) monitor population trends based on hunter surveys, and 2 states (South Carolina and North Dakota) monitor population trends based on spotlight and rural postal carrier sighting surveys, respectively. Four states are currently conducting squirrel research (South Carolina, Tennessee, and Washington) or are proposing a study (Mississippi).

Wildlife officials were asked about issues concerning squirrel hunting. Forty-seven percent of states/provinces indicated concerns. The most common concerns were declining hunter participation, habitat loss/declining populations, and hunters requesting season changes.

Literature Review

The list of manuscripts and summaries follows the tables and appendices.

DISCUSSION

The results of the surveys imply that squirrels in most states (including Minnesota), are for the most part, an under-utilized resource. The majority of Minnesota squirrel hunters we surveyed spent no more than 7 days/year hunting squirrels. Minnesota’s current squirrel season is 163 days long, indicating that few squirrel hunters take advantage of the lengthy season. Minnesota's squirrel season is slightly shorter than the average season length (172 days) reported by the other states/provinces. Minnesota's daily bag and possession limits (7/14) are similar to the average limits of other states/provinces. Most hunters in Minnesota are not considered avid squirrel hunters, with a majority harvesting only 10 squirrels or less per year. Squirrel hunters in Minnesota tend to hunt the same areas from year to year with nearly half hunting on the same properties. Finally, squirrel hunters seem to be content with the current season, but would prefer easier access to hunting areas or new public areas to hunt.

Survey responses of concern are related to the types of properties (public vs. private) that hunter groups are using, the obstacles faced by hunter groups in gaining access to hunting land, squirrel population trends, and which regulation changes, if any, could improve squirrel populations and harvest. For each of these questions, responses from the MH hunter group differed from the MNH and SNH hunter groups. MH hunters use public hunting land almost exclusively, while MNH and SNH hunters use either private or a mix of public and private hunting land. Obstacles that impact MH hunters are not the same as those that impact MNH and SMH hunters. MH hunters are unsure how to find additional public land for hunting and are uncomfortable asking permission to hunt on private land, while MNH and SNH hunters face difficulties with land that is posted as no hunting or trespassing. Most MH hunters surveyed feel that squirrel populations are decreasing on lands they hunt, but many MNH and SNH hunters believe they are stable. More MH hunters believe that changes are needed based on squirrel population trends than MNH or SNH hunters. A higher percentage of MH hunters favor hunting regulation changes than MNH and SNH hunters. MH hunters favor habitat management changes at a rate similar to MNH hunters. This question in the survey was vague in regards to the type of changes needed. If future surveys are conducted, they should separate questions concerning habitat management changes and hunting regulation changes (bag limit, season timing and season length, etc.) to better determine support among squirrel hunters. Future discussions for land access issues should focus on providing MH hunters with maps or lists of different types of public hunting land and developing a contact list of landowners willing to allow squirrel hunters on their property. A landowner list would also benefit MNH and SMH hunters who want to find additional hunting land.

It appears that low squirrel populations are a concern to some hunter groups in other parts of the U.S. A few states mentioned that populations are declining due to habitat loss (Indiana and New Jersey). Mississippi noted complaints from hunters about low populations in some regions of the state. However, many states replied that squirrels are an under-utilized resource (Illinois, Maryland, Missouri, Pennsylvania, and Vermont). It is possible that squirrel-hunting is more popular in some states than others, and hunting pressure (in addition to habitat loss) may be responsible for low squirrel numbers. A more in depth look at hunter pressure (number of hunters, number of days spent hunting, types of property hunted, etc.) for each state/province may help to explain the variable responses from this survey. Information is also needed for the demographics of squirrel hunters in other states/provinces. If hunters are restricted to an area or a type of property that is scarce, there are likely to be differing effects on squirrel populations.

If further squirrel hunter surveys are desired, we suggest surveying a larger number of hunters and expanding upon questions relating to types of property hunted, access obstacles, and acceptable regulation changes. Determining when squirrels are being harvested in the season would also provide information on potential seasonal framework changes. A survey with a larger sample size may find further differences among the hunter groups, or strengthen the existing numerical differences with statistical significance. Power analysis should be used to determine sample size. Additional factors to consider in determining an adequate sample size include an estimated response rate and percentage of small game license holders that hunt squirrels. A Hmong hunter sample could be pulled by selecting the last names of hunters that correspond to the clan surnames. MNH and SNH hunters could be selected based upon zip codes. If statistical difference could be found between the 3 groups, then metro Hmong squirrel hunters' perceptions should be recognized as being different than non-Hmong squirrel hunter' perceptions. This difference in perception between metro Hmong and non-Hmong could be taken in account in future season management decisions.

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Table 1. Response for question 2: Which county/counties did you hunt squirrels? Squirrel hunter survey, 2009, Minnesota.

	Response (%)		
County	Metro non-Hmong (n=47)	Metro Hmong (n=38)	Statewide non-Hmong (n=83)
Aitkin	9	3	2
Anoka	15	13	
Becker			1
Beltrami			1
Benton			4
Blue Earth	2		1
Brown		3	2
Carlton	2	3	2
Carver	4	3	
Cass	4		5
Chisago	4	5	1
Cottonwood			1
Crow Wing	4		2
Dakota	9	3	
Dodge			2
Douglas	4		5
Fillmore	2	5	2
Goodhue	4	8	1
Grant	2		1
Hennepin	4	5	
Houston	4	13	5
Hubbard			1

Table 1. continued.

Isanti			1
Itasca			1
Jackson	2		
Kanabec			2
Kandiyohi			2
Kittson	2		
Lake			1
Le Sueur	4	3	1
Lincoln			1
Mcleod	1		1
Mille Lacs	4	3	1
Morrison	2		7
Mower			4
Murray			1
Nicollet		4	1
Olmstead	2	4	5
Ottertail			2
Pine	13	3	
Ramsey	4	3	
Redwood			1
Renville			1
Rice		3	4
Roseau			1
Scott	11	5	2
Sherburne	4	5	4
Stearns	4	3	7
Steele			4
St. Louis	2		5
Todd	6	3	2
Wabasha		11	2
Wadena			1
Waseca			2
Washington	19	3	
Winona	2	37	4
Wright		3	6

Table 2. Response for question 3: Approximately, how many squirrels did you harvest last season? Squirrel hunter survey, 2009, Minnesota.

	Response (%)			
Number of squirrels	Overall response	Metro non-Hmong (n=46)	Metro Hmong (n=46)	Statewide non-Hmong (n=83)
1-5	46	48	48	43
6-10	27	17	28	33
11-15	15	17	15	14
16-20	7	11	4	6
21-25	3	2	2	4
26-30	1	4	0	0
31+	1	0	2	0

Table 3. Response for question 4: Approximately, how many days did you spend hunting squirrels last season? Squirrel hunter survey, 2009, Minnesota.

	Response (%)			
Number of days	Overall response	Metro non-Hmong (n=47)	Metro Hmong (n=47)	Statewide non-Hmong (n=83)
1-7	70	68	70	71
8-14	19	21	17	19
15-21	7	6	11	5
21-28	3	4	0	4
29+	1	0	2	1

Table 4. Response for question 5: How long have you hunted squirrels in Minnesota? Squirrel hunter survey, 2009, Minnesota.

	Response (%)			
Number of years	Overall response	Metro non-Hmong (n=47)	Metro Hmong (n=46)	Statewide non-Hmong (n=83)
1-5	15	11	39	10
6-10	16	15	28	10
11-15	12	11	17	10
16-20	10	11	13	8
21+	47	53	11	63

Table 5. Response for question 6: Do you hunt squirrels on public land, private land, or both? Squirrel hunter survey, 2009, Minnesota.

	Response (%)			
Type of land	Overall response	Metro non-Hmong (n=47)	Metro Hmong (n=47)	Statewide non-Hmong (n=83)
Public land	33	17	98	5
Private land	28	28	0	43
Both public and private land	40	55	2	52

Table 6. Response for question 7: In the past 5 years, have you hunted squirrels on the same properties, new properties, or both? Squirrel hunter survey, 2009, Minnesota.

	Response (%)			
Types of properties	Overall response	Metro non-Hmong (n=47)	Metro Hmong (n=46)	Statewide non-Hmong (n=83)
Same	49	38	48	55
New	2	0	9	0
Both (same and new)	49	62	43	49

Table 7. Response for question 8: What are the main obstacles for gaining access to property for squirrel hunting? Squirrel hunter survey, 2009, Minnesota.[1]

	Response (%)			
Types of obstacles	Overall response	Metro non-Hmong	Metro Hmong	Statewide non-Hmong
		(n=45)	(n=46)	(n=81)
No obstacles[2]	42	38	22	54
Land is posted [3]	62	64	50	71
Not sure how to find additional public land	36	29	64	14
Not comfortable asking for permission	42	36	64	24
Denied access by landowner	36	46	19	43
Difficulty finding owners of private land	54	57	58	46
Other	14	14	21	11

[1] Respondents could report > 1 type of obstacle
[2] Percent response was calculated using number of respondents indicating no obstacles divided by the total number of respondents for that hunter group
[3] Obstacles' response was calculated using number of respondents indicating a certain obstacle divided by the number of respondents reporting obstacles for that hunter group

Table 8. Number of access obstacles reported by hunters for question 8. Squirrel hunter survey, 2009, Minnesota.[1]

	Response (%)			
Number of obstacles	Overall response	Metro non-Hmong (n=28)	Metro Hmong (n=36)	Statewide non-Hmong (n=37)
1	23	4	7	12
2	40	14	10	16
3	20	6	11	3
4	15	4	5	6
5	2	0	2	0
6	1	0	1	0

[1] Respondents could report > 1 type of obstacle

Table 9. Response for question 9: Over the past 5 years, do you think squirrel populations in areas where you hunt are decreasing, about the same, or increasing? Squirrel hunter survey, 2009, Minnesota.

	Response (%)			
Population trend	Overall response	Metro non-Hmong (n=47)	Metro Hmong (n=46)	Statewide non-Hmong (n=83)
Decreasing	36	37	65	19
Same	51	48	35	62
Increasing	13	15	0	20

Table 10. Response for question 10: Based on your perception of squirrel population trends, which changes would you recommend? Squirrel hunter survey, 2009, Minnesota.[1]

	Response (%)			
Changes	Overall response	Metro non-Hmong (n=44)	Metro Hmong (n=46)	Statewide non-Hmong (n=77)
No Changes[2]	62	68	35	74
Hunting Regulations[3]	34	29	50	15
Habitat Management	56	64	60	45
Enforcement of Regulations	20	36	20	10
Other	27	14	27	35

[1] Respondents could report > 1 type of change

[2] Percent response was calculated using number of respondents indicating no changes divided by the total number of respondents for that hunter group

[3] Changes' response was calculated using number of respondents indicating a certain change divided by the number of respondents reporting changes for that hunter group

Table 11. Response for question 11: How could the DNR improve your hunting experience? Squirrel hunter survey, 2009, Minnesota.

Types of improvements	Number of responses
Additional public land/improved access to hunting land	20
Better information about public hunting lands	7
Habitat management	9
Change season management	14
Create sanctuaries	4
Increase number of squirrels	10
Better enforcement of regulations	3
No blaze orange requirements	2
Predator control	2
Increase safety	3
Hmong concerns	3
Other	6

Appendix 1.

Minnesota Fox and Gray Squirrel Hunter Survey

You have been selected from a group of hunters that harvested squirrels as indicated on past Small Game Hunter surveys. Because this survey is only being sent to a small number of hunters, your input is extremely valuable, please complete and return the following survey as soon as possible. Your identity will be kept confidential.

1. Did you hunt fox and/or gray squirrels last season (September 2008-February 2009)?

   Yes ___ No* ___

   *If No, then you do not need to continue the survey; please answer question 1 and return the survey.

2. In which county/counties did you hunt squirrels? ______________________________

3. Approximately, how many squirrels did you harvest last season?

   1-5 ____ 6-10 ____ 11-15 ____ 16-20 ____ 21-25 ____ 26-30 ____ 31+_____

4. Approximately, how many days did you spend hunting squirrels last season?

   1-7 days ____ 8-14 days ____ 15-21 days _____ 22-28 days ____ 29+ days ____

5. How long have you hunted squirrels in Minnesota?

   1-5 years ____ 6-10 years ____ 11-15 years _____ 16-20 years ____ 21+ years ____

6. Do you hunt squirrels on public land ___, private land ___, or both ___?

7. In the past 5 years, have you hunted squirrels:

   on the same properties ___, on new properties ___, or both ___?

(Survey continues on next side)

8. What are the main obstacles for gaining access to property for squirrel hunting? (check all that apply)

 _____ I have not encountered obstacles

_____ Land is posted as no hunting or trespassing

_____ Not sure how to find additional public hunting lands

_____ Not comfortable asking for permission to access private land from landowner

_____ Denied access by landowner(s) in the past

_____ Difficulty finding owners of private land

_____ Other (please specify)____

9. Over the past 5 years, do you think squirrel populations in areas where you hunt are: decreasing____, about the same____, or increasing_____?

10. Based on your perception of squirrel population trends, would you recommend changes to
(check all that apply):
_____ Hunting regulations
_____ Habitat management
_____ Enforcement of regulations
_____ Other (Please Specify) ____
_____ I don't recommend any changes

11. How could the DNR improve your squirrel hunting experience?

____

____

____

Thank you for completing the survey! Please return the survey in the enclosed, postage-paid envelope.

Appendix 2.

Squirrel-Hunting Survey

Minnesota DNR is being asked by our hunters to evaluate our squirrel-hunting season. As part of this effort we are interested in what your state wildlife agency is doing regarding squirrel hunting seasons. Attached is a very short survey, which we hope you can complete and return via email by May 8, 2009.

Please forward to the correct person to complete this survey, if that is not you.

Thanks, in advance, for your help.

Emily Dunbar
emily.dunbar@dnr.state.mn.us
Wildlife Biologist
Minnesota DNR
35065 800th Ave
Madelia, MN 56062

1. Your name________________________
   Your position title __________________________
   Your email address_________________________________
   Your phone number _________________________________

2. Does your state/province have a fox and/or gray squirrel hunting season?
   Yes ____ No____
   If No, then the survey is complete. Please send this survey back.

3. When does the hunting season open?

4. When does the season close?

5. What is the daily bag limit and possession limit?

6. What are the shooting/hunting hours?

7. Does your state/province manage specifically for fox and/or gray squirrels ?
   Yes ____ No____
   If Yes, what are the management activities?

8. Does your state/province estimate fox and/or gray squirrel populations?
   Yes ____ No____
   If Yes, what techniques is used?

9. Is there currently any research being conducted by your agency on fox and/or gray squirrels?

    Yes _____ No______

    If so, please describe the study/studies:

10. Are there any issues surrounding squirrel populations or squirrel hunting in your state/province?

11. Other things we should know about your squirrel season:

Gray and Fox Squirrel Manuscripts

The following is a list of manuscripts relating to ecology, harvest mortality, and habitat management for fox and gray squirrels. Many of the manuscripts (marked with an asterisk) are summarized following this list.

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*Thompson, D. C. 1978. Regulation of a northern grey squirrel (*Sciurus carolinensis*) population. Ecology 59:708-715.

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Weigl, P. D., L. J. Sherman, A. I. Williams, M. A. Steele and D. S. Weaver. 1998. Geographic variation in the fox squirrel (*Sciurus niger*): a consideration of size cline, habitat vegetation, food habits and historical biogeography. Pages 171-184 *in*: Ecology and evolutionary biology of tree squirrels, M. A. Steele, J. F. Merritt, and D. A. Zegers, editors. Virginia Museum of Natural History Special Publication 6.

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Zollner, P. A. 2000. Comparing the landscape level perceptual abilities of forest sciurids in fragmented agricultural landscapes. Landscape Ecology 15:523-533.

Summaries of Selected Manuscripts

Allen, D.L. 1943. Michigan fox squirrel management. Michigan Department of Conservation, Game Division Publication 100. 404pp.

- Oak-hickory forests can sustain high numbers of fox squirrels.
- Sanctuaries do not guarantee continuous abundance.
- Disease is an important mortality factor.
- The “breeding potential” of fox squirrels is such that the population can more than triple itself by late summer.
- Mating activity of the fox squirrel occurs primarily in January and February, and again in May and June.
- The average production per year is four young per female.
- The normal fall ratio is made up of two-thirds juvenile animals, and one-third adult animals.
- Tree dens give squirrels more protection from weather, natural enemies, and man than do leaf nests.
- Long-time management program should aim to provide tree dens.
- The domestic dog is probably the most important mammalian predator of squirrels.
- The remedy for overshooting is to limit harvest.
- The percentage of the total harvest is fairly constant across the entire season, so adding a week to the season would increase the harvest substantially, and subtracting a week would decrease the harvest.

Baumgartner, L.L. 1939. Fox squirrel dens. Journal of Mammalogy 20(4):456-465.

- Den formation depends upon 1) rate of tree growth, 2) rate of tree decay, 3) age of tree, and 4) method of scar tissue formation.
- Den cavity formation can take between 8-30 years depending on the type of tree.
- Dens are typically in use for 10-20 years and become less appealing as the cavity becomes larger.
- Dens will naturally form in older forests if mature trees are left standing.
- The artificial production of dens by girdling limbs is not practical or economically feasible.
- Observations have shown that young forests can be depleted of fox squirrels in 1 hunting season due to lack of den trees.

