SURVIVAL AND REPRODUCTION OF FEMALE EASTERN WILD TURKEYS IN THE PEMBINA VALLEY, MANITOBA

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Abstract: Information on wild turkey (*Meleagris gallopavo*) vital rates can assist managers in understanding status and health of current populations, determining limiting factors, managing harvest, and planning future introductions. Such data have never been collected at the northern fringe of the species' North American range in Manitoba, Canada, despite presence of an established population dating back to introduction efforts starting in 1958. Therefore, using radiotelemetry, we sought to gather information on spring–summer survival probability, cause-specific mortality, and reproductive parameters of female eastern wild turkeys (*M. g. silvestris*; hereafter, turkeys) in the Pembina Valley region of southern Manitoba. We captured and radiotagged 43 turkeys and monitored them during spring–summer of 2011 and 2012. We monitored turkeys 3 times per week, investigating all known mortality and reproductive activity. We used the Kaplan–Meier product limit estimator to calculate survival rates, daily nest survival rates to estimate nesting success, and nest investigation data to estimate natality throughout our study. We estimated spring–summer survival as 53% across the 269-day study period, with mammalian predation accounting for 84% of mortality events. Reproduction was characterized by 82% nesting frequency, 28% cumulative nesting success, 45% hen success, clutch sizes averaging 11.3 eggs, 89% hatching success, and a natality rate of 2.1 females hatched/female alive at breeding. Despite differences in snow depths, late winter temperature, beginning of the frost-free period, and May rainfall between study years, we did not detect annual differences in survival or nesting success. This study provides useful information on parameters necessary for modeling viability of turkey populations at their northern limit, where effects of weather, harvest, and predation remain poorly understood. Populations in Manitoba appear to be less responsive to environmental conditions than populations at more southern latitudes, exhibiting comparable vital rates despite being subjected to severe winter weather. This resiliency, combined with results of Kiss et al. (2015), suggests that turkeys can successfully inhabit other northern landscapes, particularly within those containing agricultural landscapes that provide winter food resources.

Proceedings of the National Wild Turkey Symposium 11:353–362

Associate Editor: Porter
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Key words: eastern wild turkey, hen success, Manitoba, *Meleagris gallopavo silvestris*, mortality, natality, nesting success, productivity, radiotelemetry, reproductive parameters, survival.

Eastern wild turkey (*Meleagris gallopavo silvestris;* hereafter, turkey) populations in Manitoba, Canada, are located at the northern limit of the species' North American distribution (Kimmel and Krueger 2007). Turkeys are not native to Manitoba, and were initially introduced to the southern part of the province between 1958 and 1961 (Bidlake 1966). Since these introductions, trap-and-transfer activities, propagation programs, and natural dispersal have established numerous sub-populations across the southern half of Manitoba (Bidlake 1966, Wunz 1992, Gillespie 2003). Currently, there are resident spring and fall seasons in 15 different Game Hunting Areas (GHAs) across the province, with up to 1,165 turkey licenses sold annually (Baldwin and Ryckman 2010). With an increasing interest in both turkey hunting and requests for further introductions, wildlife managers are currently exploring options for increasing hunting opportunity within Manitoba, including introducing turkeys to new areas of the province, increasing bag limits, and altering season dates.

Estimates of size, birth/hatch rates, and death rates are the foundation of population ecology and are used as parameters for population models that expose limiting factors, project growth rates, and estimate short and long term population trends (Bolen and Robinson 2003, Skalski et al. 2005). Since their introduction in 1958, no research has investigated these aspects of turkey ecology in Manitoba's established population (Kimmel and Krueger 2007). Further, extrapolation of vital rate estimates from other northern studies (e.g., Porter et al. [1983] in Minnesota, Vander Haegen et al. [1988] in Massachusetts, Roberts et al. [1995] in New York, and Paisley et al. [1998] in Wisconsin) is undesirable given considerable climatic, agricultural, and geographic differences between the northern United States and prairie Canada.

Turkey populations in Manitoba typically overwinter in close proximity to agriculture, where they forage on spilt grain, livestock feed, and grains in manure piles (Gillespie 2003). Based on other studies in northern regions, where populations with access to non-traditional foods through agriculture or supplemental feeding experience relatively great winter survival (Porter et al. 1980, Vander Haegen et al. 1988, Roberts et al. 1995), and anecdotal evidence from landowners, winter mortality is not believed to be a major limiting factor in Manitoba. Instead, it is thought that spring–summer survival rates may be more influential on population growth, because female turkeys typically experience least survival rates during the reproductive period due to increased vulnerability while nesting and brood-rearing (Vander Haegen et al. 1988, Palmer et al. 1993*a*, Roberts et al. 1995), and nest predation on upland nesting waterfowl in Manitoba during spring–summer is relatively great (Arnold et al. 1993, Howerter et al. 2014).

Like other short-lived species, turkeys tend to allocate most of their resources towards reproduction to increase fecundity due to a great degree of variability in nesting success among years and uncertainty of surviving to the next breeding season (Miller et al. 1998*b*). This results in a widespread, low-cost reproductive effort, with subsequent production having largest influence on population growth rates (Gill 2007, Townsend et al. 2008). Comparison of reproductive parameters, including nesting success, natality, and recruitment, has generally been used to assess turkey productivity during a given year and over time (Porter et al. 1983, Vander Haegen et al. 1988, Paisley et al. 1998, Nguyen et al. 2003).

