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Reproductive characteristics of female white-tailed deer (*Odocoileus virginianus*) in the Midwestern USA

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ABSTRACT

Knowledge of reproductive characteristics of wild populations is necessary to inform responsible management decisions that promote herd health. As management, goals, and free-ranging populations change over time and landscapes, updated knowledge of reproductive characteristics are needed to inform responsible management practices. We estimated reproductive characteristics of female white-tailed deer in Illinois, including pregnancy rate, litter size, fetal growth and fetal sex ratio. We found maternal age to have an important influence on several reproductive factors. Approximately 66% of tested females (n = 3884) were pregnant and pregnancy rates increased with increasing maternal age, from 20.5% in fawns to 85.8% in adult deer. Litter size ranged from 1 to 5 fetuses per pregnant female. The average litter size was 1.9 ± 0.54 fetuses per pregnant female and also increased with age, from 1.2 in fawns to 2.0 in adults, respectively. Breeding season peaked in November with the mean estimated conception dates of fetuses varying with maternal age. Fawns conceived fetuses later in the breeding season (December 2) compared to yearlings and adults (November 11 and 8, respectively). We measured the body mass index (BMI) of all fetuses and found that litter size and female age influence fetal size. We found no bias in fetal sex ratio (average 1.0:1.0, male:female) but we observed a sex bias in fetal size (mean BMI male = 0.71, female 0.67) across all maternal age classes. A comparison of the current study and previous reports indicate that variation in maternal age within a population is an important driver of reproductive metrics, likely because maternal age and body size or condition are related. Furthermore, variation in resource availability will influence reproductive rates, especially among fawn females.

1. Introduction

North American cervids, including white-tailed deer (*Odocoileus virginianus*), mule deer (*O. hemionus*), elk (*Cervus canadensis*), and moose (*Alces alces*) are recreationally valuable and popular game species. The *Odocoileus* genus has the highest numbers, highest economic value [1], and is found across a majority of North America [2]. While white-tailed deer are among the most abundant species presently, unregulated hunting threatened to eliminate this species from much of its range in the early 1900's [3]. Since that time, white-tailed deer have been managed extensively and recent decades have seen dynamic changes in white-tailed deer populations. For example, deer populations in the United States and Canada in 1948 were estimated at only about 6 million deer [4], whereas in 2015 that same number was actually harvested by hunters during legal hunting seasons [5].

Population management of wildlife species, especially large game species requires knowledge of population dynamics relative to carrying capacity of the landscape. Further, studies of other cervids have indicated that population density can influence female reproduction [6]. Reproductive parameters such as pregnancy rates, birth rates, neonate and juvenile survival (i.e., fawn recruitment), and litter size are important variables that can be used to model

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population growth or decline and ultimately guide management decisions. Given the dynamic changes in deer populations in the recent past, and the importance of having contemporary estimates of reproductive parameters to monitor variations in deer populations and guide management decisions, the purpose of this paper is to examine the reproductive characteristics of female white-tailed deer using a large dataset beginning in 2003.

The upper Midwest landscape is a mixture of fertile agricultural cropland interspersed with forests. Illinois has a long history of deer management and previous studies have investigated white-tailed deer reproduction [7,8]. However, few data on reproduction have been reported in recent years. Previous estimates of reproductive parameters may not be applicable if deer population size, habitat quality and quantity, or food resources have changed substantially over time [9]. Therefore, additional research is warranted to provide updated estimates of reproductive parameters. In order to update this information, we examined baseline reproductive characteristics of female white-tailed deer based on a large sample set obtained over a decade of sampling. Specifically, we investigated (1) pregnancy rate and estimated conception peaks, (2) litter size and sex ratio, and (3) fetal growth.

1.1. Species characteristics

White-tailed deer are seasonal breeders. Estrus and mating occurs during the rutting season, which in central Illinois ranges from October to December. With an average gestational length of 200 days [10], parturition follows from May to July [7]. Although at a later date than older females, fawns may enter estrus in the autumn of their first year [10]. Female white-tailed deer gain more than half of their adult mass of 60 kg between 0.5 yr and 2–4 yrs [11], when they attain maximum body size [10]. Males do not reach stable body mass of 80 kg until approximately 5 years [10].

