Translocating Captive Female White-tailed Deer

and

Training and Experience Increase Classification Accuracy in White-tailed Deer Camera Surveys

by

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Abstract

Thousands of captive white-tailed deer (*Odocoileus virginianus)* facilities exist across North America for the purpose of producing trophy-quality 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 white-tailed deer experience highly variable survival and reproductive success post-translocation, however, little is known about the fate of translocated white-tailed deer sourced from captive-breeding operations. We translocated 24 adult female deer over a 3-year period into a private, 300-ha high-fence enclosure in east-central Alabama. We monitored survival, reproductive success, and fawn recruitment of the translocated deer using VHF radio collars and vaginal implant transmitters (VITs). We found that survival rates were greater than studies where deer were translocated from the wild, but fawn survival and recruitment was poor. We believe our findings provide a baseline of expectations for captive deer translocations. Our following research objectives focus on improving camera survey output for white-tailed deer by reducing sex-age misclassifications. Previous research suggests that misclassifications may be an important source of error in wildlife camera surveys. We developed and tested the effects of species-specific training material designed to reduce sex-age misclassification associated with white-tailed deer images. We found exposure to training material produced the greatest significant improvement on classification accuracy of deer images compared to any other respondent-based factors we investigated. We also found that other experiential factors were positively associated with classification accuracy of deer images. Our findings suggest that use of species-specific training material can reduce misclassifications, leading to more reliable data.

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Chapter 1: Translocating Captive Female White-tailed Deer

Abstract

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. 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 using VHF radio collars and vaginal implant transmitters (VITs). We found a 12-month survival rate of 0.56 for translocated deer. We captured 9 fawns throughout our study, leading to a rate of 0.9 fawns/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. We believe our findings provide a baseline of expectations for captive deer translocations.

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. While 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 $44 million in sales (U.S. Department of Agriculture 2014), which is most likely a considerable underestimate. Male deer currently have the greatest economic value (stud fees, trophy harvest, etc.) and therefore create the most demand on the market. While 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 as 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 and growing, 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 due to 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. Since does tend to carry lower market value than 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 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 2006; 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 impact 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, as previous studies of translocated white-tailed deer have primarily involved wild deer. These studies are of little use to interested landowners and property managers since captive-reared deer likely experience different challenges with regards to translocation. Recent theoretical modeling 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.

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 2019-2021 estimated deer densities between 50-65 deer/km^2. Ten supplemental feeders containing pelletized feed (16 - 23% crude protein) and whole kernel corn were available ad libitum to deer year-round. Approximately 25 metric tons 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 was comprised of low, rolling hills 180-210 m in elevation. The property primarily consisted of 20- to 40-year-old loblolly pine (*Pinus taeda*) forests treated with low-intensity prescribed fire every 1–3 years. The study site also consisted of mixed-hardwood forests along drainages comprised mainly of 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 minimize 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 two 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-December 2020.

Methods

Translocation

Each February from 2019-2021, 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 was regularly applied to deer pens in a broadcast fog to reduce transmission of disease from insect vectors. Each deer was administered ChlorMax 50 (Chlortetracycline), 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% fiber) ad libitum. Supplemental molasses and soybean oil were also provided to deer in captivity. While these deer were bred and reared in Alabama, they are believed to have descended from Texas and northern U.S. pedigrees.

Female deer were immobilized for translocation via dart gun using the anesthetic combination of BAM™ (Butorphanol tartrate, Azaperone tartrate, and Medetomidine HCl) and MK2 (Ketamine HCl and Medetomidine HCl). 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) and a VHF radio telemetry collar (M2200, Advanced Telemetry Systems, Inc., Isanti, MN). 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 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 hours. 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/minute when temperatures are above 34° C and 80 pulses/minute when temperatures are below 30° C. This decline in temperature indicated 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 minutes. 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 familiarizing 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 ≥4 times/day, with no more than six hours 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 hours post-birth, although outliers are possible. Given our monitoring schedule of six-hour intervals, we expected neonate fawns to be within a detectible distance of the birth site by the time we attempted capture. Upon approaching the birth site, we first attempted to locate the maternal doe using telemetry equipment as the doe's position often revealed 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 nonscented 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, Isanti, MN) 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 hours 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 two 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) or disease (oral lesions, emaciation).

We also monitored fawn survival using camera traps. If we were unable to capture a fawn at the birth site, we utilized 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) 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 two 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, since captive-bred fawns molted their neonatal pelage containing spots, while native fawn pelage still contained spots (Ditchkoff 2011).

Statistical analysis

All analysis was conducted in Program R (R Core Development Team, version 3.4.1 accessed Aug 2021). We estimated 3-, 6-, and 12-month post-translocation survival rates of does using Kaplan-Meier survival curves, and any individuals with an unknown fate due 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 between years. We evaluated hazards of covariates, such as age, year released, and body size, 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 due 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 between years. Due to 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 between years using an analysis of variance (ANOVA) test.

Results

All deer translocated in our study were living and mobile upon release. We reported the known survival and reproductive fate of each deer (Appendix A). The average age of these does at the time of translocation was 3.7 years (SE = 0.49), ranged from 2-12 years, and did not vary between 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) (Figure 1.1).

We found 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, but there was no evidence for a statistical difference in 3-month survival between years ($X^2 = 0.40$, $p = 0.80$). No covariates were found to be significant predictors of mortality within 3 months, based on a full model including age (Exp(β) = 1.25 [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 hours post-release. In April 2019, one doe left the property by escaping the fence. Since 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 due to undeterminable causes). The remaining two mortalities that occurred ≤3 months post-release took place between 60-90 days and were of undeterminable causes due to 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 between years ($X^2 = 0.3$, $p = 0.9$). No covariates were found to be significant predictors of mortality within 6 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; $p = 0.98$).

We found the 12-month survival probability of 0.50 (95% CI = 0.37 – 0.97). Twelve-month survival was 0.38 in 2019 and 0.75 in 2020, but there was no evidence for a statistical difference in 6-month survival between years ($X^2 = 1.7$, $p = 0.2$). No covariates were found to be significant predictors of mortality within 12 months, based on 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 3-12 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 due to scavenging. In October 2021, one additional doe left the property by escaping the fence. Since 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 60 days of escape due to vehicle collision). Each of the three cohorts of deer translocated in this study were subject to mortality within 12 months post-release (Figure 1.2).

A total of 6 (25%) translocated does prematurely expelled their VITs prior to the fawning season and were censored from analysis. Another 4 (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 9 fawns over the course of this study (0.9 fawns/VIT). Of these captured fawns, 7 (78%) were male. We captured 1 fawn in 2019, 5 fawns in 2020, and 3 fawns in 2021. All successfully captured fawns were located within 6 hours of VIT expulsion. Surveys in October detected a total of one additional fawn born to translocated does the year of translocation beyond those that were captured. All known birthing events occurred from 30 May– 17 June (2019), 23 May– 8 June (2020), and 29 May– 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 six-month fawn survival of 0.22 (95% CI = 0.065-0.75; Figure 1.3). We were unable to determine cause of mortality for these fawns due to scavenging. Based on 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 Oct. 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 to 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 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. Though some hunting occurred on site during this study, translocated does were clearly identifiable due to 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 0–50% (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 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 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 due to degree of scavenging prior to discovery. While it's 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. 2006; Dickens et al. 2010).

We assumed that all translocated does were successfully bred in captivity, though 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, Jacobsen 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 due to premature VIT expulsion. However, our captured fawns/VIT rate of 0.9 was similar to previously rates 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. While multiple chemical immobilizations of captive, pregnant white-tailed deer produced no measurable effect on length of gestation or fawn survival (DelGuidice 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 relatively low reproductive success (e.g., <50% weaning rate) for several years within herds of deer recently captured from the wild (Asher et al. 1996). While 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. Since capture myopathy was a contributing factor to translocated doe mortality in this study, we believe it is possible to have also led to pregnancy termination in some does without being severe enough to result in death.

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 southeastern U.S., which were 20-35% (Saalfeld and Ditchkoff 2007, Kilgo et al. 2012, Jackson and Ditchkoff 2013). White-tailed deer studies in the southeastern U.S. have found fawn recruitment rates between 0.4 – 1.2 fawns/doe (Howze et al. 2009, Kilgo et al. 2012, McCoy et al. 2013). We found a fawn/doe ratio of 0.16, which is far less 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 as it relates to the efficacy of a translocation program.

Our study site contained a population of coyotes (*Canis latrans*) and bobcats (*Lynx rufus*), both of which are known predators of neonate white-tailed deer in the southeastern U.S. (McCoy et al. 2013). Since 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 behavior toward 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 due to greater naivety toward predators. Reduced antipredator reactions have previously been observed in animals translocated from captive-breeding facilities. Zidon et al. (1996) found that post-translocation antipredator reactions were suppressed in Persian fallow deer (*Dama mesopotamica*) sourced from a heavily visited public zoo compared to 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 due to 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 attribute this difference in recruitment to density-dependent factors, as translocated deer were released into an area with an estimated 4 deer/km^2, while 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 3 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 breeding between translocated and native deer within the study sight, it is likely that the deer breeding season will be substantially prolonged within this property. While a protracted breeding season will offer a longer period that 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 southeastern 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 compared to later in gestation; however, we found no scientific evidence to support this theory. In the Southeast, late winter may also provide the most optimal weather conditions for translocating deer since high temperatures during other times of the year can stress deer during transport.

Our findings may be a consequence of all translocated deer coming from two similar breeding facilities. Additionally, our results may be biased due to 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 past studies (Bishop et al. 2007, Bishop et al. 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. Based on our findings, purchasing and translocating deer from captive breeding facilities is a costly procedure that may only be supported by exceedingly marginal benefits to any genetic enhancement or herd supplementation program. While the fawn production and recruitment we observed in this study may likely be considered dismal to buyers of captive female deer, our data suggests that translocated deer may still be reproductively viable with surrounding native deer, even if breeding seasons don’t 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. This study may be of particular relevance in the event that translocating white-tailed deer from captive sources is deemed necessary to restock diminished/extirpated wild populations. We hope that our findings also provide insight and a foundation of expectations to organizations and agencies involved with conducting, managing, or regulating white-tailed deer translocation.

Management Implications

Our findings suggest 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 $3,500, a price 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 $5,600 per 1” increase in average Boone & 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.

Literature Cited

Adams, K., and M. Ross. 2013. QDMA's whitetail report 2013. Quality Deer Management, Bogart, Georgia, USA.

Adams, K. P., B. P. Murphy, and M. D. Ross. 2016. Captive white-tailed deer industry – Current status and growing threat. Wildlife Society Bulletin 40: 14-19.

Anderson, D. P., B. J. Frosch, and J. L. Outlaw. 2007. Economic impact of the Texas deer breeding industry. Texas A&M University, Agricultural and Food Policy Center Research Report 07-3, College Station, USA.

Asher, G. W., M. W. Fisher, and P. F. Fennessy. 1996. Environmental constraints on reproductive performance of farmed deer. Animal Reproductive Science 42: 35-44.

Barbknecht, A. E., W. S. Fairbanks, J. D. Rogerson, E. J. Maichak, and L. L. Meadows. 2010. Effectiveness of vaginal-implant transmitters for locating elk parturition sites. Journal of Wildlife Management 73: 144-148.

Bartsch, R. C., E. E. McConnell, G. D. Imes, and J. M. Schmidt. 1977. A review of exertional rhabdomyolysis in wild and domestic animals and man. Veterinary Pathology 14: 314-324.

Beringer, J., L. P. Hansen, W. Wildling, J. Fischer and S. L. Sheriff. 1996. Factors affecting capture myopathy in white-tailed deer. The Journal of Wildlife Management 60: 373-380.

Beringer, J., L. P. Hansen, J. A. Demand, J. Sartwell, M. Wallendorf, and R. Mange. 2002. Efficacy of Translocation to Control Urban Deer in Missouri: Costs, Efficiency, and Outcome. Wildlife Society Bulletin 30: 767-774.

Blumstein, D. T., M. Letnic, and K. E. Moseby. 2019. *In situ* predator conditioning of naive prey prior to reintroduction. Philosophical Transactions of the Royal Society B: Biological Sciences 374: 1-8.

Bishop, C. J., D. J. Freddy, G. C. White, T. R. Stephenson, L. L. Wolfe, and B. E. Watkins. 2007. Using vaginal implant transmitters to aid in capture of mule deer neonates. Journal of Wildlife Management 71:945–954.

Bishop, C. J., C. R. Anderson, Jr., D. P. Walsh, E. J. Bergman, P. Kuechle, and J. Roth. 2011 Effectiveness of a redesigned vaginal implant transmitter in mule deer. The Journal of Wildlife Management 75: 1797-1806.

Bowman J. L., and H. A. Jacobson. 1998. An improved vaginal-implant transmitter for locating white-tailed deer birth sites and fawns. Wildlife Society Bulletin 26: 295–298.

Breed, D., L. C. R. Meyer, J. C. A. Steyl, A. Goddard, R. Burroughs, and T. A. Kohn. 2019. Conserving wildlife in a changing world: Understanding capture myopathy-a malignant outcome of stress during capture and translocation. Conservation Physiology 7:coz027.

Champagnon, J., M. Guillemain, J. Elmberg, G. Massez, F. Cavallo, and M. Gauthier-Clerc. 2012. Low survival after release into the wild: assessing "the burden of captivity" on mallard physiology and behavior. European Journal of Wildlife Research 58: 255-267.

