



Commentary

Can Managers Compensate for Coyote Predation of White-Tailed Deer?

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ABSTRACT Many studies have documented that coyotes (*Canis latrans*) are the greatest source of natural mortality for white-tailed deer (*Odocoileus virginianus*) neonates (<3 months old). With the range expansion of coyotes eastward in North America, many stakeholders are concerned that coyote predation may be affecting deer populations adversely. We hypothesized that declines in neonate survival, perhaps caused by increasing coyote predation, could be offset by adjusting or eliminating antlerless harvest allocations. We used a stochastic, age-based population simulation model to evaluate combinations of low neonate survival rates, severe winters, and low adult deer survival rates to determine the effectiveness of reduced antlerless harvest at stabilizing deer populations. We found that even in regions with high winter mortality, reduced antlerless harvest rates could stabilize deer populations with recruitment and survival rates reported in the literature. When neonate survival rates were low (25%) and yearling and adult female survival rates were reduced by 10%, elimination of antlerless harvests failed to stabilize populations. Our results suggest increased deer mortality from coyotes can be addressed through reduced hunting harvest of adult female deer in most circumstances throughout eastern North America. However, specific knowledge of adult female survival rates is important for making management decisions in areas where both neonate and adult survival may be affected by predation and other mortality factors. © 2014 The Wildlife Society.

KEY WORDS *Canis latrans*, coyotes, fawn, mortality, *Odocoileus virginianus*, predation, survival, white-tailed deer.

Throughout the range of white-tailed deer (*Odocoileus virginianus*), many studies have documented that coyotes (*Canis latrans*) are the greatest source of natural mortality for neonate deer (<3 months old; Kie and White 1985, Decker et al. 1992, Vreeland et al. 2004, Saalfeld and Ditchkoff 2007, Kilgo et al. 2012). Coyotes have expanded into the eastern United States over the last 100 years, with range expansion in some areas (e.g., southeastern United States) being as recent as the last 10–40 years (Hill et al. 1987, Parker 1995, Gompper 2002, Kilgo et al. 2012).

The range expansion of coyotes has fueled concerns of many stakeholder groups that increased predation pressure by coyotes is having an adverse effect on white-tailed deer populations. For example, hunters in Pennsylvania and New York voiced concerns about coyote predation through comments at public meetings, lawsuits to halt antlerless harvest in Pennsylvania, and requests for fewer antlerless

deer permit allocations (J. Hurst, New York State Department of Environmental Conservation, personal observation; Rosenberry et al. 2011). Many members of the public, as well as politicians and some wildlife biologists, have suggested that more fawn survival studies be undertaken and that bounties for predators should be implemented (Rosenberry et al. 2011), even though there is little evidence of declines in deer populations concurrent with coyote range expansion (McShea 2012). However, predation on neonate white-tailed deer was the probable cause of recent population declines in South Carolina, prompting recommendations that coyote predation effects on neonate deer be taken into account when setting harvest management goals, regardless of deer population trends (Kilgo et al. 2010, 2012).

We believe that predation by coyotes is unlikely to require direct intervention by deer managers for 2 reasons. First, as long as deer population objectives can be met, causes of mortality of neonates before the hunting season are not important (Rosenberry et al. 2011). That is, recruitment in the context of deer management is defined as the number of fawns alive at the beginning of the deer hunting season

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(Rosenberry et al. 2011), and most predation occurs in the first 3 months of life (Ballard et al. 2001, Vreeland et al. 2004, Saalfeld and Ditchkoff 2007, Rosenberry et al. 2011, Kilgo et al. 2012), which is before most hunting seasons begin. Consequently, declining recruitment, regardless of the cause, simply needs to be offset by increased adult survival of the breeding population, which potentially could be addressed via reduced antlerless harvest rates. Second, reproductive rates (Mansell 1974, Downing and Guynn 1985, DelGiudice et al. 2007, Rosenberry et al. 2011) and adult female survival rates (excluding mortalities from hunting or winter weather conditions in the northern range; Dusek et al. 1992; Gaillard et al. 1998, 2000; Patterson et al. 2002), are relatively stable across space and time. Therefore, the effects of management actions should be relatively predictable when trying to offset reduced recruitment with increased adult female survival through reduced antlerless harvests. We hypothesized that only in extreme instances of low recruitment, possibly such as those reported for South Carolina (i.e., approx. 25% neonate survival; Kilgo et al. 2012), would deer managers not be able to stabilize deer populations through reduced antlerless harvests.

