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Translocating captive female white-tailed deer

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ABSTRACT

Context. Thousands of captive white-tailed deer (*Odocoileus virginianus*) breeding facilities exist across North America for the purpose of producing trophy-class deer (i.e. exceptionally large-antlered). Many of these deer get marketed to private landowners, with the expectation that introduced deer will enhance genetics in the population, resulting in larger-antlered male deer. Previous research suggests that survival and reproductive success of translocated wild white-tailed deer are highly variable; however, little is known about the fate of white-tailed deer translocated from captive-breeding operations. **Aims.** To assess the efficacy of translocating captive female white-tailed deer for the purpose of increasing average antler size within a high-fence property. **Methods.** We translocated 24 adult female deer into a private, 300-ha high-fence shooting preserve in east-central Alabama over a 3-year period. We monitored survival, reproductive success, and fawn recruitment for the translocated deer by using VHF radio collars and vaginal-implant transmitters (VITs). **Key results.** We found a 12-month survival rate of 0.54 for translocated deer. We captured nine fawns throughout our study, leading to a rate of 0.9 fawns per VIT, after accounting for doe mortality and premature VIT expulsion. We found 60-day and 6-month fawn survival rates of 0.33 and 0.22 respectively. **Conclusions.** Survival of translocated captive deer was comparable to rates reported in previous studies that translocated wild deer, although lower than what is found in wild populations that undergo no translocation. Translocated does produced a low number of fawns relative to the national average, although fawn recruitment was within the range of survival rates reported in studies of wild deer. **Implications.** We believe our findings provide a baseline of expectations for captive-deer translocations. Given our results, we believe it is infeasible to expect increased average antler size within this study site by translocating adult female white-tailed deer.

Keywords: captive breeding, fawn recruitment, *Odocoileus virginianus*, reproduction, survival, telemetry, translocation, white-tailed deer.

Introduction

Across the United States and Canada, thousands of captive-deer facilities are producing trophy (i.e. exceptionally large-antlered) white-tailed deer (*Odocoileus virginianus*) through selective breeding and optimal nutrition. These deer are either kept for breeding purposes, sold to other breeding operations, or marketed to private landowners. Owners of high-fence hunting properties will often purchase deer from breeding facilities, with the intention of altering genetics within their deer herd such that males produce larger antlers. Whereas this practice is beyond the reach of most landowners, it is a relatively common practice for owners of commercial or private high-fence hunting properties, also known as shooting preserves. In fact, there are an estimated 10 000 deer breeding facilities in North America, most of which solely produce white-tailed deer (Anderson *et al.* 2007; Adams *et al.* 2016). In the United States alone, the captive-deer industry is estimated to account for about US$44 million in sales (US Department of Agriculture 2014), which is most likely to be a considerable underestimate. Male deer currently have the greatest economic value (e.g. stud fees, trophy harvest, etc.) and therefore create the most demand on the market. Although female deer, or does, clearly play an essential role in the breeding process, does rarely grow antlers and are subject to far less hunting demand. However, does are still a valuable component of the captive-deer industry because they contribute more directly than bucks to growing a deer herd within an enclosure through producing fawns.

While the captive-deer industry is well established, it is not without its fair share of controversy. Proponents of the North American Model of Wildlife Conservation find some aspects of the captive-deer industry to be problematic, specifically that white-tailed deer are a resource intended to be held in the Public Trust (Miller 2012; Adams and Ross 2013). Additionally, some consider the deer breeding industry a threat to the health of wild deer populations (TWS 2012). Given the scale and nature of deer breeding facilities, the risk of spreading economically and socially important diseases to wild deer is a legitimate concern. Accordingly, the captive-deer industry has come under considerable scrutiny and increased legislation because of the cross-country spread of chronic wasting disease (CWD). The captive-deer industry also faces some resistance from the general public on the grounds of ethics. According to multiple surveys, only 20% of American adults support hunting when it occurs within fenced shooting preserves or focuses harvest on trophy male deer (Responsive Management and National Shooting Sports Foundation 2008). The growth of the captive-deer industry may threaten the preservation of the hunting tradition by negatively affecting public perceptions about the hunting experience (Adams *et al*. 2016). Additionally, the trophy deer produced by captive breeders may create unrealistic expectations for new hunters, which could negatively affect hunter recruitment and retention.

Several years ago, captive does were in high demand as shooting preserves tended to have greater interest in increasing deer populations within their enclosures; however, market demand for captive does has declined in recent years. In attempts to promote the sale of does to potential buyers, captive-breeding facilities advertise does for the purpose of enhancing antler genetics in existing deer herds. Does purchased from breeding facilities are likely to have been bred to a large-antlered buck prior to purchase and may also be proven producers of large-antlered progeny. Landowners expect that translocating these does to their property will result in the birth and recruitment of male fawns that will produce large antlers and female fawns that will eventually birth large-antlered males. Because does tend to carry lower market value than do bucks, this option hypothetically gives a landowner the chance to produce trophy bucks at a lesser cost. Additionally, translocated captive does that breed with native bucks in an enclosure in subsequent breeding seasons may pass on large-antlered genetics to resulting fawns, further enhancing antler quality within the herd.