Baumgartner, L.L. 1943. Fox squirrels of Ohio. Journal of Wildlife Management 7:193-202.

- Fox squirrel habitat in Ohio consists of maple-beech-oak woodlots of 5-300 acres in size, while gray squirrel habitat consists of maple-beech forests.
- Oak-hickory habitat is the most preferred habitat of squirrels.
- Isolated, mature forest remnants support fewer squirrels than sub-climax woodlots because 1) old trees appear to supply fewer food resources than young trees and 2) the remaining mature beech-maple forests supply a good mast crop only once every 3-5 years.
- Selective cutting, pasturing, and planted woodlots create temporary squirrel habitat that can support a squirrel population seasonally or for 1 year out of 3 - 4.
- Male squirrels moved an average of 154 yds/day, and females moved 130 yd/day.
- Squirrels may infiltrate a field that is planted adjacent to a woodlot and will go further into a cut soybean field than a corn or wheat field.
- Woodlots that are unhunted become over populated in the fall, and squirrels will emigrate to other less populated woodlots.
- Leaf nests are temporary and are used as escape cover and to bear and rear young.

Burger, G.V. 1969. Response of gray squirrels to nest boxes at Remington Farms, Maryland. Journal of Wildlife Management 33:796-801.

- Artificial dens increased the number of squirrels trapped 1 year after installation. Populations in control units remained essentially unchanged over the same period.
- On control units, age ratios averaged 1.3-1.8 young per adult. Units with den structures averaged 2.4 and 2.6 young per adult.
- Costs of construction and installation may make erection of artificial dens uneconomical in large habitat units.
- Artificial dens would appear to furnish a useful and productive tool where intensive management is needed.

Conner, L. M. 2001. Survival and cause-specific mortality of adult fox squirrels in southwestern Georgia. Journal of Wildlife Management 65(2): 200-204.

- Adult squirrel mortality in an unhunted population is about 10% each season.
- No differences in survival between sexes or seasons.
- Fox squirrels survival is higher than gray squirrels.
- Survival rates estimated during this study indicate that fox squirrels may have higher survival rates in the southeastern U.S. than in the midwestern U.S.

Conner, L.M., and I.A. Godbois. 2003. Habitat associated with daytime refugia of fox squirrels in a longleaf pine forest. American Midland Naturalist 150(1):123-129.

- Hardwood trees had a 56% greater chance of being used as a refuge tree than pine trees.
- Tree height and density was positively associated with probability of use as refugia.
- Understory vegetation appears to be an unimportant variable for fox squirrels when selecting daytime refuge sites.
- Mature hardwood trees within an open-canopy pine stand are significant refuge sites.

Derge, K. L., and R. H. Yahner. 2000. Ecology of sympatric fox squirrels (*Sciurus niger*) and gray squirrels (S*ciurus carolinensis*) at forest-farmland interfaces of Pennsylvania. The American Midland Naturalist 143(2):355-369.

- Habitat use differed between fox and gray squirrels.
- Fox squirrels occurred closer to forest edge and in areas with fewer short shrubs than gray squirrels.
- Gray squirrels used habitats with fewer understory logs and trees and habitats with greater basal areas of snags.

Edwards, J.W. and D.C. Guynn, Jr. 1995. Nest characteristics of sympatric populations of fox and gray squirrels. Journal of Wildlife Management 59:103-110.

- Gray squirrel use of cavities was greatest during winter.
- Fox squirrel use of cavities was greatest during fall and winter.
- Gray squirrels use tree dens more often than fox squirrels for all seasons.
- Fox squirrels rarely included vines in their leaf nests while gray squirrels often used them.
- Fox squirrel leafs nests were higher and located in taller trees of larger diameter than gray squirrels.
- Both squirrels built leaf nests in pine and oak trees more frequently than expected.
- Placement of artificial cavities in pines and at heights of 15-20m may increase use by fox squirrels.

Hansen, L. P., C. M. Nixon, and S. P. Havera. 1986. Recapture rates and length of residence in an unexploited fox squirrel population. The American Midland Naturalist 115:209-215.

- Adults consisted of 79% of the population during autumn and 86% during spring.
- Length of residence of fox squirrels that were juveniles at first capture was shorter than for squirrels that were subadults at first capture.

- Length of residence of both juveniles and subadult squirrels was shorter than that of yearling and adult squirrels
- Recapture rates of yearling and adult fox squirrels also were greater than juveniles and subadults.
- 99.1% population turnover in 11.7 years indicates high survival of fox squirrel on the study area.
- Results suggest that resident adults may limit recruitment of squirrels into a population, thereby controlling maximum densities.
- Annual adult survivorship is generally >60% with average annual mortality estimated as 34% for males and 37% for females.

Havera, S.P. and K.E. Smith. 1979. A nutritional comparison of selected fox squirrel foods. Journal of Wildlife Management 43:691-704.

- Shagbark hickory and mockernut hickory had the highest caloric values, whereas white oak and corn embryos had the lowest values.
- Oaks have similar coefficients of energy metabolism that fell between the lower values of the grains and the higher values of walnuts, shagbark, and mockernut hickory.
- Squirrels fed a white oak diet had the highest mean levels of food intake, metabolized energy and weight gain.
- Red oak was the only mast with a lower amount of metabolized energy per day than corn and soybeans.
- The higher coefficients of metabolism and the higher caloric values for shagbark and mockernut hickory nuts, as compared to acorns, require that adult female fox squirrels eat approximately 59% more white, bur, and black oak acorns than hickory nut.
- An average white oak crop in addition to black oak acorns, shagbark and mockernut hickories, and black walnuts, should supply fox squirrels with sufficient energy throughout the winter.
- Corn should not be used in winter as supplemental feeding due to its low energy and mineral nutritional values.

Havera, S.P. and C.M. Nixon. 1980. Winter feeding of fox and gray squirrel populations. Journal of Wildlife Management 44:41-55.

- Study found few beneficial effects on squirrel populations from winter feeding with corn during 3 winters with above-average mast crops in a mature mixed hardwood forest and an even-aged oak-hickory forest.
- In mature oak-hickory study areas, winter feeding did not increase density, survival, or reproduction, nor did it decrease the number of squirrels with mange.

- In oak-hickory study areas, the recapture rate on the feed area were significantly higher than on the control area.
- Supplemental feeding in even-aged timber may be more justified than feeding in mature timber, because fox squirrels collected on the even-aged timber control area had better physiological indices than fox squirrels collected from areas in mature timber.
- To benefit reproduction, winter feeding should be started before December.

Koprowski, J. L. 1991. Response of fox squirrels and gray squirrels to a late spring-early summer food shortage. Journal of Mammalogy 72:367-372.

- Late spring frost killed available fruit crop in 1987.
- Mulberries and hackberries are the major component of the diet of squirrels in a year of typical abundance, but declined from 79% of identified food items in 1988 to 8% of identified food items in 1987.
- In 1987, juvenile survival was lower (39%) than adult survival (94%).
- Juvenile and adult survival were similar during 1988.
- Weights of adults and juveniles were significantly less in 1987 compared with 1988.

Koprowski, J. L. 1994a. *Sciurus niger*. Mammalian Species 479:1-9.

- Article describes taxonomy, physical characteristics, distribution, and genetics of fox squirrels.
- Author conducts literature review of fox squirrel reproduction, ecology, and behavior.

Koprowski, J.L. 1994b. *Sciurus carolinensis*. Mammalian Species, 480:1-9.

- Article describes taxonomy, physical characteristics, distribution, and genetics of gray squirrels.
- Author conducts literature review of gray squirrel reproduction, ecology, and behavior.

Korschgen, L.J. 1981. Foods of fox and gray squirrels in Missouri. Journal of Wildlife Management 45:260-266.

- Fox squirrels ate 109 identified plant foods, 18 which made up > 80% of all foods eaten.
- For fox squirrels, hickories of 7 species were selected most often and in the greatest amount (29%).
- For fox squirrels, oaks of 11 species made up 23% of diet.
- Gray squirrels ate 97 identified plant foods and 14 animal foods, 18 which made up > 86% of all foods eaten.

- The most effective management for oak-hickory forest was to allow it to reach maturity.
- Uneven-aged stands that include a variety of oaks and hickories are the most dependable food producers.
- Gray squirrels rely more on oak-hickory mast (73% of annual diet) than fox squirrels (52% of annual diet).
- Mulberry, osage orange, white elm, maples, and grapes are important as seasonal or supplemental food sources.

McCleery, R.A., R.R. Lopez, N.J. Silvy, and S.N. Kahlick. 2008. Fox squirrel survival in urban and rural environments. Journal of Wildlife Management 72(1):133-137.

- Monthly survival rates of rural fox squirrels was lower than urban fox squirrels over same 12-month period.
- When comparing 24-month period for urban fox squirrels with 18-month period for rural squirrels, survival rates were similar between urban and rural squirrels.
- Data suggests that sex and season may influence survival of urban squirrels but not rural squirrels.
- >60% of fatalities on rural site caused by predation.
- >5% of fatalities on urban site caused by predation and >60% of urban squirrel fatalities caused by motor vehicle collisions.
- Management efforts should not assume demographic rates of rural populations are pertinent in the management of urban populations.

Mosby, H.S. 1969. The influence of hunting on the population dynamics of a woodlot gray squirrel population. Journal of Wildlife Management 33(1):59-73.

- Turnover period for the control group was 6.2 years compared with 7.2 for the hunted population.
- The mean annual mortality rate for the control population was 42.4% and 47.6% for the hunted population.
- Natural losses accounted for 25.2% of the mean annual mortality for the control population and only 10.2% for the hunted population.
- Study suggests that hunting removed a proportion (37.4%) of the population that would have been lost to “natural” causes.
- 37.4% of squirrels were removed from the hunted population due to harvest and 17.3% of squirrels were removed from the control population due to trap mortality.
- Author concludes that harvest of 38% of the squirrel population did not affect recruitment in the hunted population, had no significant influence on the mean annual mortality rate,

and probably removed a segment of the population that would normally be lost to "natural losses."

Nixon, C.M. and M.W. McClain. 1969. Squirrel population decline following a late spring frost. Journal of Wildlife Management 33:353-357.

- A late spring frost killed available seed crop.
- The following fall, the population had a lower reproductive rate, lighter body weight, and increased dispersal rate (for subadults).
- Breeding stopped for the rest of the year and did not resume until late summer of the next year.
- In a year with a good mast crop, 36% of females produced two litters while none did so in years of mast failure.

Nixon, C. M., R. W. Donohoe, and T. Nash. 1974. Overharvest of fox squirrels from two woodlots in western Ohio. Journal of Wildlife Management 38(1):67-80.

- Results of harvest data (1965-71) for 54 acres of public hunting woodlots in western Ohio.
- Harvest of 1 squirrel/acre for 1st 4 years, and 0.60 squirrel/acres last 3 years.
- Harvest related to preseason squirrel density, but not to hunting pressure.
- High yield due to high, sustained hunting pressure (mean= 4.3 gun-hours per acre for all years) and easy access.
- Of 759 hunters surveyed, 66% killed no squirrels, 6.0% harvested > 1 squirrel per trip, and only four hunters killed a bag limit of four squirrels.
- 73% of squirrel hunting occurred in September, 23% in October, and only 4.4% in November.
- 35.6% of September hunters were successful, but only 25.1% of October hunters were successful.
- Nearly 75% of total harvest was young-of-the-year 59.8% subadults, and 14.0% juveniles.
- Annual mortality rate of 91.8% for adults and subadults (75.2% of mortality was from hunting)
- The early hunting season was harmful to population maintenance because nursing females were harvested, resulting in the loss of nestlings that could have contributed to the harvest.
- In western Ohio, weaning of litters is almost complete by September 15th.

- Starting hunting season after September 15th would make juveniles available and would reduce the harvest of nursing adult females, who are more vulnerable to shooting at this time.

Nixon, C.M. and M.W. McClain. 1975. Breeding seasons and fecundity of female gray squirrels in Ohio. Journal of Wildlife Management 39:426-438.

- Winter breeding peaks in January.
- Spring-summer breeding peaks between mid-May and mid-June.
- The two breeding peaks occur when photoperiod and temperature are increasing.
- Mortality from implantation to mid fall of spring-born young averaged 15.9%, while summer-born young averaged 68.1%.
- 56% of yearling females breed during either the winter or summer breeding period.
- The age ratio of gray squirrels in the study area was 48% young-of-the-year.
- 60% of adult females breed during each breeding period, even in years when food availability is high.
- Gray squirrels are organized into social units that are dominated by adult females.

Nixon, C.M., M.W. McClain, and R.W. Donohoe. 1975. Effects of hunting and mast crops on a squirrel population. Journal of Wildlife Management 39:1-25.

- In Waterloo, Ohio, 63% hunters surveyed killed no squirrels per trip, 8.5% shot 1 squirrel, 8.5% shot 2 squirrels, and 6% shot 3 or more.
- Hunters were more successful in September (40.1%), than October (35.9%), or November (24.6%).
- Composition of gray squirrels was 51.4% adults and 48.6% juveniles; for fox squirrels 53.2% of the population were adults and 46.8% were juveniles.
- Juveniles made up 5.4% of the September harvest and 35% of the October harvest.
- Adults declined from 42.4% of the harvest in September to 25.3% in October.
- The average annual mortality rate for adult fox squirrels was 80%; for subadults it was 69%.
- Hunting accounted for 55.2% of the annual mortality.
- Population densities of squirrels were dependent upon the mast crop of the previous fall and harvest.
- Harvest and densities affected the survival of adult female gray squirrels.
- A good mast crop improved the survival of summer-born young, increased fecundity of breeding females, reduced emigration rates for juveniles and subadults, and increased survival of adult gray squirrels due to the larger size of hickory crop.
- An opening date after September 20th would eliminate the killing of nursing females by hunters.

Nixon, C.M., and R. Donohoe. 1979. Squirrel nest boxes-are they effective in young hardwood stands? Wildlife Society Bulletin 7:283-284.

- 10 nest boxes were placed in a 21 year-old, 1.9 ha clear-cut, located in Vinton County, Ohio, and in April 20 nest boxes were placed in a 4.0 ha, 32-36 year-old stand located in Pope County, Illinois.
- Gray squirrels made little use of boxes located in the 21-year-old woods, while gray squirrels were using 7 boxes by August and 16 boxes by December of that year.

Nixon, C.M., M.W. McClain, and R.W. Donohoe. 1980b. Effects of clear-cutting on gray squirrels. The Journal of Wildlife Management 44:403-412.

- The number of adult and subadult squirrels captured declined about 54% and densities decreased 44% 1 year after 12.9 ha clear-cut.
- Number of spring-born subadults decreased after clear-cutting from 36.6% of the squirrels captured in 1968 and 1970 to only 8.6% of the squirrels captured in 1972-1973.
- The loss of a large number of tree cavities within the clear-cut is believed to have contributed to the decline in subadults captured after 1971.
- The reluctance of squirrels to exploit clear-cuts appears to decrease after 15 years following clear-cutting.
- Food production < 22 years post-cut was lower than the uncut forest.
- Smaller clear-cuts (7.9 and 3.8 ha) did not affect squirrel densities, recovery rates, breeding rates, movements, or body weights.
- Clear-cuts kept narrower than 160m should allow most squirrels to retain some portion of their original home range, and should improve the likelihood of the squirrels tolerating the logging operation.
- The authors recommend keeping uncut travel lanes of mature trees, 50-100m wide if cutting units > 8 ha.
- Use of small (<8 ha) and narrow (<160m) clear-cuts where 40-60% of the stands are retained in a seed-producing age should not significantly reduce squirrel populations.

Nixon, C.M., S.P. Havera, and L.P. Hansen. 1984. Effects of nest boxes on fox squirrel demography, condition and shelter use. American Midland Naturalist 112:157-171.

- No evidence that use of artificial shelters by fox squirrels improves either survival or birth rate.
- The infrequent use of boxes by fox squirrels may be the result of a low rate of acceptance by breeding females.
- Survival and density of adult males increased on both study areas in the presence of boxes.
- There was a positive correlation between use by breeding females and the height of boxes.

- Male squirrels preferred boxes in mature, mixed species forests, whereas females preferred boxes close the edge of young forests with low stem density.
- The authors believe that fox squirrels have adapted to more resource-limited environments than have gray squirrels. Adaptations developed to exploit these environments may limit their ability to respond to sudden increases in a particular resource, such as shelter.
- If used, nest boxes should be place in forests <50 years old, high (>12m) in the canopy, and close to the forest edge.

Perkins, M.W., and L.M. Conner. 2004. Habitat use of fox squirrels in southwestern Georgia. Journal of Wildlife Management 68(3): 509-513

- Fox squirrels populations are decreasing in southeastern United States due to habitat loss of mixed pine-hardwood forests.
- Fox squirrels selected mature pine and mixed pine-hardwood habitats when choosing a home range.
- Results suggest that management strategies should provide a combination of mature longleaf pine-hardwood and mature pine-hardwood habitats to promote fox squirrel habitat.
- Uneven-aged forest management strategies can be supplemented with prescribed fire to support pine dominance while retaining a hardwood component.

Peterle, T.J., and W.R. Fouch. 1959. Exploitation of a fox squirrel population on a public shooting area. Michigan Department Conservation Report 2251. 4pp.

