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SURVIVAL AND REPRODUCTION OF PARENT-REARED NORTHERN BOBWHITES

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ABSTRACT

Captive-reared and released game birds typically have low reproductive success in the wild which limits their use for restoration of game bird populations. A fundamental problem with captive-rearing techniques is the absence of a mechanism for imprinting. We developed a parent-rearing technique that facilitates pre- and post-hatch imprinting using parent-reared wild strain northern bobwhite (*Colinus virginianus*) chicks in outdoor pens. Parent-reared chicks were marked with patagial wing tags and recaptured during October and the following March. We radiomarked juveniles captured in March to monitor survival and reproductive success in two separate studies, one in Georgia, and one in South Carolina, USA. Band-recapture survival estimates of parent-reared chicks from release to the following breeding season in Georgia (2005–2007) averaged 0.12 (range = 0.06 to 0.25) and was dependent on release period. Radio-marked, parent-reared bobwhites had lower survival than wild bobwhites and produced 0.3 nests per hen for the breeding season versus 1.0 nests per hen for radio-marked wild resident bobwhites. Nesting success and subsequent chick survival did not differ among groups, but sample sizes were small. Radio-marked, parent-reared hens ($n = 26$) in the South Carolina study (2008–2010) produced 0.67 nests per hen for the breeding season versus 0.62 nests per hen for radio-marked wild resident hens. Nesting success and brood-rearing success of parent-reared hens did not differ from that of wild resident hens and breeding season survival was also similar. Survival and reproduction of parent-reared wild strain bobwhites were greater than previously reported for pen-reared bobwhites and may useful for restoring or enhancing bobwhites populations at the local scale.

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Key words: chicks, *Colinus virginianus,* imprinting, nest, northern bobwhite, parent-reared, pen-reared, reproduction, survival

INTRODUCTION

Recovery of northern bobwhite populations begins with sound habitat management (NBTC 2011). However, bobwhites may exist at densities in many regions too low to permit population recovery even with increased habitat. The lack of bobwhites in many regions of their range is considered a major impediment to their recovery (NBTC 2011). A number of management strategies have been tested to re-establish 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, Sisson et al. 2012). The value of released bobwhites for restoration purposes depends on their survival and reproductive potential being sufficiently high to result in an increase in bobwhite abundance. Studies have found comparable demographics among translocated wild bobwhites and resident individuals (Terhune et al. 2010) and translocation of wild bobwhites has been shown to expedite developing huntable bobwhite populations (Sisson et al. 2012). Conversely pen-reared and released bobwhites often demonstrate survival rates too low to establish a viable population (Buechner 1950, Roseberry et al. 1987, Perez et al. 2002, Thackston et al. 2012). Pen-

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reared bobwhites that survive until the following breeding season have been found to nest (DeVos and Speake 1995, Eggert et al. 2009), but apparent lack of brooding skills results in low recruitment of young (Cass 2008, Eggert et al. 2009). Thus, release of pen-reared bobwhites is now used primarily for enhancing fall populations for greater harvest (DeVos and Speake 1995, Eggert et al. 2009).

Poor demographic rates of pen-reared bobwhites may be due to maladaptive behaviors resulting from generations in captivity (Backs 1982, Roseberry et al. 1987). Backs (1982) found greater survival of pen-reared bobwhites from wild parents than those from game farm parents suggesting a genetic causation. However, others have reported no difference in survival of pen-reared bobwhites from game farm parents and wild lineage (Roseberry et al. 1987, Perez et al. 2002). Researchers have noted important behavioral differences, thought to be linked to predator avoidance, between wild and pen-reared bobwhites (Backs 1982, Roseberry et al. 1987, Perez et al. 2002), suggesting genetic background is important to rearing a bird capable of surviving in the wild.