However, the success of purchasing and translocating captive does depends on several assumptions. The first assumption is that once released, the deer will survive in their new environment. Previous studies have demonstrated that post-translocation survival rates can be highly variable depending on a variety of factors, including the level of difficulty acquiring food, capture-related stress or injury, and naivety towards predators (Letty *et al*. 2000; Rosatte *et al*. 2002; Teixeira *et al*. 2007; Short 2009). The next assumption is that if the does do survive, they will successfully recruit fawns into the population. Again, the available literature has shown that translocation can negatively affect recruitment in deer species (Jacobson and Lukefahr 1999; Beringer *et al*. 2002; Larkin *et al*. 2002). If the released does do not survive or fail to recruit fawns, landowners have lost a significant investment. Despite the magnitude of the captive-deer industry, there has been little research to learn about the fate of translocated deer once they leave a captive-breeding facility, because previous studies of translocated white-tailed deer have primarily involved wild deer. These studies are of little use to interested landowners and property managers if captive-reared deer experience different challenges with regards to translocation. Recent theoretical modelling also suggests that altering antler genetics on a property-wide scale by introducing captive deer is an extremely intensive and costly process (Demarais *et al*. 2016).

Understanding survival and recruitment of translocated white-tailed deer is crucial to determining whether this practice might effectively alter antler genetics within the recipient population, as well as furthering our knowledge of the potential impacts of these practices on deer resources. Our goal was to develop knowledge to help inform landowners and property managers interested in supplementing deer from breeding facilities, as well as to inform wildlife agencies tasked with regulating the captive-deer industry. We studied the survival and reproduction of does translocated into a 300-ha high-fence enclosure. Our specific objectives were to examine survival and reproductive rates of translocated captive female deer, as well as survival rates of any offspring produced by these deer.

Materials and methods

Study area

This study was conducted at Agricola Farms, a privately owned, 300-ha shooting preserve located in Tallapoosa County, Alabama, USA. A 2.6-m deer-proof fence was constructed around the perimeter of the property in 2018. The population of white-tailed deer within Agricola Farms (besides the deer translocated in this study) were present or descended from those inside the property at the time of fence construction. Property-wide camera surveys conducted from 2019 to 2021 estimated deer densities to be between 50 and 65 deer/km^2. Ten supplemental feeders containing pelletised feed (16–23% crude protein) and whole kernel corn were available *ad libitum* to deer year-round. Approximately 25 Mg of feed were provided each year. Water was available to deer throughout the property from several creeks and one large pond.

Agricola Farms was situated in the southern extent of the Piedmont Plateau ecoregion and comprised low, rolling hills 180–210 m in elevation. Approximately 70% of the property primarily consisted of 20–40-year-old loblolly pine (*Pinus taeda*) forests treated with low-intensity prescribed fire every 1–3 years. Approximately 10% of the property consisted of mixed-hardwood forests along drainages comprising mainly oak (*Quercus* spp.) and sweetgum (*Liquidambar styraciflua*). About 20 ha of small food plots containing clover (*Trifolium* spp.), rye (*Secale cereale*), and brassicas (*Brassicacae* spp.) were planted seasonally across the study site. The climate in this region of east-central Alabama was moderately warm, with mean high temperatures of 33°C in July and mean low temperatures of −1°C in January. Average annual precipitation in the area was approximately 140 cm.

This property was primarily used by the landowner for recreational deer hunting. Since the fence was constructed, deer hunters and harvest numbers were highly regulated to minimise hunting pressure during the January breeding season. Harvest objectives were based on common trophy deer management principles (Hamilton *et al.* 1995). The landowner harvested 25 native adult does during the first 2 weeks of December 2019 to maintain the population at a desirable level, which was the only hunting effort of the 2019–2020 hunting season. No does were harvested during the 2020–2021 hunting season; however, one mature buck was harvested within <10 hunter-days between November and December 2020.

Translocation

Each February from 2019 to 2021, eight adult female white-tailed deer were translocated from a deer breeding facility in Alabama and released within the study site. Prior to translocation, each doe was live-bred to a breeder buck in the captive facility. Each year, the breeder buck was made available to the does throughout the months of November, December, and early January. Translocated deer were sourced from two breeding facilities, one in 2019 and another in 2020 and 2021.

The deer in our study experienced husbandry conditions typical of white-tailed deer breeding facilities in our area while in captivity. The insecticide permethrin (Martin's Permethrin 10%, Control Solutions Inc., Pasadena, TX, USA) was regularly applied to deer pens in a broadcast fog to reduce transmission of disease from insect vectors. Each deer was administered chlortetracycline (ChlorMax 50, Zoetis Inc., Troy Hills, NY, USA), a broad-spectrum antibiotic, to protect against respiratory and enteric diseases. While in captivity, deer had access to a high-protein feed (18% protein, 6.5% fat, and 10% fibre; Game Pro ND5, Martindale Feed Mill, Valley View, TX, USA) *ad libitum*. Supplemental molasses and soybean oil were also provided to deer in captivity. Although these deer were bred and reared in Alabama, they are believed to have descended from Texas (*Odocoileus virginianus texanus*) and northern USA (*Odocoileus virginianus borealis*) pedigrees.

Female deer were immobilised for translocation via dart gun by using the anesthetic combination of butorphanol tartrate, azaperone tartrate, and medetomidine HCl (BAM™) and ketamine HCl and medetomidine HCl (MK2). We collected body measurements (skull length, tail length, chest girth, right hind foot length, and total body length) to create a body-size profile of each deer prior to translocation. Each deer was also fitted with a vaginal-implant transmitter (VIT; M3930, Advanced Telemetry Systems, Inc., Isanti, MN, USA) and a VHF radio telemetry collar (M2200, Advanced Telemetry Systems, Inc.). After data collection, the deer were administered antibiotics (6cc Resflor, 6cc Exceed, and 1.5cc Draxxin).

We translocated deer on 9 February 2019, 28 March 2020, and 11 February 2021. Each year, all eight deer were transported to the study site in the same trip by using a livestock trailer with four stalls, each containing a pair of deer. Total transport time between the deer breeding facility and study site was 1–2 h. Prior to being loaded into a livestock trailer, deer were administered a drug to reverse anesthetics (Atipamozole). Deer were released from the livestock trailer one stall at a time and were not handled during release.

