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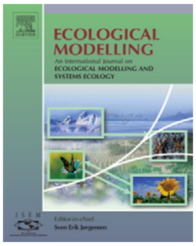

Uncertainty in age-specific harvest estimates and consequences for white-tailed deer management

Bret A. Collier[a,*], *David G. Krementz*[b]

[a] *Arkansas Cooperative Fish and Wildlife Research Unit, Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701, USA*

[b] *USGS Arkansas Cooperative Fish and Wildlife Research Unit, Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701, USA*

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ABSTRACT

Age structure proportions (proportion of harvested individuals within each age class) are commonly used as support for regulatory restrictions and input for deer population models. Such use requires critical evaluation when harvest regulations force hunters to selectively harvest specific age classes, due to impact on the underlying population age structure. We used a stochastic population simulation model to evaluate the impact of using harvest proportions to evaluate changes in population age structure under a selective harvest management program at two scales. Using harvest proportions to parameterize the age-specific harvest segment of the model for the local scale showed that predictions of post-harvest age structure did not vary dependent upon whether selective harvest criteria were in use or not. At the county scale, yearling frequency in the post-harvest population increased, but model predictions indicated that post-harvest population size of 2.5 years old males would decline below levels found before implementation of the antler restriction, reducing the number of individuals recruited into older age classes. Across the range of age-specific harvest rates modeled, our simulation predicted that underestimation of age-specific harvest rates has considerable influence on predictions of post-harvest population age structure. We found that the consequence of uncertainty in harvest rates corresponds to uncertainty in predictions of residual population structure, and this correspondence is proportional to scale. Our simulations also indicate that regardless of use of harvest proportions or harvest rates, at either the local or county scale the modeled SHC had a high probability (>0.60 and >0.75, respectively) of eliminating recruitment into >2.5 years old age classes. Although frequently used to increase population age structure, our modeling indicated that selective harvest criteria can decrease or eliminate the number of white-tailed deer recruited into older age classes. Thus, we suggest that using harvest proportions for management planning and evaluation should be viewed with caution. In addition, we recommend that managers focus more attention on estimation of age-specific harvest rates, and modeling approaches which combine harvest rates with information from harvested individuals to further increase their ability to effectively manage deer populations under selective harvest programs.

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* *Corresponding author at*: Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX 77843-2258, USA. Tel.: +1 979 458 0500; fax: +1 979 845 3786.

E-mail address: bret@tamu.edu (B.A. Collier).

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1. Introduction

Management for white-tailed deer (*Odocoileus virginianus*) is often intended to manipulate population characteristics such as abundance, age structure, and sex ratio (Demarais et al., 2000). Historical frameworks used to evaluate populations (reviewed in Roseberry and Woolf, 1991) are simplified approaches to complex systems. Effectiveness of management practices cannot be determined without population demographic data (Lubow et al., 1996), however, this information is lacking across the range of white-tailed deer (McShea et al., 1997). Because information on harvested deer is readily available (Carpenter, 2000), most management planning and evaluation by managers or state wildlife agencies (SWAs) is based on harvest data (Roseberry and Woolf, 1991; McCullough, 1990).

Typically, there is little information available on age structure of deer populations (Osborne et al., 1992; Trenkel et al., 2000). Age structure of the harvest (proportion of harvested individuals within each age/sex class, hereafter harvest proportion), is influenced by regulatory structure and hunter selectivity (McCullough, 1979; Carpenter, 2000). Harvest proportions are used to estimate age-specific abundance or age-specific harvest rates in population models (Creed et al., 1984; Euler and Morris, 1984; Xie et al., 1999; Grund and Woolf, 2004). However, harvest proportions are indexes (Anderson, 2001) of population age structure and may not be representative of true population age structure. Recent use of various selective harvest criteria (SHC; Carpenter and Gill, 1987; Strickland et al., 2001) as well as localized, intensive management programs (Collier and Krementz, 2006) has confounded use of harvest proportions for predicting changes in population structure and trajectory. Thus, harvest proportions may not be unbiased parameters for monitoring response to management actions.