The effect of rearing method on bobwhite demographics has received little research but other species indicate that early-learning is critical (Hess 1973). Dowell (1992) found that, without parent-rearing, gray partridge (*Perdix perdix*) did not show appropriate predator avoidance behaviors. Buner and Schaub (2008) reported significantly greater survival and reproduction of gray partridge chicks fostered with gray partridge parents versus those reared by bantam (*Gallus gallus*) hens or artificially-reared. Gaudioso et al. (2011) found early predator training increased survival of captive-reared red-legged partridge (*Alectoris rufa*). Filial imprinting is an important form of learning during short pre- (Lickliter 1989, 2005) and post-hatch periods in which the chicks learn to identify their parents (Jaynes 1956, 1957). Imprinting in birds has a suite of behavioral consequences including sexual selection, social-learning, predator recognition, predator avoidance, recognition of alarm calls, food selection, and parenting skills (Hess 1973, Dowell 1992, Lickliter and Harshaw 2010). Pen-reared bobwhites are reared 'communally' in brooder pens without a parent which does not allow pre-hatch conditioning to occur, results in social imprinting rather than filial imprinting, and may have implications for survival of released pen-reared bobwhites.

Our objectives were to: (1) develop a parent-rearing method for bobwhites that includes pre- and post-hatch imprinting, and (2) compare the demographics of wild strain parent-reared bobwhites to wild resident bobwhites and pen-reared bobwhites (e.g., 'fall-released'). The purpose of this research was to learn if parent-rearing and imprinting would improve the survival and reproductive success of captive-reared bobwhites.

STUDY AREAS

We conducted field research on Pinion Point Plantation (PPP) in Brooks County in the Red Hills region of southern Georgia (2005–2007) and on Mount Pleasant Plantation (MPP) near Andrews, South Carolina (2008–2010). PPP consisted of 1,821 ha of 'old field' pine (*Pinus* spp.) forests with low basal areas (3–9 BA m^2/ha) (72%), rotational fallow fields (10%), longleaf pine (*Pinus palustris*) plantings (5%), and bald cypress (*Taxodium distichum*) dome wetlands (13%). PPP was an established wild bobwhite property, but MPP was a new property developed beginning in 2005. Soils on MPP are primarily hydric and vegetation consists of dense stands of warm season grasses. Fallow fields, 1 to 2 ha in size, occur on 20% of property and are managed by annual disking. Intensive management for bobwhites at both sites includes prescribed burning, hardwood reduction, timber thinning, seasonal disking, drum chopping, nest predator reduction, and supplemental feeding. Both MPP and PPP have wild bobwhite populations with densities > 2.5 bobwhites/ha based on covey-call counts and hunting records.

METHODS

Outdoor Rearing Pens for Parent-reared Chicks

We constructed 16 trapezoidal-shaped rearing pens adjacent to one another (Stoddard 1931). The long sides of each pen were 5 m and the ends were 1 m on the short end and 3.6 m on the long end. Each pen had a 1-m^2 shelter attached to the outside of each pen to facilitate changing water and providing feed. Pens were 2 m tall. The tops of the pens consisted of netting to allow for chick acclimation to local weather. Pens were enclosed by a snake fence and a solar-powered electric fence to exclude mammalian and reptilian predators. Vegetation in pens included common weeds (e.g., *Ambrosia* spp., *Cassia* spp.) to simulate natural brood habitat. A commercial operation was developed nearby beginning in 2009 following the same procedures and same source of eggs. This produced chicks for the studies on MPP; pens at Tall Timbers Research Station produced chicks for the PPP studies.

Rearing of Bobwhites

We obtained wild-strain bobwhite eggs from deserted nests on Tall Timbers Research Station which has maintained a wild bobwhite population for more than a century. Wild-strain eggs were hatched in an incubator and chicks were reared in brooders. These birds were used as layers to obtain eggs for the study. All chicks released were one generation removed from wild bobwhites with both parents from the wild. The wild-strain bobwhite chicks were raised either in a communal brooder (brooder-reared), communally-reared in flight pens (fall-released), or with parental imprinting and adoption (parent-reared).