Many studies from the northern United States have found that turkey productivity is greatly dependent on winter and spring weather conditions. Severe winters with prolonged periods of snow >25 cm in depth (Porter 1977, Roberts et al. 1995), March temperatures (Vangilder and Kurzejeski 1995), timing of the frost-free period (Whitaker et al. 2007), and May rainfall (Roberts and Porter 1998, Fleming and Porter 2007) can impact timing of nesting season, turkey and nest survival, and overall hen success in a given year. Given Manitoba's northern extent, and propensity for severe winter conditions (Gillespie 2003), annual weather patterns may influence its turkey population.

The growing interest in expanding turkey distribution and hunting opportunity in Manitoba necessitates estimation of turkey vital rates within an established population, which would be useful for strategic planning of future releases, assessing harvest regulations, and estimating effect of weather patterns, predation, and harvest on population growth rates. Therefore, we sought to estimate turkey spring–summer survival, cause-specific mortality, and reproductive effort, success, and production in an established turkey population in southern Manitoba, Canada.

METHODS

Study Area

We conducted our study in the Pembina Valley region of Manitoba (Fig. 1). Located within the Manitou ecodistrict of the Aspen Parkland ecoregion in south–central Manitoba (Smith et al. 1998), the valley and its ecodistrict followed the Pembina River and its tributaries upstream from the south–central Canada and United States border, northwest for approximately 120 km. The region's landscape was characterized by a generally flat glacial till plain intersected by a wide glacial melt water channel (containing the Pembina River) with steep, treed slopes typically ranging from 50 to 150 m in length and a greater than 15% slope (Smith et al. 1998). Average daily temperatures recorded in Snowflake, Manitoba, 1991–2007, ranged from −15.7°C in January to 18.8°C in July. Annual rainfall and snowfall averaged 426.5 mm and 138.3 cm, respectively, during the same period (Environment Canada 2010*a*).

The largest stands of contiguous forest cover in the Manitou ecoregion existed within the Pembina River valley and its tributaries' ravines. The eastern portion of the valley

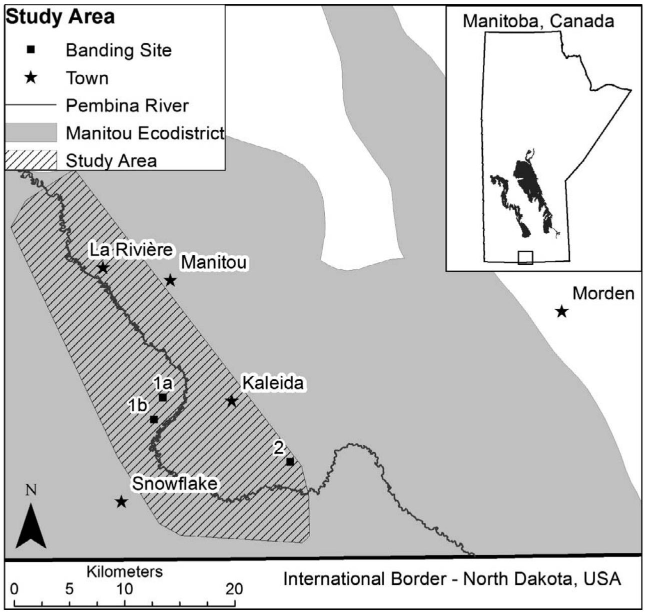

Figure 1: Study area used by radiotagged female wild turkeys (Minimum Convex Polygon around all locations) in the Pembina Valley region of southern Manitoba, 2011 and 2012 (see inset box for location within the province, noting that major lakes are shown for reference).

(this study area) contained forest stands and shrub land composed of mainly bur oak (*Quercus macrocarpa*), trembling aspen (*Populus tremuloides*), hazel (*Corylus* spp.), and saskatoon (*Amelanchier alnifolia*), interspersed with grassland patches containing tall prairie grasses and herbs (Smith et al. 1998). Cultivated fields dominated the glacial till plain, while varying in density along the valley floor. A large portion of forest and grassland portions of the valley were used as pasture, with cattle feedlots of varying size scattered across the landscape. Untilled land along the valley floor, and to a lesser extent on the glacial plain, was also commonly managed for native hay and forage crops such as alfalfa. The sub-population of turkeys in this region was selected for this study based on its long-term persistence and growth over more than 50 years, and its importance in provincial harvest (37–46% of harvest, 2009–2013; Manitoba Conservation and Water Stewardship, unpublished data).

Capture and Monitoring

Using a WCS Net Blaster™ (Wildlife Control Supplies, East Granby, Connecticut, USA), we captured turkeys at 3 farm sites during winter (January–March) of 2011 and 2012, following Bailey et al. (1980). We banded all female turkeys with a size 8A aluminum rivet leg band (National Band and Tag, Newport, Kentucky, USA). We also fitted females that appeared in good body condition, with no visible injuries or abnormalities and only moderate feather loss, with an 80-gram, model A1540 backpack-style radiotransmitter (Advanced Telemetry Systems, Isanti, Minnesota, USA). We aged turkeys as adults or juveniles based on barring pattern and shape of 9th and 10th primary feathers and tail fan shape (Pelham and Dickson 1992). We conducted all capture and monitoring in accordance with the guidelines provided by the Canadian Council on Animal Care (2003, 2008). We conducted our research under authority of the Government of Manitoba's Wildlife Act, and Industry Canada's Radio License 51110817.