1.2. Pregnancy rate and estimated conception date

Research of white-tailed deer and roe deer (*Capreolus capreolus*) indicates pregnancy rates increase with maternal age [8,12,13]. Maternal age and reproduction are linked as a high plane of nutrition (defined as the quantity and quality of per capita food intake), results in rapid growth and earlier maturity (i.e., estrus) in many species [14,15]. Conversely, females in less-than-average body condition may exhibit lower pregnancy rates. In the wild, fawn breeding rates vary with habitat quality [16] and deer habitat in Illinois generally is considered high quality [9] leading to an expectation of relatively high fawn pregnancy rates although yearly variation is expected given variation in weather conditions for plant growth (resource availability). Older females tend to conceive earlier than younger females [12] and we therefore expect the estimated breeding dates of older females to occur earlier than fawns and yearlings.

1.3. Litter size and sex ratio

White-tailed deer typically carry one or two fetuses although litter size varies with maternal age [10]. Fawns in southern Illinois (based on fetal counts) produced a single offspring compared to yearlings and adults that had higher proportions of twin and triplet litters [8]. Litter size, similar to pregnancy rate, is connected to maternal age through body condition. Because of the high metabolic cost of pregnancy, it is reasonable to expect females with larger body size (i.e., more fat) to be better suited to tolerate body fat loss, and thus multiple fetuses per pregnancy, compared to females of smaller body size. Therefore, we expect litter size to increase with maternal age among Illinois deer.

Fetal sex ratios of white-tailed deer appear responsive to maternal age and environmental conditions but the literature is divided on the interpretation of available studies [17–20]. A previous study of white-tailed deer at least 1 yr old, indicated that the percentage of male fawns declined with an increase in maternal age and litter size [17]. In Ohio, fawn and yearling females carried more male fetuses, but the sex ratio was balanced among adult females [21]. A study in Missouri found older females have more male offspring [22] whereas fetal sex ratios favored females among adult females in an Ohio farmland region [23]. Because our study area includes agricultural habitat with abundant food resources, we expect females in our study area to be in relatively good body condition and to carry a lower proportion of male offspring compared to yearlings. We expect the proportion of males to decrease with increasing litter size within an age class.

1.4. Fetal growth

White-tailed deer fetal growth is highly predictable from approximately 40 days post-conception until parturition [24]. Descriptive growth keys (e.g., Carnegie stages) for white-tailed deer provide accurate age estimates based on morphological descriptions [25,26]. Although descriptive keys may be slightly more exact, crown-rump length measurements afford a method that requires less detailed observation to provide an accurate age and conception date estimate [25]. Several factors influence birth size across most mammals including age, size and body reserves of the female at conception, and litter size [27]. Maternal size influences fetal growth because traits that influence growth are heritable and maternal size is determined by female body condition (i.e., nutrition and percent body fat), which in turn governs fetal size. Among white-tailed deer, Cothran et al. [28] indicated that maternal age, maternal weight or the number of fetuses can impact fetal growth rates after accounting for fetal age. Therefore, we expect fetal size to increase with maternal age and decrease with increasing litter size and male fetuses are expected to be larger than females [29,30].

2. Materials and methods

Live animal work was conducted under the oversight of the Illinois Department of Natural Resources. Laboratory work was conducted under the oversight of the University of Illinois Institutional Biosafety Committee.

2.1. Sampling

White-tailed deer embryos and fetuses were obtained through the state of Illinois chronic wasting disease (CWD) control program, an Illinois Department of Natural Resources (IDNR) program. Samples were collected by IDNR personnel from 15 northern Illinois counties each year from 2003 through 2013 during January through March (Fig. 1). The county where each deer was killed was recorded and used as the geographic location for all analyses. Age of each female deer was estimated based on sequential development of dentition [31]. Deer were classified into age groups using management terminology as fawn (8–11 months at time of sampling), yearling (20–23 months at time of sampling) or adult (>32 months at time of sampling). Deer were brought to one of several IDNR laboratories and processed to allow donation to local food banks after disease testing. During processing, IDNR biologists removed individual fetuses or reproductive tracts of female deer, which were subsequently transported to the University of Illinois for examination. Reproduction was assessed only in healthy animals. For each fetus, we weighed (g), measured crown-rump