Chiarello, A. G, D. J. Chivers, C. Bassi, M. A. F. Maciel, L. S. Moreira, and M. Bazzalo. 2004. A translocation experiment for the conservation of maned sloths, *Bradypus torquatus* (Xenarthra, Bradypodidae). Biological Conservation 118: 421-230.

Cromwell, J. A., R. J. Warren, and D. W. Henderson. 1999. Live-capture and small-scale relocation of urban deer on Hilton Head Island, South Carolina. Wildlife Society Bulletin 27: 1025-1031.

DelGuidice, G. D., L. D. Mech, W. J. Paul, and P. D. Karns. 1986. Effects on fawn survival of multiple immobilizations of captive pregnant white-tailed deer. Journal of Wildlife Diseases 22: 245-248.

Demarais, S., B. K. Strickland, S. L. Webb, T. Smith, and C. MacDonald. 2016. Simulated effects of releasing pen-raised deer into the wild to alter population-level antler size. Wildlife Society Bulletin 40: 41-49.

Dion, J. R., J. M. Haus, J. E. Rogerson, and J. L. Bowman. 2019. An initial performance review of vaginal implant transmitters paired with GPS collars. Animal Biotelemetry 7: 22.

Ditchkoff, S. S. 2011. Anatomy and Physiology. Pages 43-73 in D. G. Hewitt, editor. Biology and management of white-tailed deer. CRC Press, Boca Raton, Florida, USA.

Dusek, G. L., R. J. MacKie, J. D. Herriges, Jr., and B. B. Compton. 1989. Population ecology of white-tailed deer along the Lower Yellowstone River. Wildlife Monographs 104: 3-68.

Foley, A. M., B. Pierce, D. G. Hewitt, R. W. DeYoung, T. A. Campbell, M. W. Hellickson, J. Feild, S. Mitchell, M. A. Lockwood, and K. V. Miller. 2008. Survival and movements of translocated white-tailed deer in south Texas. 2008 Proceedings of Annual Conference, SEAFWA, pp. 25-30.

Fryxell, J. M., D. J. T. Hussell, A. B. Lambert, and P. C. Smith. 1991. Time lags and population fluctuations in white-tailed deer. Journal of Wildlife Management 55: 377-385.

Green, M. L., A. C. Kelly, D. Satterthwaite-Phillips, M. B. Majerovic, P. Shelton, J. Novakofski, and N. Mateus-Pinilla. 2017. Reproductive characteristics of female white-tailed deer (*Odocoileus viginianus*) in the Midwestern USA. Theriogenology 94: 71-78.

Grovenburg, T. W., J. A. Jenks, C. N. Jacques, R. W. Klaver, and C. S. Swanson. 2009. Aggressive defensive behavior by free-ranging white-tailed deer. Journal of Mammalogy 90: 1218-1223.

Hamilton, J., W. M. Knox, and D. C. Guyunn, Jr. 1995. Harvest strategies. Pages 24-46 in Quality Whitetails. Stackpole Books, Mechanicsburg, PA, USA.

Harthoorn, A. M. 1977. Problems relating to capture. Animal Regulated Studies 1: 23-46.

Haskell, S. P., W. B. Ballard, D. A. Butler, N. M. Tatman, M. C. Wallace, C. O. Kochanny, and O. J. Alcumbrac. 2007. Observations on capturing and aging deer fawns. Journal of Mammalogy 88: 1482–1487.

Haugen, A. O. 1975. Reproductive performance of white-tailed deer in Iowa. Journal of Mammalogy 56: 151-159.

Hawkins, R. E., and G. G. Montgomery. 1969. Movements of translocated deer as determined by telemetry. Journal of Wildlife Management 33: 196-203.

Hayssen, V. 1998. Effect of transatlantic transport on reproduction of agouti and nonagouti deer mice, *Peromyscus maniculatus*. Laboratory Animals 32: 55-64.

Hosmer, D. W., S. Lemeshow, and S. May. 2008. Applied survival analysis: regression modeling of time to event data, 2nd edition. Wiley-Interscience, New York, New York, USA.

Hubbard, R. D., and C. K. Nielsen. 2009. White-tailed deer attacking humans during the fawning season: a unique human-wildlife conflict on a university campus. Human-Wildlife Conflicts 3: 129-135.

Huegel, C. N., R. B. Dahlgren, and H. L. Gladfelter. 1985. Use of doe behavior to capture white-tailed deer fawns. Wildlife Society Bulletin 13: 287–289.

Ishmael, W. E., and O. J. Rongstad. 1984. Economics of an urban deer-removal program. Wildlife Society Bulletin 12: 394-398.

Ishmael, W. E., D. E. Katsma, and T. A. Isaac. 1995. Live-capture and translocation of suburban white-tailed deer in River Hills, Wisconsin. *In* J.B. McAninch editor. Urban Deer: A Manageable Resource? Proceedings of the 55th Symposium of the Midwest Fish and Wildlife Conference, 12-14 Dec. 1993. St Louis, MO: North Central section of The Wildlife Society, pp. 87-96.

International Union for Conservation of Nature. 1996. IUCN/SSC guidelines for re-introductions. In: Proceedings of the 41st Meeting of the IUCN Council. Gland Switzerland, May 1995.

Jackson, A. M., and S. S. Ditchkoff. 2013. Survival estimates of white-tailed deer fawns at Fort Rucker, Alabama. American Midland Naturalist 170:184-190.

Jacobsen, H. A., and S. D. Lukefahr. 1999. Genetics research on captive white-tailed deer at Mississippi State University. *In* D. Rollins, editor. Proceedings of the symposium on the role of genetics in white-tailed deer management. Second edition. Texas Agricultural Extension Service, Texas A&M University, College Station, USA.

Jones, J. M., and J. H. Witham. 1990. Post-translocation survival and movements of metropolitan white-tailed deer. Wildlife Society Bulletin 18: 434-441.

Keyser, P. D., D. C. Guynn, Jr., and H. S. Hill, Jr. 2005. Density-dependent recruitment patterns in white-tailed deer. Wildlife Society Bulletin 33: 222-232.

Kilgo, J. C., H. S. Ray, C. Ruth, and K. V. Miller. 2010. Can coyotes affect deer populations in southeastern North America? Journal of Wildlife Management 74: 929-933.

Kilgo, J. C., H. S. Ray, M. Vukovich, M. J. Goode, and C. Ruth. 2012. Predation by coyotes on white-tailed deer neonates in South Carolina. Journal of Wildlife Management 76: 1420-1430.

Kilgo, J. C., M. Vukovich, M. J. Conroy, H. S. Ray, C. Ruth. 2016. Factors affecting survival of adult female white-tailed deer after coyote establishment in South Carolina. Wildlife Society Bulletin 40: 747-753.

Larkin, J. L, D. S. Maehr, J. J. Cox, M. W. Wichrowski, and R. D. Crank. 2002. Factors affecting reproduction and population growth in a restored elk *Cervus elaphus nelsoni* population. Wildlife Biology 8: 49-54.

Letty, J., S. Marchandeau, J. Clobert, and J. Aubineau. 2000. Improving translocation success: an experimental study of anti-stress treatment and release method for wild rabbits. Animal Conservation 3: 211-219.

Lima, S. L. 1998. Stress and decision making under the risk of predation: recent developments from behavioral, reproductive, and ecological perspectives. Advances in the Study of Behaviour 27: 215-290.

Lima, S. L., and L. M. Dill. 1990. Behavioral decisions made under the risk of predation: a review and prospectus. Canadian Journal of Zoology 68: 619-640.

McCall T. C., R. D. Brown, and C. A. DeYoung. 1988. Mortality off pen-raised and wild white-tailed deer bucks. Wildlife Society Bulletin 16: 380-384.

McCoy, J. C., S. S. Ditchkoff, J. B. Raglin, B. A. Collier, and C. Ruth. 2013. Factors influencing survival of white-tailed deer fawns in coastal South Carolina. Journal of Fish and Wildlife Management 4: 280-289.

McDermott, J. R. 2017. Survival and cause-specific mortality of white-tailed deer (*Odocoileus* *virginianus*) neonates in a southeastern Kentucky population. Master's Thesis. University of Kentucky, Lexington, Kentucky, USA.

Miller, J. E. 2012. A growing threat: how deer breeding could put public trust wildlife at risk. The Wildlife Professional 6: 22–27.

Mylrea, G. E. 1991. Reproduction in tropical species. Proceedings of a Deer Course for Veterinarians, Deer Branch New Zealand Veterinary Association, pp. 249-261.

Nixon, C. M. 1971. Productivity of white-tailed deer in Ohio. The Ohio Journal of Science 71: 217-225.

O'Bryan, M. K. 1983. The outcome of the 1981 Angel Island Deer Relocation. M. S. Thesis, University of California, Berkley.

O'Bryan, M. K., and D. R. McCullough. 1985. Survival of black-tailed deer following relocation in California. Journal of Wildlife Management 49: 115-119.

Powell, M. C., G. D. DelGiudice, and B. A. Sampson. 2005. Low risk of marking-induced abandonment in free-ranging white-tailed deer neonates. Wildlife Society Bulletin 33: 643-655.

Responsive Management and National Shooting Sports Foundation. 2008. The future of hunting and the shooting sports: research-based recruitment and retention strategies. Produced for the U.S. Fish and Wildlife Service under Grant Agreement CT-M-6-0, Harrisonburg, Virginia, USA.

Romero, L. M., and J. C. Wingfield. 2001. Regulation of the hypothalamic-pituitary-adrenal axis in free-living pigeons. Journal of Comparative Physiology 171: 231-235.

Rosatte, R., J. Hamr, B. Ranta, J. Young, and N. Cool. 2002. Elk restoration in Ontartio, Canada: infectious disease management strategy, 1998-2001. Annals of the New York

Academy of Sciences 969: 358-363.

Roseberry, J. L., and W. D. Klimstra. 1970. Productivity of white-tailed deer on Crab Orchard National Wildlife Refuge. Journal of Wildlife Management 34: 23-28.

Saalfeld, S. T., and S. S. Ditchkoff. 2007. Survival of neonatal white-tailed deer in an exurban population. Journal of Wildlife Management 71: 940-944.

Sapolsky, R. M. 1992. Stress, the aging brain, and the mechanisms of neuron death. Cambridge, Massachusetts: MIT Press.

Short, H. L. 1964. Postnatal stomach development of white-tailed deer. The Journal of Wildlife Management 28: 445-458.

Short, J. 2009. The characteristics and success of vertebrate translocations within Australia: a progress report to Department of Agriculture, Fisheries, and Forestry by Wildlife Research and Management Pty Ltd, Perth, WA, Australia.

Shuman, R. M., M. J. Cherry, T. N. Simoneaux, E. A. Dutoit, J. C. Kilgo, M. J. Chamberlain, and K.V. Miller. 2017. Survival of white-tailed deer neonates in Louisiana. Journal of Wildlife Management 81: 834–845.

Strickland, B. and S. Demarais. 2006. Antler regulations: navigating the tangled thicket. Quality Whitetails (June): 30-34.

Teixeira, C. P., C. S. de Azevedo, M. Mendl, C. F. Cipreste, and R. J. Young. 2007. Revisiting translocation and reintroduction programs: the importance of considering stress. Animal Behaviour 73: 1–13.

The Wildlife Society. 2012. Captive Cervid Breeding Fact Sheet. https://wildlife.org/wp-content/uploads/2014/05/captive-cervid-breeding.pdf.

U.S. Department of Agriculture. 2014. 2012 Census of Agriculture, United States Summary and

State Data. Volume 1.

Williamson, N. B., R. S. Morris, and G. A. Anderson. 1978. Pregnancy rates and non-return rates following artificial and natural breeding in dairy herds. Australian Veterinary Journal 54: 111-114.

Zidon, R., D. Saltz, L. S. Shore, and U. Motro. 2009. Behavioral changes, stress, and survival following reintroduction of Persian fallow deer from two breeding facilities. Conservation Biology 23: 1026-1035.