We commenced monitoring hens $\geq$3 weeks after the last trapping date during both study years to censor any mortality events that may have been caused by capture-related injury or myopathy. We tracked radiotagged hens during a spring–summer monitoring period (18 April–1 September) for 2 consecutive years (2011 and 2012). We located each hen by either visual observation after homing or triangulation 3 times per week, at varying times of day. We investigated all mortality signals immediately after mortality was detected (<5 days after it occurred) and determined cause of death (mammalian predation, avian predation, or other factors) based on mortality descriptions outlined by Thogmartin and Schaeffer (2000). Following guidelines set by Paisley et al. (1998), we considered a hen as incubating when 3 consecutive locations indicated localized behavior or further investigation revealed a nest or associated behavior. When incubating behavior ceased, we located nests and documented evidence of hatching or predation, noting number of eggs (both hatched and unhatched) in successful nests. We considered nests hatching $\geq$1 poult as successful. We approached broods associated with radiotagged hens and flushed them at least once during the final week of monitoring in each study year to estimate brood survival to 1 September.

Data Analyses

We used the Kaplan–Meier product limit estimator (Kaplan and Meier 1958) function in SPSS 21 (IBM Corp., Armonk, New York, New York, USA) to estimate spring–summer survival based on its ability to censor individuals lost due to radiotransmitter or harness failure, or emigration out of the study area (Pollock et al. 1989). Our spring–summer monitoring period consisted of 136 days (18 April–1 September) in 2011 and 133 days (18 April–29 August) in 2012. We divided this into 20 monitoring weeks within each year and used these as time points for survival analyses. We considered hens that survived a full year to reach the start of the next study period as new individuals (Roberts et al. 1995). We censored hens that could no longer be located at any point during the monitoring period due to possible radiotransmitter or harness failure, emigration out of the study area, or unreported legal or illegal harvest. We compared survival rates between years (2011 and 2012) using all individuals radiotagged each year, and pooled years to compare survival rates between age classes (adults and juveniles). We used a log-rank test to assess the null hypothesis that spring–summer survival curves were homogeneous across all groups. This test assumes that all individuals within each group have been selected randomly, survival times are independent between individuals, and that censoring occurs randomly and is not related to a certain fate (Pollock et al. 1989). Significance was accepted as $P \leq 0.05$.

We used nest investigation data to calculate nesting frequency, renesting rate, nesting success (initial and renests), mean clutch size, hatching success, and mean

Table 1. Spring–summer (18 April–1 September) survival probability (*S*), including 95% confidence intervals, calculated using the Kaplan–Meier method, of radiotagged female wild turkeys in the Pembina Valley sub-population of southern Manitoba, 2011 and 2012.

Year or Age	*N*	*S*	95% CI
2011[a]	23	0.41	0.19–0.63
2012	18	0.67	0.43–0.90
Adult	27	0.42	0.22–0.62
Juvenile	14	0.71	0.45–0.98
Cumulative	41	0.53	0.37–0.68

[a] Fate of 1 individual was unknown, and therefore censored after week 2 in the analysis.

brood size for both study years (Porter et al. 1983). We only included hens that survived up to earliest observed date of nest initiation for that study year in nesting frequency analyses. To account for potential bias related to time since initiation when we found nests, we estimated daily nest survival rates (DSR) over the course of a 28-day incubation cycle (26 for incubation and 2 for hatching) using maximum-likelihood estimation and nest survival function in Program MARK (White and Burnham 1999). We estimated date at which hens began incubating each nest using radiotelemetry data (midpoint between onset of clustered positions and known incubation) and built an encounter history for each nest using this date, date the nest was last known to be active, and date that nest fate was determined (hatched or depredated). Given our relatively small sample size, we considered only a small set of candidate models (4) in which DSR remained constant for both study years, varied by year, varied by age, and varied as a function of age and year. We raised daily survival rates to the power of 28 days to estimate probability of nesting success (Mayfield 1975). Based on Porter et al. (1983), we summarized reproductive parameters by natality rate (M_x), number of females hatched per female alive at breeding, calculated as:

$$\text{Natality} = M_x = (nf_x)(c_x)(ns_x)(hs_x)/2$$

In which:
- nf_x = nesting frequency
- c_x = clutch size
- ns_x = nesting or hen success
- hs_x = hatching success
- dividing by 2 assumes an equal sex ratio at hatching

We defined hen success as proportion of nesting hens that hatched at least 1 poult during nesting season, regardless of their number of attempts (Vander Haegen et al. 1988). We defined brood survival as at least 1 poult from a hatched brood surviving to 1 September in each study year.

RESULTS

We captured 23 turkey hens in 2011 and 20 in 2012. We did not censor any turkeys prior to monitoring in 2011, but we censored 4 turkeys in 2012 due to mortality ($n = 2$), harness failure ($n = 1$), and unknown signal loss ($n = 1$)

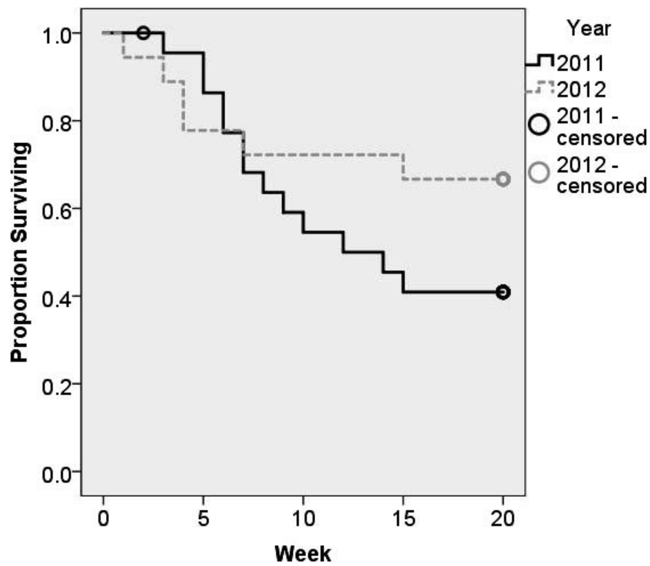

Figure 2. Spring–summer (18 April–1 September) Kaplan–Meier survival curves, per study year, for radiotagged female wild turkeys in the Pembina Valley sub-population of southern Manitoba, 2011 and 2012. Note: 1 individual was censored after week 2 in 2011.

during the censorship period. Three turkeys survived through 2011 to start of the 2012 study year and we incorporated these into analyses as new individuals in 2012.