Many wildlife management agencies, such as Maine, New York, Pennsylvania, and Vermont, monitor white-tailed deer population trends and use this information to allocate antlerless harvest permits each year, which means specific sources of mortality mostly are irrelevant to harvest management decisions (Rosenberry et al. 2011). Moreover, increases in neonate mortality theoretically can be offset by reductions in antlerless harvests by reducing the number of hunters (i.e., harvest permits), harvest per hunter (i.e., bag limits), and hunting opportunity (i.e., season length), which will increase reproduction by increasing survival of adult females, as well as increase the survival rate of neonates by affecting the numerical response of coyotes to neonate deer. The concern, however, is whether coyote predation could increase to a level where zero antlerless harvest fails to stabilize deer populations.

We used a stochastic population model of white-tailed deer, parameterized with a range of deer harvest, survival, and reproductive rates, to investigate whether deer populations can be stabilized by reducing or eliminating antlerless harvest. We created our simulation scenarios to represent the range of deer population dynamics in eastern North America. The first scenario evaluated deer populations with high winter mortality that is representative of the northern range of the species. We evaluated a second scenario to understand the role of deer harvest when winter mortality is not an important influence on deer population dynamics, similar to the mid-Atlantic region. We created a third scenario to identify the lowest survival rate for adult females that will still result in a stable population even when the highest known neonate mortality rates occur. Our goal was to evaluate the tradeoffs associated with low neonate survival rates and reductions in antlerless harvest as a management tool to stabilize deer populations.

METHODS

We assessed 3 scenarios: 1) reduced survival of all sex- and age-classes when faced with low winter survival, coupled with low neonate survival, 2) high adult female survival with low neonate survival, and 3) low adult female survival with low neonate survival and no antlerless harvest. We designed scenarios 1 and 2 to evaluate whether reductions in antlerless harvest could stabilize the population. We created scenario 3 to evaluate the lower limit of adult female survival rates, when antlerless harvest is eliminated, that result in no trend in population trajectories.

We parameterized the scenarios with values reported for white-tailed deer populations in eastern North America. We defined neonate survival as survival to 3 months and approximated the survival rates reported by Kilgo et al. (2012; mean = 0.230, 95% CI = 0.155–0.328), which are among the lowest reported neonate survival rates subject to coyote predation (e.g., Kie and White 1985, Long et al. 1998, Piccolo et al. 2010), with a normal distribution (mean = 0.23 and SD = 0.05). We simulated scenario 3 under 2 different neonate survival conditions: 1) scenario 3.1 = neonate survival rates described above, and 2) scenario 3.2 = neonate survival rates from the literature for deer populations in the northern United States, modeled as a uniform distribution on the interval 0.46–0.76 (Decker et al. 1992, Vreeland et al. 2004, Burroughs et al. 2006, Carstensen et al. 2009). For both scenario 3.1 and 3.2, we reduced female (1.5+ yr) survival rates in increments of 5% of the original mean survival rate (Table 1) to identify the lowest female survival rate that did not result in a population decline. The model assumed that predation and harvest mortalities are fully additive. Predation mortality is additive when populations are limited by predation and are below carrying capacity (Ballard et al. 2001). Most deer populations in eastern North America appear to be below carrying capacity, and Kilgo et al. (2012) believe that the coyote-related mortality in their study population likely was additive. Mortality could be compensatory in some regions, but we do not have evidence of this in deer populations in New York or Pennsylvania.

For all scenarios, we used data (winter severity, harvest rates, initial density) from an aggregate of wildlife management units (WMUs 7F, 7H, 7J) in central New York that encompassed 4,897 km² (Table 1). We chose this area because it had one of the greatest average winter severity levels in New York State, outside of the central Adirondack and Tug Hill regions. In some regions of northeastern North America, such as the central Adirondack region of New York, Quebec, and northern New Brunswick, winter severity, and resulting winter mortality, is greater (Whitlaw et al. 1998, DelGiudice et al. 2006, Carstensen et al. 2009) and could have different effects on deer-coyote dynamics. We did not have complete datasets that would allow us to model deer population dynamics in these regions of more extreme winter severity. The New York State Department of Environmental Conservation (NYSDEC) defined the winter severity index (WSI) as the ratio of the number of

Table 1. Distributions of estimates of population demographic parameters used in the white-tailed deer population model. All mortality and survival rates are for males (M) and females (F). WSI, winter severity index; FH, female harvest rate of females >2.5 years old; U, uniform distribution; Dir, Dirichlet distribution; \mathcal{N} = normal distribution.

