2017

Testing Northern Bobwhite Reintroduction Techniques in the Northern Edge of Their Range

William Macaluso
University of Delaware

Christopher K. Williams
University of Delaware

Theron M. Terhune II
Tall Timbers Research Station and Land Conservancy

Follow this and additional works at: https://trace.tennessee.edu/nqsp

Part of the Natural Resources and Conservation Commons

Recommended Citation
https://doi.org/10.7290/nqsp08nwux
Available at: https://trace.tennessee.edu/nqsp/vol8/iss1/49

This article is brought to you freely and openly by Volunteer, Open-access, Library-hosted Journals (VOL Journals), published in partnership with The University of Tennessee (UT) University Libraries. This article has been accepted for inclusion in National Quail Symposium Proceedings by an authorized editor. For more information, please visit https://trace.tennessee.edu/nqsp.
TESTING NORTHERN BOBWHITE REINTRODUCTION TECHNIQUES IN THE NORTHERN EDGE OF THEIR RANGE

William Macaluso
Department of Entomology and Wildlife Ecology, University of Delaware, 531 S. College Avenue, Newark DE 19716, USA

Christopher K. Williams
Department of Entomology and Wildlife Ecology, University of Delaware, 531 S. College Avenue, Newark DE 19716, USA

Theron M. Terhune
Tall Timbers Research Station and Land Conservancy, 13093 Henry Beadel Drive, Tallahassee FL 32312, USA

ABSTRACT

Pen-rearing young frequently fails as a reintroduction technique in game birds because of low postrelease survival rates in the wild. This may be caused by a combination of poor genetics from domestication, unhealthy birds, birds that do not exhibit wild behavior, or birds that are unfamiliar with their surroundings after hard releases. Recent research suggests that parent-rearing, involving pre- and posthatch imprinting of wild-strain northern bobwhite (Colinus virginianus) chicks by adults, may be a viable option for restoring populations. Imprinting potentially causes reintroduced birds to exhibit more natural behavior. We tested this method against a slightly modified traditional propagation tool (Surrogator®) with wild-strain birds. We conducted our research on a 170-ha property containing a mixture of early successional and hardwood habitat on Long Island, New York, during the summers of 2013 and 2014. We tested the effect of rearing methodology, mass at release (as a proxy for physical condition), release timing, and year on survival using Cox proportional hazard models. Hazard analysis revealed that only earlier release dates directly improved survival whereas treatment (parent-reared vs. Surrogator), body mass at release, and year did not affect survival. The methods tested on our study area did not result in 365-day survival rates high enough to re-establish quail in the area.


Key words: Cox proportional hazards, foster parent, Long Island, New York, northern bobwhite, reintroduction, Surrogator, survival

The northern bobwhite (Colinus virginianus; hereafter, bobwhite) is a widely distributed gamebird in eastern North America but has experienced range contractions and precipitous range-wide declines in abundance since the 1960s (Sauer et al. 2014). Historically, bobwhites were found in early successional habitats ranging as far north as Ontario, Canada (Cadman et al. 1987); however, populations at the northern end of the species’ range, including those in the Mid-Atlantic, have experienced particularly serious declines in abundance and distribution. Indeed, the northern populations in New York and New Jersey have been extirpated.

Bobwhites are near extirpation at the northern periphery of their range, so it is reasonable to employ endangered species restoration techniques. Endangered species management includes integrated strategies of habitat preservation, habitat restoration, and active management; however, Foin et al. (1998) found that 63% of endangered species would require more active management through initial habitat and population restoration or continued supplementation. Releasing captive-reared birds is one common active management strategy. Many captive breeding programs fail due to problems with 1) establishing self-sustaining captive populations, 2) poor success in reintroductions, 3) high costs, 4) loss of genetic variability due to domestication, 5) preemption of other recovery techniques, 6) disease outbreaks, and 7) maintaining administrative continuity (Snyder et al. 1996). However, in some cases, captive-breeding reintroduction programs have proven to be successful (e.g., California condor [Gymnogyps californianus] and black footed ferret [Mustela nigripes], Snyder and Snyder 1989, Jones et al. 1995). Therefore, to incorporate captive-breeding reintroduction programs, careful field studies that examine habitat suitability, genetics, physiological condition, site familiarity, and behavior must be conducted to provide measurable long-term success before their implementation (Snyder et al. 1996).