Cumulative spring–summer survival probability (*S*) for 41 hens was 0.53 (95% CI = 0.37 to 0.68; Table 1). Spring–summer survival probability did not differ ($p > 0.05$) between 2011 ($S = 0.41$, 95% CI = 0.19 to 0.63) and 2012 ($S = 0.67$, 95% CI = 0.43 to 0.90) or between adults ($S = 0.424$, 95% CI = 0.22 to 0.62) and juveniles ($S = 0.714$, 95% CI = 0.45 to 0.98). We censored one individual after 2 weeks of monitoring in 2011 due to unknown signal loss (Fig. 2 and 3).

Mammalian predation accounted for 16 of 19 (84%) spring–summer mortality events. Avian predation, unknown predation, and dehydration (as determined by Manitoba Agriculture, Food and Rural Development's Veterinary Diagnostic Services Laboratory), each accounted for one mortality event (5% each). Six mortality events (32%) occurred when a hen was either laying or incubating a nest, with 2 additional non-fatal attacks documented.

We calculated earliest date of nest initiation as 30 April in 2011 and 3 April in 2012. The simplest model in our set (constant DSR in both years) ranked greatest and there was limited support for models evaluating variation in DSR by hen age or year. Cumulative nesting success (over 28 days of incubation) derived from the constant survival model was 28% (95% CI = 16 to 41%). Although models with age and year effects were poorly supported, we also calculated these to facilitate comparison with other studies (Table 2). Nesting frequency was 82% in 2011, 100% in 2012, and 91% over both years (Table 2). Renesting rate after first nest loss was 80% across all individuals and years. Third nests were only initiated in 2012, as in 2011 only one individual survived past its second nest failure and did not initiate a third nest. Renesting rate after second nest

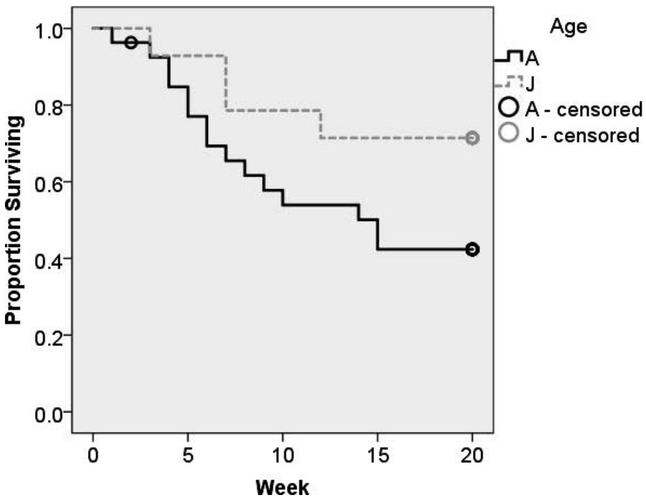

Figure 3: Spring–summer (18 April–1 September) Kaplan–Meier survival curves, per age class (adults [A] and juveniles [J]), for radiotagged female wild turkeys in the Pembina Valley sub-population of southern Manitoba, 2011 and 2012. Note: 1 individual was censored after week 2 in 2011.

loss in 2012 was 83%. Hen success was estimated at 36% in 2011, 53% in 2012, and 45% over both years. Across all hens, average clutch size was 11.3, hatching success was 89%, mean brood size was 9.9 poults, and brood survival to 1 September was 36% (Table 3).

A natality rate of 2.1 females hatched/hen alive at breeding occurred for the entire study period, with a greater rate for juveniles (2.8) as compared to adults (1.7). Between years, natality rate was 2.8 during 2012 and 1.4 in 2011 (Table 4).

DISCUSSION

Our point estimate for spring–summer survival was less than those previously reported from the northern United States (Treiterer 1987, Vander Haegen et al. 1988, Roberts et al. 1995). This lesser survival could be a result of Manitoba's increased propensity for severe winter conditions that commonly affect northern turkey populations (Porter et al. 1983, Vanguilder and Kurzejeski 1995, Roberts and Porter 1998, Ludwig 2012).

Turkey survival has been shown to decrease in years with heavy snowfalls, and is thought to be related to declines in body condition and increased vulnerability during nesting season (Porter et al. 1983, Ludwig 2012). Near our study area, snow depth exceeded 25 cm for 109 days in 2011, which was within the 2005–2014 range of 90 days (95% CI = 67 to 112 days). In contrast, winter 2012 was unusually mild, with snow depths ≥25 cm occurring for only 9 days (National Oceanic and Atmospheric Administration 2015). Although our inferences are limited by variability in estimates driven by sample size, females appeared relatively resilient to prolonged periods of snow, with no difference in survival being observed between years. Abundance of agricultural subsidies in our study area may have buffered potential effects of severe winter weather on body condition and spring survival (Porter et al. 1983).