Parameter	Range
Initial density ^a (per km ²)	U(5.4, 9.2)
Initial adult sex ratio (M:F; 0.5+ yr) ^{b,c}	U(0.20, 0.40)
Fetal sex ratio (M:F) ^{b,d}	U(0.515, 0.535)
Initial male age structure ^a (0.5 yr, 1.5 yr, 2.5+ yr)	Dir(0.51, 0.32, 0.17)
Initial female age structure ^a (0.5 yr, 1.5 yr, 2.5+ yr)	Dir(0.39, 0.24, 0.37)
1.5+ yr buck harvest rate ^b	U(0.60, 0.80)
Female 0.5 yr harvest rate ^a	0.0996*FH + 0.1116 + \mathcal{N} (0, 0.0134)
Male 0.5 yr harvest rate ^a	0.1090*FH + 0.1290 + \mathcal{N} (0, 0.0077)
0.5 yr winter mortality rate ^c	$\begin{cases} U(0.35, 0.63) & \text{if WSI} > 0.7 \\ U(0.07, 0.32) & \text{if } 0.35 < \text{WSI} < 0.7 \\ U(0.00, 0.13) & \text{if WSI} > 0.7 \end{cases}$
1.5 yr winter mortality rate ^f	$\begin{cases} \text{WSI} * 0.3 & \text{if WSI} > 0.7 \\ \text{WSI} * 0.2 & \text{if } 0.35 < \text{WSI} < 0.7 \\ \text{WSI} * 0.05 & \text{if WSI} < 0.35 \end{cases}$
2.5+ yr winter mortality rate ^f	$\begin{cases} \text{WSI} * 0.15 & \text{if WSI} > 0.7 \\ \text{WSI} * 0.1 & \text{if } 0.35 < \text{WSI} < 0.7 \\ 0 & \text{if WSI} < 0.35 \end{cases}$
Neonate (0–3 month) survival rate ^g	\mathcal{N} (0.23, 0.05)
Neonate (0–3 month) survival rate, scenario 3.2 ^{h,i,j,k}	U(0.46, 0.76)
3–12 month survival rate ^{g,l,m,n,o,p,q}	U(0.70, 0.90)
1.0–1.5 yr survival rate ^{j,l,n,p,q}	U(0.93, 1.00)
1.5 yr survival rate ^{j,l,n,p,q,r}	U(0.93, 1.00)
2.5+ yr survival rate ^{j,l,n,p,q,r}	U(0.84, 1.00)
0.5 yr reproductive rate ^{s,t,u}	U(0.03, 0.12)
1.5 yr reproductive rate ^{s,t,u}	U(1.25, 1.41)
2.5+ yr reproductive rate ^{s,t,u}	U(1.67, 1.71)

^aDerived with New York sex-age-kill model (1998–2011; E. Kautz, New York State Department of Environmental Conservation [NYSDEC], personal communication); ^bData collected by NYSDEC (1998–2011; E. Kautz, unpublished data); ^c10th–90th percentiles calculated with equation from Severinghaus and Maguire (1955); ^dCalculated with equation from Moen et al. (1986); ^eInterquartile range calculated with model from Organ (2007); ^fSage (2003); ^gApproximation of survival rates from Kilgo et al. (2012); ^hDecker et al. (1992); ⁱVreeland et al. (2004); ^jBurroughs et al. (2006); ^kCarstensen et al. (2009); ^lVan Deelen et al. (1997); ^mLong et al. (1998); ⁿPatterson et al. (2002); ^oPowell (2004); ^pRohm et al. (2007); ^qDelGiudice et al. (2006); ^rWhitlaw et al. (1998); ^sDapson et al. (1979); ^tRosenberry et al. (2007); ^uHurst and Kirsch (2012).

days with ≥ 25.4 cm of snow on the ground to the total number of days for which snow depth was measured each year. The average WSI of the central New York study area was 0.212 (variance = 0.037). Winters in this area also are similar to those experienced in southern New Brunswick and the Maritime regions of Nova Scotia (Whitlaw et al. 1998, Patterson et al. 2002). Land cover in this area was 45% agriculture, 25% forest, 18% water and wetlands, and 12% developed.

We evaluated each scenario with a stochastic age-based simulation model that was modified from the model of Collier (2004) and Collier and Kremetz (2007), which was created for deer populations in Arkansas. We used this model and data from New York and from other studies of white-tailed deer in the United States and Canada to simulate natural mortality, reproduction, and harvest across a 50-year time horizon (Table 1). The original model simulated the population dynamics of juveniles (<0.5 yr), fawns (0.5 yr), yearlings (1.5 yr), and adults (2.5+ yr) of each sex (Collier and Kremetz 2007). Briefly, each simulation began with a post-harvest age- and sex-structured population (0.5+ yr) that first underwent non-harvest mortality (winter, spring, and summer), including mortality related to winter severity. The remaining individuals reproduced with age-specific

productivity rates. Fawns that were <0.5 years old experienced summer mortality, including predator-related mortality. All individuals then recruited to the next age class (e.g., <0.5 yr became 0.5 yr, 0.5 yr became 1.5 yr, etc.) and underwent age- and sex-specific harvest (Fig. 1). The output