Fawn capture

The VITs had flexible wings designed to create pressure against the vaginal wall to keep the transmitter from falling out prematurely (Bishop *et al.* 2007). VITs are designed to remain in the cervix until parturition, at which point they are expelled at the approximate birthing site. The VITs were equipped with temperature-sensitive programming to emit 40 pulses/min when temperatures are above 34°C and 80 pulses/min when temperatures are below 30°C. This decline in temperature indicated that the VIT was no longer inside the deer and suggested that parturition had occurred. Once expelled, VITs also emitted an event timer code used to calculate the time of birth to within 30 min. Previous work suggested that VIT monitoring can be an effective method for capturing neonate cervids (Bowman and Jacobson 1998; Carstensen *et al.* 2003; Bishop *et al.* 2011).

One month prior to fawn monitoring, we began familiarising ourselves with the general location of each deer within the enclosure to improve future monitoring efficiency. VIT monitoring began on 15 May of each year and lasted until each VIT was expelled. Any does that had not expelled their VITs by July were assumed to have terminated their pregnancies. We monitored VITs more than four times per day, with no more than 6 h between monitoring events. Haskell *et al.* (2007) found that white-tailed deer fawns typically remain within 100 m of the birth site during the first 12.5 h post-birth, although outliers are possible. Given our monitoring schedule of 6-h intervals, we expected neonate fawns to be within a detectable distance of the birth site by the time we attempted capture. On approaching the birth site, we first attempted to locate the maternal doe by using telemetry equipment because the doe's position often showed hidden fawns (Huegel *et al.* 1985; Carstensen *et al.* 2003). If the doe was not nearby, or no fawns were found near the doe's location, we located the expelled VIT and birth site. If fawns were not visible from the birth site, we began a grid search that encompassed an approximate 100-m radius of the birth site. If a fawn was found, we continued searching for an additional fawn until the entire area had been covered.

In efforts to reduce scent transfer, fawn handling was performed using non-scented nitrile gloves (Powell *et al.* 2005; Saalfeld and Ditchkoff 2007). The weight and sex of the fawn was also recorded. Each fawn was ear-tagged and fitted with a breakaway VHF radio collar (M4210, Advanced Telemetry Systems) designed with stitched pleats that allowed the collar to expand as the fawn grew. We aimed to complete all fawn handling in a timely manner to reduce stress and risk of maternal abandonment.

Monitoring survival

All translocated deer and captured fawns in this study were monitored using radio collars. After ≥6 h of inactivity, radio collars would emit a unique frequency. We monitored survival status of translocated does daily during the first month post-release, which is the period when released deer are most susceptible to stress-related mortality (Jones and Witham 1990; Beringer *et al.* 1996). We monitored fawn survival daily for the first 2 weeks after birth. After this initial monitoring period, monitoring was conducted weekly. Once mortality was detected, we located the site to confirm mortality and retrieve the radio collar. Whenever possible, we tried to determine causes of mortality by examining the carcass for signs of predation (puncture wounds, predator tracks/scat [e.g. bobcats (*Lynx rufus*) or coyotes (*Canis latrans*)]) or disease (oral lesions, emaciation).

We also monitored fawn survival by using camera traps. If we were unable to capture a fawn at the birth site, we utilised image data from camera-traps across the property to estimate fawn production and survival. During mid–late October of each year, we used 14 camera traps (X Series, BuckEye Cam, Athens, OH, USA) distributed throughout the study site to capture images of deer for a property survey. Each camera trap was baited with 22.68 kg of whole kernel corn every 3 days during a 14-day survey period. Parturition dates for native does within the study site were observed to be approximately 2 months after translocated does gave birth. This asynchrony in parturition reduced the likelihood of confusing native and captive-bred fawns. By the time of the camera survey, native fawns were approximately 2.5 months old and captive-bred fawns were approximately 5.5 months old. Native and captive-bred fawns appeared visually distinct in our camera-trap data, because captive-bred fawns molted their neonatal pelage containing spots, whereas native fawn pelage still contained spots (Ditchkoff 2011).

Statistical analysis

All analysis was conducted in Program R (R Core Development Team, ver. 3.4.1, accessed August 2021, www.r-project.org). We estimated 3-, 6-, and 12-month post-translocation survival rates of does by using Kaplan–Meier survival curves, and any individuals with an unknown fate owing to transmitter failure were right censored (Hosmer *et al.* 2008). We used log-rank tests to compare differences in 3-month, 6-month, and 12-month survival curves among years. We evaluated hazards of covariates, such as age, year released, and body size, by using a Cox proportional hazards model for 3-, 6-, and 12-month survival probability (Hosmer *et al.* 2008). We evaluated body size by aggregating body measurements (skull length, tail length, chest girth, right hind foot length, and overall body length) recorded prior to translocation. Overall survival probability was estimated using a Kaplan–Meier survival curve, and any individuals with an unknown fate owing to transmitter failure were right censored (Hosmer *et al.* 2008). We estimated 60-day survival rates of fawns using Kaplan–Meier survival curve without staggered entry. We used a log-rank test to compare 60-day survival curves of fawns among years. Because of the limited sample size and survival rates of capture fawns, we chose not to evaluate the effects of any covariates (e.g. sex, weight at birth, etc.) on fawn survival probability. We also compared age of translocated deer at release among years by using ANOVA.

Results

All deer translocated in our study were living and mobile on release. We reported the known survival and reproductive fate of each deer (Table 1). The average age of these does at the time of translocation was 3.7 years (s.e. = 0.49), ranging from 2 to 12 years, and did not vary among years ($P = 0.15$). The overall survival probability for these animals over the course of this study was 0.48 (95% CI = 0.29–0.70; Fig. 1).