The structure of wildlife populations exhibits considerable variation over time (Trenkel et al., 2000). Population models are commonly used to construct and evaluate harvest regulations for game species (Walters and Gross, 1972; White et al., 2001; White and Lubow, 2002). Historically, deer modeling exercises have used deterministic models where population parameters were considered constant throughout the modeling procedures (Creed et al., 1984; McCullough et al., 1990; Xie et al., 1999). However, when constructing or implementing white-tailed deer management programs, managers need the ability to integrate and evaluate multiple management scenarios while incorporating uncertainty in population parameters to make scientifically sound management decisions (Phillips and White, 2003). Stochastic population modeling (SPM) is a powerful, yet infrequently used tool for evaluating population responses to management strategies (Lande et al., 2003; Phillips and White, 2003). SPM permits managers to approach management planning and evaluation using what-if modeling scenarios (Walters and Gross, 1972; Lande et al., 2003; Phillips and White, 2003) while accounting for temporal variation in population size and structure, individual variation in demographic parameters (Dunham and Beaupre, 1998; Pfister and Stevens, 2003), or harvest characteristics for selectively harvested species (Ratner and Lande, 2001; Strickland et al., 2001).

Due to the economic significance of white-tailed deer, many population parameter estimates are available. However, knowledge of population parameter relationships does not exist across broad temporal and spatial scales, or under most regulatory structures. In order to address the impacts of varying harvest rates and SHC (three-point rule) in Arkansas, we developed an age- and sex-structured stochastic population model to examine potential population responses to harvest regulations at two spatial scales. Our approach was designed to: (1) outline a stochastic population model to be used for evaluating white-tailed deer population trajectories under limited parameter knowledge in Arkansas, (2) assess predictions of male white-tailed deer post-harvest population age structure when using the proportional distribution of individuals in the harvest as a surrogate for age-specific harvest rates at the local and county scale for two periods of regulatory restrictions in Arkansas, and (3) determine the trajectory of post-harvest population age structure across a range of age-specific harvest rates compared to a range of harvest proportions.

2. Methods

2.1. *Population model*

The underlying population model was a stochastic age- and sex-structured simulation model written in R (R Core Development Team, 2004). The model was represented mathematically in compartments that tracked the population using 1-year time steps. The model tracked both sexes (Male [B], Female [D]) and 5 mutually exclusive age classes: (juveniles ([J]; birth to 6 months old), fawns ([F], 6 months old), yearlings ([Y], 1.5 years old), sub-adults ([S], 2.5 years old), and adults ([A], ≥3.5 years old)). Newborn juveniles were modeled independently of other age classes from birth until recruited into the fall (fawn) population because considerable variation exists in juvenile survival rates and sex ratios (Fig. 1; Carrol and Brown, 1977; Verme, 1983). The 4 non-juvenile age classes were used because: (1) female fecundity varies across age classes, (2) limited numbers of males reach age classes ≥3.5-years old in heavily hunted populations (Ditchkoff et al., 2001), and (3) the SHC used by the Arkansas Game and Fish Commission (AGFC) focused on reducing pressure on the 1.5-year-old age class to increase recruitment into the ≥2.5-year-age classes. We used model expressions following Phillips and White (2003). Demographic variation was incorporated using binomial or Poisson random variates, so that estimates of survival and recruitment were not constant within the simulation model (Phillips and White, 2003). Simulation transitions after model initiation were given by

$$N_{\mathrm{YB}}(t_{\mathrm{PRE}}) = \mathrm{binom}(N_{\mathrm{FB}}(t), \hat{S}_{\mathrm{A}}(t)),$$

$$N_{\mathrm{SB}}(t_{\mathrm{PRE}}) = \mathrm{binom}(N_{\mathrm{YB}}(t), \hat{S}_{\mathrm{A}}(t)),$$

$$N_{\mathrm{AB}}(t_{\mathrm{PRE}}) = \mathrm{binom}(N_{\mathrm{AB}}(t), \hat{S}_{\mathrm{A}}(t)) + \mathrm{binom}(N_{\mathrm{SB}}(t), \hat{S}_{\mathrm{S}}(t)),$$

$$N_{\mathrm{YD}}(t_{\mathrm{PRE}}) = \mathrm{binom}(N_{\mathrm{FD}}(t), \hat{S}_{\mathrm{F}}(t)),$$

$$N_{\mathrm{SD}}(t_{\mathrm{PRE}}) = \mathrm{binom}(N_{\mathrm{YD}}(t), \hat{S}_{\mathrm{Y}}(t)),$$