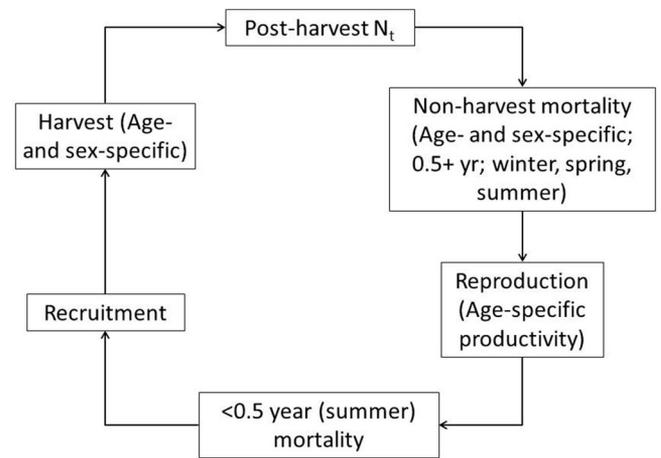


Figure 1. Structure of the white-tailed deer population simulation model. Ages represented in the model are juveniles (<0.5 yr), fawns (0.5 yr), yearlings (1.5 yr), and adults (2.5+ yr). N_t is the population size at time = t .

of interest was the mean population growth, estimated as $N_t/N_{t=0}$ where N is the post-harvest population size and t is time in years, and associated 95% confidence intervals.

We modified the Collier and Kremetz model to incorporate different rates and age ranges. For natural mortality, we subdivided <1.5-year deer into age classes of 0–3 months (neonates), 3–12 months, and 1.0–1.5 years to evaluate declines in neonate survival rates that could be attributed to coyote predation. We replaced the environmental effects of nutritional deficiency from the original model with environmental stochasticity associated with winter severity, which correlated with winter mortality. We drew a yearly WSI value from a beta distribution with the mean and variance of observed WSI values in the central New York study area, 1998–2010. We estimated ranges of winter mortality rates of fawns (E. Kautz, NYSDEC, personal communication) with the model of Organ (2007), and yearling and adult winter mortality rates with equations from an Adirondack white-tailed deer population model (Sage 2003; Table 1). We excluded winter severity for scenarios 2 and 3 to approximate conditions experienced by deer populations in the mid-Atlantic region of North America. We modified adult female harvest to include a threshold effect of population size that would approximate a manager's ability to regulate population size with deer management permits (DMPs or doe tags). Changes in pre-harvest population size of >20% or <20% of the pre-harvest population size at $t = 0$ triggered a corresponding increase or decrease in 1.5+ year female harvest rates. Fawn (0.5 yr) harvest rates were correlated with adult female harvest rates, so we used a linear regression and associated error terms to draw sex-specific fawn harvest rates for each year of the simulation (Table 1). We adjusted adult female harvest rates to stabilize the population (bounds of the 95% CI encompassing a population growth rate of 1.0) over the 50-year simulation. The initial age structure of males and females in the model was skewed slightly because fawns were underrepresented in the harvest data. We ran each model simulation for 5 years to equilibrate the age structure and set the last year of this equilibration phase as $t = 0$ (Supplementary Fig. A1, available online at www.onlinelibrary.wiley.com). Finally, because many parameters were shared among scenarios, we set a random number seed for each simulation so that the same set of parameter values was evaluated for each scenario (Irwin et al. 2008). We simulated each scenario 1,000 times and performed all population simulations in R (R Version 2.15.1, www.r-project.org, accessed 1 Mar 2012).

RESULTS

In scenarios 1 and 2, the anticipated population declines associated with low neonate survival rates (Fig. 2) were counteracted by reductions in antlerless deer harvest rates (Figs. 3 and 4). In scenario 1, winter severity caused a decline in survival of all year classes (3–18 months = 10% reduction, 1.5–2.5 yr = 3% reduction, 2.5+ yr = 1% reduction), but reduction in antlerless harvest rates provided the means for maintaining the population at the desired levels (Fig. 3). In scenario 2, winter severity was eliminated to simulate deer