We found that the 3-month post-translocation survival probability of translocated does was 0.79 (95% CI = 0.65–0.97). Three-month survival was 0.75 in 2019, 0.88 in 2020, and 0.75 in 2021 respectively, but there was no evidence for a statistical difference in 3-month survival among years ($X^2 = 0.40$, $P = 0.80$). No covariates were found to be significant predictors of mortality within 3 months, on the basis of a full model including age ($\text{Exp}(\beta) = 1.25$

Table 1. Known survival and reproductive fate of each translocated deer at Agricola Farms, AL, from 2019 to 2021.

ID	Age	Release date	Mortality date	Mortality cause	Date of VIT drop	Fawns captured	Fawns produced	Fawns recruited
A	6	2/9/2019			7/6/2019	1	1	0
B	6	2/9/2019			14/6/2019	0	1	1
C	2	2/9/2019	2/10/2019	Unknown	Premature exp.	–	0	0
D	2	2/9/2019	5/5/2019	Unknown	Premature exp.	–	0	0
E	12	2/9/2019	18/4/2019	Escaped Fence	–	–	–	0
F	2	2/9/2019			17/6/2019	0	0	0
G	7	2/9/2019	15/6/2019	Fence collision	30/5/2019	0	0	0
H	2	2/9/2019	7/9/2019	Unknown	Premature exp.	–	0	0
I	3	3/28/2020			Retained	–	–	0
J	5	3/28/2020	8/10/2021	Escaped Fence	30/5/2020	2	2	0
K	2	3/28/2020			Retained	0	–	0
L	5	3/28/2020			31/5/2020	2	2	0
M	2	3/28/2020	1/7/2021	Unknown	8/6/2020	1	1	0
N	2	3/28/2020	31/3/2020	Capture myopathy	–	–	–	0
O	4	3/28/2020	15/9/2020	Unknown	Retained	–	–	0
P	2	3/28/2020			23/5/2020	0	0	0
Q	2	2/10/2021			Premature exp.	–	0	–
R	2	2/10/2021	28/4/2021	Unknown	–	–	–	0
S	2	2/10/2021	15/8/2021	Unknown	6/9/2021	1	1	1
T	2	2/10/2021	25/8/2021	Unknown	Retained	–	–	0
U	3	2/10/2021			Premature exp.	–	0	–
V	3	2/10/2021			5/29/2021	2	2	1
W	6	2/10/2021			Premature exp.	–	0	–
X	5	2/10/2021	11/2/2021	Capture myopathy	–	–	–	0

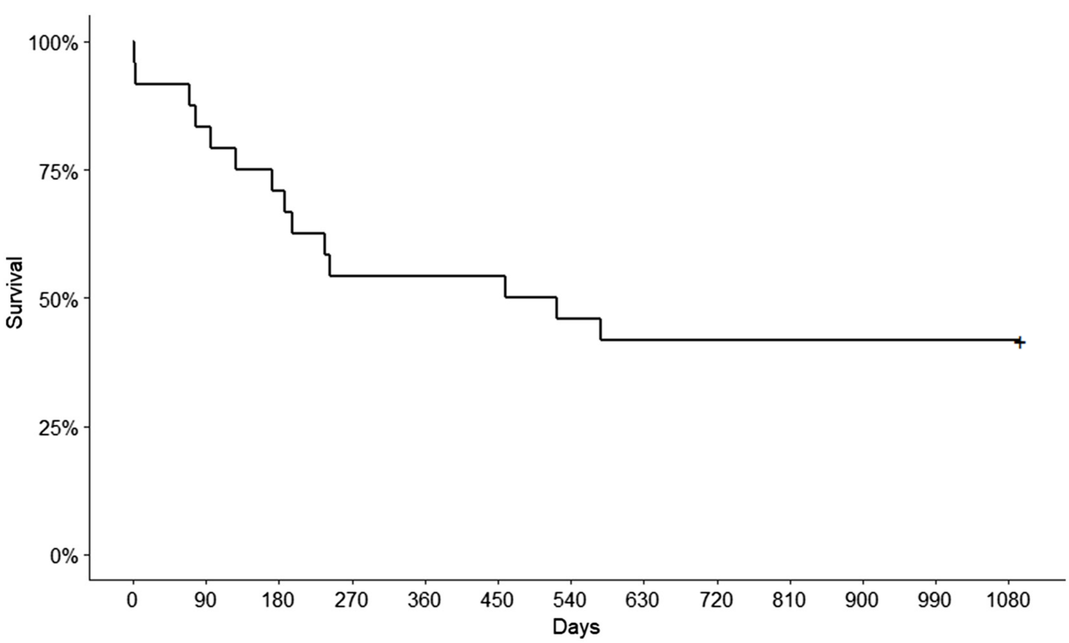

Fig. 1. Post-translocation overall survival of female white-tailed deer at Agricola Farms in Tallapoosa County, AL, during 2019–2021.

[95% CL = 0.86–1.80; P = 0.24), body size (Exp(β) = 0.99 [95% CL = 0.95–1.04; P = 0.69), and year released (Exp(β) = 1.28 [95% CL = 0.37–4.42; P = 0.69). Two mortalities were caused by capture myopathy, and occurred ≤72 h post-release. In April 2019, one doe left the property by escaping the fence. Because this doe was no longer able to contribute to the population within the study site, we treated this event as a mortality (actual mortality was detected within 14 days of escape owing to undeterminable causes). The remaining two mortalities that occurred ≤3 months post-release took place between 60 and 90 days and were of undeterminable causes because of scavenging.