- Harvest from 1952 to 1958 was 0.68 squirrels/acre.
- Hunters recovered 67% of juvenile males, 59% of juvenile females, 46% of adult males, and 58% of the adult females.
- Hunters removed up to 60% of population without reducing the reproductive potential.
- 10 squirrel nest boxes/acre in a 10-acre oak-hickory woodlot failed to increase the squirrel population.
- 24,000-board foot cut in same 10-acre woodlot did not change the number of squirrels harvested.
- 3-year study of the mast production shows no relationship between mast crops and squirrel population.
- Public pressure on this public shooting area is 4 to 5 times greater than on private land.

Salsbury, C.M., R.W. Dolan, and E.B. Pentzer. 2004. The distribution of fox squirrel (*Sciurus niger*) leaf nests within forest fragments in central Indiana. The American Midland Naturalist 151(2):369-377.

- Squirrels preferred certain tree species over others to build leaf nests in. Preference was not the same at all 6 study sites.
- The presence of vines in the tree canopy and large trees are important factors influencing nest tree choice for fox squirrels.
- The higher leaf nest densities at the disturbed sites suggest that fox squirrels prefer to nest in woodlots with a dense shrub layer, and may not negatively affected by habitat disturbance and fragmentation of urbanization.

Salsbury, C.M. 2008. Distribution patterns of *Sciurus niger* (Eastern Fox Squirrel) leaf nests within woodlots across a suburban/urban landscape. Northeastern Naturalist 15(4):485-496.

- 8.0% of leaf nests were found in trees with at least one other nest.
- Nest density was negatively related to woodlot area.
- The leaf-nest density within woodlots was not influenced by woodlots size, approximate age, shape, or degree of isolation.
- Leaf nests were not more likely to be located near the woodlot edge than in the woodlot interior.
- Forest fragmentation does not appear to negatively affect abundance of fox squirrels as shown by leaf-nest density.

Sanderson, H. R. 1975. Den-tree management for gray squirrels. Wildlife Society Bulletin 3:125-131.

- Den requirements and formation are discussed.
- A mixture of tree species will decay and develop den cavities at varying rates.
- Clear-cut management options to supply tree dens are discussed.
- Option A: Retention of existing den trees. In the regeneration cut, leave 2 den trees per 5 acres, and keep all known den trees in intermediate treatment. This option has the lowest management intensity and highest risk of not attaining the mast or timber yield.
- Option B: Retention of existing and potential den trees. Follow Option A in the regeneration cut, or leave no den trees. For intermediate treatments, retain all known den trees, and thin to keep a mixture of tree species for mast. This option has low management intensity and high risk of not achieving the squirrel management goal.
- Option C: Treatment of selected trees to form dens. In the regeneration cut, follow options A and B; as intermediate treatments, follow Option B and treat selected trees to

form dens. This option provides medium management intensity and moderate risk of not attaining the squirrel management goal.

- Option D: Provision of artificial dens. The regeneration cut is the same as for all other options; intermediate treatments include those of Option B plus providing artificial dens. High management intensity and low risk of not attaining the squirrel management goal.
- A minimum of 1 den/0.8 ha is required to maintain a density of 1 squirrel/1.6 ha.

Smith, C.C., and D. Follmer. 1972. Food preferences of squirrels. Ecology 53(1):82-91.

- Gray and fox squirrels show similar food preferences.
- Squirrels' preferences are based on speed at which they can ingest food energy and digestibility of the food eaten.
- Niche distinction between squirrel species probably related to differences in foraging behavior and predator escape behavior, not food preferences or feeding efficiency.
- Fox squirrels are adapted to open forest and forest edges and gray squirrels to dense forests.
- Activity patterns of gray and fox squirrels make hickory nuts and walnuts most efficient in fall and spring, and acorns most efficient in winter.
- A squirrel will have to ingest almost twice the weight of white oak or bur oak acorn kernels as hickory nut kernels in order to obtain the same daily energy requirements.
- Both fox and gray squirrels prefer hickory nuts and oak acorns to other food sources.

Thompson, D.C. 1978. Regulation of a northern grey squirrel (*Sciurus carolinensis*) population. Ecology 59:708-715.

- 70.7% of females gave birth during each breeding period.
- 48.8% of females weaned a litter averaging 3.1 young.
- 51.9% of adult females weaned litters averaging 3.2 young, and 42.9% of the yearlings weaned an average of 2.8 young.
- 11% of spring-born animals emigrated each fall.
- The sex ratio was 1:1.
- Dispersal losses were estimated at 10.4% of young.
- Adult annual mortality was 54%
- Spring-born and summer-born juveniles had similar annual mortality (63-66%).
- The dispersal of surplus young squirrels is considered a major factor in the determination of local population size.

WILD TURKEY FOOD HABITS ON THE NORTHERN FRINGE OF THEIR RANGE IN MINNESOTA

Eric M. Dunton, Darren Mayers, John Fieberg, and Kurt J. Haroldson

SUMMARY OF FINDINGS

The purpose of this study was to evaluate diet selection and body condition of eastern wild turkeys (*Meleagris gallopavo silvestris)* in agricultural and forested areas on the northern fringe of their range in Minnesota. We collected 15 turkeys in forested habitat (7 in 2009 and 8 in 2010) and 55 turkeys in agricultural habitat (24 in 2009 and 31 in 2010). Diets of turkeys consisted of a mixture of high energy (acorns) and low energy (grass, leaf litter, and sensitive fern) food items in forested habitat, while diets of turkeys located in agricultural habitats consisted primarily of high energy (corn) food items. In 2009, adult females in forested habitat had 32% less body weight, 72% less body fat, and were assigned to lower body condition classes than adult females in agricultural habitat. In 2010, adult females in forested habitat had 24% less body weight, 49% less body fat, and most birds were assigned to a lower body condition class than adult females in agricultural habitat. Further range expansion of wild turkeys in Minnesota's northern forests may be limited by availability of high energy food sources during winter, which are generally associated with agricultural practices.

INTRODUCTION

The current range of the eastern wild turkey extends far north of what was identified by Schorger (1966) as their historical range. This northern expansion has been associated with increased availability of food during winter (Wunz 1992, Wunz and Pack 1992, Kubisiak et al. 2001), which was considered limiting prior to settlement by European farmers. Wild turkey range in Minnesota and throughout the northeastern United States and southeastern Canada is currently expanding northward beyond agricultural areas (Kimmel and Krueger 2007). It is unknown how far turkeys will expand outside of mixed forest-agriculture areas into northern forest areas, and what their diet will include. Understanding winter diet selection of turkeys on the northern periphery of their range and the interaction of agriculture, snow conditions, and food habits will provide managers with improved information on wild turkey management needs outside of an agriculturally dominated landscape.

The eastern wild turkey is a food generalist with a winter diet ranging from >20 species (Korschgen 1967) to a restricted diet of only corn (Porter et al. 1980). As wild turkey range expanded north through mixed forest-agricultural habitats, Porter (2007) concluded, "Looking back at the field studies of the 1970s, it is clear that they were telling us more than we realized: snow and cold are not the issue, the key is food." Survival of wild turkeys in northern habitats was enhanced for birds with access to agricultural foods (Porter et al. 1980, Vander Haegen et al. 1989, Kane et al. 2007, Restani et al. 2009), but information is lacking on turkey food habits in northern non-agricultural areas. In central Minnesota, Restani et al. (2009) demonstrated that wild turkeys that had access to food plots had higher survival than turkeys without access.

Our objectives in this study were to: (1) identify winter foods used by wild turkeys on the northern fringe of their range in Minnesota; (2) describe diet as a function of agriculture and snow condition; and (3) compare body condition of wild turkeys with access to high-energy agricultural diets to those without.

STUDY AREA

We conducted this study within the Western Superior Uplands and Northern Minnesota Drift and Lake Plain Ecological Sections of the Laurentian Mixed Forest Ecological Province (MNDNR 2003). The study area is located north of Minnesota's historical wild turkey range (Leopold 1931, Schorger 1966, Snyders 2009) where wild turkey populations were established by translocation during the 1990s - 2008. The 25,959 km^2 study area is comprised of 35% upland deciduous forest, 31% crop/grass, 16% aquatic environment, 10% shrubland, 4% upland conifer forest, 2% lowland conifer forest, 2% lowland deciduous forest, and 1% non-vegetated (GAP Analysis Program MNDNR 2008).

METHODS

Using fixed wing aircraft, we located wintering flocks of turkeys in agricultural areas. To aid in locating wild turkeys with access to agricultural foods, we stratified the study area using a 500 ha grid and classified each cell to 1 of 3 habitat categories based on reclassified GAP land cover data: agricultural cells contained ≥30% cropland and ≥20% forested habitat; forested cells contained ≥50% forested habitat and 0% cropland; and other cells contained all other combinations of habitats. We used real-time, moving-map software (MNDNR 2005) coupled to a global positioning system receiver and a tablet-style computer to guide transect navigation and record turkey locations and aircraft flight paths directly to a geographic information system (Haroldson 2007). Turkeys located from aircraft were then relocated on the ground within 1-3 days. We attempted to collect by shooting 1-5 turkeys from each flock in late afternoon or early evening, when their crops were most likely to contain food (Hillerman et al. 1953). We did not conduct aerial surveys of forested strata in 2010 because no turkeys were observed in 122 surveys of forested strata during 2009. Instead, forested turkeys were located by soliciting observations from MNDNR employees and private landowners, and searching areas where turkey flocks were observed before winter.

At each collection site, we recorded date, snow depth, snow condition (e.g., crusted versus powder snow), habitat class (agricultural versus forested), and geographic coordinates. We verified habitat class by plotting collection sites on Farm Service Agency 2008 aerial imagery, and identifying presence or absence of cropland within a 1,545-m radius buffer (based on the 750 ha winter home range of wild turkeys in Minnesota reported by McMahon and Johnson [1980]). Habitat was classified as forested if no cropland was located within the buffer; otherwise habitat was classified as agricultural.

We determined frequency of occurrence and weight of food items present in the crops and gizzards according to the methods of Korschgen (1967). We determined dry matter content of foods by drying to a constant weight at 50°C (Decker et al. 1991). We assigned each food item 1 of 4 classes (high, medium, low, and unknown) based on estimated energy content of individual food items (Decker et al. 1991).

We evaluated body condition of wild turkeys collected in forested and agricultural habitats based on relative body weight and 3 estimates of body fat. We estimated total body fat of adult hens using a formula from Pekins (2007). We also assigned turkeys to 1 of 4 body condition classes based on amount and color of visible fat (Carter 1970). Finally, we assigned turkeys to 1 of 3 classes based on the amount of fat visible on the gizzard. We tested for differences in estimated weights and in the distribution of body condition classes among birds collected in agricultural and forested habitats using permutation tests that controlled for age, sex, and year. Similarly, we tested for a difference in mean estimated body fat for adult females in agricultural and forested habitats using a permutation test that controlled for year. Lastly, we calculated mean weights by age, sex, and year and 95% confidence intervals for these means. Tests were conducted using the independence-test function in the coin package (Hothorn et al. 2006) in the R programming language (R Development Core Team 2008).

RESULTS

In 2009, we aerially surveyed 122 forested strata and 103 agricultural strata and located 0 turkeys in forested strata and 1,130 turkeys (mean flock size = 23) in agricultural strata. In 2010, we aerially surveyed 50 agricultural grids and observed 289 turkeys (mean flock size = 14). Over the 2 year study period we collected 70 turkeys, including 15 from forested habitat (7 in 2009 and 8 in 2010) and 55 from agricultural habitat (24 in 2009 and 31 in 2010). Mean collection dates were similar between years for turkeys collected in forested habitat (24 January 2009 versus 31 January 2010) and agricultural habitat (30 January 2009 versus 13 January 2010). The geographic distribution of collected birds was similar between years, but included a larger proportion of the study area in 2010 (Figure 1). Snow depth in forested habitat averaged 39 cm in 2009 and 24 cm in 2010, and we classified snow conditions as crusted at 6 sites (0 in 2009 and 6 in 2010) and powder at 9 sites (7 in 2009 and 2 in 2010). Snow depth in agricultural habitat averaged 27 cm in 2009 and 22 cm in 2010, and we classified snow conditions as crusted at 29 sites (14 in 2009 and 15 in 2010) and powder at 26 sites (10 in 2009 and 16 in 2010).

High energy food (e.g., acorn [*Quercus spp.*]) was found in 86% and 63% of the crops from forest-habitat turkeys but formed only 47% and 25% of the crop contents by weight in 2009 and 2010, respectively (Table 1). For agricultural habitat turkeys, high energy foods (e.g., corn [*Zea mays*]) was found in 92% and 77% of the crops and formed 86% and 62% of the crop contents by weight in 2009 and 2010, respectively (Table 2).

In both years, wild turkeys from forested habitats were generally in poorer condition than birds from agricultural habitats. In 2009, adult females in forested habitat had 32% less body weight, 72% less body fat, and were assigned to lower body condition classes than adult females in agricultural habitat (Table 3, Figure 2). In 2010, adult females in forested habitat had 24% less body weight, 49% less body fat, and most birds were assigned to a lower body condition class than adult females in agricultural habitat (Table 3, Figure 2). Based on body condition we classified 4 forested turkeys as thin (3 in 2009 and 1 in 2010), 9 lean (4 in 2009 and 5 in 2010), 1 fat (2010), and 1 very fat (2010). In agricultural habitat we classified 1 thin (2010), 19 lean (5 in 2009 and 14 in 2010), 28 fat (12 in 2009 and 16 in 2010), and 7 very fat (2009). Body fat estimates were slightly higher in forested and agricultural strata in 2010 compared to 2009, but year effects were larger for forested turkeys (Figure 3). Observed differences in mean weights, estimated body fats (adult females only), and body condition classes were statistically significant (alpha=0.05 level). We classified gizzard fat for 8 forested turkeys as no fat (6 in 2009 and 2 in 2010), 3 fat (1 in 2009 and 2 in 2010), and 4 very fat (0 in 2009 and 4 in 2010. In agricultural habitat we classified gizzard fat for 1 turkey as no fat (2010), 19 fat (10 in 2009 and 8 in 2010), and 36 very fat (14 in 2009 and 22 in 2010).

DISCUSSION

Although the wild turkeys that we collected in this study consumed a wide variety of foods, birds collected in agricultural habitats consumed a larger amount of corn and other high energy foods than birds collected in forested habitats. The habitat-specific difference in consumption of high energy foods would likely have been greater if 3 of the 8 turkeys (2 adult females that weighed 3.28 and 3.81 kg and 1 adult male 8.913 kg) collected in forested habitat did not have access to residential bird feeders containing high energy food. The opportunistic feeding behavior of wild turkeys has long been known (Porter et al. 1980, 1983; Vander Haegen et al. 1989, Healy 1992). Because the distribution and abundance of bird feeders and other anthropogenic food sources is unknown, we consider them unreliable as a management strategy for maintaining turkey populations, particularly on the fringe of their current range.

Body weights of adult and juvenile hens collected in forested habitats in this study were below average whereas body weights of adult and juvenile hens collected in agricultural habitats were within the average range reported by Porter (1980) in Minnesota, Vander Haegen et al (1989) in Massachusetts, and Coup and Pekins (1999) in New Hampshire. Pekins (2007) suggested that adult hens weighing <3.0 kg have minimal body fat and were approaching a critical threshold of malnutrition. Thus, most adult hens collected from forested habitats in this study were showing signs of food deprivation. As supporting evidence, in 2009 we frequently observed turkeys in forested habitats remaining in their roosts late in the morning. This behavior was only occasionally observed in 2010 and is generally considered an indication of stress (Hayden and Nelson 1963).

Findings from this study indicate that turkeys in agricultural areas were able to find sufficient food (primarily corn) to maintain energy balance and fat reserves throughout the winter, even in 2009 when snow depth was >25 cm. In contrast, turkeys using exclusively forested habitats in deep snow were in poor body condition with little to no fat reserves. Even in 2010, when mean snow depth at collection sites was 24 cm, birds were in poor condition compared to their counterparts in agricultural habitat. Powder snow >15-20 cm hinders mobility, and >30 cm can prevent movement of wild turkeys (Austin and DeGraff 1975, Porter 1977, Healy 1992). Deep persistent snow cover can ultimately result in starvation. Wild turkeys began starving when snow depth was >30cm for >2 weeks in Pennsylvania (Wunz and Hayden 1975), 49 days in Wisconsin (Wright et al. 1996), and 40-59 days in New York (Roberts et al. 1995). Wright et al. (1996) documented starvation when deep snow restricted movements even though food was available within 0.8 km.

Further range expansion of wild turkeys in Minnesota's northern forests may be limited by availability of high energy food sources during winter, which are generally associated with agricultural practices. Wild turkey range may expand during periods with consecutive mild winters and then contract during severe winters. Because opportunities for agriculture are limited in this region, unharvested crops, stored crops, and livestock feeding operations may attract large concentrations of wintering turkeys, resulting in depredation complaints. Our inability to detect any wild turkeys during aerial surveys of 122 forested strata during 2009 leads us to suspect that some wild turkeys in forested areas moved to agricultural habitats to take advantage of high energy food sources.

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Table 1. Crop contents and estimated energetic value of food items for 8 wild turkeys collected in forested habitats on the northern fringe of their range in Minnesota during winter, 2010.