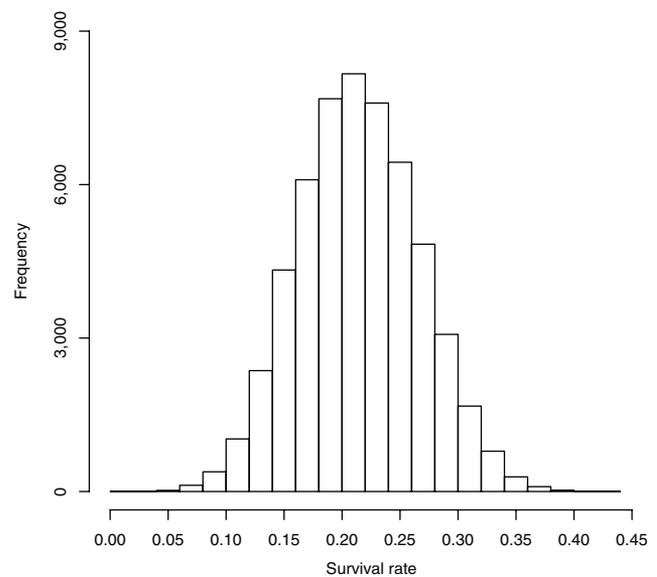


Figure 2. Frequency of neonate (0–3 month) survival rates in each scenario of simulations of the stochastic white-tailed deer population model. Each scenario encompassed 1,000 simulations of 50 years.

populations outside of the northern range of the species. Scenario 2, therefore, allowed for antlerless harvest rates that were an average of 66% greater at year 50, as compared to scenario 1 (Fig. 4). Additionally, the age structure of each sex remained constant throughout the simulated time frame under scenarios 1 and 2.

In scenario 3, we evaluated populations with lower adult female survival and no antlerless harvest. When neonate survival rates were in the range reported by Kilgo et al. (2012) and adult female survival rates were reduced by 10% (yearling survival = 0.83–0.90, 2.5+ yr survival = 0.75–0.91), the population declined by an average of 90% after 50 years, whereas the population grew an average of 11% after 50 years under a 5% reduction in adult female survival rates (yearling survival = 0.88–0.95, 2.5+ yr survival = 0.79–0.95; Fig. 5a, b). When we used values of neonate survival from the literature for northeastern North America, the population almost doubled, on average, after 50 years under reductions in average adult female survival as great as 20% (yearling survival = 0.74–0.81, 2.5+ yr survival = 0.66–0.82), but declined by an average of 46% after 50 years under a 25% reduction in average adult female survival (yearling survival = 0.71–0.78, 2.5+ yr survival = 0.63–0.79; Fig. 5c,d).

DISCUSSION

Deer population growth was stabilized, even with winter mortality, by reducing or eliminating antlerless harvest, and we achieved this condition in all but extreme cases of low adult female survival and recruitment. Generally speaking, limiting deer harvest and other mortality sources to rates that do not exceed reproductive output will result in population maintenance or growth (McShea 2012). In addition to increasing survival, reductions in antlerless harvest could have an effect on the numerical response of coyotes to deer fawns, because lower adult female mortality results in greater