Across years, 6-month adult doe survival was 0.71 (95% CI = 0.55–0.92). Six-month survival was 0.63 in 2019, 0.75 in 2020, and 0.75 in 2021, but there was no evidence for a statistical difference in 6-month survival among years (X^2 = 0.3, P = 0.9). No covariates were found to be significant predictors of mortality within six months, based on a full model including age (Exp(β) = 1.29 [95% CL = 0.94–1.77; P = 0.11), body size (Exp(β) = 0.99 [95% CL = 0.95–1.03; P = 0.67), and year released (Exp(β) = 1.01 [95% CL = 0.35–2.98; P = 0.98).

Each of the three cohorts of deer translocated in this study was subject to mortality within 12 months post-release (Fig. 2). We found the 12-month survival probability of 0.54 (95% CI = 0.38–0.78). Twelve-month survival was 0.38 in 2019, 0.75 in 2020, and 0.50 in 2021, but there was no evidence for a statistical difference in 12-month survival among years (X^2 = 1.8, P = 0.4). No covariates were found to be significant predictors of mortality within 12 months, on the basis of a full model including age (Exp(β) = 1.21 [95% CL = 0.86–1.69; P = 0.27), body size (Exp(β) = 0.95 [95% CL = 0.86–1.04; P = 0.28) and year released (Exp(β) = 0.07 [95% CL = 0.002–2.72; P = 0.16). The only known source of mortality that occurred between 3 and 12 months post-translocation was a fence collision that resulted in fatal spinal injury during June 2019. All other doe mortalities during this period were of undeterminable cause because of scavenging. In October 2021, one additional doe left the property by escaping the fence. Because this doe was no longer able to contribute to the population within the study site, we treated this event as a mortality (the actual mortality was detected within 60 days of escape, as a result of vehicle collision).

In total, six (25%) translocated does prematurely expelled their VITs prior to the fawning season and were censored from analysis. Another four (17%) translocated does are believed to have terminated their pregnancies or never became pregnant, because they retained their VITs well past the possible fawning season. Ten (42%) does expelled their VIT at a birth site, which resulted in the capture of nine fawns over the course of this study (0.9 fawns/VIT). Of these captured fawns, seven (78%) were male. We captured one fawn in 2019, five fawns in 2020, and three fawns in 2021. All successfully captured fawns were located within 6 h of VIT expulsion. Surveys in October detected a total of one

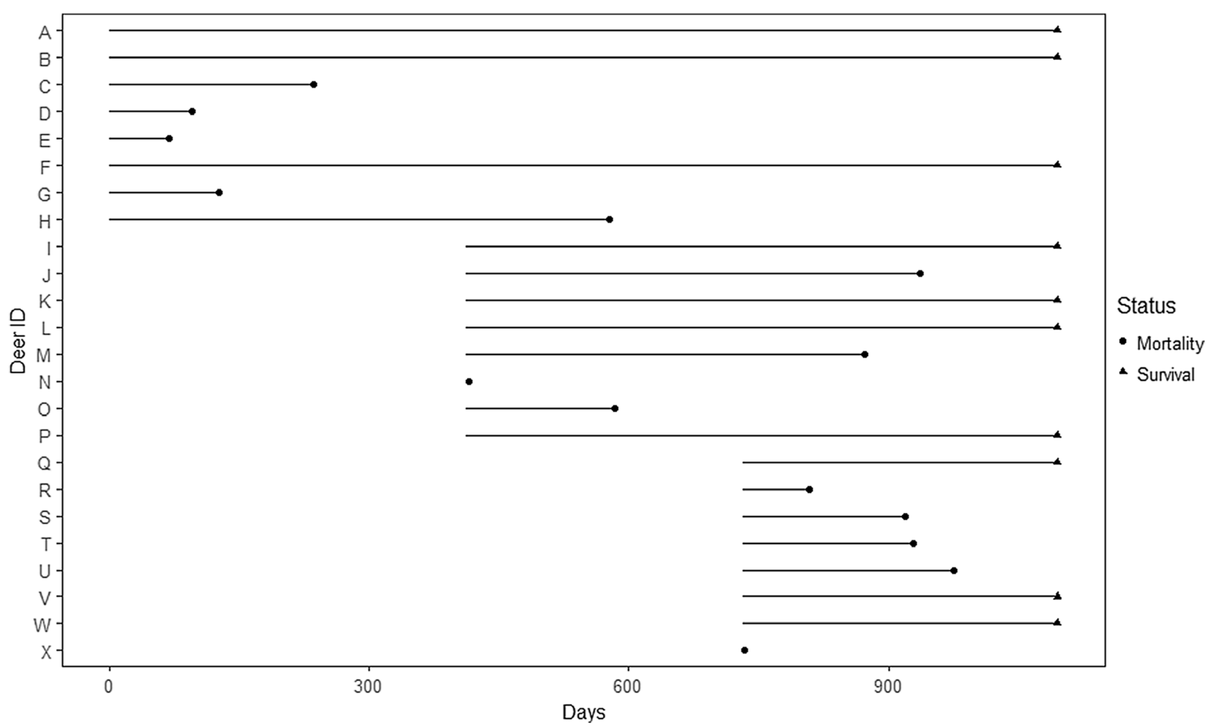

Fig. 2. Timeline depicting survival and mortality of each deer translocated to Agricola Farms in Tallapoosa County, AL, from 2019 to 2021.

additional fawn born to translocated does the year of translocation, beyond those that were captured. All known birthing events occurred from 30 May to 17 June (2019), 23 May to 8 June (2020), and 29 May to 9 June (2021). These date ranges do not include potential births following premature VIT expulsion. We found no significant effects of age (P = 0.94), fitness (P = 0.12), or year of release (P = 0.25) on fawn production of translocated does.