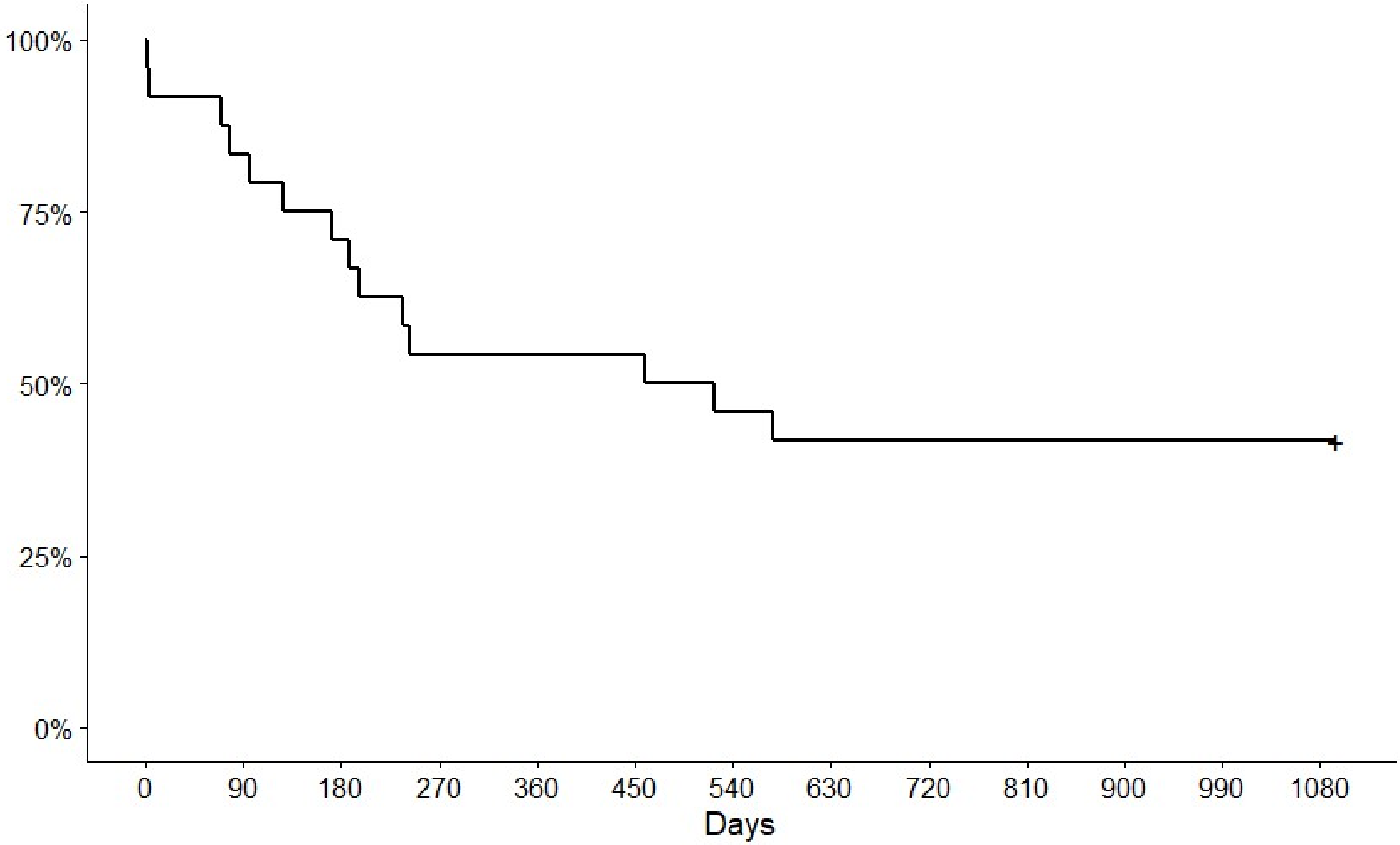


Figure 1.1 – Post-translocation overall survival of female white-tailed deer at Agricola Farms in Tallapoosa County, AL during 2019-2021.

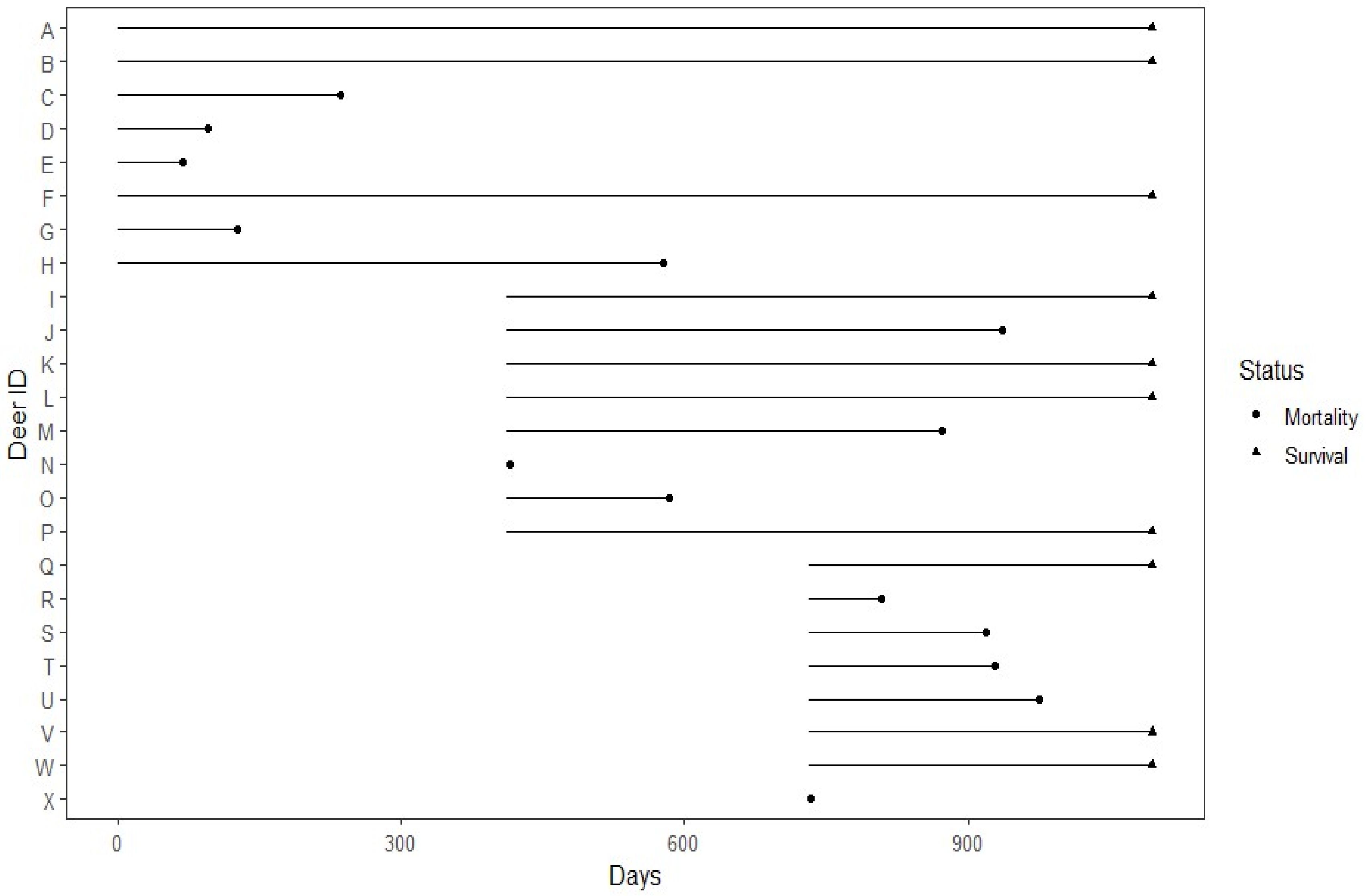


Figure 1.2 – Timeline depicting survival and mortality of each deer translocated at Agricola Farms in Tallapoosa County, AL from 2019-2021.

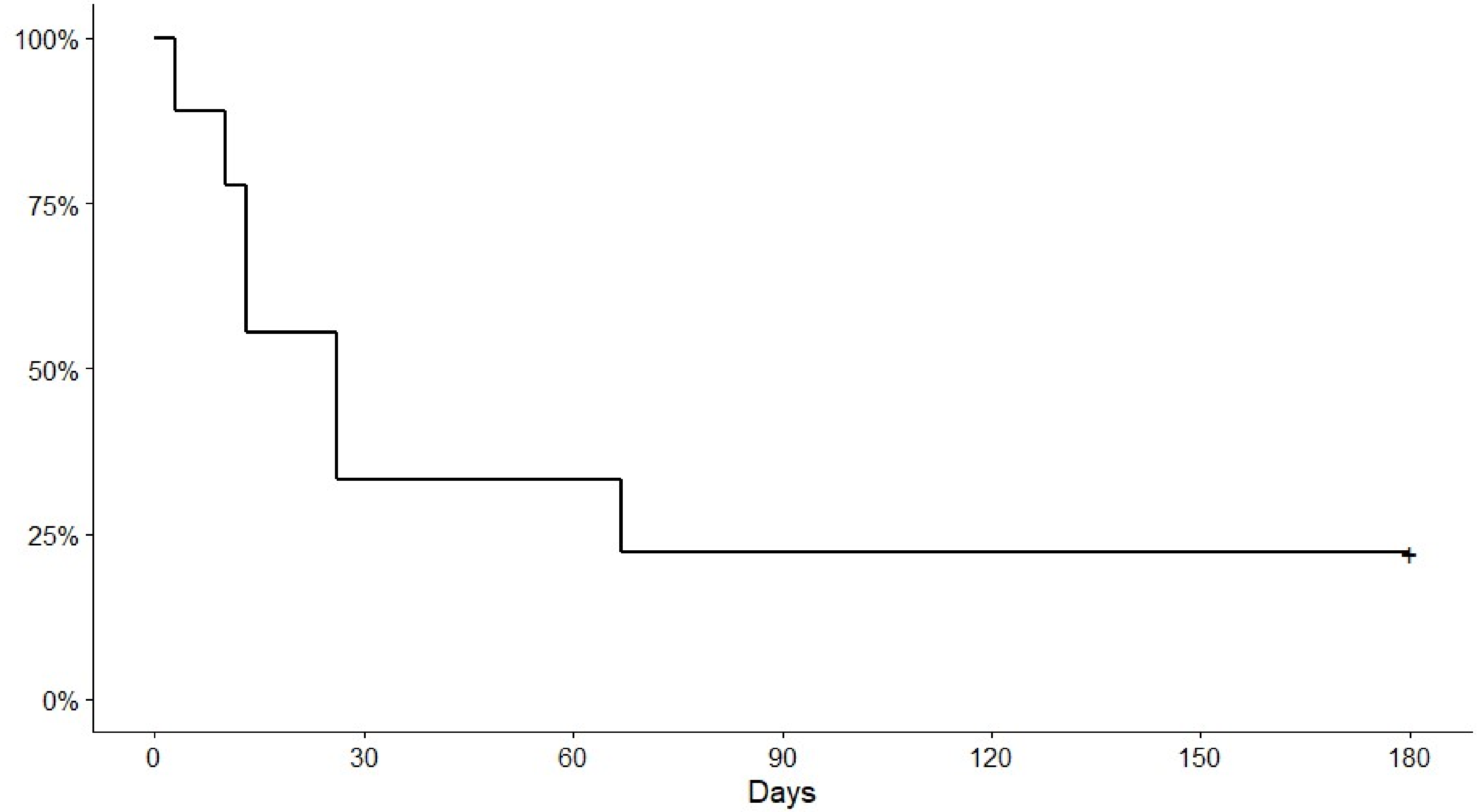


Figure 1.3 – Survival of white-tailed deer fawns from birth to 6 months at Agricola Farms in Tallapoosa County, AL during 2019-2021.

Appendix A – Known survival and reproductive fate of each translocated deer at Agricola Farms, AL from 2019-2021.

ID	Age	Release Date	Mortality Date	Mortality Cause	Date of VIT Drop	Fawns Captured	Fawns Produced	Fawns Recruited
A	6	2/9/2019			6/7/2019	1	1	0
B	6	2/9/2019			6/14/2019	0	1	1
C	2	2/9/2019	10/2/2019	Unknown	Premature exp.	-	0	0
D	2	2/9/2019	5/5/2019	Unknown	Premature exp.	-	0	0
E	12	2/9/2019	4/18/2019	Escaped Fence	-	-	-	0
F	2	2/9/2019			6/17/2019	0	0	0
G	7	2/9/2019	6/15/2019	Fence collision	5/30/2019	0	0	0
H	2	2/9/2019	9/7/2019	Unknown	Premature exp.	-	0	0
I	3	3/28/2020			Retained	-	-	0
J	5	3/28/2020	10/8/2021	Escaped Fence	5/30/2020	2	2	0
K	2	3/28/2020			Retained	0	-	0
L	5	3/28/2020			5/31/2020	2	2	0
M	2	3/28/2020	7/1/2021	Unknown	6/8/2020	1	1	0
N	2	3/28/2020	3/31/2020	Capture myopathy	-	-	-	0
O	4	3/28/2020	9/15/2020	Unknown	Retained	-	-	0
P	2	3/28/2020			5/23/2020	0	0	0
Q	2	2/10/2021			Premature exp.	-	0	-
R	2	2/10/2021	4/28/2021	Unknown	-	-	-	0
S	2	2/10/2021	8/15/2021	Unknown	6/9/2021	1	1	1
T	2	2/10/2021	8/25/2021	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	2/11/2021	Capture myopathy	-	-	-	0

Chapter 2: Training and Experience Increase Classification Accuracy in White-tailed Deer Camera Surveys

Abstract

Use of camera trap data in wildlife research is reliant on accurate classification of animals at the species, sex-age category, or individual level. One such example is white-tailed deer (*Odocoileus virginianus*) camera surveys, which are often conducted to produce demographic estimates used by managers to establish harvest goals for a population. Previous research suggests that misclassification of deer by sex-age category (e.g., adult male, adult female, fawn) is common in these surveys, and represents a source of bias that could misinform important management decisions. We developed and tested the efficacy of species-specific training material designed to reduce sex-age misclassifications associated with white-tailed deer images. Exposure to training material resulted in the greatest improvement in classification accuracy of deer images compared to any other respondent-based factors we investigated. Other factors, such as professional experience as a wildlife biologist, field experience viewing white-tailed deer, and experience viewing deer images from camera traps, were positively associated with classification accuracy of deer images. Our findings suggest that training material has the ability to reduce misclassifications, leading to more accurate demographic estimates for white-tailed deer populations.