Physiological condition is important for successful reintroduction programs. Being transferred from one place to another, whether from one wild population to a new area or from captivity to the wild, puts stress on animals (Groombridge et al. 2004, Calvete et al. 2005,
Franceschini et al. 2008) causing immune system suppression, leading to increased disease susceptibility, reduced reproductive capacity, and diminished fight-flight response, which could lead to increased predation (Dickens et al. 2009). Release methodology is also important for improving the chances of survival after release. Soft releases gradually introduce animals to the wild, often by releasing them into an on-site enclosure with shelter and food for a period of time in an effort to improve survival rates (Kleiman 1989). Using a soft release method may provide the animals time to safely learn about the environment (e.g., what type of food is available, what predators are on the landscape) without the actual hazards associated with being fully in the wild (Bright and Morris 1994, Mitchell et al. 2011). Hard releases, where animals are released directly into the wild without any acclimation in a contained environment or other support, can unnecessarily stress animals. A well-planned captive breeding program will carefully consider the implications of each of these factors to offer released animals the highest probability of survival.

A number of management strategies have been tested to reestablish northern bobwhites in areas of suitable habitat, including release of pen-reared bobwhites and translocation of wild bobwhites (Roseberry et al. 1987, Terhune et al. 2010). Attempts to restore bobwhite populations in suitable habitat using game-farm or pen-reared quail have been made since the early 1900s and continue into the present (Handley 1938, Wilson 1986, Perez et al. 2002). Propagation of game birds in captivity has long been regarded as a “quick fix” for better hunting (Hart and Mitchell 1947) and has been well-documented during the 1930s and 1940s (McAtee 1930, Hart and Mitchell 1947). However, this method of replenishing quail populations has proven unsuccessful for establishing sustainable populations. Pen-raised bobwhites often exhibit low rates of postrelease survival, averaging 8–15 days (Roseberry et al. 1987, Perez et al. 2002) and long-distance dispersal from release sites (Baumgartner 1944, Buechner 1950, Oakley et al. 2002). Additionally, pen-reared bobwhites that are released and survive until the following nesting seasons have been found to readily nest (DeVos and Speake 1995, Eggert et al. 2009) but they tend to have poor parenting skills and therefore low recruitment of young (Cass 2009, Eggert et al. 2009).

In response to historical problems associated with failed attempts of using pen-reared individuals to restore populations and the difficulty of obtaining wild birds for translocation, Wildlife Management Technologies (WMT; Wichita, KS, USA) developed a soft release methodology for pen-reared birds called “The Surrogator.” The Surrogator® is a game bird propagation tool that provides food, water, heat, and shelter for incubator-raised chicks from day one through the first 5 weeks of life. Wildlife Management Technologies asserted that 300,000 quail were released from the Surrogator in 2006 with a subsequent survival rate from release to autumn harvest season of 0.65 (WMT 2009). However, recent multistate research failed to reproduce these results. Bobwhites reared in the Surrogator in Kansas had survival rates of 0.35 through 8 weeks and long-term survival was nil (Kinsey et al. 2012, Thackston et al. 2012).

As an alternative to releasing pen-reared birds, translocation of wild birds is the preferred and proven method to restore populations in suitable habitat. Translocation eliminates the behavioral and genetic problems associated with captive breeding programs, thus producing survival rates, nest production, and nest survival that are comparable to wild resident bobwhites (Terhune 2008, Terhune et al. 2010). However, translocation of wild bobwhites is often not an option because of legal (i.e., state restrictions to release birds to other states) and financial restrictions preventing the removal of wild birds from their current range (Hernández and Perez 2007).