Across years, 60-day survival for captured fawns was 0.33 (95% CI = 0.132–0.84). Sixty-day survival for captured fawns was 0.0 in 2019, 0.0 in 2020, and 1.0 in 2021, but there was no evidence for a statistical difference in 60-day fawn survival among years (X^2 = 7.9, P = 0.20). All fawns captured in 2019 and 2020 experienced mortality within 30 days of capture. We found a 6-month fawn survival of 0.22 (95% CI = 0.065–0.75; Fig. 3). We were unable to determine the cause of mortality for these fawns because of scavenging. On the basis of camera-trapping data, we determined that one non-captured fawn born in 2019 survived beyond 6 months. In addition to this one non-captured fawn, an additional three fawns were detected by camera-traps in October 2020. These three fawns were born to two does translocated in 2019 that bred with native bucks within the study site during their first post-release breeding season.

Discussion

Although rates of adult doe survival in our study were relatively low compared with what we would expect in a wild population (Kilgo et al. 2016), they were greater than what has been reported in most prior deer translocation research (Hawkins and Montgomery 1969 [0.32]; O'Bryan and McCullough 1985 [0.15]; McCall et al. 1988 [0.38]; Jones and Witham 1990 [0.34]; Beringer et al. 2002 [0.30]). However, several factors that led to lesser survival rates in past investigations were not present at this study site. For instance, others have reported vehicle collision accounting for 9–36% of mortalities within 12 months post-release (O'Bryan and McCullough 1985; Ishmael et al. 1995; Beringer et al. 2002). Similarly, hunting-associated mortality was the source of >50% of translocated deer mortalities in some studies (Ishmael et al. 1995; Beringer et al. 2002). Neither hunting nor vehicle collision were factors in this study given the private, controlled conditions of the study site. All roads and trails within Agricola Farms were rugged, unpaved, and received fairly minimal use at low speeds, therefore limiting the potential for deer–vehicle collisions. Although some hunting occurred on site during this study, translocated does were clearly identifiable because of their ear-tags and radio-collars, and were deliberately protected from harvest.

White-tailed deer are fairly susceptible to capture myopathy (Beringer et al. 1996), and capture myopathy was attributed to two (8%) translocated doe mortalities during our study. Previously reported rates of capture myopathy for white-tailed deer during relocation/translocation have ranged from 0 to 50% (O'Bryan and McCullough 1985 [23%]; McCall et al. 1988 [0%]; Jones and Witham 1990 [12%]; Ishmael et al. 1995 [4%]; Cromwell et al. 1999 [48%]; Beringer et al. 2002 [29%]). Studies that experienced high rates of capture myopathy (>10%) employed deer capture methods such

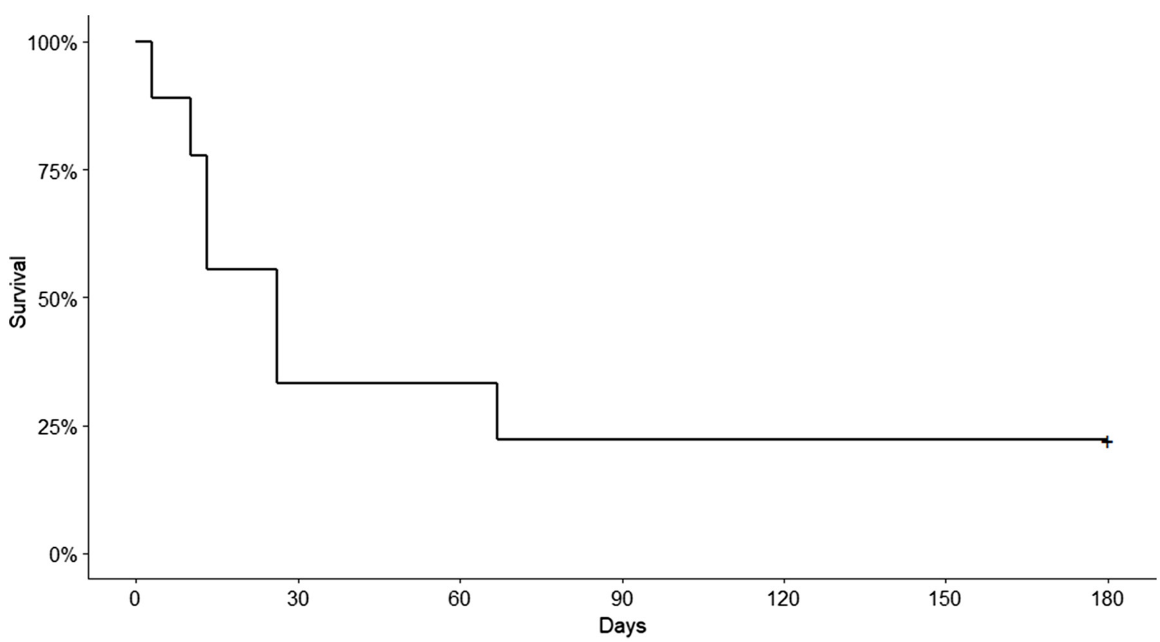

Fig. 3. Survival of white-tailed deer fawns from birth to 6 months at Agricola Farms in Tallapoosa County, AL, during 2019–2021.

as collapsible clover traps (O'Bryan and McCullough 1985), rocket nets (Jones and Witham 1990; Cromwell *et al.* 1999), or a combination of the two (Beringer *et al.* 2002), which were not used in our study. Captured deer that undergo relocation/translocation have also experienced greater rates of capture myopathy than do captured, non-transported deer (Cromwell *et al.* 1999; Beringer *et al.* 2002). Cause-specific mortality of 8 (62% of adult doe mortalities) of the translocated does in this study, all of which died >1-month post-release, could not be determined because of the degree of scavenging prior to discovery. While it is less probable that the acute effects of capture myopathy caused mortality for these deer >1-month post-capture (Bartsch *et al.* 1977; Harthoorn 1977), chronic stress resulting from translocation to a novel environment could lead to increased vulnerability to other mortality factors such as predation, disease, and starvation (Teixeira *et al.* 2007; Dickens *et al.* 2010).