Brooder-reared.—Brooder-reared chicks were removed from the incubator at hatching, placed into universal box type brooder pens (G. Q. F. Manufacturing Co., Savannah, GA, USA), and reared to 35 days of age. Brooder-reared chicks received commercial gamebird starter feed (Purina, St. Louis, MO, USA) with freestanding waterers. Proso millet was mixed into the commercial feed at 2 weeks of age and grain sorghum was mixed into commercial feed at 4 weeks of age. Brooder-reared chicks were weighed at 12-days-of-age and numbered bands were attached to their right wing patagium (National Band and Tag Co., Newport, KY, USA). Brooder heaters were reduced at 21 to 35-days-of-age to prepare chicks for ambient temperatures upon release.

Parent-reared.—We played a recording of the calls hens produce on the nest when their eggs are hatching ~ 36 hrs prior to hatching. This call series was previously recorded by placing a recording microphone in the clutch of wild bobwhite nests. Pre-hatch audio stimulation from parents has been found to have behavioral consequences in several bird species (Lickliter 2005). Chicks were taken from the incubator within 6 hrs of hatching and introduced to a wild-strain, bobwhite foster parent. We first placed foster parents in adoption boxes for 10–15 min after which 20 chicks were added behind a plexiglass divider. The divider was removed if the foster parent remained calm so chicks and adult came into contact and began the imprinting and adoption process. We removed the parent if a brood was rejected and added another potential parent. Parents of successfully-adopted chicks brooded and vocalized with chicks. We held adopted chicks and foster birds in a brooding box overnight in an attempt to strengthen their bond (Stoddard 1931). We released the brood with parent into the rearing pens the following morning where they remained for 35 to 42 days until release. No supplemental heating was provided. Chicks were fed, watered, and banded as described for pen-reared birds. All care, housing, and capture of bobwhites were in compliance with requirements of the University of Georgia's Institutional Animal Care and Use Committee (AUP # A3437-01).

Fall-released Bobwhites.—This group of bobwhites was reared by a cooperating game bird breeder (Quail Call Farms, Beachton, FL, USA). Bobwhites were reared communally in the same age groups with minimal exposure to people and no exposure to adult bobwhites. Chicks were maintained in a heated brooder room attached to flight pens for 5 weeks and then released into flight pens until 10-weeks-of-age. Fall-released bobwhites were released on a separate section of the PPP property in fall 2005 and 2006 to avoid influencing the wild bobwhites and parent-reared bobwhites on our study area. Birds were banded the day before release with size 7 aluminum leg bands (National Band and Tag Company, Newport, KY, USA).

Study 1. Survival of Brooder-reared and Parent-reared Chicks

We released broods during 3 monthly periods during 2005 and 2006. Quail in 2005 were released in July, August, and September while in 2006 quail were released in July, August, and October. Release locations were selected based on known use of the area by wild bobwhite broods, and sites were recorded with global positioning systems (Trimble XT, Sunnyvale, CA, USA) for importing into ArcGIS 9.2 (ESRI 2009). Release locations were ≥200 m apart to avoid mixing of parent-reared and brooder-reared chicks. The actual release site for each group was randomly selected and paired for each group (brooder- and parent-reared). Grain sorghum was broadcast around the release location before the release and a recording of a bobwhite hen call played over a speaker to attract males or possibly females to the area to facilitate mixing with wild bobwhites for brood amalgamation (Faircloth et al. 2005). Quail were left with the release boxes which were removed the following day to minimize chick disturbance and provide shelter if needed.

Post-release Monitoring.—Recapture sessions were conducted in October and March following releases of parent-reared and brooder-reared bobwhites. October trapping sessions were ~ 2 weeks in length and the March trapping periods were ~ 4 weeks. Bobwhites were captured using walk-in funnel traps baited with commercial grain sorghum (Stoddard 1931). Captured quail were classified to age and sex, weighed, and banded (if weighing ≥ 120 g) with an aluminum number 7 leg band. All birds were released at trap locations.