In an attempt to combine the advantages of wild translocation along with the logistical ease of captive breeding, Palmer et al. (2012) developed a parent-rearing method for bobwhites that includes prenatal and postnatal learning with wild-strain bobwhites in group sizes that were similar to brood sizes. Bobwhite eggs removed from wild nests and hatched from incubators produced the breeding stock for the wild-strain bobwhites. This rearing method addresses the genetic and behavioral concerns of typical captive-rearing programs. In the past, some captive-rearing programs have been able to reduce behavioral limitations by using conspecific foster parents (Wiley et al. 1992, Snyder et al. 1996). Filial imprinting is an early form of learning during short prenatal (Lickliter 1989, 2005) and posthatch periods in which the chicks learn to identify their parents (Jaynes 1956, Hess 1973). Avian imprinting facilitates behaviors that enhance survival of offspring through sexual identification, social learning, predator recognition, predator avoidance, recognition of alarm calls, food selection, and parenting skills (Hess 1973, Dowell 1992, Lickliter and Harshaw 2010). Palmer et al.’s (2012) research on incorporating parent-rearing of wild-strain chicks found that nest success and chick survival were similar between parent-reared birds and wild birds, indicating that this method may be a successful alternative to the Surrogator for population restoration. However, Palmer et al.’s (2012) work was conducted in southern Georgia and South Carolina, where populations are more robust than those at the periphery of the bobwhite range. We do not know if parent-rearing can achieve similar levels of success at the edge of the bobwhite’s range where density-independent stochasticity may introduce a complicating factor.

We tested these captive-rearing techniques on the bobwhite range periphery of Long Island, New York, where the bobwhite population is at or near extirpation. This research is intended to fill knowledge gaps in the area of bobwhite restoration techniques in northeastern/Mid-Atlantic states (Castelli et al. 2009); captive-bred bobwhites could be a valuable tool for preventing population collapse after major weather events in these peripheral populations. Our study was conducted with 3 main objectives. Our first objective was to test the effect of parent-rearing on bobwhites compared with those reared without parents (Surrogator). If parent-reared birds experienced higher survival rates, the results would point
toward the importance of imprinting (i.e., natural behavior) for successful bobwhite reintroduction efforts. Second, we examined the effect of body mass at release date as a proxy for the effect of physiological condition on postrelease survival. We assumed that individuals with a higher body mass at time of release were in better physiological condition than individuals with a lower body mass. Finally, we examined the effect of release date on daily survival rates. We did not examine the effects of habitat suitability or site familiarity because all of the bobwhites were released with a soft release methodology into the same habitat.

STUDY AREA

We conducted our research during May–December of 2013 and 2014 at the Greentree Foundation, a 170-ha area in western Long Island, New York, USA (Fig. 1). Approximately half of the property consists of dense hardwood forest comprising mostly oak (Quercus spp.), American beech (Fagus grandifolia), and maple (Acer spp.) trees. Dense understory in the woodland area provided ample bobwhite escape cover. The remainder of the property consists of early successional and grassland habitat and facility buildings. Areas of nonnative turf grass were gradually being replaced with native grass and forb mixes including species such as Indian grass (Sorghastrum nutans), little bluestem (Schizachyrium scoparium), big bluestem (Andropogon gerardii), and partridge pea (Chamaecrista fasciculata). Native grass and forb plantings provided nesting and foraging habitat. Food availability was supplemented with 2 food plot areas on opposite ends of the property consisting of mainly grain sorghum and proso millet. The predator community on the study area included feral cats (Felis catus), red foxes (Vulpes vulpes), great horned owls (Bubo virginianus), and various Accipiter and Buteo species. The annual mean temperature at the Greentree Foundation during 1981–2010 was 12.4°C with 118.3 cm of precipitation. The mean summer temperature was 22.9°C with 30.4 cm of precipitation. Mean winter temperatures were 1.8°C with 26.6 cm of precipitation (60.5 cm of snow; NOAA 2015). The mean summer temperature at Greentree was 22.6°C in 2013 and 22.8°C in 2014 with 32.9 cm of precipitation in 2013 and 29.6 cm in 2014. The mean winter temperature was 2.1°C in 2013 with 30.7 cm of precipitation and 0.74°C in 2014 with 36.7 cm of precipitation. The Greentree Foundation began raising bobwhites from domestic stock in the Surrogator for release on the property in 2011 (M. Afonso, Greentree Foundation, personal communication). Overwinter survival of these bobwhites was low and none of the birds released prior to the study were documented to have successfully reproduced.