The captive background of the deer translocated in this study may have created additional challenges for survival. Innate resistance to haemorrhagic diseases has been shown to vary in white-tailed deer at the subspecies level (Gaydos *et al.* 2002). For instance, northern white-tailed deer (*Odocoileus virginianus borealis*) are more likely to present severe clinical signs or experience mortality from epizootic haemorrhagic disease (EHD) than are Texas white-tailed deer (*Odocoileus virginianus texanus*; Gaydos *et al.* 2002). As previously described, the deer translocated in this study were believed to descend from both Texas and northern lineages, which raises questions regarding their innate resistance to this disease, which is known to be present within the region this study took place (Zhang 2017). Additionally, the diet of the deer while in captivity would have comprised almost entirely high-protein pelleted feed. Once they had been translocated, the quantity of native vegetation in their diet would likely have increased substantially, despite availability of pelleted feed in their new environment. Rapid shifts in the diet of ruminants can present nutritional challenges owing to a lag in shifting of rumen microflora (Grilli *et al.* 2016). Tajima *et al.* (2001) suggested that it can be up to 4 weeks before rumen microflora fully adjust to a new diet. However, we believe the dietary shift experienced by deer in this study would have had only minor effects, given the *ad libitum* access to high protein feed within the study site.

We assumed that all translocated does were successfully bred in captivity, although nearly 17% of our does retained their VITs beyond possible parturition dates. Pregnancy rates for adult white-tailed deer are often 85–100% in wild populations (Roseberry and Klimstra 1970; Nixon 1971; Haugen 1975; Green *et al.* 2017). While we could find no data regarding pregnancy rates for naturally inseminated, captive white-tailed deer, Jacobson *et al.* (1989) reported that artificial insemination (AI) of captive white-tailed deer led to a 75% pregnancy rate. Pregnancy rates in cattle resulting from AI and live-breeding are similar (Williamson *et al.* 1978). We were unable to confirm overall reproductive rates for translocated does in this study because of premature VIT expulsion. However, our captured fawns/VIT rate of 0.9 was similar to rates previously reported in the literature (Cartensen *et al.* 2003 [1.25]; Saalfeld and Ditchkoff 2007 [1.28]; Jackson and Ditchkoff 2013 [0.8]).

Stress associated with capture, handling, transport, and release of pregnant does into a novel environment can produce severe prenatal consequences. Whereas multiple chemical immobilisations of captive, pregnant white-tailed deer produced no measurable effect on length of gestation or fawn survival (DelGiudice *et al.* 1986), prolonged elevations of the stress hormone glucocorticoid have been shown to effectively halt gestation in some animals (Sapolsky 1992; Hayssen 1998; Lima 1998; Romero and Wingfield 2001). Red deer (*Cervus elaphus*) farms in New Zealand commonly experience low reproductive success (e.g. <50% weaning rate) for several years within herds of deer recently captured from the wild (Asher *et al.* 1996). Although deer in this study experienced the reverse translocation protocol as the New Zealand example (captive-to-wild vs wild-to-captive), reproductive success may have still been affected by their release to a novel environment. Because capture myopathy was a contributing factor to translocated doe mortality in this study, we believe it is possible that is also led to pregnancy termination in some does, without being severe enough to result in death. Additionally, white-tailed deer have been found to adhere to social hierarchies that often benefit the fitness of socially dominant individuals (Robinson 1962; Taillon and Côté 2007; Donohue *et al.* 2013). In high-density populations, quality fawning cover may be more accessible to socially dominant females that exclude subdominant individuals from these areas (Ozoga *et al.* 1982). If does translocated in this study ranked low within the social dominance hierarchy of the study site, it is possible that these deer were forced to occupy suboptimal habitat during fawn-rearing, which may have affected reproductive success.

In addition to low reproductive success in translocated does, fawns that were successfully birthed experienced low survival, which is an obvious concern for translocation programs involving female deer. Six-month fawn survival (22%) was on the low end of the estimates reported in other studies conducted in the south-eastern USA, which were 20–35% (Saalfeld and Ditchkoff 2007; Kilgo *et al.* 2012; Jackson and Ditchkoff 2013). White-tailed deer studies in the south-eastern USA have found fawn recruitment rates between 0.4 and 1.2 fawns/doe (Howze 2009; Kilgo *et al.* 2012; McCoy *et al.* 2013). We found a fawn:doe ratio of 0.16, which is far lower than what has generally been reported in similar studies. Unlike 6-month survival rates, a fawn:doe ratio captures the number of viable does in the measurement. For this reason, we believe that our fawn:doe ratio is a more accurate reflection of fawn recruitment because it relates to the efficacy of a translocation program. (Table 1).