	Weight			
Food item	Total (g)	% of total	Frequency (%)	Estimated energetic value of food item
Crab apple (*Malus spp*.)	51.5	36	12.5	Medium
Acorn (*Quercus spp*.)	35.64	24.9	62.5	High
Grass stem and leaves (*Poa spp*.)	18.02	12.6	87.5	Low
Unknown forb seed	10.18	7.1	25	High
Smartweed seed (*Polygunum spp*.)	7.79	5.4	25	High
Bittersweet plant and seed (*Celastrus sp.*)	7.29	5.1	12.5	Medium
Sensitive fern frond (*Onoclea sensibilis*)	6.78	4.7	12.5	Low
Oat seed (*Avena sativa*)	2.03	1.4	25	High
Brome grass seed (*Bromus inermis*)	1.7	1.2	25	High
Curly dock plant and seed (*Rumex crispus*)	0.42	0.3	12.5	Medium
Poison ivy fruit (*Toxicodendron spp.*)	0.22	0.2	12.5	Medium
Soybean (*Glycine spp*.)	0.22	0.2	12.5	High
Sunflower seed (*Helianthus spp*.)	0.09	0.1	12.5	High
White cockle plant and seed (*Silene latifolia)*	0.14	0.1	12.5	Medium
Hazel catkin (*Corylus spp*.)	0.93	TR[a]	50	Low
Beetle (*Coleoptera spp.*)	0.01	TR[a]	12.5	Unknown
Club moss (*Lycopodium spp*.)	0.01	TR[a]	12.5	Low
Total	142.97			

[a] Trace (TR) amount of food item present in diet < 0.1

Table 2. Crop contents and estimated energetic value of food items for 31 wild turkeys collected in agricultural habitats on the northern fringe of their range in Minnesota during winter, 2010.

Food item	Weight		Frequency (%)	Estimated energetic value of food item
	Total (g)	% of total		
Corn kernel (*Zea mays*)	1038.77	61.9	77.4	High
Acorn (*Quercus spp*.)	213.16	12.7	12.9	High
Sunflower seed (*Helianthus spp*.)	78.83	4.7	29	High
Soybean (*Glycine spp*.)	76.12	4.5	12.9	High
Ash samara (*Fraxinus spp*.)	33.54	2	22.6	Low
Soybean plant parts (*Glycine spp*.)	33.08	2	9.7	Low
Buckthorn fruit (*Rhamnus cathartica*)	30.25	1.8	6.5	Medium
Crab apple (*Malus spp*.)	26.09	1.6	6.5	Low
Grass plant parts (*Poa spp*.)	25.71	1.5	77.4	Low
Manure	21.67	1.3	22.6	Unknown
Oat seed (*Avena sativa*)	19.54	1.2	16.1	High
Millet seed (*Panicum spp*.)	14.85	0.9	9.7	High
Black cherry fruit (*Prunus serotina*)	13.07	0.8	3.2	Medium
Corn plant parts (*Zea mays*)	13.54	0.8	22.6	Low
Brome grass seed (*Bromus inermis*)	11.64	0.7	9.7	High
Smartweed seed (*Polygunum spp*.)	5.9	0.4	6.5	High
Club moss (*Lycopodium spp*.)	5.04	0.3	16.1	Low
Unknown forb seed	3.86	0.2	12.9	High
Canada lettuce plant and seed (*Lactuca canadensis*)	2.8	0.2	6.5	Medium
Sweet cicely plant and seed (*Osmorhiza berteroi*)	2.93	0.2	9.7	Medium
Unknown legume seed	2.71	0.2	3.2	High
Grit	1	0.1	3.2	N/A
Basswood fruit (*Tilia americana*)	0.36	TR[a]	3.2	Medium
Curly dock plant and seed (*Rumex crispus*)	0.11	TR[a]	3.2	Medium
Hazel catkin (*Corylus spp*.)	0.04	TR[a]	3.2	Low
Beetle (*Coleoptera spp.*)	0.04	TR[a]	6.5	Unknown
Leaf litter	0.38	TR[a]	3.2	Low
Pine needle (*Pinus spp*.)	0.23	TR[a]	12.9	Low
Quack grass seed (*Elymus repens*)	0.69	TR[a]	3.2	High
Ragweed seed (*Ambrosia spp*.)	0.36	TR[a]	3.2	High
Red clover seed (*Trifolium spp*.)	0.25	TR[a]	3.2	High
Sensitive fern (*Onoclea sensibilis*)	0.35	TR[a]	6.5	Low
Thistle seed (*Cirsium spp*.)	0.43	TR[a]	6.5	High
Unknown forb seed	0.08	TR[a]	3.2	High
Wheat seed (*Triticum spp*.)	0.28	TR[a]	3.2	High
Total	1677.7			

[a] Trace (TR) amount of food item present in diet < 0.1

Table 3. Estimates of body fat for 70 wild turkeys collected in forested versus agricultural habitats on the northern fringe of their range in Minnesota during winter, 2009 - 2010.

						Body condition class				Mean estimated total body fat[e]	
Habitat	Year	Gender	Age	*n*	Mean weight (kg)	Very fat[a]	Fat[b]	Lean[c]	Thin[d]	Kg	%
Forest	2009	F	A	5	3.24	0	0	2	3	0.21	5.80
Forest	2009	F	J	1	3.81	0	0	1	0	-	-
Forest	2009	M	A	1	6.48	0	0	1	0	-	-
Forest	2009	M	J	0	0	0	0	0	0	-	-
Forest	2010	F	A	3	3.71	0	0	2	1	0.43	11.46
Forest	2010	F	J	0	0	0	0	0	0	-	-
Forest	2010	M	A	4	8.8	1	1	2	0	-	-
Forest	2010	M	J	1	3.57	0	0	1	0	-	-
Ag	2009	F	A	14	4.75	5	5	4	0	1.02	20.57
Ag	2009	F	J	3	3.91	0	2	1	0	-	-
Ag	2009	M	A	3	9.26	2	1	0	0	-	-
Ag	2009	M	J	4	6.41	0	4	0	0	-	-
Ag	2010	F	A	18	4.9	0	10	8	0	1.1	22.49
Ag	2010	F	J	2	4.83	0	1	1	0	-	-
Ag	2010	M	A	4	8.23	0	2	1	1	-	-
Ag	2010	M	J	7	5.87	0	3	4	0	-	-
Total				70		8	29	28	5		

[a] Large deposits of fat on mid-line of breast, thighs, back, around crop, at the posterior of the body cavity, and immediately beneath skin. Fat is bright yellow (Carter 1970).
[b] Large fat deposits on back and thighs and reduced deposits elsewhere. Fat may be orange in color. (Carter 1970).
[c] Fat deposits are completely resorbed. Breast muscle has “normal” contour. Dark orange color in cellular framework of resorbed fat deposits (Carter 1970).
[d] Breast muscle attains wedge-like appearance (“hatchet-breast”). Skin resembles parchment (Carter 1970).
[e] Body fat (g) = 571.3 x (kg body weight) – 1696; $R^2 = 0.59$, $P < 0.05$. Applies to adult females only (Pekins 2007)

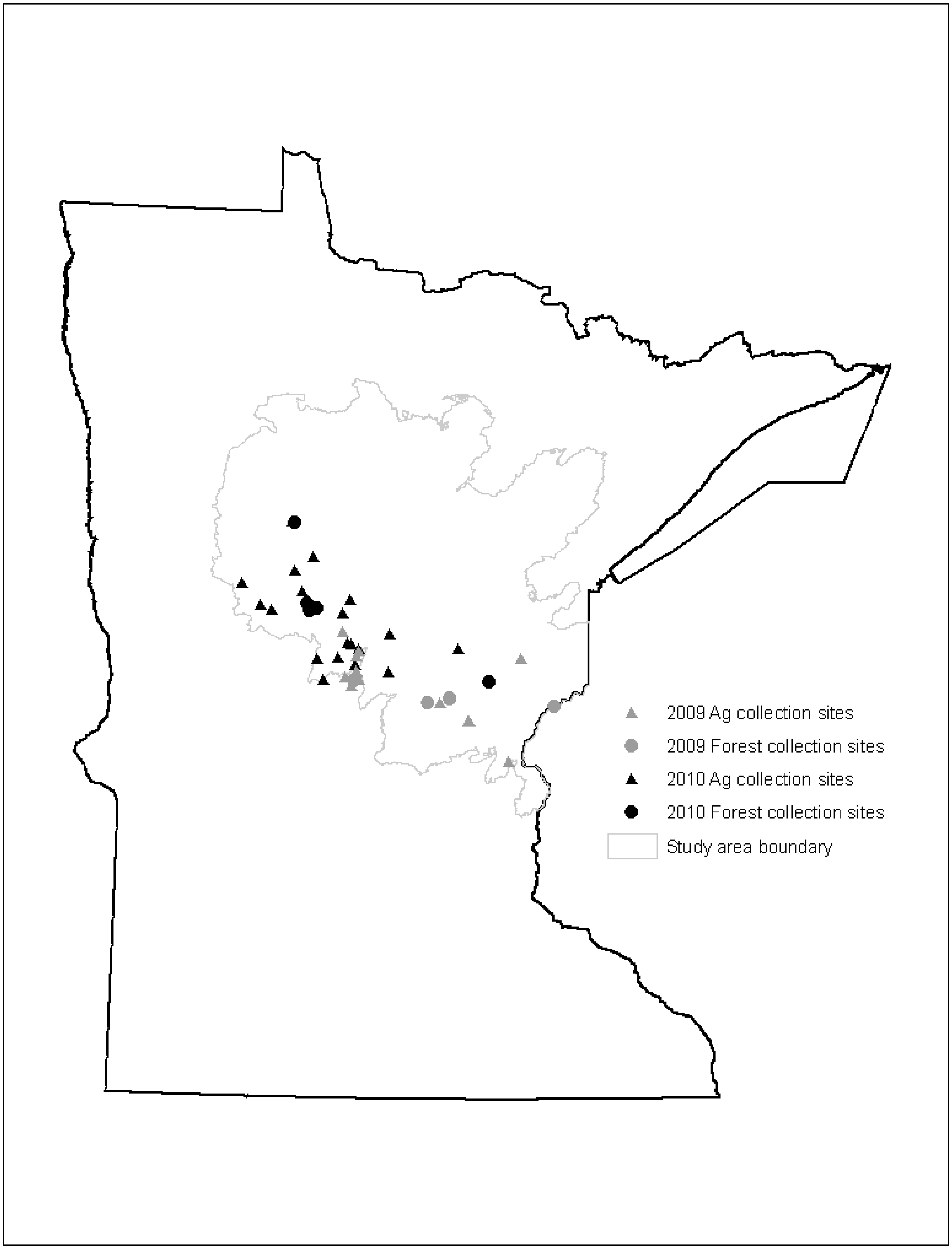

Figure 1. Study area location and collection sites for 15 wild turkeys collected in forested habitat and 55 turkeys collected in agricultural habitat as part of the winter food habits project on the northern fringe of wild turkey range in Minnesota, 2009 – 2010.

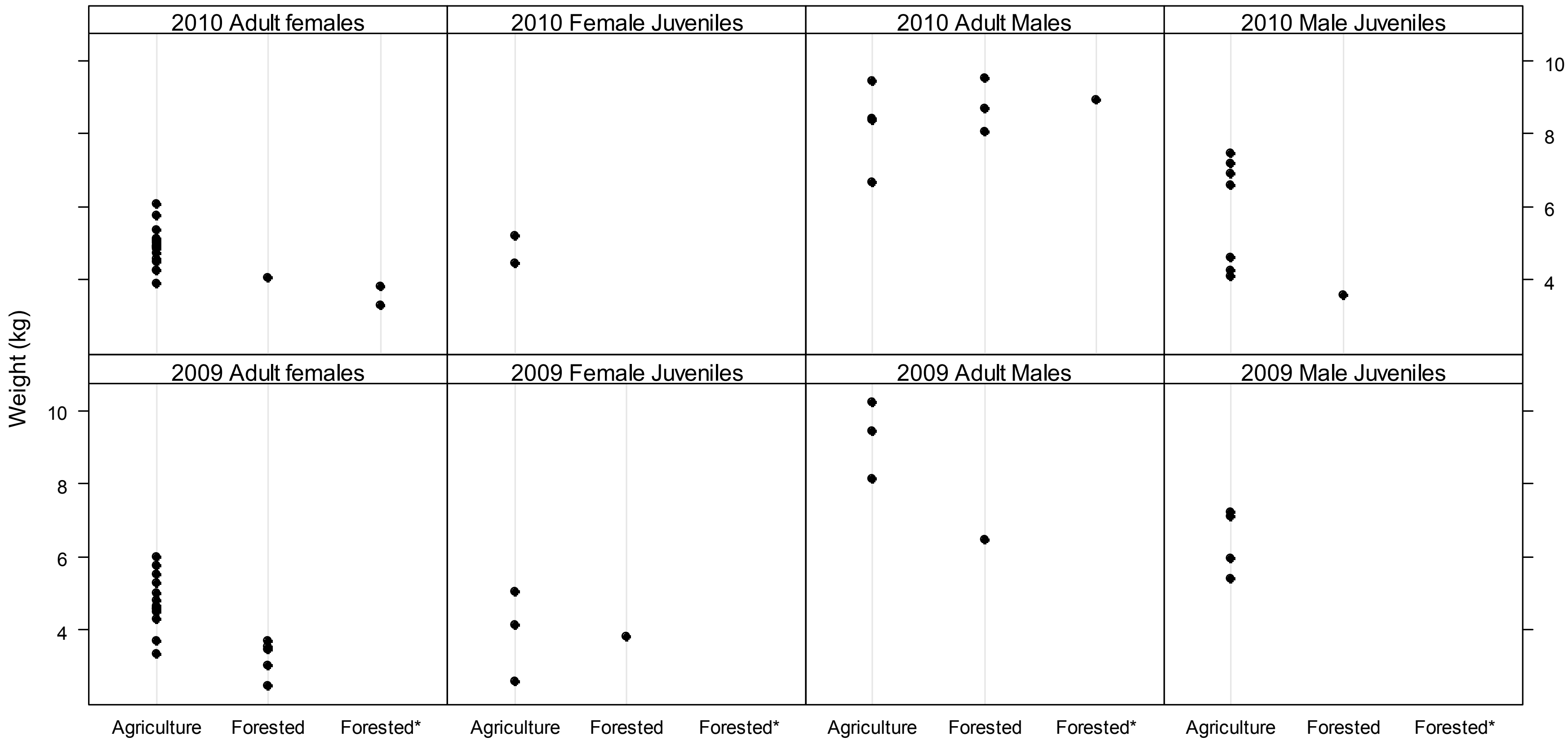

Figure 2. Body weight for 70 wild turkeys collected in forested habitat (n = 15) and agricultural habitat (n = 55) for winter food habits project on the northern fringe of wild turkey range in Minnesota, 2009 – 2010. Note: in 2010, 3 turkeys sampled in forested habitats had access to a high energy food (these birds are listed as “Forested*” in the above figure).

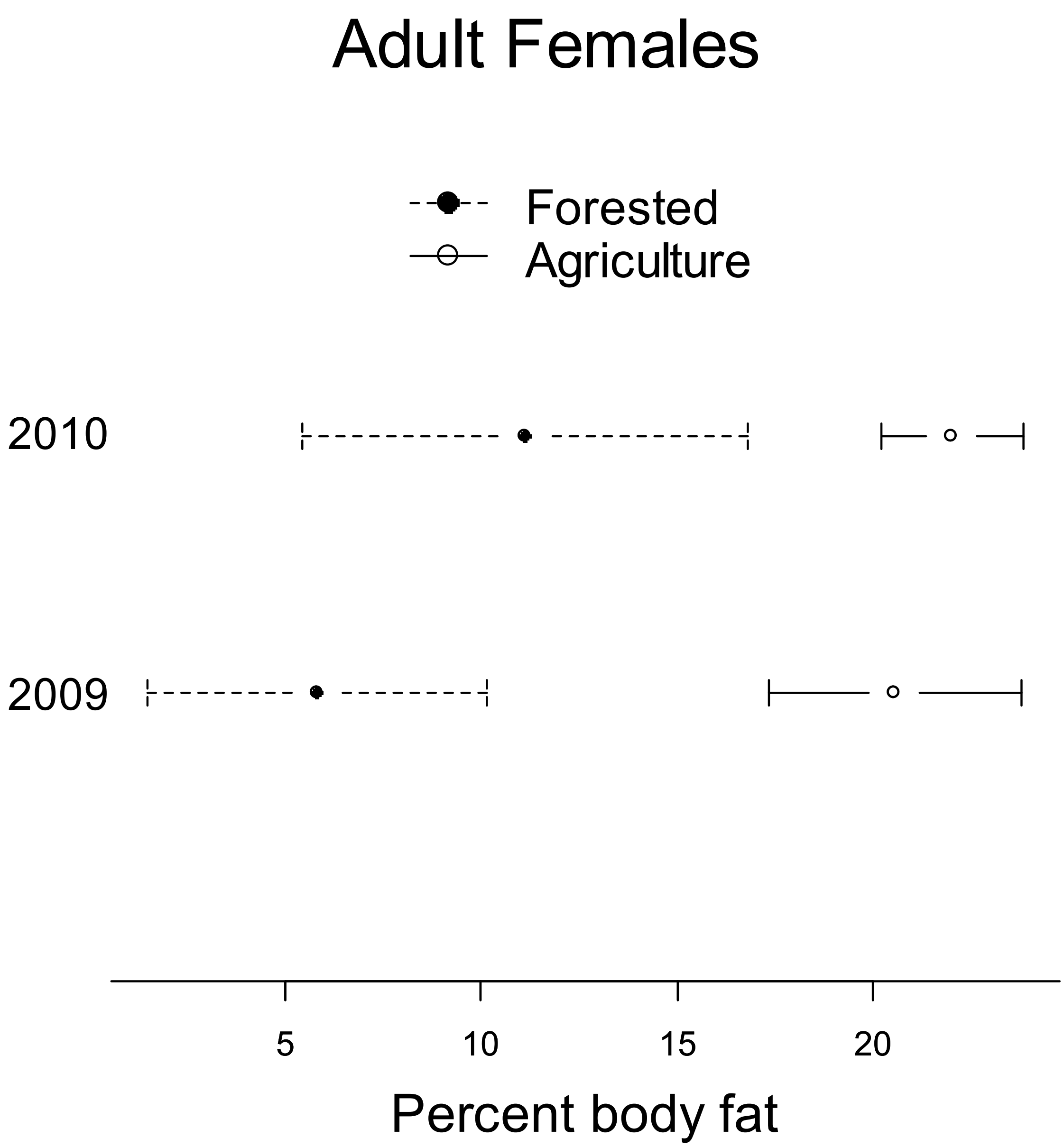

Figure 3. Mean estimated body fat and 95% confidence intervals for adult female wild turkeys in forested habitats (*n* = 8; 5, 2009 and 3, 2010) and agricultural habitats (*n* = 32; 14, 2009 and 18, 2010) collected as part of the winter wild turkey food habits project on the northern fringe of wild turkey range, Minnesota. Note: in 2010, 2 adult females sampled in forested habitats had access to a high energy food.