Introduction

In recent decades, the practice of collecting animal data through camera traps has rapidly grown in popularity within the conservation and ecology fields due to increasingly available and affordable equipment (Rowcliffe and Carbone 2008). Camera traps also offer a relatively non-invasive and passive approach to monitoring elusive species (McCarthy et al. 2019). Camera trapping is considered a superior sampling tool when compared to alternative methods, such as live traps or scat surveys, due to their ability to efficiently detect a high number of species and generate a large number of detections for individual species (Wearn and Glover-Kapfer 2019). Camera traps are particularly useful in determining animal occupancy (Gálvez et al. 2016), creating species inventories (Silveira et al. 2003), estimating abundance indices (Palmer et al. 2018), and increasing understanding of population dynamics (Karanth et al. 2006). However, these techniques generally depend on reliable and accurate classification of animals at either the species, sex, age, or individual level (Rovero et al. 2013).

While classification accuracy is subject to variability from aspects such as image-based constraints (Stevick et al. 2001, Meek et al. 2015) and vegetation conditions (Wearn and Glover-Kapfer 2019), observer-based factors, such as experience with target species, can also have an effect on classification accuracy (Newbolt and Ditchkoff 2019). It is generally recognized that species with high visual variation between conspecifics, such as unique natural markings (e.g., spots of a cheetah [*Acinonyx jubatus*]) or secondary sexual traits (e.g., antlers of a white-tailed deer [*Odocoileus virginianus*]), may lead to more reliable classification at the individual, sex, or age-class category (Johansson et al. 2020). Conversely, accurately classifying species where individuals may appear visually similar to each other (cougars, *Puma concolor*), may provide additional challenges for observers (Kelly et al. 2008, Oliveira-Santos et al. 2010).

Since a novel approach was developed by Jacobson et al. (1997), commonly referred to as the Individual Branched Antlered Method (IBAM), camera surveys have become a widespread method of estimating parameters of white-tailed deer populations. The IBAM method relies on identifying individual bucks based on unique antler characteristics and creating a sightability (photos/deer) ratio (Jacobson et al. 1997). This ratio is then applied to the numbers of doe and fawn images captured with the same camera traps to generate estimates for these sex-age classes. Of course, this method primarily relies on an observer's ability to identify individual bucks based on unique antler characteristics (Jacobson et al. 1997, Koerth 1997); however, resulting estimates also are heavily influenced by correct classification at the sex-age level. For instance, misclassifying a fawn (<12 months) deer as an adult doe would artificially deflate fawn recruitment estimates and inflate doe estimates. While the antlers of adult bucks provide ubiquitous distinguishing features for this sex-age class, the ability to distinguish a fawn from an adult doe relies on far more subtle determinants. Once fawns molt their neonatal pelage containing definitive spots around 3-4 months after birth (Ditchkoff 2011), observers must base their classification on fairly subjective traits like relative body size or body proportions (Newbolt and Ditchkoff 2019). Additionally, a lack of foundational familiarity with white-tailed deer life history may cause an observer to mistake a yearling buck, particularly small spike-antlered individuals, for a fawn.

Misidentification error is a serious concern in white-tailed deer camera surveys, as it reduces the reliability of population estimates. Several studies have demonstrated varying rates of error between observers identifying individual animals within the same set of images (Kelly et al. 2008, Oliveira-Santos et al. 2010). Further, misclassifications may be a critical source of survey error when comparative sex-age groups lack clear distinctions (Newbolt and Ditchkoff 2019). Additionally, experienced-based factors such as familiarity with target species and experience conducting camera surveys likely influence rates of misclassification (Newbolt and Ditchkoff 2019). In attempts to reduce error rates, recommendations have been made to utilize multiple observers to independently classify survey images, evaluate, and monitor observer bias

(Kelly et al. 2008), as well as conducting camera surveys during seasonal periods that maximize variation among conspecific individuals or classification groups (Newbolt and Ditchkoff 2019).

Mendoza et al. (2011) identify two primary strategies that have been used to overcome misclassifications in wildlife camera-trapping data. First, creating models designed to incorporate rate of misclassification into population estimates can be effective, but only if the magnitude of error is well-known (Yoshizaki et al. 2009). Second, automated tools have been created to assist with the process of identifying individuals in the population (Kelly 2001, Speed et al. 2007, Azhar et al. 2012). However, neither of these strategies deal with the ultimate cause of misclassification, which is human error. Educational material may be a way to eliminate some level of misclassification by training observers to correctly classify wildlife based on objective physical traits or characteristics. For example, practical training and educational materials are frequently provided to respondents of citizen-science or volunteer-based projects with the intent of improving data reliability (Newman et al. 2003, Cohn 2008, Steger et al. 2017, Parsons et al. 2018). Recent studies exploring the influence of longer-term (Danielsen et al. 2014, van der Wal et al. 2016) and single-session (Katrak-Adefowora et al. 2020, Perry et al. 2021) training programs on identifying wildlife images have generally found training to improve data reliability. However, the majority of previous research in this area has simply required respondents to classify wildlife images to the species level. While the task of identifying animals to the species level can vary in difficulty among different species (Swanson et al. 2016), visual differentiation of unique wildlife species tends to be based on objective morphological criteria. Performing intraspecific sex-age classifications may rely more heavily on subtle, subjective criteria, such as relative size or body proportions (Newbolt and Ditchkoff 2019).

Newbolt and Ditchkoff (2019) found that the sex-age category of a white-tailed deer was the most important predictor of classification accuracy with branch-antlered bucks classified most accurately, followed by does and fawns, respectively. However, certain observer-based factors, such as professional experience in a wildlife-related field and experience using trail cameras to view deer, had strong associations with classification accuracy as well. The authors postulated that developing species-specific training may improve reliability and accuracy of sex-age classifications for observers (Newbolt and Ditchkoff 2019), and this study aims to take their findings a step further by introducing species-specific training material to observers designed to reduce sex-age misclassification associated with white-tailed deer images. The specific objectives of this study are to: (1) examine whether training material has an effect on overall classification accuracy; (2) measure how training material affects classification accuracy for each sex-age category of white-tailed deer; and (3) explore other observer-based, experiential factors as they relate to classification accuracy.

Study Area

We collected images of marked, known-age deer for this study at Auburn University's Deer Research Facility, located in the Piedmont region of east-central Alabama, USA. The facility was constructed in October 2007 and consisted of 174 ha enclosed by a 2.6-m steel fence designed to inhibit deer movements. The enclosed deer population consisted of approximately 100 individuals and comprised wild animals captured during construction and their descendants. Deer in the facility bred during mid-December to mid-February, with peak conception at approximately 18 January (Neuman et al. 2016).

Vegetation within the enclosure was approximately 40% open fields maintained for hay production, 13% bottomland hardwoods (*Quercus* spp.), 26% mature, naturally regenerated mixed oak-hickory-pine forest (oak and hickory [*Carya* spp.], loblolly pine [*Pinus taeda*]), 11% early regenerated thicket areas consisting primarily of *Rubus* spp., sweetgum (*Liquidambar styraciflua*), eastern red cedar (*Juniperus virginiana*), and Chinese privet (*Ligustrum sinense*), and 10% 10–20-year-old loblolly pine forest. A second-order creek bisected the property and provided a stable source of water year-round. Three feeders provided a 16–18% extruded protein feed (Record Rack®, Nutrena Feeds, Abilene, TX, USA) available *ad libitum*. Four timed feeders each provided deer approximately 2 kg/day of corn during October–March each year when we were actively capturing deer as part of additional research objectives.

Methods

Deer Image Collection

We used chemical immobilization to capture deer in our research facility during 8 trapping seasons (~1 Oct–15 Mar) from 2007 to 2015 as part of additional research objectives. All methods were approved by the Auburn University Institutional Animal Care and Use Committee (PRNs 2008-1417, 2008-1421, 2010-1785, 2011-1971, 2013-2372, 2016-2964, 2016-2985), and followed the American Society of Mammologists' guidelines (Sikes and Gannon 2011). We gave captured deer a unique 3-digit identification number corresponding with age and order of capture, which was displayed on highly visible ear tags.

We collected images containing marked deer ($n > 100{,}000$) using infrared-triggered cameras (Reconyx PC 800 [Reconyx, Holmen, WI, USA]; time-lapse image capture; 1-minute delay; factory default image resolution settings) placed at camera-trap sites ($n = 8$) baited with corn during February–March during the years of 2016–2020. This camera model captured full-color images with no flash during daylight hours and black-and-white images using an infrared flash during low-light periods. Postseason deer surveys in Alabama typically occur from the end of hunting season (10 Febuary) until spring green-up (~15 March–1 April). We selected this period of time in an effort to mirror a typical post hunting-season camera survey in our area. We attached cameras to an adjustable mounting bracket at a height of approximately 132 cm and placed a 22-kg pile of corn 3.66 m from each camera. We adjusted the vertical angle of cameras such that the lens was focused at a point 72 cm above the center of the bait pile.

We first classified collected images as adult male, adult female, fawn (i.e., 6-8-month-old deer born during the most recent fawning season), and unknown (i.e., unidentifiable). Images of adult deer used in the survey were of ear-tagged animals for which age and sex were known. Since our deer capture protocol does not include darting fawns, all fawn images used in this survey were of untagged individuals. We feel that the relatively low abundance of untagged adults (<10%), combined with the abundance of visual information provided by 1-minute time-lapse imagery, allowed us to minimize instances where we erroneously classified untagged adults as fawns. Images that contained >1 deer were classified according to each individual and placed into multiple categories as needed. For example, an image with an adult female deer and a fawn would be included in both of the 2 appropriate categories.

Online Survey Development

We used Qualtrics® survey software (Qualtrics, Provo, UT, USA; accessed Feb 2020) to develop an online survey that tested the abilities of respondents to accurately classify deer images according to sex and age (i.e., adult vs. fawn) and also tested the effect of species-specific training material on classification accuracy. This survey was developed in accordance with Auburn University policies regarding research involving human subjects (Auburn Institutional Review Board protocol #20-485; approved 08 Oct 2020). We randomly selected images (*n* = 62 images containing 75 deer) from the pool of sorted images, ensuring that all classification groups were represented in our survey (adult females = 37.3% [female deer 1.5 years and older], adult males = 29.3% [male deer 1.5 years and older], fawns = 28% [male and female deer younger than 1.5 years], unknown = 5.4% [not enough visible information to classify]). We chose the number of images for the survey to minimize time commitments (<40 min) of respondents while maintaining adequate sample size. Ages of adult male and female deer in the selected images ranged from 1.5 to 6.5 years of age. We edited deer images using Pixlr® photo-editing software (www.pixlr.com; accessed March 2021) to remove all artificial identifying markings given to deer during capture (i.e., ear tags). We added a single-digit identification number to each deer image to link them to specific response areas in our survey.

Adult male images consisted mostly (21 of 22 images) of spike-antlered deer. The training material made available to the test group of respondents was specifically designed to focus on reducing misclassifications of spike-antlered bucks, and so we also intentionally manipulated our image set so that buck images were primarily (95.5%) comprised of spike-antlered individuals. Our justification for this decision was based on findings that branch-antlered bucks were relatively easy to accurately identify due to this conspicuous physical trait (Newbolt and Ditchkoff 2019); therefore, we were less interested in examining the effects of training material on branch-antlered bucks.

We developed a species-specific training guide designed to reduce misclassification in white-tailed deer camera surveys (Appendix B). This training material identified distinguishing physical features between adult females, adult males, and fawns. The training material primarily focused on 1) correctly distinguishing fawns from adult females, 2) correctly distinguishing spike-antlered bucks from fawns, and 3) correctly classifying unknown (i.e., unidentifiable) deer.

The distinguishing features related to relative proportions of the head, face, neck, and body used to differentiate adult females from fawns were described. The training material also included definitional information relating to these sex-age categories. The training material instructed respondents to classify a deer as “unknown” when 1) images did not provide a clear view of the top of a deer’s head or 2) the respondent was uncertain of how to classify an image for any reason. Finally, a series of 9 images followed that reviewed the training material and provided example classification for 14 deer. The training material was made randomly available to approximately half (48.6%) of the respondents (those in the test group) prior to answering the deer classification questions. Training material was not available to 51.4% of respondents (those in the control group).

We solicited volunteers from across the U.S. for our survey with assistance from multiple partners and web-based outlets, including national deer conservation/hunting organizations and social media. Adults 19 years of age or older were eligible to participate in our survey. The online survey was open for access during 26 April to 31 May 2021. We took precautions to prevent respondents from taking the survey more than once by enabling the “Prevent Ballot Box Stuffing” survey option. This option placed a cookie in the respondent's browser when they submitted a response that aided in restricting them from using the web link for our survey more than once. We first presented respondents with an information letter describing the purpose of the research, participation requirements, and privacy information as required by our institutional review board protocol. Respondents were then asked 4 questions focused on general demographic information (Table 2.1), followed by 8 questions that addressed factors we felt might influence an individual's ability to accurately classify deer images (Table 2.2).

We gave respondents specific information concerning the deer images prior to completing our survey. This information included 1) general geographic and captive facility details, 2) dates the images were taken, and 3) biological information for the captive deer herd (i.e., breeding season dates; approximate ages of fawns; and mass ranges for adult males, adult females, and fawns). We also notified survey respondents that all adult males were in hard antler. We then provided instructions detailing the format of our survey and how to submit responses. Respondents were presented multiple choice boxes corresponding to each numbered deer and asked to classify the image as one of 4 possible responses. Responses included and were defined as adult male ("male deer that are 1.5 years of age or older"), adult female ("female deer that are 1.5 years of age or older"), fawn ("male or female deer that are younger than 1.5 years of age. These are young-of-the-year deer born during the most recent fawning season. You do not need to determine if these are male or female deer"), and unknown ("not enough visible information to classify"). We randomized the order of questions for each respondent to help prevent sharing of answers, and respondents were notified that images were not in chronological order. Respondents were allowed to take as long as necessary to complete the survey, and we included only completed surveys in our analyses.