Parent-reared Survival Estimate.—We used Program MARK (White and Burnham 1999) to estimate survival of parent-reared bobwhites. We used the Burnham model incorporating live and dead recoveries (Palmer and Wellendorf 2007, Terhune et al. 2007) to calculate survival (φ), recapture (ρ), and recovery (r) estimates (White and Burnham 1999). We used 5 intervals (LD-LD-LD-LD-LD) where the first 3 intervals were release periods and the following were October and March trapping sessions, respectively. Each interval designated as L included live trapping encounters, and the D interval included dead recoveries or encounters outside the designated trapping sessions. We defined interval lengths from July to August, August to September, September to October, and October to March for 2005 and 2006. Interval lengths in days for 2005 releases were 39, 39, 15, and 133, respectively, and interval lengths in days for 2006 releases were 39, 39, 15, and 128, respectively. We also modeled year as a covariant to assess variation in annual survival. We imposed several constraints prior to the analysis: recapture probabilities (ρ) for periods 1 and 2 were constrained to 0 because recapture (no trapping occurred) was not possible during these periods; recovery periods (r) 1, 2, and 3 were constrained to 0 because these were designated release periods and no harvest (recovery) occurred providing 0 probability of recovery; we constrained site fidelity (F) to 0.99, because radiotelemetry revealed that movement from the study site was minimal. We used information-theoretic approaches to evaluate our biologically-derived candidate models (Burnham and Anderson 1998, Anderson et al. 2000). We used QAIC*c* to compare the set of candidate models and considered the best model to have the lowest QAIC*c* value (Burnham and Anderson 1998). We increased the precision of our estimates and accounted for model uncertainty by averaging parameter estimates over all candidate models that included the parameter of interest (Burnham and Anderson 1998, White and Burnham 1999).

Table 1. Survival (φ), recapture (*p*), recovery (*r*), and fidelity (*f*) models for parent-reared bobwhite chicks tested for year effect (year) at Pinion Point Plantation in south Georgia during 2005–2007.

Models	QAIC*c*	ΔQAIC*c*	Parameters	Deviance	w_i
φ.ρ.r.f.	278.494	0	3	272.460	0.40883
φ_{year}ρ.r.f.	279.101	0.6074	4	271.044	0.30175
$\varphi_{year}\rho_{year}r_{year}$f.	280.150	1.6557	6	268.029	0.17865
$\varphi_{year}\rho_{year}$r.f.	281.106	2.6116	5	271.019	0.11077

Study 2. Reproductive Effort and Success on PPP

Parent-reared, brooder-reared, fall-released, and wild bobwhites weighing ≥ 140 g during March capture efforts received a 6-g (150–151 MHz), pendant-style, radio transmitter (American Wildlife Enterprises, Monticello, FL, USA) to monitor breeding season demographics. All birds were released at trap locations. Daily monitoring began in mid-April to document breeding season demographics and continued through September. Weekly monitoring began after this time period until the next breeding season. We monitored radio-marked quail ≥ 5 days a week. We flagged supposed nest sites when we found a bobwhite at the same location over a 2-day-period. We recorded clutch size when the incubating bird was on recess from incubation. We captured broods of radio-marked bobwhites at 8 days-of-age (Smith et al. 2003).

Data Analysis.—We report nests and broods per hen, nesting success, and brood survival for radio-marked hens. We based nests per hen and broods per hen on the number of radio-marked hens alive on 15 April. Nests per hen was the total number of nests divided by available radio-marked hens. Nest success was the proportion of nests that hatched ≥ 1 egg. Broods per hen was the number of successful hens hatching ≥ 1 egg divided by the number of radio-marked hens alive on 15 April. Apparent chick survival was based on calculations of chick survival rates for each brood and obtaining an average chick survival for all broods. We assumed there would be no differences among broods in rates of brood amalgamation (Faircloth et al. 2005).

Study 3. Reproductive Effort and Success on MPP

Parent-reared chicks were released on MPP during July through August 2008 and 2009 following protocols established for Studies 1 and 2. Chicks were recaptured the March following the year of release and a sample of wild and parent-reared bobwhites were banded and radio-marked as in Studies 1 and 2. We monitored summer survival and nesting activity of radio-marked bobwhites. We did not capture broods and band chicks in this study, but conducted flush counts at 3 weeks to compare brood-rearing success between wild and parent-reared bobwhites.