METHODS

General Methods

In order to assess the impact of imprinting and physiological condition on survival of pen-reared bobwhites, we performed 3 trials during June, July, and September each year for 2 years using 2 Surrogators and 2 outdoor rearing pens placed at different locations on the property (<1.5 km apart) in areas considered to be suitable bobwhite habitat. We obtained “wild-strain” eggs from Quail Call Farms in Beachton, Florida, USA, although we could not definitively test the accuracy of their product. We placed eggs in 2 GQF Digital Sportsman (Savannah, GA, USA) cabinet-style incubators for 23 days at the start of each trial. We maintained the incubators at 37.5°C and 60% humidity for the first 20 days of incubation. We raised the temperature to approximately 37.8°C with a humidity of 75% for the last 3 days of incubation and while chicks were hatching. We divided “wild-strain” chicks hatched from one incubator between 2 separate Surrogators at 1 day of age. “Wild-strain” chicks hatched in the other incubator were imprinted to adult bobwhites and we moved them to trapezoidal outdoor rearing pens (4.9 m long, 2 m wide, and 2.84 m tall on one end, and 1.82 m high on the other end) within 48 hours of hatching.

Nonparent Rearing Methods

We used the 2 Surrogators already established on the Greentree property since 2011. We removed all vegetation and leaf litter from the immediate surrounding area for ease of maintenance. The Surrogators were set up and maintained according to all guidelines provided by the “Surrogator System Guide” (WMT 2009). During the 5-week period between hatching and release. The only contact chicks had with humans was during weekly maintenance of the Surrogator and when removing daily mortalities.
Chicks received commercial gamebird starter feed (Purina, St. Louis, MO, USA) with freestanding waterers. A wild-bird seed mix (consisting of proso millet [\textit{Panicum miliaceum}], grain sorghum [\textit{Sorghum bicolor}], cracked corn [\textit{Zea mays}], wheat [\textit{Triticum spp.}], and black oil sunflower seeds [\textit{Helianthus annuus}]) was mixed into the commercial feed when the chicks reached 3 weeks of age. We gradually reduced brooder heaters from 21 to 35 days of age to prepare chicks for ambient temperatures upon release.

Chicks received a color band (corresponding to the treatment type; i.e., Surrogator vs. parent-reared) and a uniquely numbered metal leg-band for future identification at 5 weeks of age. A randomly selected subset of juveniles from the Surrogators were fitted with a 3-g expanding radiotransmitter (American Wildlife Enterprises QC 300-day necklace transmitter, Monticello, FL, USA) before each release. We divided the bobwhites from each Surrogator into groups of approximately 5–20 to simulate a natural brood size (Stoddard 1931) before their release. We radiomarked 2–3 birds in each brood. We waited to release the juveniles until the majority of the birds were ≥100 g; this was the minimum size where we could safely outfit the juveniles with radiocollars. Surrogator birds grew faster than parent-reared birds but could safely outfit the juveniles with radiocollars.

Juveniles received a color leg-band and a uniquely numbered metal leg-band for future identification and we fitted 2–3 birds from each brood with an expanding radiotransmitter after 5 weeks. Then, we released each group approximately 30 minutes after sunrise without the foster parent at a unique location on the study area near a similar sized nonparent-reared group. Parent-reared birds were released into areas of similar habitat as Surrogator birds but we released each treatment in a unique location. We released birds from each treatment near enough to each other that it was possible for birds from different treatments to encounter each other and interact because of the size of the study area. We used the same release locations for each trial.

We made 2 modifications to the original pen design after observing low survival rates in the pens for the first 2 trials. First, a 1-m-long, 2-m-wide, 0.5-m-high plexiglass “greenhouse” with a door to the rest of the pen and a roof that slid open was built in each pen. Chicks were held in these “greenhouses” for 2 weeks before the door to the rest of the pen was opened. This allowed the chicks to grow to a size that allowed them to thermoregulate more effectively before being fully exposed to the environment. When the door to the uncovered pen was opened, the lid to the greenhouse remained closed to provide a refuge from cold temperatures and precipitation. Instead of holding to a rigid release schedule of 5 weeks old, we waited to release the juveniles until the majority of the birds were ≥100 g; this was the minimum size where we could safely outfit the juveniles with radiocollars.