Statistical Analysis

We organized responses into 2 groups for our analyses: 1) unknown responses and 2) known responses for adult male, adult female, and fawn images. While our training material specified conditions that would make "unknown" a correct response, we recognized that there may be multiple reasons for a respondent selecting this response. Therefore, unknown responses were neither correct nor incorrect and were evaluated independently. The goal of our first analysis was to evaluate factors influencing accuracy of responses, without consideration of unknown responses. We determined whether responses were correct or incorrect based upon comparison with our classifications of known deer in images. All analyses were conducted in Program R (R Core Development Team, version 3.4.1 accessed Aug 2021). We used generalized mixed-effects regression models with binomial distribution to examine classification accuracy as a function of 1) the influence of exposure to species-specific training material, 2) professional experience with wildlife, 3) experience hunting deer, 4) field experience viewing deer, 5) local deer hunting experience, 6) general experience with using trail cameras to view deer, 7) experience conducting deer surveys using trail cameras, and 8) classification of the "known" deer image (adult male, adult female, fawn) on classification accuracy. Random effects terms for respondent identification (ID) and deer image ID were included to account for variation associated with these effects. We calculated variance inflation factors (VIFs) and pairwise correlation coefficients among predictors associated with volunteer responses to personal information questions (Q1-Q12), in addition to exposure to training material, to evaluate collinearity in these data. We determined associations between response and predictor variables using odds ratios. The odds ratio for a predictor variable is the relative amount by which the odds of the outcome increase (odds ratio >1.0) or decrease (odds ratio <1.0) with each unit increase in the predictor variable (Hosmer et al. 2013). We calculated overall mean correct response rates for both trained (received training material) and nontrained (did not receive training material) respondents using a data set restricted to only include known responses of known deer images (i.e., adult male, adult female, fawn).

In addition to the previous analysis, we aimed to examine the effects of the training material on classification accuracy of specific sex-age categories of deer images. We restricted our data to include only known responses (excluding "unknown" response), then organized these data into 3 subgroups according to our classification of the deer image (i.e., adult male, adult female, fawn). We used generalized mixed-effects regression models with binomial distribution to compare classification accuracy of each of these subgroups and included the same predictor variables and random effects terms used in the previous analysis. This analysis allowed us to determine the specific effect of exposure to training material on each category of deer image (i.e., adult male, adult female, fawn). We also calculated mean correct response rates for each category of known deer image using a data set restricted to only known responses.

We performed a separate analysis to examine the effects of the training material on classification accuracy of deer images we classified as unknown (i.e., unidentifiable). First, we restricted our data to include only images of deer we classified as unknown. Next, we used generalized mixed-effects regression models with binomial distribution to examine the influence of all previous predictor variables on classification accuracy of unknown deer, including previous random effects terms. We calculated mean correct response rates for unknown deer images using the data restricted to only images we classified as unknown.

We also aimed to examine the specific types of error associated with incorrect responses. First, we organized our data into two subgroups according to whether respondents were exposed to training material. Next, we restricted our data to include only incorrect responses, then organized this data set into 3 subgroups according to our classification of the deer image (i.e., adult male, adult female, fawn). We used generalized mixed-effects regression models with binomial distribution in Program R to model each of these subgroups with a conditional response of one of the 2 possible incorrect answers. Random effects terms for respondent ID and deer image ID were included to account for variation associated with these effects. This analysis allowed us to determine the likelihood of occurrence for the 2 possible incorrect responses respective to each of the 3 known deer classification groups as a function of the respondent being in the test group (received training material) or control group (did not receive training material).

Finally, we focused on examining factors contributing to unknown responses. We used our full data set to create a conditional variable based on unknown responses for this analysis. We used generalized mixed-effects regression models with binomial distribution to examine unknown response rate as a function of 1) exposure to species-specific training material, 2) professional experience with wildlife, 3) experience hunting deer, 4) field experience viewing deer, 4) local hunting experience, 5) general experience with using trail cameras to view deer, experience conducting deer surveys using trail cameras, and classification of the "known" deer image (adult male, adult female, fawn). Random effects terms for respondent identification and deer image ID were included to account for variation associated with these effects. We also calculated an overall mean unknown response rate for both trained and nontrained respondents using a data set restricted to only unknown responses.

Results

We had 1,757 respondents complete our survey during the 5-week study period. We excluded 16 respondents from analysis due to incomplete responses. Respondents were primarily male and from a wide range of age groups, income levels, and education levels. 84.1% of respondents lacked professional experience in a wildlife-related field. Respondents that did have professional experience primarily identified as wildlife biologists, and those identifying as OTHER included game warden (n = 2), law enforcement (n = 2), alligator farmer (n = 1), aquatic ecologist (n = 1), and bear guard (n = 1). Most respondents had experience viewing (94.4%) or hunting (97.6%) white-tailed deer, though only 31.2% had experience hunting or viewing white-tailed deer in Alabama or surrounding states. 82.6% of respondents indicated they had a HIGH or MODERATE level of experience using trail cameras to view deer for any purpose; however, 77.5% had never conducted a camera survey to estimate deer population information. 61.6% of respondents with experience conducting camera surveys for white-tailed deer indicated they had completed ≤4 surveys. Estimates of collinearity among predictors related to respondent personal information were low (Q1= 3.58, Q2= 4.32, Q3= 1.62, Q4= 1.81, Q5= 1.16, Q6= 1.47, Q7= 1.14, Q8= 1.07, Q9= 1.43, Q10= 1.15; Table 1, Table 2). Estimates of collinearity for whether respondents received training material was also low (1.03). We did not explore collinearity among predictors that were conditional of a specific response to a separate predictor (Q5a and Q10a).

Our analysis suggested that accuracy of deer classifications was associated positively with professional/working experience in a wildlife-related field, general experience using trail cameras to view deer, and field experience viewing white-tailed deer. Respondents with professional experience were 1.13 (95% CL = 1.04 – 1.24; $p = 0.005$) times as likely to correctly classify deer images than nonprofessionals, with wildlife biologists primarily accounting for the positive effect: Wildlife Biologist, 1.14 (95% CL = 1.01 – 1.29; $p = 0.03$); Forestry, 1.02 (95% CL = 0.85 – 1.24; $p = 0.80$); Land Management, 1.11 (95% CL = 0.95 – 1.31; $p = 0.19$); Hunting Guide, 0.95 (95% CL = 0.79 – 1.14; $p = 0.56$); Outdoor Industry, 0.79 (95% CL = 0.65 – 0.97; $p = 0.02$); and Other 1.13 (95% CL = 0.96 – 1.34; $p = 0.13$). Respondents with HIGH experience using trail cameras to view deer were 1.11 (95% CL = 1.03 – 1.19; $p = 0.004$), 1.18 (95% CL = 1.07 – 1.31; $p = 0.001$), and 1.20 (95% CL = 1.01 – 1.45; $p = 0.05$) times as likely to correctly classify deer than those with MODERATE, LOW, and NONE experience, respectively. Accuracy of classifications was similar between those with MODERATE and LOW experience ($\mathrm{Exp}(\beta) = 1.06$ [95% CL = 0.96 – 1.17; $p = 0.20$]), MODERATE and NONE experience

($\text{Exp}(\beta) = 1.08$ [95% CL = 0.90 – 1.30; $p = 0.39$]), and LOW and NONE experience ($\text{Exp}(\beta) = 1.01$ [95% CL = 0.84 – 1.23; $p = 0.86$]). Respondents with field experience viewing white-tailed deer were 1.20 (95% CL = 1.04 – 1.38; $p = 0.014$) times as likely to accurately classify deer images than respondents without field experience viewing white-tailed deer. We did not detect relationships between classification accuracy and general experience hunting deer ($\text{Exp}(\beta) = 1.18$ [95% CL = 0.95 – 1.48; $p = 0.14$]), local experience hunting deer ($\text{Exp}(\beta) = 0.96$ [95% CL = 0.90 – 1.03; $p = 0.31$]), or experience conducting deer surveys with trail cameras ($\text{Exp}(\beta) = 1.06$ [95% CL = 0.98 – 1.16; $p = 0.1$]).

We found that accuracy of classifications was related to the sex–age category of deer. Images of adult females were 2.43 (95% CL = 1.18 – 5.03; $p = 0.016$) times as likely to be classified correctly than adult male images. We did not detect a difference between classification accuracy of adult male and fawn images ($\text{Exp}(\beta) = 1.58$ [95% CL = 0.74 – 3.4; $p = 0.23$) or between adult female and fawn images ($\text{Exp}(\beta) = 1.53$ [95% CL = 0.73 – 3.14; $p = 0.25$). Adult female images that were incorrectly classified were 26.72 (95% CL = 12.14 – 58.84; $p < 0.001$) and 15.42 (95% CL = 7.61 – 31.22; $p < 0.001$) times as likely to be misclassified as fawn than adult male for trained and nontrained respondents, respectively. Adult male images that were incorrectly classified were 4.40 (95% CL = 2.22 – 8.74; $p < 0.001$) and 7.46 (95% CL = 3.26 – 17.06; $p < 0.001$) times as likely to be misclassified as fawn than adult female for trained and nontrained respondents, respectively. Fawn images that were incorrectly classified were 46.62 (95% CL = 20.28 – 107.17; $p < 0.001$) and 35.16 (95% CL = 20.62 – 59.95; $p < 0.001$) times as likely to be misclassified as adult female than adult male for trained and nontrained respondents, respectively.

Our analysis suggested that accuracy of deer classifications was associated positively with exposure to training material (Figure 2.1). Respondents that received training material were 1.71 (95% CL = 1.60 – 1.82; $p < 0.001$) times as likely to accurately classify deer images. We found an overall correct response rate of 80.5% and 73.4% for trained and nontrained respondents, respectively. We found that exposing respondents to training material had varying effects of classification accuracy in regard to sex-age class. Respondents that received training material were 6.42 (95% CL = 5.11 – 7.92; $p < 0.001$) times as likely to accurately classify images of adult bucks and 1.35 (95% CL = 1.21 – 1.51; $p < 0.001$) times as likely to accurately classify images of fawns than nontrained respondents. Accuracy of adult female deer classifications was similar between trained and nontrained respondents (Exp(β) = 1.0016 [95% CL = 0.92 – 1.09; $p = 0.971$). We found an accurate response rate for adult female images of 81.9% and 82.2% for trained and nontrained respondents, respectively. We found an accurate response rate for adult male images of 80.4% and 61.4% for trained and nontrained respondents, respectively, and an accurate response rate for fawn images of 78.8% and 74.5% for trained and nontrained respondents, respectively.

Our results suggested that accuracy of classifying unknown (i.e., unidentifiable) deer was positively associated with exposure to training material. Respondents that received training material were 27.66 (95% CL = 21.37 – 36.28; $p < 0.001$) times as likely to correctly classify an unknown deer. We found an accurate response rate for unknown images of 72.1% and 31.6% for trained and nontrained respondents, respectively. Our analysis also indicated that local (Alabama or immediately surrounding states) experience viewing or hunting deer was positively associated with accurate classification of unknown deer. Respondents with local experience were 1.28 (95%

CL = 0.90 – 1.84; p = 0.036) times as likely to accurately classify images of unknown deer than respondents without local experience.

We did not find a relationship between classification accuracy of unknown deer and any other of the investigated factors related to the individual respondent. Wildlife professional and nonprofessionals had similar classification accuracy of unknown deer (Exp(β) = 1.01 (95% CL = 0.75 – 1.36; p = 0.95). Individuals with HIGH level of experience using trail cameras to view deer had similar classification accuracy of unknown deer as those with MODERATE (Exp(β) = 1.05 [95% CL = 0.820 – 01.34; p = 0.69]), LOW (Exp(β) = 1.28 [95% CL = 0.89 – 1.84; p = 0.17]), and NONE (Exp(β) = 1.49 [95% CL = 0.79 – 2.83; p = 0.22]). Those with MODERATE experience had similar classification accuracy of unknown deer as those with LOW (Exp(β) = 0.81 [95% CL = 0.59 – 1.14; p = 0.24]) and NONE (Exp(β) = 1.41 [95% CL = 0.76 – 2.66; p = 0.27]), and classification accuracy of unknown deer for those with LOW experience were similar to NONE (Exp(β) = 1.16 [95% CL = 0.60 – 2.25; p = 0.65]). Accuracy of classifying unknown deer was not different between respondents with and without experience using cameras to conduct deer population surveys (Exp(β) = 0.83 [95% CL = 0.70 – 1.20; p = 0.53]). Accuracy of classifying unknown deer was not different between respondents with and without field experience hunting (Exp(β) = 0.64 [95% CL = 0.30 – 1.38; p = 0.26]) or viewing (Exp(β) = 0.83 [95% CL = 0.50 – 1.37; p = 0.47]) deer.