Similar to Vangilder and Kurzejeski's (1995) findings in Missouri, differences in March temperature appeared to affect spring phenology and vegetative concealment between years, resulting in a 27-day difference in earliest date of nest initiation. Mean daily temperature in March 2011 was –7.2°C, compared to 2.4°C in 2012 (Environment Canada 2010*b*), which preceded a 1-month difference in beginning of the frost-free period in our study area (26 May

Table 2: Estimates of nesting frequency (% that nested); first, second, third, cumulative nesting success (at least 1 egg hatched); first and second renest rates (initiated another nest after a failed attempt); and hen success (% of nesting females that hatched at least 1 poult, regardless of the number of attempts) for radiotagged female wild turkeys in the Pembina Valley sub-population of southern Manitoba monitored during spring–summer (18 April–1 September) 2011 and 2012.

	Nesting frequency[a]		First nest success[b]		First renest rate[c]		Second nest success[b]		Second renest rate[c]		Third nest success[b]		Cumulative nesting success [bd]		Hen success[f]	
Year and Age	%	*n*	%	*n*	%	*n*	%	*n*	%	*N*	%	*n*	%	*n*	%	*n*
2011																
All	82	17	28	14	60	5	41	3	0	1	-	-	30	17	36	14
Adult	85	13			75	4			0	1			24	14	36	11
Juvenile	75	4			0	1							45	3	33	3
2012																
All	100	18	15	13	90	10	26	9	83	6	61	5	27	27	53	17
Adult	100	9			100	5			100	3			22	13	33	9
Juvenile	100	9			80	5			67	3			32	14	75	8
Pooled																
All	91	35	22	27	80	15	30	12	71	7	61	5	28	44	45	31
Adult	91	22			89	9			75	4			24	27	35	20
Juvenile	92	13			67	6			67	3			35	17	64	11

[a] Percentage of hens that made at least 1 nesting attempt. Only hens that survived to the first recorded nesting attempt were included.
[b] $(\text{daily survival rate})^{28\ \text{days}}$ to account for exposure during incubation and hatching (Mayfield 1975). Successful when at least 1 egg in clutch was hatched.
[c] Only individuals that survived nest predation were included.
[d] Fate of all first, second, and third nests combined.
[e] Percentage of nesting hens that hatched at least 1 poult, regardless of the number of attempts (Vander Haegen et al. 1988).

Table 3: Estimates of clutch size (number of eggs), hatching success (proportion of eggs hatched in successful nests), brood size (number of poults per brood) and brood survival (% of broods that survived to 1 September) for radiotagged female wild turkeys in the Pembina Valley sub-population of southern Manitoba monitored during spring–summer (18 April–1 September) 2011 and 2012.

	Clutch size			Hatching success			Brood size			Brood survival[a]	
Year and Age	x	SD	n^b	x	SD	n^b	x	SD	n^b	%	n^b
2011											
All	11.0	1.5	7	0.87	0.17	5	9.2	1.6	5	20	5
Adult	10.8	1.6	6	0.93	0.15	4	9.5	1.7	4	25	4
Juvenile	12.0		1	0.67		1	8.0		1	0	1
2012											
All	11.4	1.1	9	0.91	0.90	7	10.4	1.8	7	44	9
Adult	11.8	1.5	4	1.00	0.00	2	12.0	1.4	2	67	3
Juvenile	11.2	0.8	5	0.87	0.80	5	9.8	1.3	5	33	6
Pooled											
All	11.3	1.3	16	0.89	0.13	12	9.9	1.7	12	36	14
Adult	11.2	1.5	10	0.95	0.12	6	10.3	2.0	6	43	7
Juvenile	11.3	0.8	6	0.84	0.11	6	9.5	1.4	6	29	7

[a] At least 1 poult from brood survived to 1 September.
[b] Sample sizes not the same for all parameters because some nests were either not found or disturbed before investigation, making a reliable estimate of hatched/unhatched eggs unavailable.

2011 and 26 April 2012). We observed a similar difference in earliest date of nest initiation between 2011 and 2012, at 30 April and 3 April, respectively, likely the result of late-winter and spring temperature differences.

It has also been suggested that increased precipitation during nesting can increase detection of nests by predators and reduce nesting success (Palmer et al. 1993*b*, Roberts and Porter 1998, Lowrey et al. 2001, Fleming and Porter 2007). Incubation of first nests peaked during May both study years, and precipitation totaled 84.2 mm and 45.6 mm in May 2011 and May 2012, respectively (Environment Canada 2010*b*). Even though total precipitation in May 2011 was nearly double that of May 2012, we did not detect annual differences in survival or nesting success. However, we did observe more hens being attacked on nests in 2011 ($n = 6$) than in 2012 ($n = 2$), and lesser estimates of hen success in 2011 predictably influenced that year's lesser estimate of natality.

Table 4: Natality rates (females hatched per female alive at breeding) calculated using estimates of nesting frequency (proportion of females that nested), clutch size (number of eggs), hen success (proportion of nesting females that successfully hatched a clutch), and hatching success (proportion of eggs hatched in successful nests), for radiotagged female wild turkeys in the Pembina Valley sub-population of southern Manitoba during spring–summer (18 April–1 September) 2011 and 2012.

Year and Age	Nesting frequency	Clutch size	Hen success[a]	Hatching success	Natality rate[b]
2011					
All	0.82	11.0	0.36	0.87	1.4
Adult	0.85	10.8	0.36	0.93	1.5
Juvenile	0.75	12.0	0.33	0.67	1.0
2012					
All	1.00	11.4	0.53	0.91	2.8
Adult	1.00	11.8	0.33	1.00	2.0
Juvenile	1.00	11.2	0.75	0.87	3.7
Pooled					
All	0.91	11.3	0.45	0.89	2.1
Adult	0.91	11.2	0.35	0.95	1.7
Juvenile	0.92	11.3	0.64	0.84	2.8

[a] Percentage of nesting hens that hatched at least 1 poult, regardless of the number of nesting attempts (Vander Haegen et al. 1988).
[b] Females hatched/females alive at breeding.