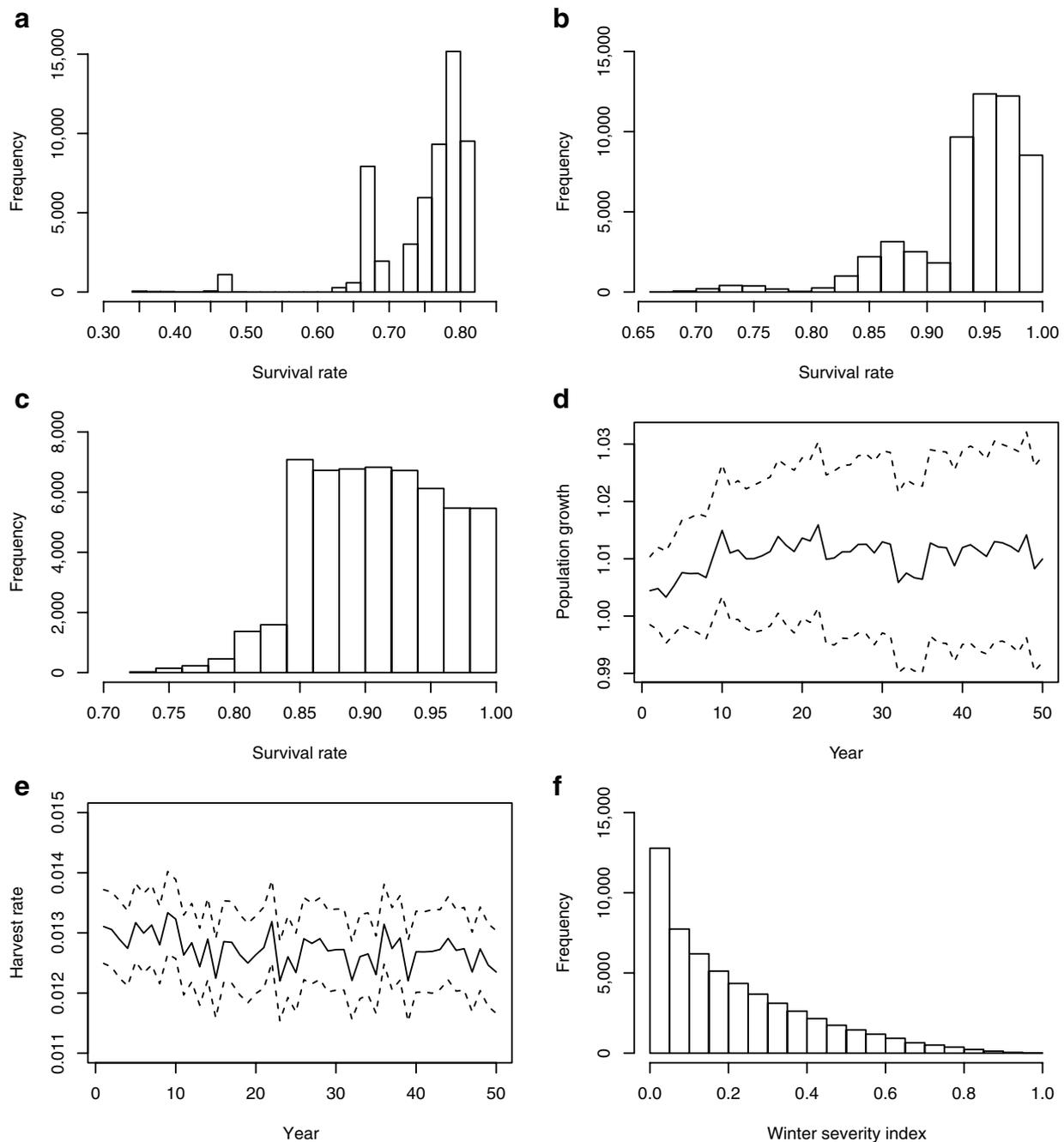


Figure 3. Observed output of scenario 1 (severe winters and low neonate [0–3 month] survival) after 1,000 simulations of the stochastic white-tailed deer population model. Observed frequency of survival rates (1,000 simulations \times 50 yr) of a) all 3–18 month deer, b) 1.5 year females, and c) 2.5+ year females. d) Observed average population growth (solid line) and 95% confidence intervals (dashed lines) over 50 years. e) Observed average 2.5+ year female harvest rates (solid line) and 95% confidence intervals (dashed lines) over 50 years. f) Observed frequency of winter severity indices.

numbers of fawns produced in the spring. This effect on the numerical response of coyotes may not be as strong in the southeastern United States, where parturition is less synchronous than in the northern part of the range (Diefenbach and Shea 2011). White-tailed deer have high lifetime fecundity, which allows deer population numbers to adjust quickly to reductions in mortality (McShea 2012), such as reductions in antlerless harvest. Based on the ability of antlerless harvest adjustments to compensate for increased neonate mortality, we believe taking specific sources of

mortality into account and managing for those sources likely is unnecessary to meet deer abundance objectives.

Adjustments to antlerless harvest rates in response to deer population trends at the WMU-level are routine for managers in New York and Pennsylvania (Rosenberry et al. 2011, NYSDEC 2011); states such as Massachusetts and Vermont also regulate antlerless harvest with antlerless licenses. Similarly, in many areas of eastern North America, hunting is the major source of mortality for white-tailed deer (Nixon et al. 1991, Whitlaw et al. 1998, Brinkman