Parent Rearing Methods

The Greentree Foundation constructed 2 sets of rearing pens housed 845 m apart in early successional habitat. Each set of rearing pens consisted of 4 pens adjacent to each another (Stoddard 1931). Each pen had a 1-m² shelter attached to its exterior where food was provided. A system of nipple waterers, similar to those used in the Surrogator, fed from a 5-gallon bucket of water was mounted to each pen. Sides and tops of the pens were covered in fine mesh wire fencing, allowing chicks to acclimate to local weather. The pens were enclosed by an electric fence to exclude mammalian predators after foxes depredated penned birds in summer 2014. Vegetation (e.g., grain sorghum, proso millet, etc.) was planted inside and outside of each pen to simulate natural brood habitat. We manually removed sod-forming grasses from the pens before each trial to facilitate movement throughout the pens by small chicks.

Bobwhite chicks were imprinted to adult foster birds and raised in outdoor pens following methods described by Palmer et al. (2012). Only domesticated bobwhites were available as a source for foster parents in the first year. However, in the second year, Quail Call Farms supplied “wild-strain” adults that had undergone the same imprinting process to be used as foster parents.

There was no supplemental heating provided for trials that took place from June through November. We retrofitted a heater from the Surrogator to the wooden box attached to the pens to provide supplemental heat for trials that started in December of 2013 and 2014. We fed chicks the same diet as for the Surrogator birds. The wild-bird seed mix was spread on the floor of the foster parent rearing pen instead of being mixed into the feeders for the Surrogator-reared birds. Spreading grain in the pen was intended to help prepare parent-reared chicks for foraging outside of the pens once they were released; this is not possible in the Surrogator because of its design. We expected insects to naturally enter the pens, allowing for additional protein and foraging training.

In three winters, we used funnel traps (Stoddard 1931) and night-roost cast-netting (Brinkley 2011) to trap bobwhites that were released on the Greentree property beginning in June 2013 to supplement sample size of radiocollared bobwhites. We replaced transmitters in each group as mortalities occurred when we were able to capture uncollared birds. We identified recaptured birds to their treatment group and release date based on their uniquely numbered aluminum leg-band and corresponding color band. Over...
the course of the study, we captured and radiocollared 17 Surrogator birds and 8 parent-raised birds.

Analyses

We used radiotelemetry data to estimate and compare survival rates between the treatments. The pulse rate of radiotransmitters doubled after they remained stationary for >18 hours. If a collar began to transmit a mortality signal, we located the collar and attempted to determine the cause of death for the bobwhite (Dumke and Pils 1973, Curtis et al. 1988). We pooled the data for all birds released from the Surrogators throughout the study and used a maximum likelihood estimator (Bart and Robson 1982) to calculate daily survival rates (Krebs 1999). In order to assess the effects of body mass and imprinting, we created Cox proportional hazard models (Cox 1972) using package Survival in R (Therneau and Grambsch 2000, Therneau 2015). We created 12 competing Cox proportional hazard models, including mass of birds at release, imprinting, trial (to account for effects of weather in different release months), and year effect. In order to avoid biasing the effect of trial on the models, we disregarded birds released in the third trial while creating our models because there were no Surrogator birds released in the third trial. We used Akaike’s Information Criterion corrected for small sample size (AIC$_c$; Akaike 1976) to select the top survival model.

RESULTS

We incubated 709 eggs over 4 trials for the Surrogator treatment. We released 278 Surrogator juveniles total and fitted 108 with radiocollars. We incubated 959 eggs over 6 trials for the parent-rearing treatment. We released 120 parent-reared juveniles total and fitted 54 with radiocollars (Table 1; see Macaluso 2016 for details about each trial). The third trial of each year was dedicated to only parent-reared birds as an effort to improve sample sizes for survival analysis.