Our estimates of nesting frequency, clutch size, and hatching success were within the range documented in other northern studies at 81–93%, 10–14.8 eggs, and 72–90%, respectively (Green 1982, Porter et al. 1983, Vander Haegen et al. 1988, Roberts et al. 1995, Paisley et al. 1998, Sphor et al. 2004). First nest success and cumulative nesting success were less than the typical nesting success range (36–62%) found in other northern turkey studies, while renesting rates were greater (18–65%; Porter et al. 1983, Vander Haegen et al. 1988, Roberts et al. 1995, Paisley et al. 1998, Sphor et al. 2004). Our hen success estimate over 2 years of study (45%) was within the range (22–55%) found in other northern studies (Vander Haegen et al. 1988, Roberts et al. 1995, Paisley et al. 1998). However, it is important to note that estimation methods differed among studies. Many other turkey studies have failed to document third nests, and those that did reported lesser second renesting rates (10–33%) and third nest success (0–33%; Vander Haegen 1988, Paisley et al. 1998, Thogmartin and Johnson 1999). The greater second renest rate and third nest success observed in our study, at 71% and 61% respectively, may be good indicators of body condition and reproductive potential within this sub-population (Vander Haegen et al. 1988).

Role of predator abundance on hen survival remains unclear in our study area. However, it is suspected that predators such as coyotes (*Canis latrans*), great-horned owl (*Bubo virginianus*), and red fox (*Vulpes vulpes*) are relatively abundant, while bobcat (*Lynx rufus*) are uncommon in southern Manitoba (Manitoba Conservation and Water Stewardship, unpublished data). While differentiating between types of mammalian predators remains a consistent problem (Miller et al. 1998*a*, Lariviere 1999, Parent et al. 2011), coyotes can be key predators of turkeys and their nests during the reproductive period (Miller et al. 1995, Hubbard et al. 1999, Houchin 2005). In our study area, a 12-year peak of 29 coyote–livestock depredation claims occurred in the Rural Municipality of Pembina (overlapping our study area) during 2011, but decreased to 11 the following year (Manitoba Agricultural Services Corporation, unpublished data). Similarly, predator management research approximately 140 km north of our study area found that trapped coyote density was nearly twice as great in 2011 than in 2012 (Delta Waterfowl, unpublished data). Although we did not detect annual differences in spring–summer survival, nor did we determine type of mammalian predator for most mortality events, we did observe an increase in predation during a year of large coyote populations. Based on this and the well-documented role of predation in notably limiting waterfowl production on the Canadian prairie landscape (Arnold et al. 1993, Beauchamp et al. 1996, Howerter et al. 2014), we suggest further research be directed at understanding relationships between coyote and mesopredators populations, and their relative influence on turkeys in our study area and similar landscapes.

Despite not detecting differences in survival and nesting success between years, lesser estimates of hen success in 2011 appeared to impact natality, suggesting that successive years with severe winter conditions or great rainfall could negatively influence populations. Lesser survival (41%) through the reproductive period in 2011 resulted in only 1 hen surviving past 2 failed nesting attempts. Greater survival in 2012 (67%) resulted in 5 of 6 hens initiating third nests in 2012. Increased survival directly influenced an increase in hen success between years, which produced a greater natality rate of 2.8 in 2012, compared to 1.4 in 2011. Natality in 2011 was slightly above replacement levels and, although the population presumably rebounded the next year, several years with less nesting frequency, less renesting rates, and natality rates similar to 2011 could lead to population declines (Miller et al. 1998*b*).

Similar to our natality rate of 2.1, Vander Haegen et al. (1988) calculated a natality rate of 2.57 in a Massachusetts population that was believed to be relatively stable, based on densities of wintering turkeys during the study. Furthermore, a population undergoing rapid growth in southern Minnesota (based on gobbling counts; Porter and Ludwig 1980), had natality rates of 2.6 and 2.1 during first and second nesting attempts, respectively (Porter et al. 1983). Conversely, Nguyen et al. (2003) found a natality rate of 1.18 during the first 2 years after introducing a population in central Ontario, and Thogmartin and Johnson (1999) found a rate of 0.42 in an Arkansas population that was presumably declining, based on a 50% decrease in turkey harvest.

MANAGEMENT IMPLICATIONS

Survival and reproduction data we acquired over the course of this study will prove useful in modeling growth of turkey populations in Manitoba and other populations at the northern periphery of the species' distribution. Pairing these results with additional survival and harvest rate data collected through banding studies conducted during the same time period will allow managers to forecast effects of weather conditions and varying levels of harvest, without having to extrapolate figures from studies conducted in vastly different landscapes. These models will improve managers' understanding of adaptability in northern environments, and assist in establishing new populations in suitable habitat via trap-and-transfer.

Despite the combination of prolonged snow cover, delayed nesting period, large coyote populations, and abundant spring precipitation observed in 2011, turkeys in our study were quite resilient, displaying a natality rate of 2.1 over the course of the study. Our study suggests that turkeys at northern latitudes can withstand environmental conditions present in our study as these turkeys exhibited reproductive parameters which were not greatly different than their more southern counterparts. Based on our results and those of Kiss et al. (2015), we suggest that turkey populations in the Canadian prairies that are regularly associated with agricultural areas may be less affected by extreme weather conditions due to access to food resources during winter. This apparent reliance on agriculture in winter necessitates careful planning of releases and cooperation and coordination among wildlife agencies, conservation groups, and farmers.