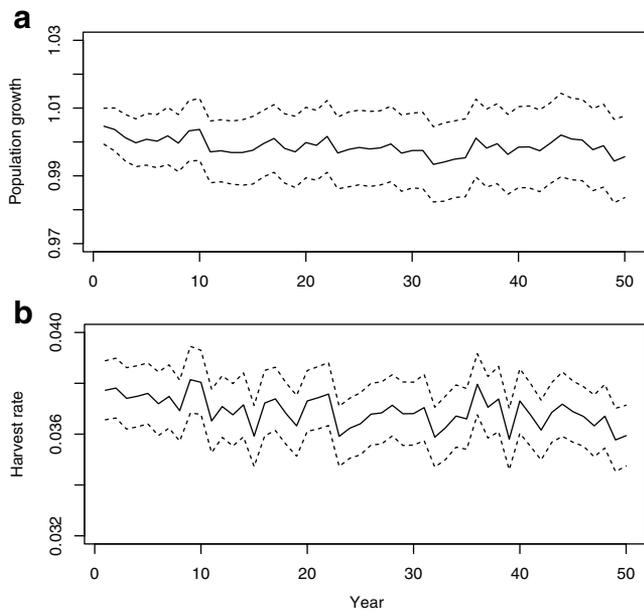


Figure 4. Observed output of scenario 2 (high 1.5+ yr female survival [$1.5 \text{ yr} = U(0.93, 1.00)$, $2.5+ \text{ yr} = U(0.84, 1.00)$] and low neonate [0–3 month] survival) after 1,000 simulations of the stochastic white-tailed deer population model. a) Average change in population size (solid line) and 95% confidence intervals (dashed lines) over 50 years. b) Average 2.5+ year female harvest rate (solid line) and 95% confidence intervals over 50 years.

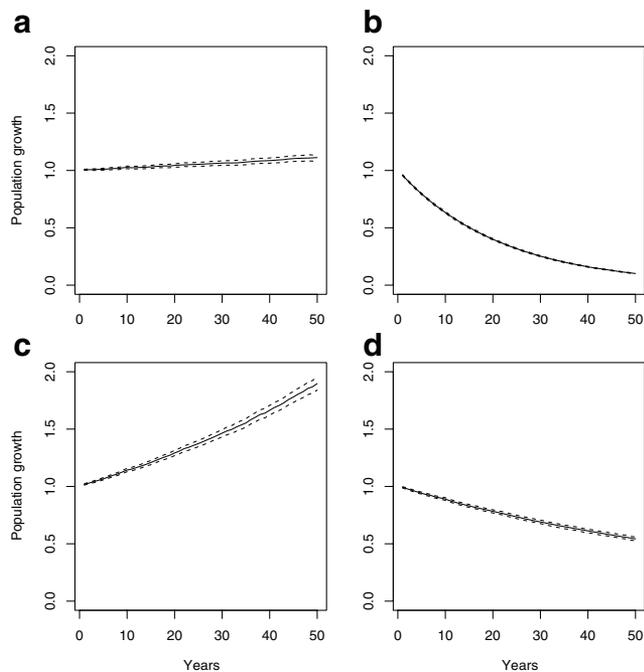


Figure 5. Observed average change in population size (solid line) and 95% confidence intervals (dashed lines) over 50 years under scenario 3.1 (neonate [0–3 month] survival = $NJN [0.23, 0.05]$) and scenario 3.2 (neonate survival = $U[0.46, 0.76]$). Each scenario was simulated 1,000 times with the stochastic white-tailed deer population model. Reductions in average 1.5+ year female survival rates of a) 5% (scenario 3.1), b) 10% (scenario 3.1), c) 20% (scenario 3.2), and d) 25% (scenario 3.2).

et al. 2004, Keenan 2010, Norton 2010, Rosenberry et al. 2011), and antlerless harvest is the most readily manipulated management strategy for declining populations. Our results indicate that even with increased mortality from coyote predation and severe winters, harvest management decisions do not need to specifically account for coyote-related mortality. In the extreme northern range of the species, winter mortality could limit the ability of reduced antlerless harvest to compensate for increased coyote predation if neonate mortality rates are as low as those reported by Kilgo et al. (2012). Rosenberry et al. (2011) provided a decision chart that describes the management actions that can be taken, even when a population is declining, before juvenile survival studies and predator management are considered. The results from our simulations reinforce the claim by Rosenberry et al. (2011) that even when a deer population is in decline, modifications to antlerless harvest rates are the first and most effective management action to be taken. Our simulations indicate that this is likely the case for most deer populations throughout eastern North America.

Our model assumes that predation and harvest are fully additive, and although compensation could be occurring in some regions, populations in which predation is limiting population growth likely are experiencing additive mortality from these sources (Ballard et al. 2001). Additionally, most predation on deer occurs on fawns (Ballard et al. 2001, Vreeland et al. 2004, Saalfeld and Ditchkoff 2007, Rosenberry et al. 2011, Kilgo et al. 2012), except in northern areas where overwinter predation of adults can be problematic (Dusek et al. 1992; Gaillard et al. 1998, 2000; Patterson et al. 2002). Because fawn predation occurs prior to harvest, knowledge of recruitment rates are more important for making management decisions than whether pre-hunting mortality is compensatory or additive.

Although many managers and hunters are concerned about the increased mortality rates that might accompany a growing coyote population, other sources of mortality can be just as important and could be assessed with our model (see R code, available online at www.onlinelibrary.wiley.com). For example, black bears often comprise a large percentage of the predation rate on white-tailed deer neonates (e.g., 48% in the central Adirondacks, New York (Mathews and Porter 1992); 10% in New Brunswick (Ballard et al. 1999); 12.5–36.6% in central Pennsylvania (Vreeland et al. 2004)). These reported rates of black bear predation on neonates underscore the importance of management strategies, such as reduction in antlerless harvest, that compensate for multiple sources of neonate mortality.