Our analysis indicated that exposure to species-specific training material was associated positively with unknown responses. Respondents that received training material were 4.57 (95% CL = 4.02 – 5.50; $p < 0.001$) times as likely to select an unknown response as respondents who did not receive training material. Unknown responses accounted for 8.5% and 4.8% of all responses for trained and nontrained respondents, respectively. We found that unknown response rate was related to our sex-age classification group of the deer image. Respondents were 2.59 (95% CL = 1.21 – 5.62; *p* =0.011) times as likely to select an unknown response for adult female images than adult male images. Respondents were 2.34 (95% CL = 1.08 – 5.10; *p* = 0.031) times as likely to select an unknown response for adult female images than fawn images. Unknown response rates were similar for adult male and fawn images (Exp(β) = 1.11 [95% CL = 0.39 – 2.02; *p* = 0.79]).

Our results suggested that unknown responses were associated positively with general experience using trail cameras to view deer. Respondents with NONE level of experience using trail cameras to view deer were 1.68 (95% CL = 1.07 – 2.65; *p* = 0.02) times as likely to select an unknown response than those with HIGH level of experience. Individuals with HIGH level of experience using trail cameras to view deer provided similar numbers of unknown responses as those with MODERATE (Exp(β) = 1.11 [95% CL = 0.93 – 1.33; *p* = 0.24]) and LOW (Exp(β) = 1.19 [95% CL = 0.93 – 1.55; *p* = 0.16]). Those with MODERATE experience provided similar numbers of unknown responses as those with LOW (Exp(β) = 1.07 [95% CL = 0.85 – 1.37; *p* = 0.53]) and NONE (Exp(β) = 1.52 [95% CL= 0.97 – 2.36; *p* = 0.06]). Unknown responses for those with LOW experience were similar to NONE (Exp(β) = 1.51 [95% CL = 0.88 – 2.23; *p* = 0.15]). Our results indicated that unknown responses were not related to any other of the investigated factors related to the individual respondent. Wildlife professional and nonprofessionals provided similar numbers of unknown responses (Exp(β) = 1.004 (95% CL = 0.81 – 1.25; *p* = 0.97). Unknown responses were not different between respondents with and without experience hunting deer (Exp(β) = 0.64, [95% CL = 0.37 – 1.10; *p* = 0.11]) and between respondents with and without field experience viewing deer (Exp(β) = 0.98 [95% CL = 0.69 – 1.41; *p* = 0.95]). Respondents with experience viewing or hunting deer in Alabama and surrounding states provided similar numbers of unknown responses as those without local experience (Exp(β) = 1.17 [95% CL = 0.99 – 1.39; *p* = 0.06]), and unknown responses were not different between respondents with and without experience using cameras to conduct deer population surveys (Exp(β) = 0.90 [95% CL = 0.74 – 1.10; *p* = 0.31]).

Discussion

Of all investigated factors related to the individual respondent, training material resulted in the greatest decrease in misclassification rates. These results are similar to previous studies which demonstrate that training material can improve quality of wildlife survey data (Ratnieks et al. 2016, Katrak-Adefowora et al. 2020, Perry et al. 2021). Specifically, we saw the greatest reductions in error among adult males and fawns. Newbolt and Ditchkoff (2019) had previously identified spike-antlered males and fawns as being associated with the greatest degree of error during classification of trail camera images. Both of these sex-age categories are of particular relevance to population estimates resulting from camera survey data and consequently the management decisions they inform. For instance, misclassifying images of fawns could lead to underestimation of fawn recruitment. Similarly, misclassifying spike-antlered males leads to skewed adult sex ratio estimates

Our results showed the greatest reduction of misclassification in trained respondents was primarily for adult males, hereafter referred to as bucks, relative to other known sex-age categories (Figure 2.2). For both trained and nontrained respondents, a notable portion of buck image misclassification came from erroneously selecting “adult female”, though most misclassified buck images were mistaken for fawns. In the nontrained group of respondents, a greater proportion of misclassifications in the buck image set resulted from respondents selecting “fawn” relative to the set of doe images. All spike-antlered bucks in our image set were yearlings

(~1.5 years) which tend to have more similarities to fawn body proportions than would deer >1.5 years old. Since the doe images used in the survey contained more non-yearling adult deer (median age = 4.5 years), doe images may have been easier to discern from fawns based on body proportions. However, all buck images contained deer with visible hard antlers, which should have provided an indication that such deer were adult males provided that respondents were aware of this sex-specific trait. Newbolt and Ditchkoff (2019) also found that spike-antlered buck images were most frequently misidentified as fawns, which the authors attributed to misinformation regarding antler growth patterns. The training material we offered respondents specifically addressed this issue by clearly describing the physical distinctions between male fawns and spike-antlered bucks. Not only were respondents who received training more likely to accurately classify buck images, but we also observed a major reduction in the proportion of buck images misclassified as fawns. Based on these findings, we believe the training material was effective for informing respondents on correct antler growth patterns.

The significant reduction in the rate of misclassification of fawn images we reported with trained respondents provided further evidence that deliberately targeting specific sources of error in training material can be effective. Fawns were most frequently misclassified as adult females, hereafter referred to as does, across both trained and nontrained groups of respondents. While the reduction in misclassification of fawn images may not have been as drastic as for buck images, most of the reduced error was a result of fewer trained respondents mistaking fawns for does. We attribute the reduction of this particular mistake in trained respondents to the multiple strategies for differentiating fawns from does that we outlined in our training material. Newbolt and Ditchkoff (2019) attributed a relatively high rate of misclassification between fawns and does to the lack of distinct physical traits between these two sex-age categories. Rather than looking for relatively obvious physical traits, such as the presence of hard antlers, observers must rely on the ability to use subjective criteria, such as relative size and body proportions to make accurate classifications between fawns and does. We attribute this reasoning to the small, yet significant, effect size of improved accuracy in trained respondents for classifying fawns relative to classifying bucks.

While the training material appeared to have a positive effect on classification accuracy for fawn and buck images, our results did not support an improvement in accurate doe classification. While accurate classification rates were not different between trained and nontrained respondents for doe images, a lesser proportion of misclassification was due to mistaking a doe for a buck in trained respondents compared to nontrained respondents. As wildlife professionals, we often make false assumptions about the public's level of understanding regarding fundamental aspects of wildlife biology due to them being "obvious" or "rudimentary". However, previous work on the topic reveals a low level of knowledge regarding the basic biology of wildlife species among members of the general public (Brooks et al. 1999, Casey et al. 2006). In the context of this study, assuming that all respondents understand the difference between a buck and a doe based on the presence of hard antlers would be fallacious, considering the notable proportions of misclassification that resulted from mistaking these sex-age categories. However, exposing respondents to training material prior to classifying images appears to have lowered the proportion of bucks mistaken for does. While the provided training material never explicitly stated that female deer rarely grow antlers, that detail may have been inferred to a greater degree by trained respondents based on only discussing the presence of hard antlers in the context of bucks.

Relative to all the known sex-age categories of deer in the survey images (i.e., buck, doe, fawn), our results showed that training material had the greatest effect of reducing rate of misclassification for unknown (i.e., unidentifiable) deer. Every wildlife camera survey is likely to include images of individual animals that are unidentifiable due to uncertainty caused by distance from the camera, position/orientation of the animal, or a number of other factors. By classifying an unidentifiable animal as unknown, an observer limits the potential error in a survey that may arise from misclassification. If an observer misclassifies an unidentifiable animal at the individual or sex-age category level based on erroneous assumptions, resulting population estimates, such as recruitment or sex ratio, could become biased. Both trained and nontrained respondents were instructed to classify individuals as unknown given "not enough visible information to identify"; however, trained respondents received advanced instruction regarding unknown classifications in the training material in addition to viewing two example images of unidentifiable deer correctly classified as unknown. We believe that exposure to such training material can be attributed to the reported improvement in correct classification of unknown deer.

Our results also suggested that exposure to training material resulted in respondents being more likely to select "unknown" when faced with uncertainty in classifying deer images. These findings are contradictory to those of Katrak-Adefowora et al. (2020), who reported a lower unknown (i.e., "Don't Know") response rate for trained than nontrained respondents. However, we believe our study required respondents to perform more difficult classifications (e.g., differentiating sex-age categories based on subjective criteria) than the previously mentioned study (i.e., identifying animals to the "species" level [bird, cat, dog, skunk, etc.]) and therefore we assume that our respondents faced greater levels of uncertainty in classifying images. The implications of these findings can be interpreted in two ways. First, data generated by respondents receiving training material may potentially result in less biased population estimates due to lower rates of misclassification from respondents incorrectly attempting to classify deer of which they are uncertain. This builds on our earlier argument regarding the importance of classifying unidentifiable individuals as unknown. However, greater rates of unknown responses can have negative implications for camera survey output as well. Each time an unknown response is selected for an individual that could be accurately classified, the pool of usable data shrinks, thereby weakening survey estimates. Despite these conflicting interpretations of an increased unknown response rate, we believe that encouraging unknown responses in the cases of unidentifiable images or general uncertainty will tend to result in net benefits for the reliability of resulting population estimates.

Newbolt and Ditchkoff (2019) also found that the sex-age category of deer was a major predictor of classification accuracy; however, differences between the image sets used in their study and this current study produced contrasting rates of classification accuracy among sex-age categories. Specifically, the fact that this study included buck images that were vastly comprised of spike-antlered individuals (21 of 22) was different from Newbolt and Ditchkoff (2019), which primarily used images of branch-antlered bucks (28 of 32). We believe this difference in image sets resulted in greater misclassification of buck images compared to Newbolt and Ditchkoff (2019), who found that spike-antlered bucks were misclassified at a far greater rate than branch-antlered bucks. We believe the difference in rate of misclassified buck images between trained and nontrained respondents reported in this study supports the hypothesis of Newbolt and Ditchkoff (2019) that much of the misclassification of spike-antlered bucks they observed in their study resulted from misinformation about antler growth patterns rather than visual inaccuracy.

We also found experiential factors to be important predictors of classification accuracy in this study. These conclusions are corroborated by findings from Newbolt and Ditchkoff (2019), who also found that experience played a role in the accuracy of deer classifications. Specifically, professional experience as a wildlife biologist, field experience viewing deer, and experience viewing deer using trail cameras were important determinants of accurately classifying deer images. However, each of these factors had relatively little effect on classification accuracy compared to the effect of training material or the sex-age category of deer images being classified. Newbolt and Ditchkoff (2019) also reported small, yet significant, effects of similar experiential factors such as professional experience as a wildlife biologist and experience viewing deer using trail cameras. Although findings suggest experiential factors may only account for a low rate of error in wildlife camera surveys, any significant source of error must be critically assessed to maximize reliability of survey output (Newbolt and Ditchkoff 2019). Multiple studies have reported that low rates of error when identifying camera images can contribute to considerable biases in survey estimates. For instance, previous work suggests that false positive errors in capture-recapture studies, even when minimal, have the potential to cause substantial biases in abundance estimates (Gunnlaugsson and Sigurjónsson 1990, Stevick et al. 2001). Similarly, Morrison et al. (2011) found that ignoring misidentification error in capture-recapture studies can lead to biased survival estimates.

We found wildlife biologists to be the group of respondents most accurate at classifying images among those that indicated professional or working experience in a wildlife-related field. Several ecological studies have revealed an advantage in the reliability of data collected by professional researchers compared to non-professional volunteers (Darwall and Dulvy 1996, Lovell et al. 2009, Ahrends et al. 2011). Within the context of wildlife surveys, other studies have shown professionals tend to produce more accurate data than nonprofessional observers (Garel et al. 2005, Lewandowski and Specht 2015). Receiving training material remained a stronger predictor of classification accuracy than professional experience, even for wildlife biologists; however, we acknowledge that the overall proportion of respondents that indicated experience as a wildlife biologist (<8%) was likely too small to responsibly draw definitive conclusions from this comparison.

Respondents' level of experience viewing deer using trail camera images was also shown to have a significant effect on unknown response rate. Respondents who indicated no experience viewing deer using trail cameras were nearly 70% more likely to select "unknown" than respondents who indicated a high level of experience. Since this trend was found irrespective of exposure to training material, we attribute the difference in unknown response rate to respondent confidence in classifying deer images. Inexperienced respondents may have felt more inclined to err on the side of selecting "unknown" when faced with uncertainty, while respondents that believed they were highly experienced were either more inclined to provide their best guess or were generally more certain about how to classify deer images. This interpretation is supported by findings from Perry et al. (2021) who found greater self-reported confidence levels regarding species identification in respondents that had prior experience identifying target species.

We feel it is important to note that the pool of respondents in this study may not accurately represent the demographics and experience level of the individuals who typically conduct wildlife surveys, primarily based on the fact that a vast majority of our respondents lacked professional or working experience in a wildlife-related field. We also acknowledge that our respondents were not representative of the general public. Rather, our pool of respondents were an artifact of the methods used to elicit participation, primarily through deer hunting-based media platforms. The deer images presented to our respondents were intended to reflect those collected in an actual camera survey. However, the integrity of our data required presenting images in a random order, rather than in a chronological series common under normal field situation. This departure from real-world conditions must be considered when interpreting our reported rates of classification accuracy, which may have been greater had images been presented chronologically due to deer potentially being captured more than once and from multiple angles. Regardless, we believe that our research reveals important trends and factors that contribute to misclassification in wildlife camera surveys.