ACKNOWLEDGMENTS

We thank Manitoba Conservation and Water Stewardship for initiating and funding a large portion of this research. We appreciate funding and in-kind support provided by the National Wild Turkey Federation (NWTF) Canada Super Fund, Manitoba Wildlife Federation, Wild Gobblers Unlimited, Safari Club International Foundation, Ducks Unlimited Canada (IWWR), Alice Chambers-Hyacinth Colomb Student Assistantship, and the Richard C. Goulden Memorial Award, Manitoba Conservation and Water Stewardship's Manitou District Office, and S. G. Sealy. Furthermore, this study would not have been possible without help from the many people who volunteered to assist with trapping activities, especially J. and T. Moores, Pembina Game and Fish; E. Bodykevich, Wild Gobblers Unlimited; and landowners L. and R. Lea, D. and C. Dymond, and R. Edwards, who allowed access to their farm sites for trapping operations.

LITERATURE CITED

Arnold, T. W., M. D. Sorenson, and J. J. Rotella. 1993. Relative success of overwater and upland mallard nests in southwestern Manitoba. Journal of Wildlife Management 57:578–581.

Bailey, W., D. Dennett, H. Gore, J. Pack, R. Simpson, and G. Wright. 1980. Basic considerations and general trapping recommendations for trapping the wild turkey. Proceedings of the National Wild Turkey Symposium 4:10–23.

Baldwin, F., and M. Ryckman. 2010. 2009 wild turkey hunter and harvest survey. Manitoba Conservation, Wildlife and Ecosystem Protection Branch, Winnipeg, Manitoba, Canada.

Beauchamp, W. D., R. R. Koford, T. D. Nudds, R. G. Clark, and D. H. Johnson. 1996. Long-term declines in nest success of prairie ducks. Journal of Wildlife Management 60:247–257.