Through a literature search, we found that adult female survival information is rare in the southeastern United States, especially studies in which total mortality has been deconstructed into natural and hunting mortality. Some previous studies have assumed total adult female mortalities of 25% (South Carolina; Comer et al. 2005) to 30% (with negligible non-harvest mortality, Mississippi; Gruver et al. 1984), and 1 study assumed a non-hunting mortality rate of 10% for populations in Illinois, Georgia, and Virginia

(Keyser et al. 2006). The combined adult female survival rates that we used in our scenarios are similar to these published rates. Although researchers have indicated that survival rates (excluding winter mortality) of adult female large herbivores have low variability across space and time (Dusek et al. 1992; Gaillard et al. 1998, 2000; Patterson et al. 2002), the lack of relevant natural mortality estimates for adult females in the Southeast is an important area of uncertainty for management decisions. The results from scenario 3 indicate that there is a lower limit to the ability of antlerless harvest reduction to offset low neonate survival, and the reduction required is much less than what a population with greater neonate survival rates can withstand (<10% reduction with low neonate survival vs. >20% reduction with greater neonate survival). Knowledge of female survival rates in these situations would provide managers with better data for making informed decisions about possible management actions.

In many areas of the country, deer densities are above historical levels (McShea 2012), and antlerless harvest rates are below those necessary for population control (Brown et al. 2000, Giles and Findlay 2004, Van Deelen et al. 2010, McShea 2012). In some cases, antlerless harvest rates cannot be increased by simply allocating more deer management permits (Brown et al. 2000, Giles and Findlay 2004). In many areas, deer populations are increasing, while hunter numbers are stable or declining, such that hunter capacity to harvest more deer has been reached, and deer refugia associated with limited hunter access are on the rise (Brown et al. 2000). In these areas, coyote predation may have little effect on deer population trends and deer management in general. Our simulations, however, represent a best-case scenario, where hunter access and hunter numbers do not decline and can keep pace with the deer population.

For most deer populations in eastern North America, we believe antlerless harvest can be adjusted to meet population abundance objectives. An important issue, however, is public perception. Many stakeholders perceive coyotes to be a threat to their hunting opportunity and experience, and would like to see management agencies take action against predators such as coyotes (Rosenberry et al. 2011). In that sense, many hunters would prefer to retain exclusive access to deer that may otherwise be taken by coyotes. However, researchers throughout the United States have found that hunters often are reluctant to participate in population reduction through antlerless harvest when necessary to achieve other management goals, particularly concerning adverse effects of deer on ecosystems (Diefenbach et al. 1997, Holsman 2000, Ward et al. 2008, Van Deelen et al. 2010). As with most natural resource management issues, balancing the tradeoff of coyote versus human predation on deer should incorporate perspectives from a broader group of stakeholders and reflect relative values of society for coyote and deer populations and management.

Management of deer populations through harvest regulations requires making tradeoffs among the values of potentially competing stakeholder groups and taking into account multiple sources of uncertainty. For example,

collateral effects, such as hunter recruitment and retention, which are concerns for many states, could be affected by reduction of antlerless harvest, though we are uncertain of the direction of this effect. Although Minnesota has reduced antlerless harvest and deer densities, hunter numbers have not changed, indicating that any dissatisfaction with this management technique has not resulted in decreased hunter participation (D.C. Fulton, U.S. Geological Survey, personal communication). Additionally, uncertainty regarding hunter behaviors under reduced antlerless harvest potential should be incorporated in the decision-making process. In our model, we assumed that changes in regulations would result in changes in hunter behavior but still included a range of potential antlerless harvest rates to encompass stochasticity in changes in hunter behavior. Overall, we suggest that managers faced with these sorts of tradeoffs and sources of uncertainty consider using techniques such as structured decision-making (e.g., Gregory et al. 2012) to formally evaluate potential management alternatives and their implications on stakeholder values, including hunter satisfaction and deer population dynamics.

MANAGEMENT IMPLICATIONS

Reducing antlerless harvest rates is likely to stabilize declining deer populations in most management situations currently experienced by state and provincial agencies responsible for white-tailed deer management in eastern North America. Concerns about coyote predation causing reduced neonate survival and leading to population declines could be addressed by better evaluating deer management alternatives. However, research to document adult female survival rates may be important for making better management decisions in the southeastern United States because we are not aware of any research estimating female survival rates and cause-specific mortality.

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