MOVEMENTS, HABITAT SELECTION, ASSOCIATIONS, AND SURVIVAL OF GIANT CANADA GOOSE BROODS IN CENTRAL TENNESSEE[1]

Eric M. Dunton and Daniel L. Combs

ABSTRACT

The brood-rearing period in giant Canada geese (*Branta canadensis maxima*) is one of the least-studied areas of goose ecology. We monitored 32 broods in Putnam County, Tennessee, from the time of hatching through fledging (i.e., when the goslings gained the ability to fly) and from fledging until broods left the brood-rearing areas during the spring and summer of 2003. We conducted a fixedkernel, home-range analysis for each brood using the Animal Movement Extension in ArcView® 3.3 GIS (ESRI, Redlands, Calif.) software and calculated 95% and 50% utilization distributions (UD) for each brood. We classified 25 broods as sedentary (8 ha 95% UD), three as shifters (84 ha 95% UD), two as wanderers (110 ha 95%UD); two were unclassified because of low sample-size. We measured 5 habitat variables (i.e., percentage of water, percentage of pasture, percentage of development, number of ponds, and distance to nearest unused pond) within a 14.5-ha buffer at nesting locations. We used linear regression, using multi-model selection, information theoretic analysis, to determine which, if any, habitat variables influenced home-range size at a landscape level. The null model was the best information-theoretic model, and the global model was not significant, indicating that landscape level habitat variables selected in this study cannot be used to predict home-range size in the Upper Cumberland region goose flock. We analyzed associations between broods, using a coefficient of association of at least 0.50, and determined association areas by overlaying individual home ranges. Overall gosling survival ($\hat{S}$) during the brood-rearing period was 0.84 (95% CL = 0.78, 0.92), using a staggered-entry Kaplan-Meier survival curve. We believe that abundance of quality forage and pond habitat, high survivorship, and a lack of movement corridors (i.e., rivers, lakes, and reservoirs) were responsible for the relatively small home ranges of geese in the Upper Cumberland region. Associations formed during brood rearing may reduce predation risks and serve as a template for lifelong social bonds with family members and unrelated geese that are reared in the same locations.

[1]Human-Wildlife Interactions 4(2): Fall 2010 *in press*

BULLET FRAGMENTATION AND LEAD DEPOSITION IN WHITE-TAILED DEER AND DOMESTIC SHEEP[1]

Marrett Grund, Lou Cornicelli, Leah T. Carlson, and Erika Butler

ABSTRACT

In February 2008, a private physician in North Dakota radiographed hunter-harvested venison and found that 60 of 100 packages contained metal fragments. This discovery had implications for public-funded venison donation programs and prompted several Midwest states to examine their programs. Approximately 500,000 deer hunters harvest >200,000 deer annually in Minnesota and the state has a similar donation program as the program operated in North Dakota. Therefore, we analyzed fragmentation patterns and lead deposition in carcasses of 8 white-tailed deer (*Odocoileus virginianus*) and 72 domestic sheep (*Ovis aries*). Five different bullet types were fired from centerfire rifles, and we also fired projectiles from a shotgun and blackpowder muzzleloader. We then described fragmentation patterns and lead deposition among treatment groups. Centerfire bullets designed to expand quickly upon impacting the animal had bullet fragments and lead deposited throughout the entire abdominal cavity of carcasses. We also used 2 types of centerfire bullets that were purportedly designed to resist fragmentation. One of these bullet types had fragmentation patterns and lead deposition rates similar to the rapid expanding bullets, the other bullet type resisted fragmentation, and no lead was detected in muscle tissue that we sampled. We determined that a centerfire bullet made from copper resisted fragmentation, and of course did not deposit any lead in muscle tissues. Projectiles fired from the shotgun and blackpowder muzzleloader did deposit lead into carcasses but did not fragment as much as bullets fired from centerfire rifles. Our study suggests that rinsing the abdominal cavity may spread the lead contaminant to other areas of the carcass thereby worsening the contamination situation. We frame conclusions based on our interpretation of limited data but suggest hunters who use centerfire rifles and are concerned about lead exposure should purchase 1 of 2 bullet types that resist fragmentation.

[1]Human-Wildlife Interactions 4(2): Fall 2010 *in press*

EVALUATION OF EARLY ANTLERLESS SEASONS IN THE NORTH METRO AND IN NORTHWEST MINNESOTA

Marrett Grund and Lou Cornicelli

SUMMARY OF FINDINGS

We conducted a study to determine if including an early antlerless season into the deer management hunting framework would increase the harvest of antlerless deer and reduce deer densities in northwest Minnesota and in the north metro region. We monitored deer harvest data, hunter success rates, and conducted aerial surveys to determine if populations were reduced. Based on these trend indicators and surveys, we concluded that the early antlerless season was very effective at reducing deer numbers in the northwest region, but was ineffective at reducing deer numbers in the north metro region. Consequently, more aggressive management options need to be employed in the north metro region and additional research is warranted to explain these differences.

INTRODUCTION

Over the past 70 years, white-tailed deer (*Odocoileus virginianus*) management has changed from focusing on augmenting population growth through habitat protection, hunting regulations, and predator control, to concern about how best to limit deer densities and the consequent impacts of deer on society and forest ecosystems. In fact, managing overabundant deer has emerged as one of the most significant natural resource management challenges over the past 2 decades for many state wildlife agencies in the midwestern and eastern United States (Warren 1997).

The deer program currently used in Minnesota is based on a framework that was created in the early 1970s (Cornicelli 2009). Essentially, the seasonal framework allowed for an unlimited number of hunters to hunt each year, but allow the population to grow as well. This was accomplished by setting the annual bag limit at 1 and providing hunters with a license that allowed the harvest of antlered deer only. A limited number of antlerless permits were offered to hunters to harvest a prescribed quota of antlerless deer. This deer management system worked well throughout the 1970s and 1980s, when the management goal was to increase deer numbers throughout the state.

Modifications to the seasonal framework began in the 1990s and 2000s as the management goal shifted from population growth to attempting to stabilize or reduce deer numbers. The bag limit was increased so that hunters could harvest up to 5 antlerless deer. Survey data collected in 2004 suggested that >70% of hunters taking antlerless deer were only harvesting 1 deer per year. Consequently, additional changes in the bag limit would likely not be effective, because a low percentage of hunters were utilizing the maximum bag limit. Starting in 2005, an early antlerless season was added to 7 deer permit areas (DPAs) in northwest Minnesota and in the north metro region (a region including and around Minneapolis and St. Paul) to evaluate its potential to increase antlerless harvest and reduce deer densities. This study examines harvest data that occurred in these 7 DPAs from 2005-2009.

OBJECTIVES

1) Evaluate the early antlerless season by examining hunter harvest data;
2) Document trends in hunter success rates; and
3) Evaluate the early antlerless season by using population estimates derived from aerial surveys and population modeling.

STUDY AREAS

The northwestern Minnesota study area included 4 DPAs, which encompassed approximately 5,600km^2 (2,250mi^2). The study area in the north metro was 3,800km^2 (1,465mi^2). The northwest study area can be considered mostly flat terrain with a relatively low percentage of woody cover (13%). The north metro is a mosaic of woodlots which comprise 25% of the landscape. Winter severity indices (Lenarz 2009) are higher in the northwest than in the north metro (Grund 2001). However, buck harvest trends suggest that winters have been relatively mild along the transition zone of Minnesota since 1997 (Grund 2009, Lenarz 2009).

METHODS

Seasonal Framework

Minnesota Department of Natural Resources (MNDNR) offered an unlimited number of early antlerless licenses at 25% of the cost of a regular firearms license. The early antlerless license could only be used to harvest an antlerless deer during the early antlerless season. The early antlerless season occurred during the second weekend of October, which was typically 3 weeks before the regular firearms season. The bag limit during the early antlerless season was 2 antlerless deer. A hunter could harvest another 5 antlerless deer during other hunting seasons in these DPAs: the regular firearms season was a 9-day season that started on the Saturday closest to 6 November, the muzzleloader season was a 16-day season that began the Saturday after Thanksgiving, and the archery season began in mid-September and ended 31 December. In all seasons except for the early antlerless season, there were an unlimited number of hunting licenses available to hunters, which allowed hunters to take a deer of either sex. An unlimited number of antlerless-only licenses were available, but an individual hunter could only purchase up to 5 of these licenses. Only 1 antlered buck could be harvested per hunter during 1 hunting year, which encompassed all hunting seasons.

Harvest Data

Successful hunters were required to register deer at a designated registration station within 24 hours of the close of the hunting season. Hunters were required to report their deer as an adult male, adult female, fawn male, or fawn female. Registration station operators were not required to inspect deer or verify that registration information provided by the hunter was correct. We used the percentage of females in the harvest as an index to the harvest pressure on antlerless deer (Roseberry and Woolf 1991, Grund 2001) and we discuss numerical trends in harvest across years for each permit area from 2005-2009.

We measured hunter effort based on total hunter numbers. Hunters were asked by store clerks which DPA they intended to hunt when they purchased their hunting license. We assumed that effort per hunter was constant across years and changes in catch-per-unit-effort (i.e., hunter success rates) reflected changes in deer densities (Roseberry and Woolf 1991).

Population Monitoring and Modeling

Aerial surveys were conducted during the first year (winter 2006) and last year (winter 2010) of this project to assess population change over the 5 years. Methods for aerial surveys can be reviewed in Haroldson (2008).

Population modeling was conducted using an accounting-type model similar to POP2 (Bartholow 1986). The model we used was a management model that incorporated numeric harvest values of adult males, adult females, fawn males, and fawn females, and simulated non-hunting survival rates based on literature reviews and previous field studies (Grund 2001). Reproductive values were derived from fetus surveys conducted on car-killed female deer. We ran simulations with the entire harvest that occurred and we removed deer harvested during the early antlerless season to assess where each population might be in 2010 had the early antlerless season not been held for 5 consecutive years.

RESULTS AND DISCUSSION

Harvests

Excluding DPA 210, the average female harvest increased 30% in each northwestern DPA during the first year of the early antlerless season (Table 1). The boundaries for DPA 210 changed significantly in 2005, therefore, a comparison between years cannot be made for that DPA. The average antlered male harvest increased only 3% in each northwestern DPA during the first year of the early antlerless season. In contrast to the 30% increase in female harvest observed in northwestern study areas, the average female harvest only increased 7% in each north metro DPA during 2005 whereas the average buck harvest decreased by 5% the same year. The results from the first year suggested that the early antlerless season may be more effective in the northwestern DPAs than in the north metro DPAs due to the substantial increase in females harvested (30% vs. 7%).

The percentage of females in the harvest averaged almost 53% in the northwest DPAs from 2005-2009 (Table 2). In comparison, the percentage of females in the harvest was only 47% in the north metro DPAs during the same years. The average percentage of females in the harvest from 2003-2004 for the northwestern and north metro DPAs was 46% and 45%, respectively. Thus, the early season increased the percentage of females in the harvest by 7% whereas it only increased the percentage by 2% in the north metro.

The antlered male harvest (Table 1) and the total antlered male harvest (Figure 1) declined >12% over the 5 years in the northwest but was unchanged in the north metro (Table 1). However, hunter success rates on antlered males were stable in DPA 210, which may reflect a deer density that did not remarkably change over the course of 5 years (Table 3). Most likely, hunter success rates on antlered males will continue to decline in DPAs 256 and 257 as they have the prior 2 years if the early antlerless season were continued in those areas. Between year variability is apparent in hunter success in the north metro study areas, but there is not a clear downward trend indicating that success is worsening due to fewer deer being on the landscape.

Population Monitoring and Modeling

In northwest Minnesota, deer densities declined on average about 6% per year in each permit area based on aerial survey counts. Over the course of 5 years, each northwest deer population had an approximate 32% reduction in aerial counts (Figure 2). In contrast, deer counts in the north metro increased approximately 28% over the 5-year time period (Figure 3). However, it is noteworthy that the counts in DPA 236 were reduced >10% over the 5-year period (Figure 3). These results agree with the aforementioned harvest results, but suggest that 2 populations (DPAs 225 and 227) actually increased under these aggressive management strategies. Certainly, the study was continued too long in DPA 256 because the management goal was only to reduce deer densities by 33% in that DPA.

In northwest Minnesota, population modeling we conducted suggests deer densities declined each year under early antlerless seasons but would have increased under regular firearms seasons (Figure 4). Thus, the additive harvest was critical to managing the population according to its population objective. In the north metro study area; however, the harvest should be deemed additive (Grund 2007) but insufficient to meet its population management objective because the population was not reduced even with the early antlerless harvests (Figure 5). It is noteworthy that the population would have increased >50% in the north metro had EA seasons not been used over the 5-year season.

Management Implications

Harvest management strategies in the northwest study areas should become more conservative as many of those areas were brought below the management goal of 33%. However, harvest management strategies on antlerless deer in the north metro study areas should be liberalized so that survey and harvest data indicate that populations are being managed according to goal.

Preliminary results from the alternative deer management study indicate including an antler-point restriction regulation to the seasonal framework would increase the antlerless harvest by about 12% and that earn-a-buck regulations would increase the antlerless harvest by >50% during the first year they are implemented in Minnesota (Grund 2007). Preliminary modeling would suggest using earn-a-buck for 1 year then using antler-point restrictions as an approach to maintain high harvest rates on antlerless deer in the north metro study area.

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Table 1. Harvest, by deer permit area and sex, of white-tailed deer in the north metro and northwestern Minnesota early antlerless season study areas, 2000-2009. The early antlerless season began in 2005.

	Northwest								Northmetro					
	209		210		256		257		225		227		236	
Year	M	F	M	F	M	F	M	F	M	F	M	F	M	F
2000	534	364	801	523	633	421	612	471	2077	1501	1347	799	1365	782
2001	634	421	905	589	748	721	729	728	2175	1780	1488	1006	1374	949
2002	639	435	922	666	642	514	607	499	2039	1539	1392	909	1364	1093
2003	720	611	1035	843	792	745	735	656	2422	2113	1611	1302	1513	1385
2004	795	611	966	862	752	720	729	607	2081	1576	1480	1119	1314	1153
2005	850	851	1571	1398	783	846	708	793	1943	1722	1310	1208	1348	1202
2006	834	959	1565	1558	820	1094	669	727	2229	2176	1502	1404	1242	1217
2007	870	979	1485	1556	842	909	633	726	2002	1886	1478	1467	1387	1275
2008	709	819	1466	1436	680	681	566	582	1773	1575	1261	1062	1174	1015
2009	778	808	1433	1365	598	668	521	629	2045	1728	1429	1249	1198	1032

Table 2. Percentage of female deer in total deer harvest for each deer permit area in the north metro and northwestern Minnesota early antlerless season study areas, 2000-2009.

	Northwest				Northmetro		
Year	209	210	256	257	225	227	236
2000	41	40	40	43	42	37	36
2001	40	39	49	50	45	40	41
2002	41	42	44	45	43	40	44
2003	46	45	48	47	47	45	48
2004	43	47	49	45	43	43	47
2005	50	47	52	53	47	48	47
2006	53	50	57	52	49	48	49
2007	53	51	52	53	49	50	48
2008	54	49	50	51	47	46	46
2009	51	49	53	55	46	47	46

Table 3. Hunter success rates on antlered male white-tailed deer for each deer permit area in the north metro and northwestern Minnesota early antlerless season study areas, 2005-2009.