Management Implications

Our study demonstrates that misclassification of sex-age categories may be a surprisingly widespread source of error in wildlife camera surveys. Sex-age misclassification has the potential to bias survey output, thereby leading to skewed population estimates. Oftentimes, important management decisions are informed by survey estimates, and resulting management actions may be misinformed if operating on biased population estimates. Misinformed wildlife biologists or managers operating on biased data may take inappropriate measures that have harmful consequences for wildlife populations. Additionally, ill-informed management practices could potentially lead to waste of capital. Therefore, accuracy of survey data and resulting estimates are paramount to proper management of wildlife populations. Our findings suggest that training material has the ability to improve population estimates from camera surveys by reducing rates of misclassification. We encourage wildlife biologists and managers to develop their own training material based on their target species, while accounting for considerations specific to region and seasonal timing of conducted surveys. The training material in this study was extremely concise and simplistic, yet still significantly increased classification accuracy at the sex-age level. We suggest that similar tools be readily accessible and frequently utilized, even for experienced practitioners, to minimize potential bias resulting from sex-age misclassification.

Literature Cited

Ahrends, A., C. Rahbek, M. T. Bulling, N. D. Burgess, P. J. Platts, J. C. Lovett, V. W. Kindemba, N. Owen, A. N. Sallu, A. R. Marshall, B. E. Mhoro, E. Fanning, and R. Marchant. 2010. Conservation and the botanist effect. Biological Conservation 144: 131-140.

Azhar, M. A. H. B., S. Hoque, and F. Deravi. 2012. Automatic identification of wildlife using local binary patterns. IET Conference on Image Processing.

Brooks, J. J., R. J. Warren, M. G. Nelms, and M. A. Tarrant. Visitor attitudes toward and knowledge of restored bobcats on Cumberland Island National Seashore, Georgia. Wildlife Society Bulletin 27: 1089-1097.

Casey, A. L., P. R. Krausman, W. W. Shaw, and H. G. Shaw. 2006. Knowledge of and attitudes toward mountain lions: a public survey of residents adjacent to Saguaro National Park, Arizona. Human Dimensions of Wildlife 10: 29-38.

Cohn, J. P. 2008. Citizen science: can volunteers do real research? BioScience 58: 192-197.

Darwall, W. R. T., and N. K. Dulvy. 1996. An evaluation of the suitability of non-specialist volunteer researchers for coral reef fish surveys, Mafia Island, Tanzania – a case study. Biological Conservation 78: 223-231.

Ditchkoff, S. S. 2011. Anatomy and Physiology. Pages 43-73 in D. G. Hewitt, editor. Biology and management of white-tailed deer. CRC Press, Boca Raton, Florida, USA.

Danielsen, F., P. M. Jensen, N. D. Burgess, R. Altamirano, P. A. Alviola, H. Andrianandrasana, J. S. Brashares, A. C. Burton, I. Coronado, N. Corpuz, M. Enghoff, J. Fjeldså, M. Funder, S. Holt, H. Hübertz, A. E. Jensen, R. Lewis, J. Massao, M. M. Mendoza, Y. Ngaga, C. B. Pipper, M. K. Poulsen, R. M. Rueda, M. K. Sam, T. Skielboe, M. Sørensen, and R. Young. A Multicountry Assessment of Tropical Resource Monitoring by Local Communities. 2014. BioScience 64: 236–251.

Gálvez, N., G. Guillera-Arroita, B. J. T. Morgan, and Z. G. Davies. 2016. Cost-efficient effort allocation for camera-trap occupancy surveys of mammals. Biological Conservation 204: 350-359.

Garel, M., J. M. Cugnasse, J. M. Gaillard, A. Loison, Y. Santosa, and M. L. Maublanc. 2005. Effect of observer experience on the monitoring of a mouflon population. Acta Theriologica 50: 109-114.

Gunnlaugsson, T., and J. Sigurjónsson. 1990. A note on the problem of false positives in the use of natural marking data for abundance estimation. Report of the International Whaling Commission 12: 143-145.

Hosmer, D. W., S. Lemeshow, and R. X. Sturdivant. 2013. Applied logistic regression, John Wiley and Sons, Hoboken, New Jersey, USA.

Jacobson, H. A., J. C. Kroll, R. W. Browning, B. H. Koerth, and M.H. Conway. 1997. Infrared-triggered cameras for censusing white-tailed deer. Wildlife Society Bulletin 25: 547-556.

Johansson, O., G. Samelius, E. Wikberg, G. Chapron, G. Mishra, and M. Low. 2020. Identification errors in camera-trap studies result in systematic population overestimation.

Scientific Reports 10: 6393.

Karanth, K. U., J. D. Nichols, N. S. Kumar, and J. E. Hines. Assessing tiger population dynamics using photographic capture-recapture sampling. Ecology 87: 2925-2937.

Katrak-Adefowora, R., J. L. Blickley, and A. J. Zellmer. 2020. Just-in-time training improves accuracy of citizen scientist wildlife identifications from camera trap photos. Citizen Science: Theory and Practice 5: 8.

Kelly, M. J. 2001. Computer-aided photograph matching in studies using individual identification: an example from serengeti cheetahs. Journal of Mammalogy 82: 440-449.

Kelly, M. J., A. J. Noss, M. S. DiBitetti, L. Maffei, R. L. Arispe, A. Paviolo, C. D. DeAngelo, and Y. E. DiBlanco. 2008. Estimating puma densities from camera trapping across three study sites: Bolivia, Argentina, and Belize. Journal of Mammalogy 89: 408-418.

Lewandowski, E., and H. Specht. 2015. Influence of volunteer and project characteristics on data quality of biological surveys. Conservation Biology 29: 713-723.

Lovell, S., M. Hamer, R. Slotow, and D. Herbert. 2009. An assessment of the use of volunteers for terrestrial invertebrate biodiversity surveys. Biodiversity and Conservation 18: 3295-3307.

McCarthy, M. S., M. Despres-Einspenner, D. R. Farine, L. Samuni, S. Angedakin, M. Arandjelovic, C. Boesch, P. Dieguez, K. Havercamp, A. Knight, K. E. Langergraber, R. M. Wittig, and H. S. Kühla. 2019. Camera traps provide a robust alternative to direct observations for constructing social networks of wild chimpanzees. Animal Behaviour 157: 227-238.

Meek, P. D., G. A. Ballard, and P. J. S. Fleming. 2015. The pitfalls of wildlife camera trapping as a survey tool in Australia. Australian Mammalogy 37: 13-22.

Mendoza, E., P. R. Martineau, E. Brenner, and R. Dirzo. 2011. A novel method to improve individual animal identification based on camera-trapping data. The Journal of Wildlife Management 75: 973-979.

Morrison, T. A., J. Yoshizaki, J. D. Nichols, and D. T. Bolger. 2011. Estimating survival in photographic capture–recapture studies: overcoming misidentification error. Methods in Ecology and Evolution 2: 454–463.

Neuman, T. J., C. H. Newbolt, S. S. Ditchkoff, and T. D. Steury. 2016. Microsatellites reveal plasticity in reproductive success of white-tailed deer. Journal of Mammalogy 97: 1441– 1450.

Newbolt, C. H., and S. S. Ditchkoff. 2019. Misidentification error associated with classifications of white-tailed deer images. Wildlife Society Bulletin 43: 527-536.

Oliveira-Santos, L. G., C. A. Zucco, P. C. Antunes, and P. G. Crawshaw. 2010. Is it possible to individually identify mammals with no natural markings using camera-traps? A controlled case-study with lowland tapirs. Mammalian Biology 75: 375-378.

Palmer, M. S., A. Swanson, M. Kosmala, T. Arnold, and C. Packer. 2018. Evaluating relative abundance indices for terrestrial herbivores from large-scale camera trap surveys. African Journal of Ecology 56: 791-803.

Parsons, A. W., C. Goforth, R. Costello, and R. Kays. 2018. The value of citizen science for ecological monitoring of mammals. PeerJ 6:e4536.

Perry, J. R., S. Sumner, C. Thompson, and A. G. Hart. 2021. 'Citizen identification': online learning supports highly accurate species identification for insect-focused citizen science. Insect Conservation and Biology. doi:10.1111/icad.12528.

Ratnieks. F. L. W., F. Schrell, R. C. Sheppard, E. Brown, O. E. Bristow, and M. Garbuzov. 2016. Data reliability in citizen science: learning curve and the effects of training method, volunteer background and experience on identification accuracy of insects visiting ivy flowers. Methods in Ecology and Evolution 7: 1226-1235.

Rovero, F., F. Zimmermann, D. Berzi, and P. Meek. 2013. "Which camera trap type and how many do I need?" A review of camera features and study designs for a range of wildlife research applications. Hystrix 24: 148– 156.

Rowcliffe, J. M., and C. Carbone. 2008. Surveys using camera traps: are we looking to a brighter future? Animal Conservation 11: 185-186.

Silveira, L., A. T. A. Jacomo, and J. A. F. Diniz-Filho. 2003 Camera trap, line transect census and track surveys: a comparative evaluation. Biological Conservation 114: 351–355.

Speed, C. W., M. G. Meekan, and C. J. A. Bradshaw. 2007. Spot the match – wildlife photo-identification using information theory. Frontiers in Zoology 4: 1-11.

Steger, C., B. Butt, M. B. Hooten. 2017. Safari science: assessing the reliability of citizen science data for wildlife surveys. Journal of Applied Ecology 54: 2053-2062.

Stevick, P. T., P. J. Palsbøll, T. D. Smith, M. V. Bravington, and P. S. Hammond. 2001. Errors in identification using natural markings: rates, sources, and effects on capture–recapture estimates of abundance. Canadian Journal of Fisheries and Aquatic Sciences 58:1861–1870.

Swanson, A., M. Kosmala, C. Lintott, and C. Packer. 2016. A generalized approach for producing, quantifying, and validating citizen science data from wildlife images. Conservation Biology 30: 520-531.

Van der Wal, R., N. Sharma, C. Mellish, A. Robinson, and A. Siddharthan. 2016. The role of automated feedback in training and retaining biological recorders for citizen science. Conservation Biology 30: 550-561.

Wearn, O. R. and P. Glover-Kapfer. 2019. Snap happy: camera traps are an effective sampling tool when compared with alternative methods. Royal Society Open Science 6: 1-13.

Yoshizaki, J., K. H. Pollock, C. Brownie, R. A. Webster. 2009. Modeling misidentification errors in capture-recapture studies using photographic identification of evolving marks. Ecology 90: 3-9.

Table 2.1 – Demographics of all respondents that took part in online survey conducted 26 April–31 May 2021. Survey respondents consisted of individuals from across the United States that responded to online solicitations from Auburn University Deer Laboratory social media, National Deer Association (www.deerassociation.com) and Deer and Deer Hunting (www.deeranddeerhunting.com).

	Frequency	**Percentage**
Q1 - Please indicate your gender.		
Male	1652	95.27%
Female	82	4.73%
Prefer not to say	8	-
Q2 - Please indicate your age.		
19-24	77	4.42%
25-34	242	13.88%
35-44	312	17.89%
45-54	365	20.93%
55-64	443	25.40%
65 or older	305	17.49%
Prefer not to say	13	-
Q3 - Which best describes your highest level of education?		
High School Degree	231	13.42%
Some College	412	23.94%
College Degree	723	42.01%
Graduate Degree	355	20.63%
Prefer not to say	35	-
Q4 - Which best describes your annual income level?		
$10,000-$25,000	52	3.40%
$25,000-$50,000	213	13.91%
$50,000-$75,000	376	24.56%
$75,000-$100,000	329	21.49%
$100,000+	561	36.64%
Prefer not to say	195	-

Table 2.2 – Experiential predictors of all respondents that took part in online survey conducted 26 April–31 May 2021. Survey respondents consisted of individuals from across the United States that responded to online solicitations from Auburn University Deer Laboratory social media, National Deer Association (www.deerassociation.com) and Deer and Deer Hunting (www.deeranddeerhunting.com).