We calculated summer survival (1 Apr to 30 Sep) for resident wild and parent-reared, radio-marked bobwhites using Kaplan-Meier staggered entry (Pollock et al. 1989). We recognized sample sizes were low for Kaplan-Meier estimates and viewed these estimates with caution. However, low sample size is more likely to bias survival rates lower than higher (Pollock et al. 1989, Palmer and Wellendorf 2007) and may be considered conservative for the purpose of estimating parent-reared bobwhite summer survival.

RESULTS

Study 1. Parent-reared Chick Survival on PPP

We released 595 chicks for each treatment over the 2-year study. We released 58, 45, and 50 parent-reared and brooder-reared bobwhites each in July, September, and August, respectively. Releases in 2006 for parent-reared and brooder-reared bobwhites each were 165, 96, and 181 for July, September, and October, respectively. We recaptured 68 parent-reared chicks in October and 35 in March; 3 were recovered during hunting. One of the brooder-reared chicks was recaptured in October and 5 were recaptured in March; 1 was recovered during hunting.

Low recapture of brooder-reared chicks ($n = 6$) precluded estimating their survival rates. Parent-reared bobwhites had sufficient recaptures to estimate survival, recapture, and recovery probabilities. The model that minimized QAIC*c* (φ.*p.r.f.*) included the parameters survival, recapture, recovery, and site fidelity (fixed) being constant (Table 1). Model weight for the QAIC*c* lowest model ($w_i = 0.41$) provided evidence this was the top model. The second best fitting model (φ_{year}*p.r.f.*) included year dependence for survival, but all other parameters were constant. Model weight for this model was close to the top model ($w_i = 0.30$) and was 1.3 times less likely than the model that minimized QAIC*c*.

Survival estimates for parent-reared bobwhites released in July, August, and September 2005 until the October trapping session were 24.7, 44.4, and 79.8%, respectively (Table 2) and 42.6, 60.9, and 87.1%, respectively in 2006. Survival estimates for parent-reared bobwhites released in July, August, and September 2005 until the following March trapping session were 3.5, 6.2, and 11.1% , respectively (Table 3) and 12.8, 18.3, and 26.2% , respectively in 2006. Over-winter survival (Oct to Mar) estimates of parent-reared bobwhites was 14.0% and 30.1% for 2005 and 2006 releases, respectively.

Study 2. Reproductive Effort and Success on PPP

Wild ($n = 35$), parent-reared ($n = 7$), and fall-released ($n = 14$) hens during 2006 incubated 37, 2, and 2 nests, respectively. Bobwhites successfully hatched 26, 1, and 1

Table 2. Parent-reared bobwhite modeled averaged survival estimates and confidence intervals from release to fall trapping sessions, Pinion Point Plantation, Brooks County, Florida, 2005–2006.

			95% CI	
Periods	Year	Estimate	LCI	UCI
Jul-Oct	2005	0.247	0.0333	0.5652
	2006	0.426	0.3080	0.5388
Aug-Oct	2005	0.444	0.1386	0.718
	2006	0.609	0.5047	0.6983
Sep-Oct	2005	0.798	0.5776	0.9121
	2006	0.871	0.8270	0.9051

of these nests, respectively. Nests per hen was 1.06 ($n =$ 37) for wild, 0.29 ($n = 2$) for parent-reared, and 0.14 ($n =$ 2) for fall-released bobwhites. Apparent nest success was 0.83, 0.50, and 0.50 for wild, parent-reared, and fall-released bobwhites in 2006, respectively. Average clutch sizes were similar 12.5 (11.5-13.6, 95% CI), 13.0 (9.1–16.9, 95% CI), and 12.5 (9.6-15.4, 95% CI) for wild, parent-reared, and fall-released bobwhites. One female fall-released bobwhite had a clutch size of 27 eggs of which 21 hatched but had no chicks at 8-days-of-age. Apparent chick survival of wild, parent-reared, and fall-released bobwhite broods was 24.0% ($n = 16$), 71.0% ($n =$ 1), and, 0.0% ($n = 1$), respectively.