	Northwest				Northmetro		
Year	209	210	256	257	225	227	236
2005	23	26	23	24	20	20	29
2006	26	28	25	28	25	26	28
2007	28	26	27	27	24	25	32
2008	23	26	22	23	20	23	28
2009	25	26	20	21	22	24	29

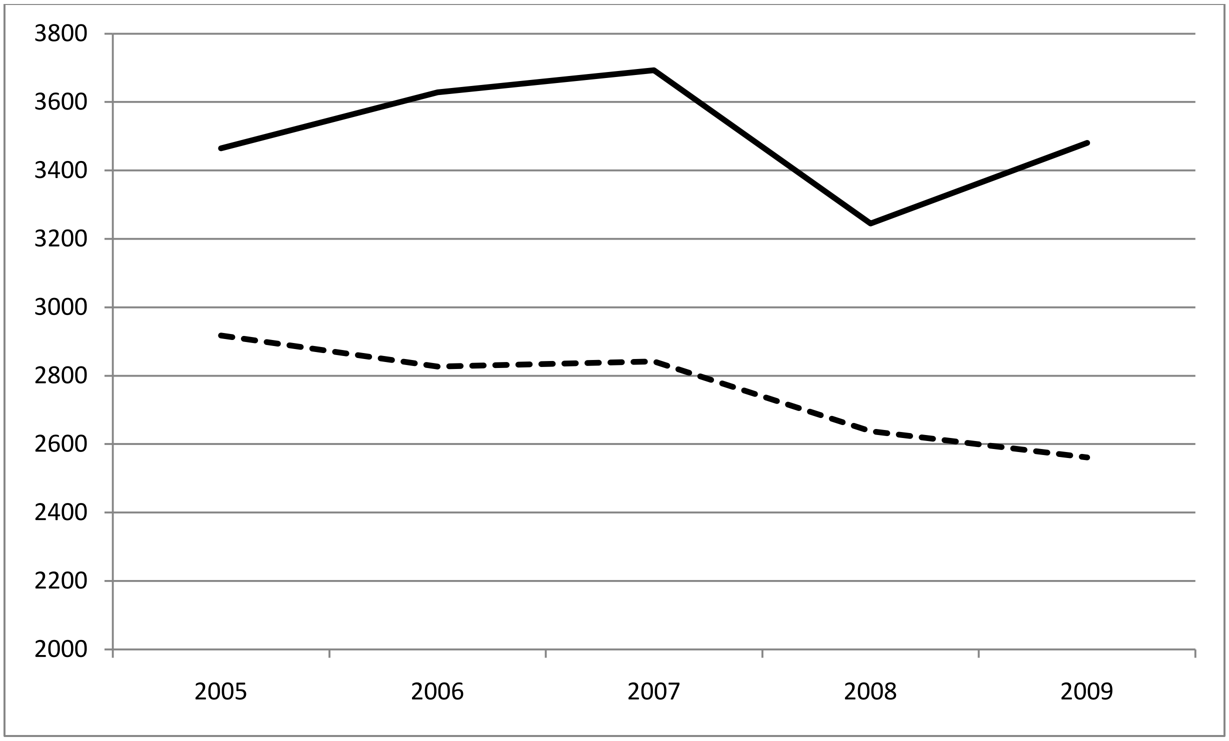

Figure 1. Number of antlered males harvested in early antlerless study areas in northwestern Minnesota (dashed line) and in the north metro (solid line), Minnesota.

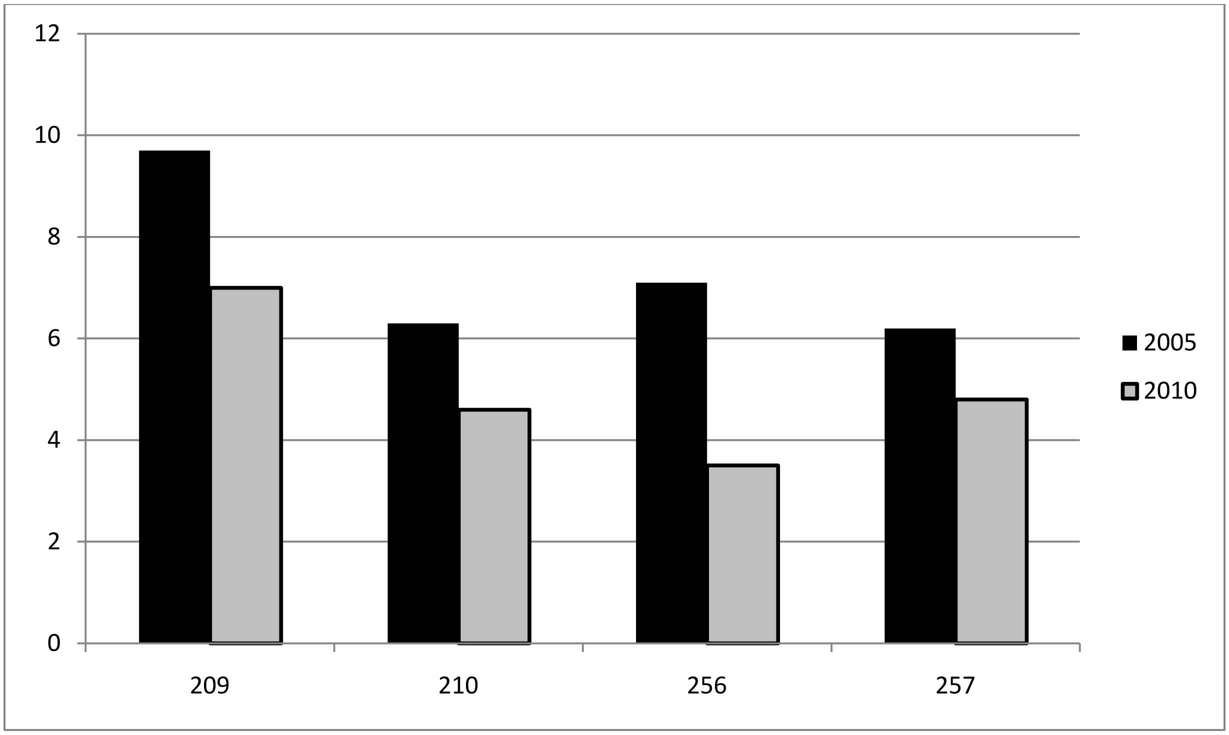

Figure 2. Aerial count results in early antlerless deer permit areas in northwest Minnesota, 2005 and 2010.

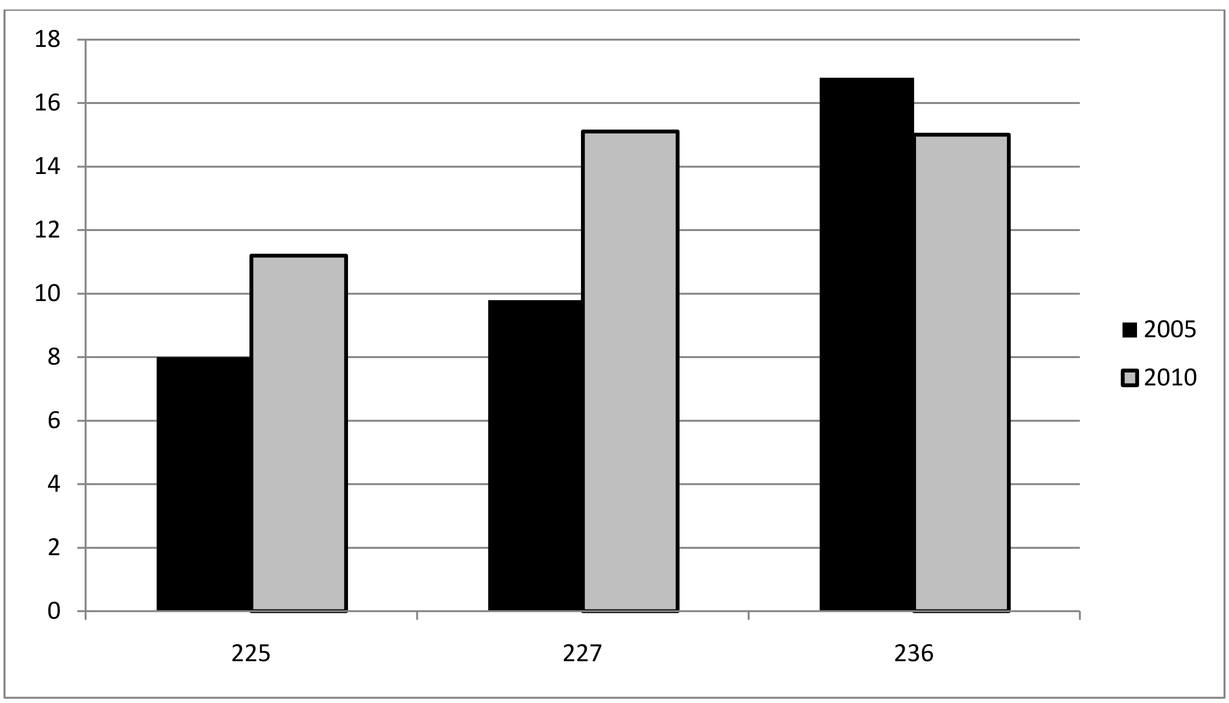

Figure 3. Aerial count results in early antlerless deer permit areas in the north metro, Minnesota, 2005 and 2010.

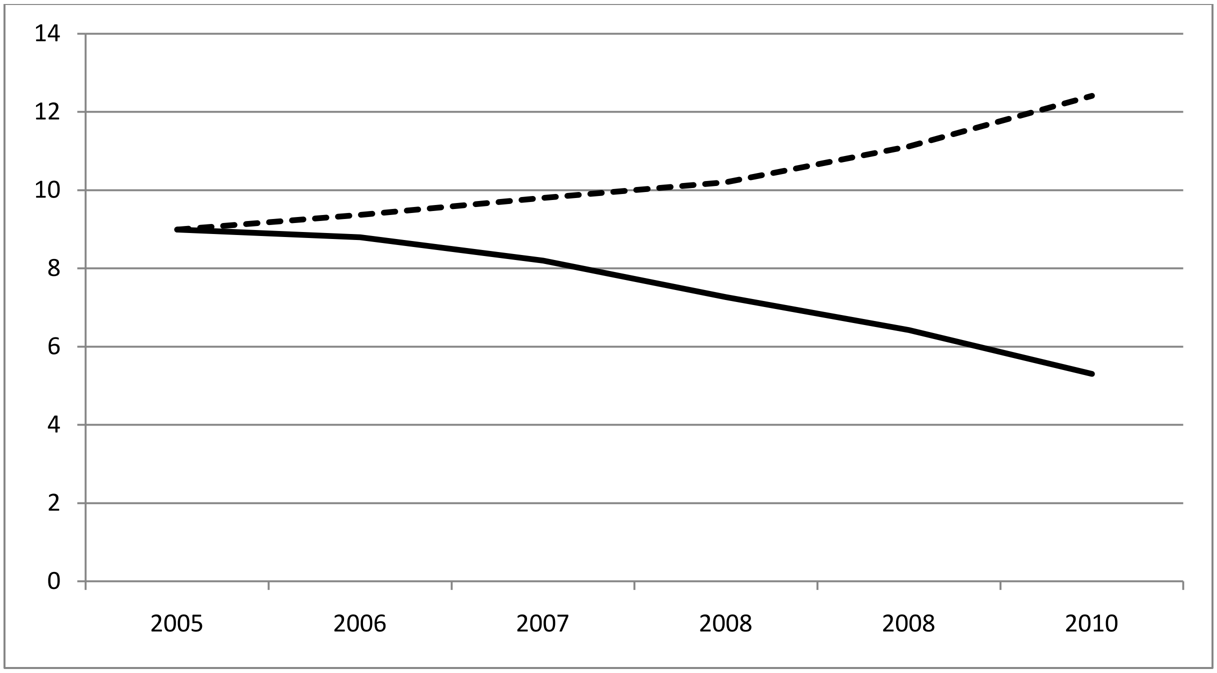

Figure 4. Modeling results depicting what actually occurred through modeling harvest data including harvests from the early antlerless season (solid line) and what would have occurred had the early antlerless season had not been held (dashed line) in northwest Minnesota deer permit areas, 2005-2010.

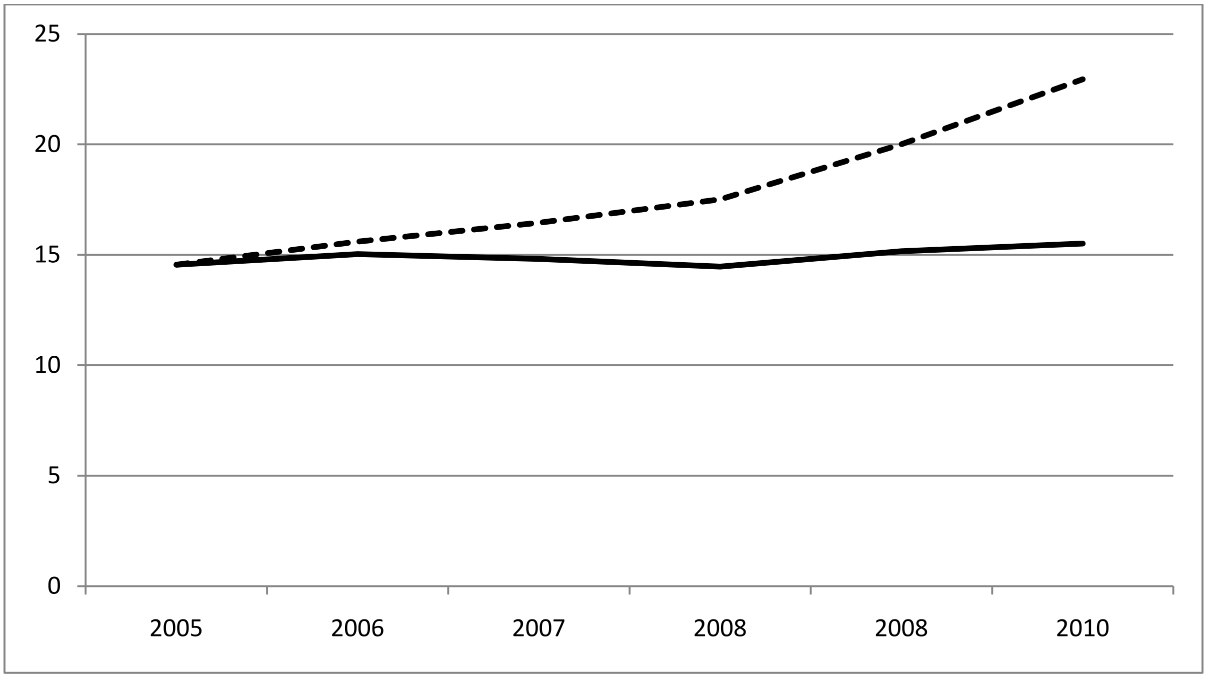

Figure 5. Modeling results depicting what actually occurred through modeling harvest data including harvests from the early antlerless season (solid line) and what would have occurred had the early antlerless season had not been held (dashed line) in north metro Minnesota deer permit areas, 2005-2010.

SURVIVAL ANALYSIS AND COMPUTER SIMULATIONS OF LETHAL AND CONTRACEPTIVE MANAGEMENT STRATEGIES FOR URBAN DEER[1]

Marrett Grund

ABSTRACT

I monitored survival of 34 female white-tailed deer (*Odocoileus virginianus*) in Bloomington, Minnesota, between October 1996 and December 1999. Twenty deer died: 19 were killed by vehicles, and 1 was killed in a deer removal program conducted by an adjacent suburb. Summer survival was high and varied little across the 3 years of study (range = 0.93–0.95), fall survival ranged from 0.84–1.00, and winter survival was generally high during the 3 years of study except during a severe winter (range = 0.72–0.95). I calculated population growth rates (λ) from Leslie matrix projections using these survival estimates and productivity data collected from roadkilled female deer in the Twin Cities metropolitan area. When winter survival was high (0.94), my model simulations indicated the Bloomington deer population increased by 21% when no deer management program was in place. When a low winter survival rate (0.72) was modeled, the population decreased by 7% even when no deer management program was implemented. I modeled the impact contraception may have on population growth and concluded that treating >50% of adult females was necessary to stabilize population growth and treating all females was necessary to decrease population growth under high winter survival conditions. I concluded that removal programs are more effective than immunocontraception programs because survival contributes more to population growth rates in deer populations than fecundity. I recommend removing 20% and 40% of adult females in the population to cause the population to stabilize or to reduce deer numbers, respectively. I recommend managers collect deer-vehicle collision data because these data potentially represent the most accurate and easily obtainable life history component of an urban deer herd.

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RESEARCH PROPOSAL: CONTROLLING ENCROACHMENT OF WOODY VEGETATION IN GRASSLANDS

Kurt Haroldson

SUMMARY OF FINDINGS

Expansion of woody vegetation has become one of the greatest threats to grassland and prairie landscapes. The purpose of this study is to compare the effectiveness of various combinations of burning, mechanical, and herbicide treatments for reducing abundance of woody vegetation in grasslands in the prairie-transition zone of Minnesota. Because woody plants have developed strategies to recover from periodic disturbance, we will apply burning, mowing, and herbicide treatments repeatedly over 3 years in an attempt to deplete root reserves and ultimately kill woody plants on treated sites. We will assess the effectiveness of treatments on woody vegetation by measuring the change in canopy cover and stem density in response to each treatment. To evaluate potential unintended effects of treatments on herbaceous vegetation, we will estimate cover and frequency of grasses and forbs twice annually during each growing season. The results of this study will help guide managers in identifying the most effective approaches to maintaining high quality prairie and grasslands.

JUSTIFICATION

Grassland management is one of the most important activities of wildlife managers in Minnesota's prairie and transition zones. Restoring and maintaining grassland/prairie habitats are necessary for successful management of grassland wildlife, including waterfowl (Minnesota Department of Natural Resources [MNDNR] 2006a), sharp-tailed grouse (*Tympanuchus phasianellus*; Berg 1997), prairie chickens (*Tympanuchus cupido*; Svedarsky et al. 1997), pheasants (*Phasianus colchicus*; MNDNR 2005), and grassland songbirds (MNDNR 2006b).