	Frequency	**Percentage**
Q5 - Do you have any professional/working experience in a wildlife-related field?		
Yes	279	15.88%
No	1478	84.12%
Q5a - If yes, how would you classify your professional/working experience in a wildlife related field? Select all that apply		
Wildlife biology	138	49.46%
Forestry	118	42.29%
Land management	69	24.73%
Hunting guide	60	21.51%
Outdoor industry	44	15.77%
Other	55	19.71%
Q6 - Do you have experience hunting white-tailed deer?		
Yes	1713	97.55%
No	43	2.45%
Q7 - Do you have field experience viewing white-tailed deer?		
Yes	1657	94.42%
No	98	5.58%
Q8 - Do you have hunting/field experience viewing white-tailed deer in AL or the immediately surrounding states (FL, GA, MS, TN)?		
Yes	548	31.19%
No	1209	68.81%
Q9 - In your opinion, what level of experience do you currently have using trail cameras to view white-tailed deer for any purpose?		
High	617	35.12%
Moderate	834	47.47%
Low	241	13.72%
None	65	3.70%
Q10 - Have you ever conducted a trail camera survey specifically for the purpose of estimating deer population information, such as adult sex ratio, deer density, or fawn recruitment?		
Yes	396	22.54%
No	1361	77.46%
Q10a - If yes, how many of these kinds of trail camera surveys have you completed?		
4 or less	244	61.62%
5 to 11	86	21.72%
11 or more	66	16.67%

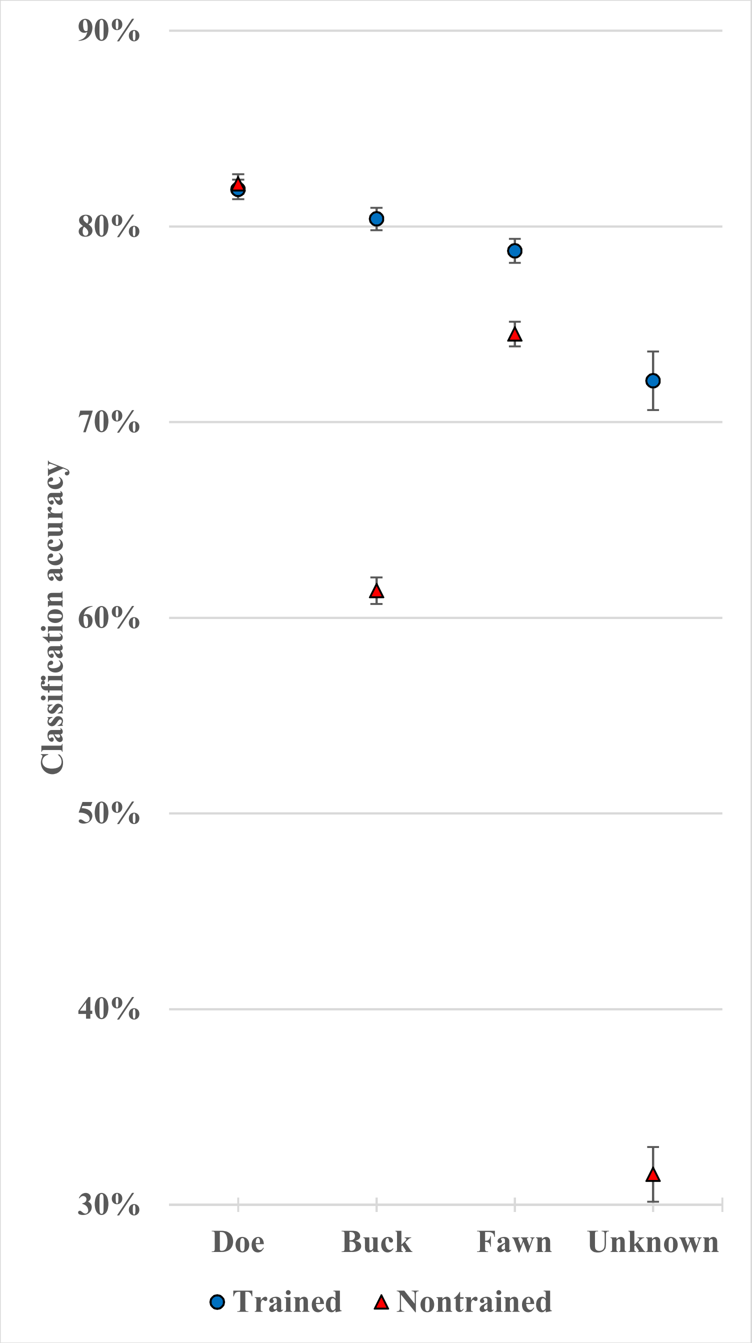


Figure 2.1 – Mean (95% CL) classification accuracy scores of both trained and untrained respondents for each sex-age category of deer image. Adult male ≥1.5 years of age: 'buck'; adult female ≥1.5 years of age: 'doe'; juvenile of approximately 6–8 months of age: 'fawn.'; not enough visible information to classify: 'unknown'. The survey was conducted 26 April–31 May 2021, and respondents consisted of individuals from across the United States that responded to online solicitations from Auburn University Deer Laboratory social media, National Deer Association (www.deerassociation.com) and Deer and Deer Hunting (www.deeranddeerhunting.com).

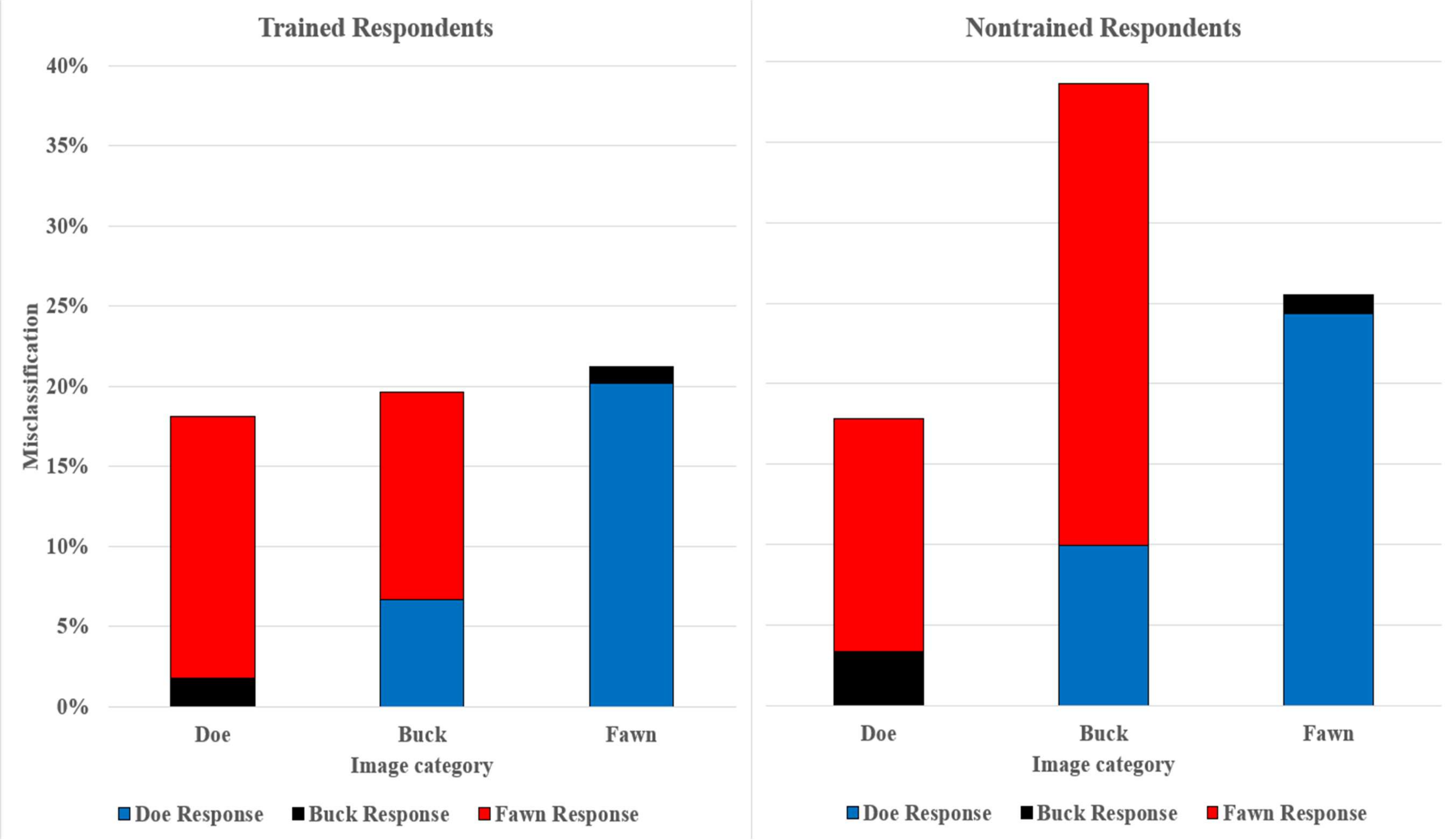
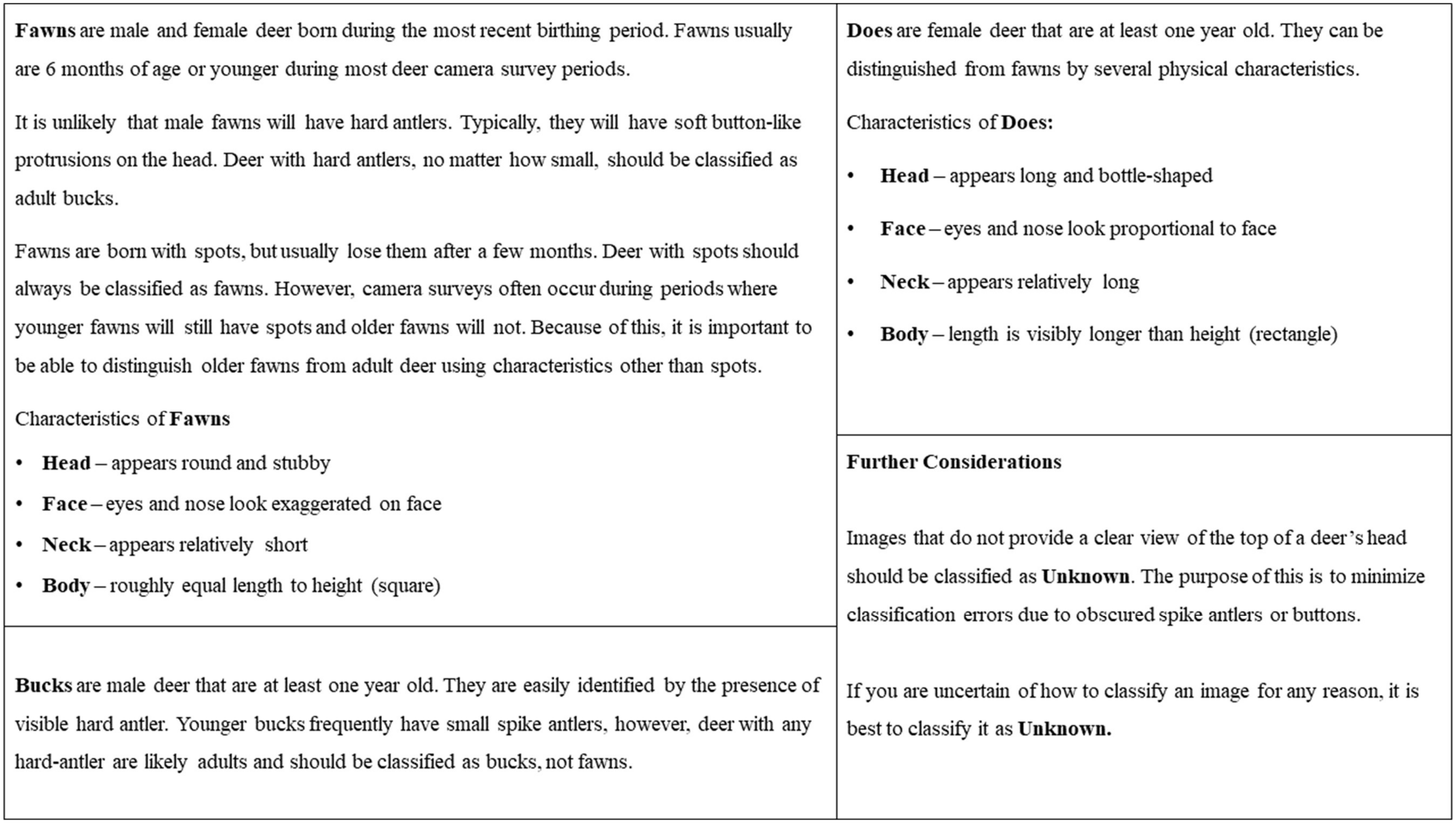


Figure 2.2 – Misclassification of each known sex-age category of deer image for trained and untrained respondents. Stacked bars represent proportion of misclassification due to each incorrect response. The survey was conducted 26 April–31 May 2021, and respondents consisted of individuals from across the United States that responded to online solicitations from Auburn University Deer Laboratory social media, National Deer Association (www.deerassociation.com) and Deer and Deer Hunting (www.deeranddeerhunting.com).



Fawns are male and female deer born during the most recent birthing period. Fawns usually are 6 months of age or younger during most deer camera survey periods.

It is unlikely that male fawns will have hard antlers. Typically, they will have soft button-like protrusions on the head. Deer with hard antlers, no matter how small, should be classified as adult bucks.

Fawns are born with spots, but usually lose them after a few months. Deer with spots should always be classified as fawns. However, camera surveys often occur during periods where younger fawns will still have spots and older fawns will not. Because of this, it is important to be able to distinguish older fawns from adult deer using characteristics other than spots.

Characteristics of **Fawns**

- **Head** – appears round and stubby
- **Face** – eyes and nose look exaggerated on face
- **Neck** – appears relatively short
- **Body** – roughly equal length to height (square)

Bucks are male deer that are at least one year old. They are easily identified by the presence of visible hard antler. Younger bucks frequently have small spike antlers, however, deer with any hard-antler are likely adults and should be classified as bucks, not fawns.

Does are female deer that are at least one year old. They can be distinguished from fawns by several physical characteristics.

Characteristics of **Does:**

- **Head** – appears long and bottle-shaped
- **Face** – eyes and nose look proportional to face
- **Neck** – appears relatively long
- **Body** – length is visibly longer than height (rectangle)

Further Considerations

Images that do not provide a clear view of the top of a deer's head should be classified as **Unknown**. The purpose of this is to minimize classification errors due to obscured spike antlers or buttons.

If you are uncertain of how to classify an image for any reason, it is best to classify it as **Unknown.**

Appendix B – Training material presented to respondents of Qualtrics® white-tailed deer identification survey. The survey was conducted 26 April–31 May 2021, and respondents consisted of individuals from across the United States that responded to online solicitations from Auburn University Deer Laboratory social media, National Deer Association (www.deerassociation.com) and Deer and Deer Hunting (www.deeranddeerhunting.com).