Wild (n = 29), parent-reared (n = 12), and fall-released ($n = 21$) hens in 2007 incubated 31, 4, and 19 clutches and successfully hatched 19, 3, and 8, respectively. Nests per hen was 1.07 ($n = 31$) for wild, 0.33 ($n =$ 4) for parent-reared, and 0.90 (n = 19) for fall-released bobwhites. Average clutch sizes were 14.4 (12.8-15.9, 95% CI), 14.3 (10.6-17.9, 95% CI), and 17.1 (15.3-19.0, 95% CI) for wild, parent-reared, and fall-released bobwhites in 2007, respectively. Parent-reared males incubated 4 nests in 2007 that were not included in the nests per hen statistic. Males hatched all 4 clutches and 2 broods were captured at 8-days-of-age. Apparent chick survival for wild, parent-reared, and fall-released bobwhites for the 2007 breeding season was 31.0% ($n = 13$), 28.0% ($n = 6$), and 13.0% ($n = 8$), respectively.

Study 3. Reproductive Effort and Success on MPP

We released 843 and 2,345 parent-reared chicks on MPP during July-September 2008 and 2009. We radiomarked 27 parent-reared and 22 wild bobwhites in March and April. Summer Kaplan-Meier survival was 0.39 ± 0.18 for wild bobwhites and 0.27 ± 0.12 for parent-reared bobwhites. We monitored reproductive success of parent-reared hens ($n = 11$) and wild resident hens ($n = 19$) on MPP. Parent-reared hens produced 7 nests and hatched 6 broods resulting in nests per hen and broods per hen of 0.64 and 0.55, respectively. Clutch size averaged 14.3 ± 1.76 eggs. Wild bobwhites produced 10 nests and hatched 6 clutches resulting in nests per hen at 0.53 and hatches per hen at 0.32. Clutch size averaged 12.2 ± 0.84 eggs. The proportion of hens with broods at 3 weeks was 20% for both wild and parent-reared bobwhites.

Table 3. Parent-reared bobwhite modeled averaged survival estimates and confidence intervals on Pinion Point Plantation from release to capture in March 2005 and 2006, Brooks County, Florida.

			95% CI	
Periods	Year	Estimate	LCI	UCI
Jul-Mar	2005	0.035	0.0003	0.253
	2006	0.128	0.0586	0.2255
Aug-Mar	2005	0.062	0.0011	0.3214
	2006	0.183	0.0961	0.2923
Sep-Mar	2005	0.111	0.0048	0.4083
	2006	0.262	0.1574	0.3788
Oct-Mar	2005	0.140	0.0083	0.4476
	2006	0.300	0.1904	0.4185

We radiomarked 25 wild bobwhites and 31 parent-reared bobwhites in 2010. Summer Kaplan-Meier survival was 0.387 ± 0.119 and 0.295 ± 0.101 for parent-reared bobwhites. We monitored reproductive success of parent-reared hens ($n = 13$) and wild resident hens ($n = 25$) on MPP. Parent-reared hens produced 9 nests and hatched 4 clutches resulting in nests per hen and brood per hen of 0.69 and 0.31, respectively. Clutch size averaged 10.45 ± 1.06 eggs. Wild bobwhites produced 18 nests and hatched 9 clutches resulting in nests per hen of 0.36 and broods per hen of 0.31. Clutch size averaged 11.8 ± 1.01 eggs. Fifty percent of parent-reared hens had broods at 3 weeks (2 of 4 hens) compared to 33% of wild bobwhites (3 of 9 hens).

Sixteen nests were produced by 24 parent-reared hens and 28 nests were produced by 44 wild hens over both years. Nests per hen was 66.7% for parent-reared and 63.6% for wild bobwhites. Ten broods were produced by the parent-reared bobwhites and 15 broods were produced by wild hens. Broods per hen was 41.7% for parent-reared and 34.1% for wild bobwhites.