Historically, the dominant threat to grasslands in the U.S. was conversion to agriculture (Samson and Knopf 1994). Although agricultural conversions continue today, expansion of woody vegetation has become one of the greatest threats to grasslands (Heisler et al. 2003, Briggs et al. 2005). Prior to European settlement, expansion of woody vegetation was constrained by frequent fire and low abundance of woody vegetation. During the past 150 years, however, fire suppression and deliberate planting of trees and shrubs for windbreaks and shelterbelts have resulted in a relatively uniform distribution of woody seed sources throughout the prairie-transition zones of Minnesota. Furthermore, human and lightning-caused fires before European settlement occurred during spring, summer, and fall (Bragg 1982, Higgins 1984, McCain and Elzinga 1994), but grassland/prairie management today emphasizes spring burning. Thus, proximity to woody seed sources and season of burning have changed since European settlement.

Heisler et al. (2003) reported that expansion of woody vegetation in a tallgrass prairie of eastern Kansas was constrained by annual spring burning, but not by spring burning on a return interval ≥4 years. Spring burning acted as a pruning mechanism for aboveground shoots of woody vegetation, but post-fire increases in light and nitrogen stimulated vigorous resprouting and growth of woody vegetation (McCarron and Knapp 2003). Thus, spring fire may be required annually to constrain expansion of some woody species once established in grasslands, but spring fire alone may not be sufficient to eliminate co-dominance of woody vegetation (Heisler et al. 2003, McCarron and Knapp 2003, Briggs et al. 2005).

Carbohydrate reserves in plants vary seasonally following a cycle of depletion and restoration related to the growth cycle of the plant (Miller 2000). Mortality rates of woody vegetation can be enhanced by repeated prescribed burning during low carbohydrate periods. Hardwoods in the understory of conifer forests were effectively controlled in Minnesota (Buckman 1964), Colorado (Harrington 1989), and the Southeast (Hodgkins 1958, Waldrop and

Lloyd 1991) by repeated prescribed burning during summer when carbohydrate reserves were low. In grassland environments, however, researchers have expended comparatively little effort to investigate effects of growing-season fire on woody and herbaceous plants. Adams et al. (1982) eliminated dogwood (*Cornus drummondii*), green ash (*Fraxinus pennsylvanica*), and cottonwood (*Populus deltoides*) from an Oklahoma grassland with a summer burn. Growing season fire controlled woody vegetation and enhanced desirable forbs in a Tennessee grassland better than dormant season fire, herbicides, or summer mowing (Gruchy et al. 2006). Howe (1995) found that summer fires in a floodplain grassland in Wisconsin delayed the progression to dominance of large, late-flowering C_4 (warm season) grasses (e.g., big bluestem [*Andropogon gerardii*]) and allowed early flowering species, which virtually disappeared in spring-burned or unburned plots, to persist or even prosper. However, 2 cycles of summer fire over 3 years favored a mixture of C_3 (cool season) and C_4 grasses, including the aggressive C_3 reed canary grass (*Phalaris arundinacea*), which was planted in the study plots (Howe 2000).

In a survey of grassland information needs, MNDNR wildlife managers requested help in finding solutions for managing woody encroachment of grasslands (Tranel 2008). The purpose of this study is to compare the effectiveness of various combinations of burning, mechanical, and herbicide treatments for reducing abundance of woody vegetation in grasslands in the prairie-transition zone of Minnesota. Our objectives are to: (1) measure the change in density and cover of woody vegetation in response to treatments; (2) describe relative responses of C_3 versus C_4 grasses and forbs to treatments and seasonal timing of treatments; and (3) identify factors that influence the response of woody and herbaceous vegetation to treatments.

STUDY AREA

This study will be conducted on grassland sites in the prairie-transition zone of Minnesota that have experienced recent encroachment by woody vegetation. Sites suitable for this study should have been protected from grazing and fire for at least 1 year prior to application of study treatments, and encroaching woody vegetation should be relatively young (largest trees ≤ 4 inches in diameter). Sites may include properties managed as Wildlife Management Areas, Waterfowl Production Areas, National Wildlife Refuges, The Nature Conservancy Reserves, or private lands (e.g., Conservation Reserve Program lands). The location and number of sites will be determined based on pilot study results, conformity of sites to criteria described above, willingness of managers to fully participate in the study design, and available budget.

METHODS

Because woody plants have developed strategies to recover from periodic disturbance (Miller 2000), repeated applications of burning, mowing, and herbicide treatments will likely be required over time to deplete root reserves and ultimately kill woody plants on study sites. Therefore, this study will be conducted over 5 years (2011-2015). A pilot study during 2010 will be used to evaluate sampling techniques, determine the number of study sites needed, and select suitable study sites. Pre-treatment vegetation surveys will be conducted during 2011. Treatments (Table 1) will be applied during 2012-2014. The number of treatments used and their assignment to study sites will depend on results of the pilot study. We will attempt to use the pilot (pre-treatment) data to define strata (or blocking factors) within which treatments will be randomly assigned. When forming strata, we will consider factors such as size and density of woody cover patches, species composition, site hydrology, and geographic region.

We will attempt to apply seasonal treatments based on phenology of woody vegetation rather than absolute date. Mowing and herbicide treatments will be applied only to those portions of plots that contain woody vegetation. Vegetation cut during mowing treatments will not be harvested or otherwise removed from study sites. Because variability in quality of burns may confound effects of burn season, we will estimate fire conditions associated with each burn.

Prior to application of burn treatments, we will estimate fuel load using dry mass of clippings of live herbaceous vegetation and dead litter. On the day of a burn, we will record weather conditions (e.g., air temperature, wind speed, humidity) and estimate fuel moisture and fire intensity (Johnson 1992). The proportion of above-ground standing vegetation and litter that is consumed by fire will be estimated after each prescribed burn. We will attempt to distinguish portions of plots burned by head fires versus back fires and flank fires.

Vegetation surveys will be conducted twice annually during the growing season (late spring and late summer) during 2011-2015. Canopy cover and density of woody vegetation will be estimated by line-intercept methods (Canfield 1941) using permanent transects established through patches of woody vegetation. In addition, a sample of individual woody plants located along transects will be selected for detailed study. Species, diameter at breast height, and life status (alive versus dead) will be recorded for selected trees during each sampling period. Similarly, species, clump diameter (measured along cardinal axes), and life status will be recorded for selected shrubs during each sampling period.

Cover and frequency of herbaceous plant species will be measured along permanent transects, half located in patches containing woody vegetation (the same transects used for woody vegetation sampling) and half located in herbaceous-only vegetation. Each transect will contain circular 10 m^2 plots distributed at 10-m intervals. During each sampling period, canopy cover of each plant species will be estimated using a modified Daubenmire scale (Daubenmire 1959, Abrams and Hulbert 1987). Frequency of plant species will be estimated as the proportion of plots containing a species.

Because initial canopy cover, frequency, and density estimates will vary among sites, we will calculate change in values from 2011. When seasonal estimates differ, we will use the larger of the 2 values for subsequent analyses. Effects of treatments on changes in vegetation canopy, frequency, and density will be tested with analysis of variance.

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Table 1. Examples of burning, mowing, and herbicide treatments being considered for application during 2012-2014 to control woody vegetation on grasslands in the prairie-transition zone of Minnesota.

Treatment	2012	2013	2014
1	Spring burn	Rest	Rest
2	Spring burn	Spring burn	Spring burn
3	Spring burn, summer mow	Rest	Spring burn, summer mow
4	Summer mow	Summer mow	Summer mow
5	Summer burn	Summer mow	Summer burn
6	Summer mow	Summer herbicide[a]	Summer mow

[a]Folier application of Garlon 3A.

SURVIVAL OF WILD TURKEY HENS TRANSPLANTED BEYOND THEIR CURRENT DISTRIBUTION IN MINNESOTA[1]

Chad J. Parent, Brett J. Goodwin, and Eric M. Dunton

ABSTRACT

The current distribution of eastern wild turkeys in Minnesota extends well beyond their ancestral range. Severe winter conditions are believed to prevent turkeys from persisting in areas beyond their current northern distribution. Biologists and wildlife managers understand that turkeys are physiologically capable of surviving outside of their current distribution if food is available during winter. However, winter severity influences the availability of food. We transplanted radioed female wild turkeys to northwestern (Red Lake and Pennington Counties) Minnesota during winter in 2006 and 2007 to investigate the viability of turkeys north of their current distribution. These areas were located approximately 55 km north of the current distribution of turkeys in Minnesota, and represent one of the northern most transplants in North America. We estimated winter (1 January – 31 March) and annual survival probabilities of female wild turkeys using the Kaplan-Meier method, compared winter conditions to historical climate data to evaluate winter severity, and identified the cause of mortality during winter. Winter in 2006 was average (i.e., winter conditions similar to climate averages) at our study areas and survival estimates were 0.300 (SE = 0.077). Survival estimates increased to 0.820 (SE = 0.075) in 2007 following a mild winter (i.e., higher temperature and less snow relative to climate averages). Survival estimates in 2006 were low, but consistent with survivorship estimates previously observed in central Minnesota. Survival estimates in 2007 were among the highest observed in Minnesota. We identified the cause of mortality in 61% of female turkeys (50% due to predation, 9%, due to starvation, and 2% due to vehicle collision), while a lack of evidence precluded us from identifying the cause in the remaining mortality events. Turkeys are capable of persisting in northwestern Minnesota and winter is not a limiting factor. However, in extreme northern regions, localized periods of severe winter conditions appear to influence survival.

[1]Proceedings of the National Wild Turkey Symposium 10. *in press*

EFFECTS OF SUPPLEMENTAL FOOD AND EXPERIENCE ON WINTER SURVIVAL OF TRANSPLANTED WILD TURKEYS[1]

Marco Restani, Richard O. Kimmel, John R. Fieberg, and Sharon L. Goetz

ABSTRACT

Wildlife biologists have provided supplemental food during winter to improve post-release survival of Wild Turkeys (*Meleagris gallopavo*) transplanted north of their ancestral range in Minnesota. We evaluated the effectiveness of this action by monitoring overwinter and annual survival of 140 transplanted turkeys on three supplemental food and three control study areas in 2004 and 2005. Both winters of study were mild relative to historic snowfall levels and temperature. Patterns of mortality during winter were consistent across years with most mortalities occurring on control study sites. Turkeys that had been released in the prior year and survived until January of the current year had little mortality, regardless of supplemental food. The relative risk of death estimated from proportional hazards models for turkeys at supplemental food sites relative to those at control sites during winter was 5.0 in 2004 and 9.7 in 2005. Estimates of relative risk for newly released relative to experienced turkeys during winter were 9.4 in 2004 and 12.6 in 2005. Site-to-site variability in risk decreased during the non-winter period with treatment and control sites having more similar risk levels. Ninety-one turkeys died and mammalian predation was the most common cause of known mortality.

[1]The Wilson Journal of Ornithology 121(2):366–377, 2009

ESTABLISHMENT AND MAINTENANCE OF FORBS IN EXISTING GRASS STANDS- PILOT SEASON UPDATE

Molly Tranel

SUMMARY OF FINDINGS

Managers requested more information on establishing and maintaining an abundance and diversity of forbs in grasslands. Survival of forbs interseeded directly into existing vegetation may be enhanced by management treatments that reduce competition with established grasses. In this study, I will investigate the effects of 2 mowing and 2 herbicide treatments on diversity and abundance of forbs interseeded into established grasslands in the farmland region of Minnesota, and I will monitor insect response to interseeding treatments. I selected 17 study sites, each ≥4 ha and characterized by similar soils and a relatively uniform stand of forb-deficient native grass. I will apply 2 mowing treatments (once or twice per season) and 2 grass-selective herbicide treatments (high and low rate) during the 2010 growing season while interseeded forbs are becoming established. During 2011-2013, I will compare species richness and structural characteristics of vegetation among treatment and control plots at each study site. I will also estimate insect abundance and diversity on all sites as well as some additional native prairie sites.

INTRODUCTION

In a survey on grassland information needs (Tranel 2008), 82% of Minnesota Department of Natural Resources (MNDNR) wildlife managers indicated a need for information on maintaining plant species diversity in restored grasslands. In particular, managers wanted more information on establishing and maintaining an abundance and diversity of forbs in grasslands. A diversity of forbs in grasslands provides the heterogeneous vegetation structure needed by some bird species for nesting and brood rearing (Volkert 1992, Sample and Mossman 1997). Forbs also provide habitat for invertebrates, an essential food for grassland birds and their broods (Buchanan et al. 2006). Insect abundance in chick diets has been positively correlated with growth rates and survival in gallinaceous birds such as grouse (Park et al. 2001, Huwer et al. 2008), gray partridge (*Perdix perdix;* Sotherton and Robertson 1990), and pheasants (*Phasianus cholchicus*; Hill 1985). Broods of gallinaceous birds such as prairie chickens (*Tympanuchus cupido*) move directly from nests to brood habitat (Svedarsky 1979), and habitats with high forb abundance were preferred (Jones 1963, Drobney and Sparrow 1977).

The forb component on many restored grasslands has been lost or greatly reduced. Managers interested in increasing the diversity and quality of forb-deficient grasslands are faced with the costly option of completely eliminating the existing vegetation and planting into bare ground, or attempting to interseed forbs directly into existing vegetation. Management techniques that reduce competition from established grasses may provide an opportunity for forbs to become established in existing grasslands (Collins et al. 1998). Temporarily suppressing dominant grasses may increase light, moisture, and nutrient availability to seedling forbs, ultimately increasing forb abundance and diversity (Schmitt-McCain 2008). Williams et al. (2007) found that frequent mowing of grasslands in the first growing season after interseeding increased forb emergence and reduced forb mortality. Similarly, Hitchmough and Paraskevopoulou (2008) found that forb density, biomass, and richness were greater in meadows where a grass herbicide was used.

In this study, I will investigate the effects of 2 mowing and 2 herbicide treatments on diversity and abundance of forbs interseeded into established grasslands in southern Minnesota. In addition, I will monitor insect abundance in response to interseeding treatments.

Finally, I will track the cost of implementing each management technique and conduct a cost-benefit analysis.

STUDY AREA

I selected 17 study sites distributed throughout the southern portion of Minnesota's prairie/farmland region (Figure 1), including 16 sites on state-owned Wildlife Management Areas (WMA) and 1 site on a federally owned Waterfowl Production Area (WPA). Each site was ≥4 ha and characterized by similar soils, hydrology, and vegetative composition. All sites were dominated by relatively uniform stands of native grasses with no or few forbs, although invasive grasses were present at most sites. I evaluated feasibility of treatments and potential for identifying forb seedlings on a separate pilot site, Wood Lake WMA.

METHODS

Although I intended to prepare each site for dormant-season interseeding by burning in fall 2009, an unusually wet October did not allow for burning at 9 of the 17 sites (Figure 1). As a result, 8 sites were burned in fall 2009 and frost interseeded during late fall and winter, and the remaining 9 sites were burned and interseeded during spring 2010. Seed used on spring-burned sites was cold-moist stratified for 3-5 weeks in a mixture of wet sand to stimulate germination during spring 2010 at all sites.

Treatments

After each site was prepared and seeded, I divided them into 10 plots of approximately equal size. I randomly assigned each of 4 treatments and the control to 2 of the 10 plots (i.e., each of the 4 treatments and control will be replicated twice within each site). The following treatments, which are designed to suppress grass competition, will be applied during the 2010 growing season while the forbs are becoming established:

- Mow to a height of 10-15 cm once when vegetation reaches 25-35 cm in height.
- Mow to a height of 10-15 cm twice when vegetation reaches 25-35 cm in height.
- Apply grass herbicide Clethodim (Select Max) at 108 mL/ha (9 oz/A) when vegetation reaches 10-15 cm.
- Apply grass herbicide Clethodim (Select Max) at 215 mL/ha (18 oz/A) when vegetation reaches 10-15 cm.

Vegetation Sampling

Prior to burning and interseeding, all sites were surveyed by a botanist in summer 2009 to determine species already present and general condition of each site. This also allowed for field testing of the vegetation survey protocol. Four transects 50 meters in length were randomly located within each study plot and recorded using a Global Positioning System unit. We estimated percent cover of live vegetation (Daubenmire 1959) every 5 m and litter depth every 10 meters. We recorded visual obstruction readings (VOR; Robel et al. 1970) in the 4 cardinal directions at the beginning and the end of each transect. Species richness was estimated by counting the number of species present in each sampling frame.

Insect Sampling

I will estimate insect abundance and diversity at each site as a separate part of this study. Protocols for collection of insects will be determined in a pilot study during the summer of 2010. Insect sampling will begin in full during the summer of 2011, one year after management treatments (and disturbance to insects) have ended.

Timeline

Summer 2010: apply management treatments, begin insect pilot sampling
Summer 2011: monitor vegetation and insects (sample June and September)
Summer 2012: monitor vegetation and insects (sample June and September)
Summer 2013: monitor vegetation and insects (sample June and September)

RESULTS

The Wood Lake pilot site was frost interseeded in January 2009. Three of the 4 treatments (mow once, herbicide at low rate, and herbicide at high rate) were applied at the site during the summer of 2009. Due to staffing limitations, herbicide treatments were applied when the grass was taller (31 cm) than prescribed (10-15 cm). One month after treatments were applied, average VOR was shorter in treated plots than in control plots (Figure 2), indicating that the prescribed treatments were effective in suppressing growth of grass. VOR was similar for low and high herbicide treatments. Black-eyed susan (*Rudbeckia hirta*) and goldenrod (*Solidago spp.*) seedlings were observed in most of the treatment plots. Also observed occasionally in some of the plots were partridge pea (*Chamaechrista fasciculata*), and purple prairie clover (*Dalea purpurea*) seedlings.