Our study site contained a population of coyotes (*C. latrans*) and bobcats (*L. rufus*), both of which are known predators of neonate white-tailed deer in the south-eastern USA (McCoy *et al.* 2013). Because the fawns in this study were born approximately 2 months prior to the native fawning season, it is possible that this small, asynchronous fawn crop may not have benefited from the protective effect of prey saturation and, therefore, may have experienced greater rates of predation (Mylrea 1991; Asher *et al.* 1996). Additionally, maternal does unsuccessful at recruiting fawns often fail to exhibit prolonged evasive or aggressive behaviour towards predators (Ozoga *et al.* 1982). The aggressive tendencies of maternal does to defend neonates against perceived predators has been well documented in free-ranging populations (Grovenburg *et al.* 2009; Hubbard and Nielsen 2009), but captive-reared does may be less likely to display defensive aggression because of greater naivety toward predators. Reduced antipredator reactions have previously been observed in animals translocated from captive-breeding facilities. Zidon *et al.* (2009) found that post-translocation antipredator reactions were suppressed in Persian fallow deer (*Dama mesopotamica*) sourced from a heavily visited public zoo compared with a group sourced from a breeding preserve with limited human interactions. We believe that the captive background of the translocated does may have led to reduced effort to conceal and defend fawns, which may have exacerbated the diminished effect of prey saturation because of asynchronous timing of parturition.

Recruitment rates of translocated white-tailed deer have been rarely examined in past work. Beringer *et al.* (2002) found a greater recruitment rate in translocated deer (0.96 fawns/doe) than resident deer (0.86 fawns/doe) in the same study. The authors attributed this difference in recruitment to density-dependent factors, because translocated deer were released into an area with an estimated density of four deer per square kilometre, whereas resident deer in the study occupied an area with an estimated 31 deer/km^2 (Beringer *et al.* 2002). October camera surveys detected deer densities in excess of 50 deer/km^2 within the study site in 2019 and 2020. The influence of deer density on fawn recruitment has been well examined, with many studies suggesting that per capita fawn recruitment rates may be inversely related to deer density (Dusek *et al.* 1989; Fryxell *et al.* 1991; Keyser *et al.* 2005).

Despite asynchrony between breeding seasons of translocated and wild deer at the study site, camera-survey data suggested that breeding successfully occurred between these two groups in the years following translocation. Images from the October 2020 camera survey detected three fawns born to does translocated in 2019. These fawns were detected daily in close association with their maternal, translocated does throughout the survey. Even though these fawns were sired by wild bucks native to the study site, they still theoretically possess ‘trophy’ genetics from the maternal doe. However, in light of Demarais *et al.* (2016), it is improbable that these individuals would produce any measurable increase to average antler size within a property. Given the observed differences in parturition dates between translocated and native deer within the study site, it is likely that the deer breeding season will be substantially prolonged within this property. Although a protracted breeding season will offer a longer period when bucks may be more susceptible to harvest, this also may lead to greater post-rut mortality (Strickland and Demarais 2006).

Our translocation protocol followed the industry standard for releasing captive deer onto private land in the south-eastern United States. Specifically, translocation of adult does normally occurs in late winter (February–March) after conception occurs in the source facility. Many captive-deer breeders also believe that translocating does in the early stages of pregnancy results in lower rates of pregnancy termination than does translocating later in gestation; however, we found no scientific evidence to support this theory. In the south-east, late winter may also provide the most optimal weather conditions for translocating deer because high temperatures during other times of the year can stress deer during transport. Additionally, this timeframe roughly corresponds with spring green-up in this region, providing ample foraging opportunities for deer.

Our findings may be a consequence of all translocated deer coming from two similar breeding facilities. Additionally, our results may be biased as a result of releasing all translocated deer onto the same property. Another limiting factor of our data was the premature expulsion of VITs. Premature VIT expulsion has been well documented in past cervid reproductive studies, and our reported rate of premature VIT expulsion (25%) is comparable to that in past studies (Bishop *et al.* 2007, 2011; Dion *et al.* 2019). Potential causes of premature VIT expulsion include improper insertion during placement, early dilation leading up to birth, mechanical self-removal, or removal by other deer. Future research should seek to improve understanding on specific causes of mortality in captive-to-wild translocation programs. The use of real-time GPS technology may assist in quicker detection of mortality, resulting in less scavenging prior to discovery.

This research was intended to provide insight into a common, yet largely unexamined, practice within the realm of white-tailed deer management and husbandry. The survival rates of translocated does, coupled with poor offspring survival, bring the efficacy of the translocation practice into major question. On the basis of our findings, purchasing and translocating deer from captive-breeding facilities is a costly procedure that may be supported only by exceedingly marginal benefits to any genetic enhancement or herd supplementation program. Although the fawn production and recruitment we observed in this study may be considered dismal to buyers of captive female deer, our data suggested that translocated deer may still be reproductively viable with surrounding native deer, even if breeding seasons do not perfectly align. However, resulting progeny would not be sired by trophy-antlered, captive-breeder bucks, thereby diluting the effects of introducing genetics from captive-breeding facilities. Although not directly examined in this study, the risk of disease transmission should be considered in any translocation program. Our findings suggested that the efficacy of translocating captive female white-tailed deer to a shooting preserve to enhance antler genetics may be impractical, if not infeasible. Each of the 24 does sourced from a captive-breeding facility cost US$3500, a price that we believe fairly represents this category of deer marketed in the region and time that this study was conducted. Demarais *et al.* (2016) simulated a cost of US$5600 per 1″ increase in average Boone and Crockett antler score in fenced population of 200 deer. However, this model was estimated using an annual doe survival of 0.88 and a recruitment rate of 1.5 fawns/doe. The cost to benefit estimate generated in the Demarais *et al.* (2016) model would be exponentially greater considering the lower survival/reproductive success reported in this study. We believe that increasing average antler size within a deer population is possible through following quality deer management principles, as well as appropriate habitat management strategies, which may be more efficient and less costly alternatives to captive-translocation programs.

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Data availability. The data that support this study will be shared upon reasonable request to the corresponding author.

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