DISCUSSION

Study 1. Survival of Released Chicks

Over-winter survival estimates of parent-reared bobwhites were higher than previous survival estimates of released pen-reared bobwhites. Pierce (1951) reported pen-reared bobwhite over-winter survival of 7% whereas DeVos and Speake (1995) reported 20% survival of pen-reared bobwhites to April. Perez et al. (2002) reported no survival of released bobwhites. Brooder-reared chicks in our study had low survival rates unlike parent-reared chicks. This was likely a combination of improper rearing and lack of imprinting. Ring-necked pheasants (*Phasianus colchicus*) reared with species-specific foster parents had greater clutch and brood survival than brooder-reared counterparts (Brittas et al. 1992). We noticed that when chicks imprinted to a species-specific parent, they immediately developed fear of humans and were more likely to express normal predator avoidance behaviors (Dowell 1992). Parent-reared chicks rarely gave lost calls; whereas, brooder-reared chicks frequently gave lost calls which also likely influenced survival. Parent-reared chicks were more often captured with wild bobwhites; whereas, brooder-reared bobwhites were often found in like groups. Brooder-reared chicks were also less fearful of humans and were less likely to hide in vegetation than parent-reared bobwhite chicks.

Our survival estimates suggest a demographically-significant number of parent-reared chicks could survive until the following breeding season and positively influence future populations if recruitment was adequate. The combination of imprinting to species-specific foster parents and rearing in a semi-natural environment may have increased chick survival through appropriate behavioral responses (Roseberry et al. 1987, Dowell 1992). Wild bobwhites may have also had a role in increased survival through adoption of chicks by wild bobwhite broods (Faircloth et al. 2005).

Survival estimates for parent-reared bobwhites released in 2006 were higher than in 2005 possibly because of different weather and habitat conditions. Rainfall amounts were greater during summer months from tropical storms and hurricanes in 2005, which likely reduced chick survival. Thinning of timber stands and intensive dragging of steel tracks over burned areas to increase soil disturbance resulted in thin cover and possibly attributed to increased winter mortality. Prescribed burning was conducted using recommended management guidelines in 2006 (Masters et al. 2003) and other habitat manipulations were minimal on study areas.

Study 2. Reproductive Effort and Success on PPP

Sample sizes were low for parent-reared chicks and likely an artifact of sampling. For example, based on our survival estimates and releases scattered across the study area, ~150 chicks should have survived until the March trapping session over the 2 years. We recaptured ~23% of these in March. Our sample size of hens were small given half of recaptures were males. However, the data reflected important biological distinctions among groups, specifically in differences between parent-reared versus fall-released bobwhites.

Fall-released bobwhites nested as readily as wild bobwhites, although nesting success was numerically lower. Other studies have shown a propensity to nest and hatch clutches (Dollar 1969, DeVos and Speake 1995). However, nesting activity does not provide a complete view of recruitment because of poor parenting skills of fall-released bobwhites. Reduced chick survival is common after fall-released bobwhites leave the nest, possibly due to lack of brooding ability and poor anti-predator behaviors (Dowell 1992). Fall-released hens during brood captures displayed abnormal behavior such as flying into trees and gave lost chick calls. Other abnormal behaviors included lack of fear of humans. For example, fall-released bobwhites would circle < 1 m from observers or attack observers conducting the brood capture. Typical behavior of wild bobwhites during brood captures is to flush from observers and remain at a distance in vegetation, calling to regroup the chicks. Collectively, these abnormal parenting behaviors indicate fall-released bobwhites have low potential to rear young.

Parent-reared bobwhites had similar success rearing broods as wild bobwhites. Habitat use, home range size, and movements (not reported in this paper) of parent-reared bobwhites were similar to wild broods. Male parent-reared bobwhites also demonstrated typical incubation and brooding behaviors. The apparent normal successful brooding ability demonstrated in this study, while preliminary, is an important finding and demonstrates a probability that released parent-reared bobwhites may be useful for restocking purposes.