We pooled birds released from the Surrogators each year into one group to calculate maximum likelihood estimates of daily survival rates because of our small sample sizes. Daily survival rate of “wild-strain” chicks released on the Greentree Foundation was 0.95 (95% CI = 0.84–1.00), thus producing <0.001 cumulative survival rate after 105 days.

We compared Kaplan–Meier survival of radiocollared birds between parent-reared and Surrogator birds for the first 2 trials of each year without the examining potential interaction effects from other variables (e.g., year or mass; Fig. 2). We did not examine the survival curve for Trial 3 because there was no Surrogator group to compare with the parent-reared birds released in that trial. In 2013–2014, the survival rate 31 weeks after initial

![Graph](attachment:image.png)

**Fig. 2.** Survival rates of radiocollared parent-reared and Surrogator northern bobwhite after release on the Greentree Foundation Property with 95% confidence intervals, Manhasset, New York, USA, comparing rates from birds released in the first (a) and second (b) trial per year, 2013–2015.
release (regardless of release date) was 0.123 for Surrogator birds and 0.0 for parent-reared birds. In 2014–2015, the survival rate 31 weeks after initial release (regardless of release date) was 0.033% for Surrogator birds and 0.0% for parent-reared birds. Despite the lack of long-term survival in both treatments regardless of trial date, birds from each treatment survived longer in the second trial.

The top Cox proportional hazard models (ΔAICc < 2) included only imprinting, mass, and trial number as covariates; study year was not a covariate in any of the top models (Table 2). We used model-averaging within the R package AICcmodavg (Mazerolle 2015) to calculate model-averaged estimates of hazard covariates based on their slope coefficient for mass (0.00, 95% CI = 0.01–0.01), imprinting (0.29, 95% CI = 0.57–0.56), and trial (−0.6, 95% CI = −1.6–0.4) based on entire model set. All of the covariates for the model-averaged data had confidence intervals that included 0; therefore, none of the model-averaged covariates were significant either. Trial was the closest covariate to achieving significance and the trial-only model was the top performing model aside from the null model. Maximum likelihood estimates of daily survival rates decreased for both Surrogator and parent-reared bobwhites from Trial 1 through 3 (Fig. 3).

DISCUSSION

Lohr (2009) found wild bobwhites in New Jersey had a daily survival rate of 0.9934 and a cumulative October–March survival rate of 0.3. Population models for bobwhites in the Mid-Atlantic predicted that bobwhite populations need a daily survival rate of 0.9968 (winter survival rate of 0.561) to maintain a stable population (Williams et al. 2012). Although our reintroduction efforts did not produce a sustainable population, there are possible improvements to foster parent-rearing that might enhance probability of success or future attempts.

First, habitat suitability is considered the primary factor in any reintroduction study. We did not directly examine effects of habitat quality because birds were released in the same locations. Therefore, we acknowledge that our reintroduction into a fragmented northern landscape could have influenced the long-term success of quail reintroduction on Long Island. Nevertheless, our research design still allowed for a direct comparison of reintroduction techniques for future efforts.

Our estimated survival of “wild-strain” bobwhites raised in the Surrogators throughout the course of this study was 0.95. Although our rate is slightly higher than Kinsey et al.’s (2012) reported daily survival rates with domestic bobwhites raised in the Surrogators of 0.92, both studies exhibited survival rates that approached zero after 105 days. Our study did not provide evidence that improving the genetic makeup of bobwhites can significantly improve survival rates compared with the more traditional domestic birds. However, these results do not mean that genetics should be ignored when rearing bobwhites for reintroduction projects. Previous research with other species has proven that loss of genetic variability through domestication can negatively impact reintroduction efforts (Leopold 1944, Knoder 1959, Barbanera et al. 2010). Some might argue that “wild-strain” bobwhites used in this study came from Florida.

Table 2. Cox proportional hazards models comparing the effects of mass, imprinting, trial, and study year on survival rates of northern bobwhites released on the Greentree Foundation Property, New York, USA, 2013 and 2014. ΔAIC values < 2.0 were considered to be the top competing models.