Bidlake, L. J. 1966. The status of wild turkeys in Manitoba. MNR-g-

225. Department of Mines and Natural Resources, Wildlife Branch.
Bolen, E. G., and W. L. Robinson. 2003. Wildlife ecology and management. Fifth edition. Prentice Hall, Upper Saddle River, New Jersey, USA.
Canadian Council on Animal Care. 2003. CCAC guidelines on: the care and use of wildlife, 2003. Canadian Council on Animal Care.
Canadian Council on Animal Care. 2008. CCAC species-specific recommendations on: birds. Canadian Council on Animal Care.
Environment Canada. 2010*a*. Climate normals 1981–2010 station data, collected at Snowflake, Manitoba, Canada. <http://climate.weather.gc.ca/>. Access 19 March 2014.
Environment Canada. 2010*b*. Daily climate 2010–2012 station data, collected at Morden, Manitoba, Canada. <http://climate.weather.gc.ca/>. Access 12 May 2014.
Fleming, K. K., and W. F. Porter. 2007. Synchrony in a wild turkey population and its relationship to spring weather. Journal of Wildlife Management 71:1192–1196.
Gill, F. B. 2007. Ornithology. Third edition. W. H. Freeman, New York, New York, USA.
Gillespie, M. 2003. Manitoba wild turkey status report. Pages 34–35 *in* R. O. Kimmel, W. J. Krueger, and T. K. Klinkner, compilers. Northern Wild Turkey Workshop. Minnesota Department of Natural Resources.
Green, H. 1982. Reproductive behavior of female wild turkeys in northern Lower Michigan. Journal of Wildlife Management 46:1065–1071.
Houchin, R. L. 2005. Coyote predation on the Rio Grande wild turkey in the Texas panhandle and southwestern Kansas. Thesis, Texas Tech University, Lubbock, Texas, USA.
Howerter, D. W., M. G. Anderson, J. H. Devries, B. L. Joynt, L. M. Armstrong, R. B. Emery, and T. W. Arnold. 2014. Variation in mallard vital rates in Canadian aspen parklands: the Prairie Habitat Joint Venture assessment. Wildlife Monographs 188:1–37.
Hubbard, M. W., D. L. Garner, and E. E. Klaas. 1999. Factors influencing wild turkey hen survival in southcentral Iowa. Journal of Wildlife Management 63:731–738.
Kaplan, E. L., and P. Meier. 1958. Nonparametric estimation from incomplete observations. Journal of the American Statistical Association 53:457–481.
Kimmel, R. O., and W. J. Krueger. 2007. Northern wild turkeys: issues or opportunity. Proceedings of the National Wild Turkey Symposium 9:263–272.
Kiss, B. W., F. B. Baldwin, R. K. Baydack, B. L. Joynt, and D. J. Walker. 2015. Female eastern wild turkey movement and habitat use in the Pembina Valley, Manitoba. Proceedings of the National Wild Turkey Symposium 11:155–164.
Lariviere, S. L. 1999. Reasons why predators cannot be inferred from nest remains. The Condor 101:718–721.
Lowrey, D. K., G. A. Hurst, S. R. Priest, and B. S. Weemy. 2001. Influences of selected weather variables on predation of wild turkey females and nest success. Proceedings of the National Wild Turkey Symposium 8:173–178.
Ludwig, E. L. 2012. Reproductive ecology of eastern wild turkey hens in Sussex County Delaware. Thesis, University of Delaware, Newark, Delaware, USA.
Mayfield, H. F. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456–466.
Miller, D. A., L. W. Burger, B. D. Leopold, and G. A. Hurst. 1998*a*. Survival and cause-specific mortality or wild turkey hens in central Mississippi. Journal of Wildlife Management 62:306–313.
Miller, D. A., B. D. Leopold, and G. A. Hurst. 1998*b*. Reproductive characteristics of a wild turkey population in central Mississippi. Journal of Wildlife Management 62:903–910.
Miller, M. S., D. J. Buford, and R. S. Lutz. 1995. Survival of female Rio Grande turkeys during the reproductive season. Journal of Wildlife Management 59:766–771.
National Oceanic and Atmospheric Administration. 2015. National Operational Hydrologic Remote Sensing Center interactive snow information, collected at Langdon, North Dakota, USA. <http://www.nohrsc.noaa.gov/>. Access 26 January 2015.
Nguyen, L. P., J. Hamr, and G. H. Parker. 2003. Survival and reproduction of wild turkey hens in central Ontario. Wilson Bulletin 115:131–139.
Paisley, R. N., R. G. Wright, J. F. Kubisiak, and R. E. Rolley. 1998. Reproductive ecology of eastern wild turkeys in southwestern Wisconsin. Journal of Wildlife Management 62:911–916.
Palmer, W. E., G. E. Hurst, J. E. Stys, D. R. Smith, and J. D. Burk. 1993*a*. Survival rates of wild turkey hens in loblolly pine plantations in Mississippi. Journal of Wildlife Management 57:783–789.
Palmer, W. E., S. R. Priest, R. S. Seiss, P. S. Phalen, and G. A. Hurst. 1993*b*. Reproductive effort and success in a declining wild turkey population. Proceedings of the Annual Conference of the Southeast Association of Fish and Wildlife Agencies 47:138–147.
Parent, C. J., B. J. Goodwin, and E. M. Dunton. 2011. Survival of female wild turkeys transplanted beyond their current range distribution in Minnesota. Proceedings of the National Wild Turkey Symposium 10:183–189.
Pelham, P. H., and J. G. Dickson. 1992. Physical characteristics. Pages 32–45 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole, Mechanicsburg, Pennsylvania, USA.
Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. The Journal or Wildlife Management 53:7–15.
Porter, W. F. 1977. Home range dynamics of wild turkeys in southeastern Minnesota. Journal of Wildlife Management 41:434–437.
Porter, W. F., and J. R. Ludwig. 1980. Use of gobbling counts to monitor the distribution and abundance of wild turkeys. Proceedings of the National Wild Turkey Symposium 4:61–68.
Porter, W. F., G. C. Nelson, and K. Mattson. 1983. Effects of winter conditions on reproduction in a northern wild turkey population. Journal of Wildlife Management 47:281–290.
Porter, W. F., R. D. Tangen, G. C. Nelson, and D. A. Hamilton. 1980. Effects of corn food plots on wild turkeys in the Upper Mississippi Valley. Journal of Wildlife Management 44:456–462.
Roberts, S. D., J. M. Coffey, and W. F. Porter. 1995. Survival and reproduction of female wild turkeys in New York. Journal of Wildlife Management 59:437–447.
Roberts, S. D., and W. F. Porter. 1998. Relation between weather and survival of wild turkey nests. Journal of Wildlife Management 62:1492–1498.
Skalski, J. R., K. E. Ryding, and J. J. Millspaugh. 2005. Wildlife demography: analysis of sex, age, and count data. Elsevier Academic Press, Burlington, Massachusetts, USA.
Smith, R. E., H. Veldhuis, G. F. Mills, R. G. Eilers, W. R. Fraser, and G. W. Lelyk. 1998. Terrestrial ecozones, ecoregions, and ecodistricts, an ecological stratification of Manitoba's landscapes. Agriculture and Agri-Food Canada, Research Branch, Brandon Research Centre. Technical Bulletin 98-9E
Spohr, S. M., F. A. Servello, D. J. Harrison, and D. W. May. 2004. Survival and reproduction of female wild turkeys in a suburban environment. Northeastern Naturalist 11:363–374.
Thogmartin, W. E., and J. E. Johnson. 1999. Reproduction in a declining population of wild turkeys in Arkansas. Journal of Wildlife Management 63:1281–1290.
Thogmartin, W. E., and B. A. Schaeffer. 2000. Landscape attributes associated with mortality events of wild turkeys in Arkansas. Wildlife Society Bulletin 28:865–874.
Townsend, C. R., M. Begon, and J. L. Harper. 2008. Essentials of ecology, third edition. Blackwell, Oxford, United Kingdom.

Treiterer, B. E. 1987. Reproductive ecology and habitat use of female wild turkeys in Waldo County, Maine. Thesis, University of Maine, Orono, Maine, USA.

Vander Haegen, W. M., W. E. Dodge, and M. W. Sayre. 1988. Factors affecting productivity in and northern wild turkey population. Journal of Wildlife Management 52:127–133.

Vangilder, L. D., E. W. Kurzejeski. 1995. Population ecology or the eastern wild turkey in northern Missouri. Wildlife Monographs 130:3–50.

Whitaker, D. M., J. C. Pack, G. W. Norman, D. F. Stauffer, and S. D. Klopfer. 2007. A range-wide meta-analysis of wild turkey nesting phenology and spring season opening dates. Proceedings of the National Wild Turkey Symposium 9:351–360.

White, G. C., and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46 (Supplement):S120–S139.

Wunz, G. A. 1992. Wild turkeys outside their historic range. Pages 361–385 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole, Mechanicsburg, Pennsylvania, USA.

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