Nesting attempts by parent-reared chicks were lower than either wild or fall-released bobwhites at PPP. This was possibly an artifact of small sample sizes, but we did observe 2 parent-reared bobwhites that nested, added to the clutch daily, but did not initiate incubation of the clutch. Lower breeding season survival of the parent-reared bobwhites versus wild bobwhites also reduced opportunity to lay clutches. Nesting attempts were lower, but nesting success of parent-reared bobwhites was similar to that of wild bobwhites and numerically greater than fall-released bobwhites. Parent-reared bobwhites hatched their clutches and brooded normally. This was not the case for wild-strain fall-released bobwhites. We observed one fall-released bobwhite leaving the nest with 1 chick while the remainder of the clutch hatched.

Study 3. Reproductive Effort and Success on MPP

We monitored 26 parent-reared bobwhites over the course of 2 breeding seasons. This sample size was improved by a combination of factors, including more intensive management and a larger sample of chicks released on MPP each year of the study. There was no difference in nesting parameters of parent-reared and wild bobwhites. Nesting rate of parent-reared hens was identical to radio-marked wild bobwhite hens. Nesting success was not different between groups, similar to Study 2 at PPP, and flush counts showed similar brood-rearing success between groups. We did not observe parent-reared hens abandoning nests. Habitat use of parent-reared broods on MPP was similar to wild broods as with the parent-reared broods on PPP. Hens hatched clutches and took their broods to areas similar to wild bobwhites. Percent locations by habitat for broods of parent-reared bobwhites was 78% fields, 13% burned woods, and 9% unburned wood versus 60, 33, and 9% for the same habitats, respectively, by wild bobwhites. Similar behaviors by parent-reared bobwhites typical of wild bobwhites included covey and single flushes, flight behavior, covey calling in autumn, and covey sizes. Quantification of the magnitude of behavioral differences between wild and parent-reared bobwhites, and their offspring, is needed. We observed some parent-reared bobwhites with broods to display the broken-wing behaviors more aggressively than their wild counterparts. This may be a function of watching their parents defend them in our rearing facilities when observers entered pens. Refinements in rearing protocols should be tested to develop best management practices.

Summer survival rates of parent-reared bobwhites were slightly lower than wild bobwhites but typical of summer survival from other telemetry studies in good habitat (Sisson et al. 2009). Additional anti-predator training and avoiding human contact may be important to increasing survival of parent-reared bobwhites (Gaudioso et al. 2011).

MANAGEMENT IMPLICATIONS

Parent-reared, wild-strain, bobwhite demographic rates appeared sufficiently high to be useful for restocking management areas with depleted quail populations, similar to translocation of wild bobwhites, although additional testing is needed. Our study areas had existing wild bobwhites that may have facilitated survival of parent-reared chicks. Further testing is needed to examine if this technique could be used to actually establish a population rather than increase numbers. This technique may have usefulness for restoring bobwhite populations at the scale of an individual management area where habitat is sufficiently managed and few or no wild bobwhites exist (e.g., the piedmont or northeastern U.S.). However, recovery of bobwhites over large landscapes will not be solved with releases of quail but rather long-term commitment to habitat management (NBTC 2011).

We suspect land use history of a site may be as important as current habitat conditions to demographics of released bobwhites. Areas with an on-going practice of releasing pen-reared, fall-released bobwhites appear to be less successful than those that have not and do not release pen-reared bobwhites. Areas with a history of, or active releasing, bobwhites may predispose the local predator community to foraging on naïve bobwhites. Success of parent-reared chicks and translocation of wild bobwhites appears to be improved following major habitat improvement projects, possibly because both habitat and predator communities are more favorable for their survival.

Captive-rearing programs for game birds should consider implementing pre- and post-hatch imprinting, and species-specific parent-rearing to avoid maladaptive behaviors of released birds. Pre- and post-hatch imprinting appears to be important to fitness of released bobwhites, but additional research is needed to better understand limiting factors to chick and adult survival.

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