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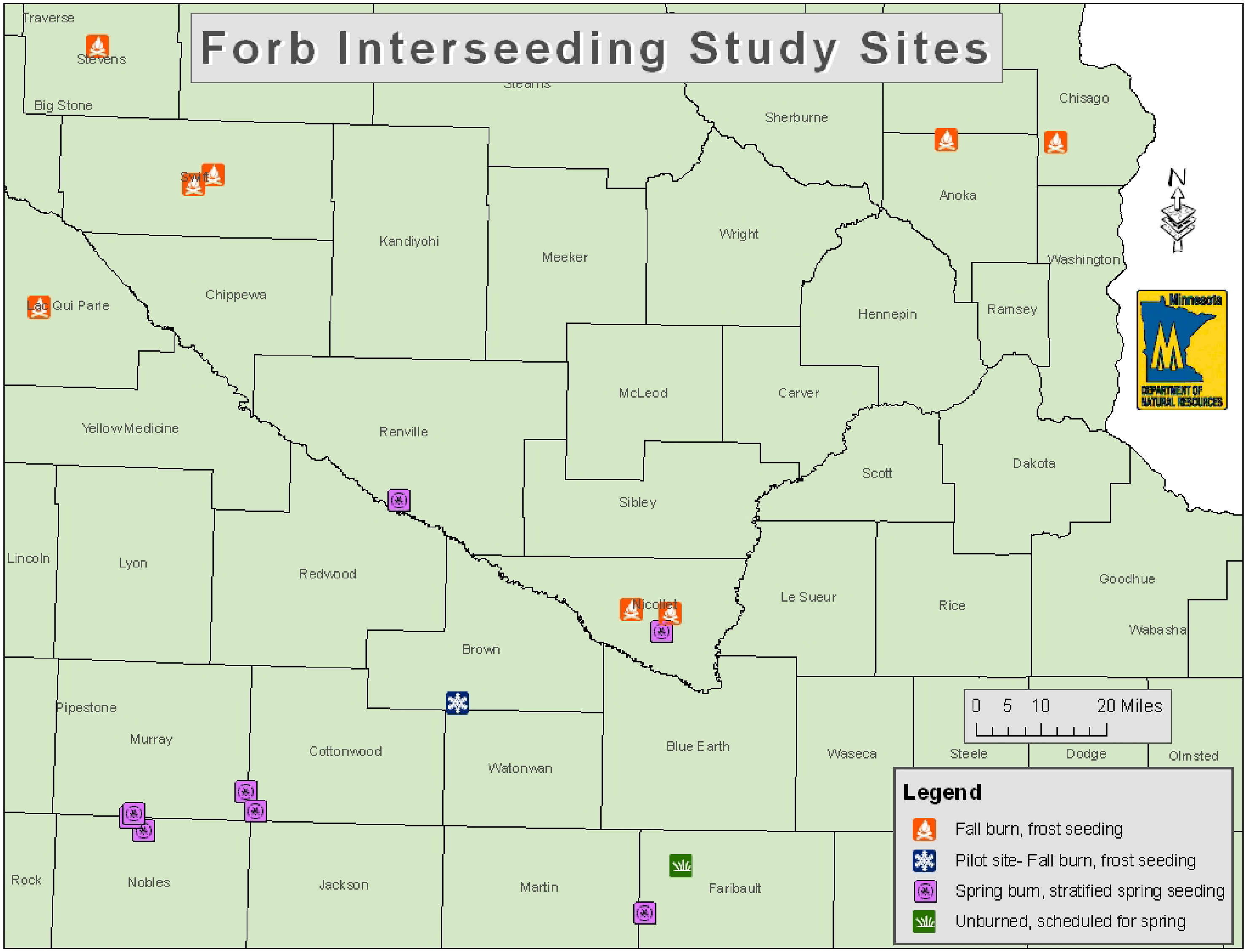

Figure 1. Locations of study sites for forb interseeding study, categorized by season of interseeding, southern Minnesota, 2009.

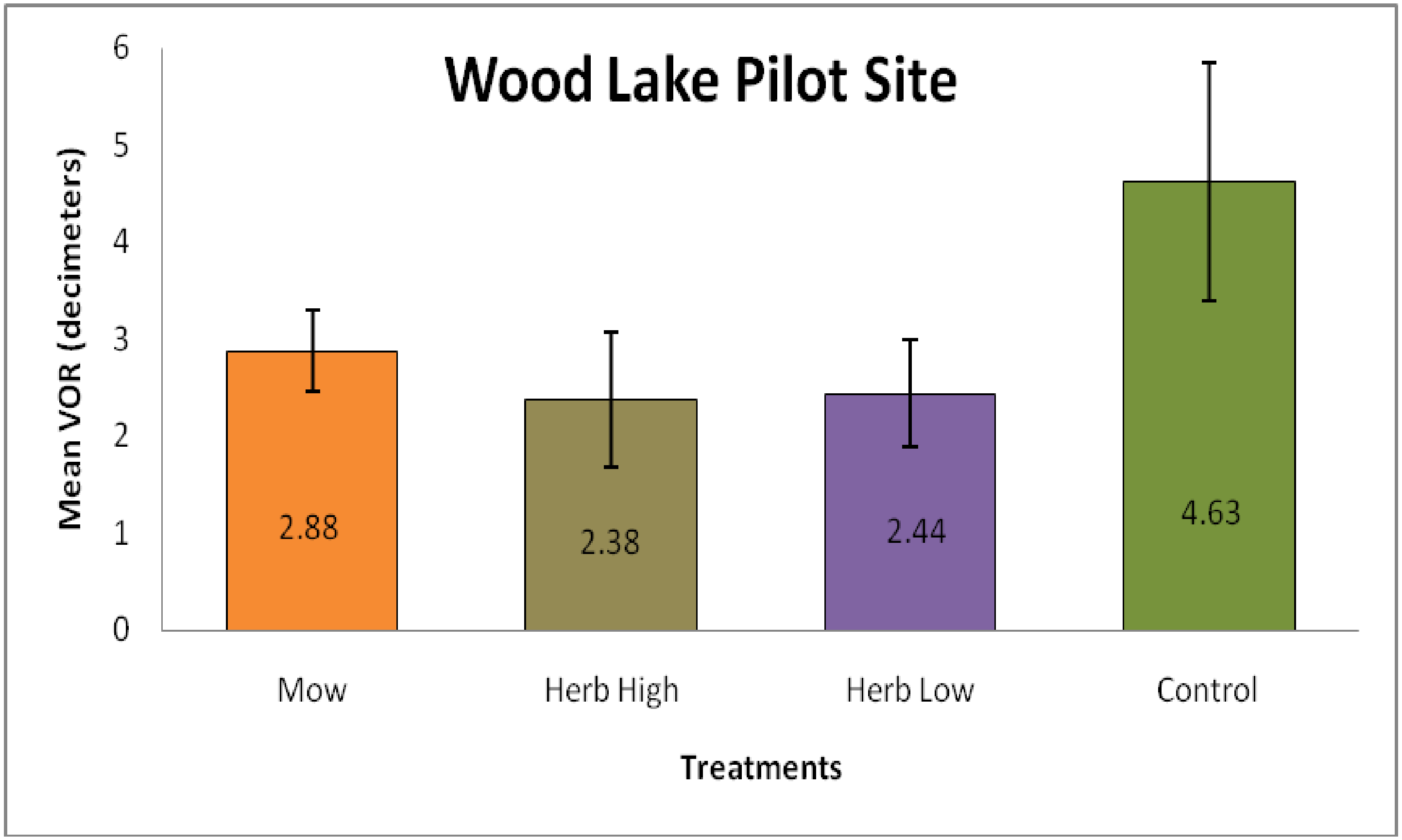

Figure 2. Mean (± SD) VOR by treatment type at the pilot study site, Wood Lake, Minnesota, 2009. Treatments included mow once, herbicide at high rate (215 mL/ha), and herbicide at low rate (108 mL/ha).

RESEARCH PROPOSAL: MONITORING PRAIRIE INVERTEBRATE ABUNDANCE AND DIVERSITY TO INFORM BEST GRASSLAND MANAGEMENT PRACTICES

Molly Tranel and Daren Carlson

INTRODUCTION

Invertebrates play critical functional roles in the prairie community from pollination to serving as essential food sources for grassland birds and other animals. The goal of this project is to evaluate methods to estimate diversity and abundance of invertebrates in grassland habitats, and to use the developed protocol to monitor invertebrate communities in both native prairies and planted grasslands. The project will be conducted on a series of native prairie sites paired with planted grassland sites located primarily in Minnesota's Prairie Parkland Province. The results from this project will provide information to more effectively monitor important components of native prairie and surrogate grasslands, and identify grassland management techniques that maintain or improve prairie and surrogate grassland habitat for prairie Species of Greatest Conservation Need (SGCN) and other wildlife.

JUSTIFICATION

Because many invertebrates are solely associated with native prairie and play critical functional roles, they have been identified as a key animal group for monitoring (Kremen et al. 1993). Fifteen insect species and 8 spider species, including the Red Tailed Prairie Leafhopper (*Aflexia rubranura*), Dakota Skipper (*Hesperia dacotae*), and *Marpissa grata* – a species of jumping spider, are prairie-associated SGCN. Invertebrates are crucial to healthy prairie ecosystems functions such as pollination, nutrient cycling (Arenz and Joern 1996), and decomposition (Whiles and Charlton 2005). Furthermore, invertebrates are an essential food for grassland birds and their broods (Buchanan et al. 2006). Yet, information on prairie invertebrates is sparse.

Recent acceleration of efforts to maintain or restore prairies have accentuated the need for long term data collection, storage, and analysis using a consistent set of monitoring protocols to: 1) detect changes and long-term trends (status and trend monitoring) and 2) evaluate the success of prairie management and restoration activities (effectiveness monitoring). Estimates of invertebrate diversity and abundance are the best measures of habitat quality for prairie invertebrates. However, some invertebrate species with a close functional relationship to prairie plant species may serve as indicators of prairie condition and quality.

The purpose of this project is to develop methods for monitoring the status and trends of invertebrate communities across a range of grassland habitats from high quality prairies to planted grasslands, and for monitoring the effectiveness of management treatments intended to maintain or improve quality of grassland habitats. Our objectives are to: 1) evaluate the effectiveness of 3 invertebrate sampling methods (i.e., pit traps vs. sweep nets vs. vacuum sampler) for estimating invertebrate diversity and abundance; and 2) identify invertebrate taxa that may serve as indicators for trend and effectiveness monitoring of grassland habitats. This proposal expands on 2 studies currently in progress. The first is a study on vegetation and bird diversity on high-quality prairie sites in western Minnesota. The second is a study evaluating methods for establishing and maintaining forbs in existing species-poor grasslands (Tranel 2009).

STUDY AREA

Study sites will be chosen from high quality prairie sites and planted grasslands in Anoka, Chisago, Stevens, Pope, Swift, Lac Qui Parle, Chippewa, Redwood, Renville, Brown, Nicollet, Blue Earth, Faribault, Nobles, Murray, and Cottonwood Counties (Figure 1). Sites will be paired to include a native prairie and a restored grassland site. Paired sites will be chosen so that they are geographically close and have similar soils, topography, and plant communities (e.g. dry, mesic, or wet prairie). Most sites will be located in the Prairie Parkland Province, but there may also be some sites in the Eastern Broadleaf Forest Province of Minnesota.

METHODS

During the first year of this study we will evaluate sampling methods that best estimate invertebrate diversity and abundance in both native prairies and planted grasslands. Successful methods will be those that effectively sample the greatest number of arthropods across functional groups for the least time and monetary cost. Invertebrate sampling methods will include pit traps, sweep nets, and vacuum sampling. We will preserve and identify collected invertebrates to the order and, if possible, family. We will identify a subsample of targeted taxonomic groups (e.g., ground beetles, leafhoppers) to species to determine if they could serve as indicator taxa. We will evaluate the utility of insect extractor devices (Molano-Flores 2002) to sort invertebrate samples after collection. During the first year of this study, we will also track time and monetary costs associated with collecting and processing the invertebrate samples. Based on spatial and temporal variability, we will estimate the number of samples needed per site and season to monitor invertebrate communities in native prairies and planted grasslands.

During the second and third years of this study, we will monitor invertebrates in selected prairies and planted grasslands, based on the methods developed in the first year of this study, to assess short-term trends and effects of different management techniques. We will use monitoring results to guide the development of a long-term monitoring program for invertebrate communities in grassland habitats in Minnesota.

Timeline

- Spring and Summer 2010: (*Pilot study phase*)

  Conduct literature review, determine sampling methodology, hire field staff, and begin field testing sampling methods

- Summer 2011: (*Full study phase*)

  Collect samples at all field sites, process/sort/identify invertebrate samples, send subset of samples to expert for further identification

- Summer 2012:

  Collect samples at all field sites, process/sort/identify invertebrate samples, send subset of samples to expert for further identification

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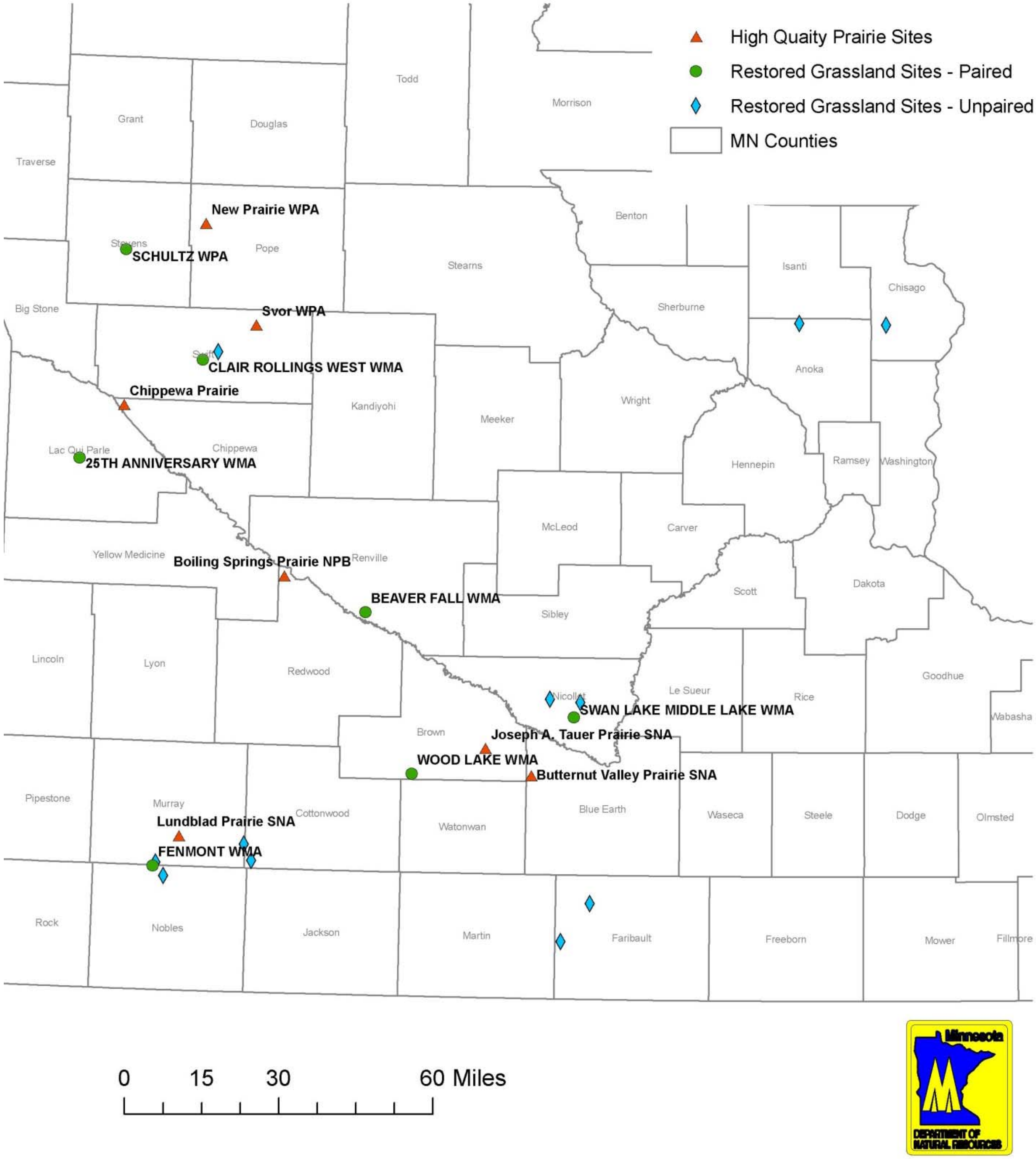

Figure 1. Potential invertebrate monitoring sites. Sites were paired to include 1 restored grassland site (green circle) and 1 high quality prairie site (orange triangle) with similar topographic and plant community characteristics near one another. Unpaired sites (blue diamond) will not be sampled. Southern MN, 2010.