<table>
<thead>
<tr>
<th>Model</th>
<th>K</th>
<th>AICc</th>
<th>ΔAICc</th>
<th>AICc wt</th>
<th>Cumulative wt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Null</td>
<td>1</td>
<td>507.63</td>
<td>0.00</td>
<td>0.288</td>
<td>0.288</td>
</tr>
<tr>
<td>Trial</td>
<td>2</td>
<td>508.30</td>
<td>0.66</td>
<td>0.206</td>
<td>0.494</td>
</tr>
<tr>
<td>Mass</td>
<td>2</td>
<td>509.51</td>
<td>1.87</td>
<td>0.113</td>
<td>0.607</td>
</tr>
<tr>
<td>Imprint</td>
<td>2</td>
<td>509.64</td>
<td>2.01</td>
<td>0.105</td>
<td>0.712</td>
</tr>
<tr>
<td>Mass + Trial</td>
<td>3</td>
<td>510.28</td>
<td>2.65</td>
<td>0.077</td>
<td>0.789</td>
</tr>
<tr>
<td>Imprint + Trial</td>
<td>3</td>
<td>510.37</td>
<td>2.73</td>
<td>0.073</td>
<td>0.862</td>
</tr>
<tr>
<td>Mass + Imprint</td>
<td>3</td>
<td>511.58</td>
<td>3.95</td>
<td>0.040</td>
<td>0.902</td>
</tr>
<tr>
<td>Trial × Year</td>
<td>4</td>
<td>511.89</td>
<td>4.25</td>
<td>0.034</td>
<td>0.936</td>
</tr>
<tr>
<td>Imprint + Trial + Mass</td>
<td>4</td>
<td>512.30</td>
<td>4.66</td>
<td>0.028</td>
<td>0.964</td>
</tr>
<tr>
<td>Imprint × Year</td>
<td>4</td>
<td>512.98</td>
<td>5.35</td>
<td>0.020</td>
<td>0.984</td>
</tr>
<tr>
<td>Imprint × Year + Trial</td>
<td>5</td>
<td>513.90</td>
<td>6.26</td>
<td>0.013</td>
<td>0.997</td>
</tr>
<tr>
<td>Imprint × Year + Trial + Mass</td>
<td>7</td>
<td>517.75</td>
<td>10.11</td>
<td>0.002</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Fig. 3. Mean daily survival rates of radiocollared northern bobwhites after release on the Greentree Foundation Property with 95% confidence intervals, Manhasset, New York, USA, comparing rates between first, second, and third trial of 2013 and 2014.
and could therefore contain different genetics from those that a source population at a higher latitude source site would have. Although it would have been ideal to source the birds as near in location to the study area as possible, the reality is there was no other breeding program available to provide “wild-strain” bobwhite eggs. Furthermore, genetic studies of the current bobwhite population have shown little genetic variability between populations at different latitudes within the United States (Ellsworth et al. 1989, Wehland 2006).

Variation in body mass did not affect survival probability in this study. Previous research has tied body mass to survival of northern bobwhites (Buckley et al. 2015), but there may be other metrics to consider when assessing the effect of physiology on survival. For example, stress hormones could be collected from fecal samples to measure an index of stress for comparisons with survival rates (Rothschild et al. 2008). Birds that survived longer may have been in better physical condition than their brood mates; metrics other than mass might have been able to reveal this correlation.

Although imprinting was a variable in our top models, it was not a significant covariate in any of the models. Imprinting has been proven to have powerful behavioral consequences in other bird species (Hess 1973, Dowell 1992, Lickliter and Harshaw 2010) and has improved survival, predator avoidance, and reproduction for species other than bobwhites (Brittas et al. 1992, Dowell 1992, Buner and Schaub 2008, Gaudioso et al. 2011). Previous research showed that imprinting produced survival rates and reproductive success similar to those of wild bobwhites (Palmer et al. 2012). It is difficult to explain the discrepancy between this study and past reintroduction efforts that incorporated imprinting. There could be a latitudinal or other geographic effect on survival of using the parent-rearing methods. Further studies at latitudes between the 2 studies or in areas closer to or within the current bobwhite range would help determine the strength of these effects. Additionally, Palmer et al. (2012) speculated that the high survival rates of parent-reared bobwhites in their study might have been partially attributable to the wild bobwhites that already existed on their study area adopting the chicks post-release.

Daily survival decreased from Trial 1 through Trial 3. This suggests that bobwhites that are released later in the season face greater hazards compared with birds that are released earlier in the season. Weather can play a large role in the survival of bobwhites (Stoddard 1931); it stands to reason that releasing birds earlier in the season gives them time to acclimate to the landscape before winter comes. Admittedly, our early release dates may have been late compared with natural conditions, and our third trial was well outside typical fledging times for wild bobwhites. However, when one considers the timing of availability and limited supply of wild-strain eggs, our release dates are not outside a typical timeline for reintroduction efforts in our area.

Despite our best efforts to improve the rearing and release methods from the first year of the study to the next, there was no effect of year on survival of bobwhites in our study, although Cox proportional hazard rates were slightly higher in the second year of the study. It is difficult to determine why survival might have been lower in the second year compared with the first. It is possible that predation rates were higher because of an increased prevalence of predators on the study area. Predators may have developed a “search image” for quail or learned that prey was plentiful in the area because bobwhites were consistently being released there. This could have caused some predators to increase hunting efforts within the study area. Kinsey et al. (2012) found a positive relationship between dispersal distance and survival duration. A larger study area would have allowed the released birds to avoid predation by dispersing further from the release site. Alternatively, we could have varied the release sites more to avoid teaching the predators where their prey was likely to be. Weather might have also negatively affected survival more strongly in the second year of the study. Mean precipitation rates were below average during August–September and above average during October–December 2014. The lack of precipitation in late summer may have decreased available forage in 2014 while increased precipitation in the autumn and winter may have introduced extra stress to the birds, causing them to allocate more energy toward thermoregulation in the rain and snow.

**MANAGEMENT IMPLICATIONS**

Our research revealed that timing of release is one of the most important factors to consider when planning a bobwhite reintroduction effort. Future reintroduction efforts should not only build upon our methodology but expand it to multiple sites to reveal habitat effects on postrelease survival or to use experimental releases to identify potential source habitats. Although imprinting was shown to improve success rates in other studies, it did not have a significant impact on survival in our study system. Body mass did not contribute to the hazards experienced by bobwhites, so it would be worth experimenting with releasing birds at younger ages. Wild adult bobwhites stop caring for their chicks after approximately 2 weeks (Rosene 1969). Releasing chicks at a younger age would reduce the amount of time spent in captivity and could produce birds that behave more like their wild counterparts. Additionally, holding chicks for shorter periods of time would free up pen space faster, allowing more trials to take place early in the season when survival rates are higher. Future reintroduction efforts should strive to release birds early in the season, close to the average timing of bobwhite breeding, to ensure success. Survival of parent-reared birds was higher compared with Surrogator birds in the second year of our study (Fig. 2). This could have been due to improvements in learned behavior during the second year because foster parents were also parent-reared “wild-strain” birds compared with the domestic bobwhites used in the first year. Further research on the effect of foster parent source could prove interesting and valuable to future parent-reared introduction efforts.
ACKNOWLEDGMENTS
Quail Call Farms provided “wild-strain” bobwhite eggs and parent-reared adult birds. Sonrise Farms provided adult domestic bobwhites. Funding was provided by the Greentree Foundation, the University of Delaware, and Tall Timbers Research Station.

LITERATURE CITED
Brinkley, S. K., 2011. Factors related to nest survival and over-winter survival of a northern bobwhite (Colinus virginianus) population in Southwest Florida. Thesis, University of Tennessee, Knoxville, USA.
Castelli, P. M., A. W. Burnett, and J. R. Garris. 2009. New Jersey northern bobwhite action plan. New Jersey Fish and Game Council Miscellaneous Publication, Trenton, USA.


Rosene, W. 1969. The bobwhite quail: its life and management. The Sun Press, Hartwell, Georgia, USA.


Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation, and increase. Charles Scribner’s Sons, New York, New York, USA.

Therneau, T. M. 2008. Effects of translocation on population genetics and demographics of a northern bobwhite (Colinus virginianus) population among a fragmented landscape in southwestern Georgia. Dissertation, University of Georgia, Athens, USA.


