National Quail Symposium Proceedings

Volume 7 Article 94

2012

Efficacy of Targeted Mist-Netting to Capture Northern Bobwhites During the Non-Breeding Season in Ohio

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EFFICACY OF TARGETED MIST-NETTING TO CAPTURE NORTHERN BOBWHITES DURING THE NON-BREEDING SEASON IN OHIO

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ABSTRACT

Baited funnel traps and nightlighting are well established northern bobwhite (*Colinus virginianus*) capture techniques, but their use is not always appropriate, particularly on private land where cooperating landowners may place constraints on research activities. Alternative capture techniques may be more effective under conditions considered to be unfavorable for established techniques (e.g., periods with abundant natural food). Targeted mist-netting, where mist nets are erected near the known location of specific individuals, has been used to capture gallinaceous species and may be an effective alternative to established bobwhite capture techniques. We evaluated the effectiveness of using targeted mist-netting to capture bobwhites during the non-breeding season in Ohio. We tested for differences in survival and age and sex ratios of individuals captured with targeted netting and baited funnel traps. We captured 257 individuals with targeted netting during 1 October-28 February 2009–2011 and concurrently captured 253 individuals with baited funnel traps. There was a short-term influence of capture and handling, but there was no significant difference in post-capture survival of bobwhites captured with targeted netting or trapping. Capture rates of age and sex classes were similar ($P = 0.488$ and $P = 0.973$, respectively) between targeted netting and trapping. Body mass of bobwhites captured by targeted netting was less than that of bobwhites captured by trapping ($P = 0.009$) suggesting that netting may provide more accurate estimates of body mass. We used targeted netting to capture bobwhites in a variety of situations where use of funnel traps was ineffective or problematic. Targeted netting was effective and often more compatible with constraints of working on private land than established capture techniques.

Citation: Wiley, M. J., A. K. Janke, and R. J. Gates. 2012. Efficacy of targeted mist-netting to capture northern bobwhites during the non-breeding season in Ohio. Proceedings of the National Quail Symposium 7:235–240.

Key words: capture techniques, *Colinus virginianus*, mist netting, northern bobwhite, Ohio, private land, Program MARK, radiotelemetry, survival, trapping

INTRODUCTION

Northern bobwhites have been studied for > 80 years (Scott 1985, Brennan 1999), but capture techniques used during the non-breeding season are largely unchanged. The 2 most commonly used, baited funnel traps (Stoddard 1931: 422) and nightlighting (Labisky 1968), have been effective in a variety of habitat types and seasons making use of alternative capture techniques generally unnecessary (e.g., Hernández et al. 2006). However, their use is not always compatible with working on private land. Both techniques require frequent investigator presence that could disrupt alternative activities on private lands (e.g., hunting, farming) and cause landowners to deny or rescind permission for access to their properties (Hilty and Merenlender 2003). The effectiveness of traditional techniques can vary with environmental conditions (e.g., periods with abundant food). Capture techniques that minimize investigator presence and are effective in a variety of environmental conditions may be more compatible with working on private lands and provide researchers with an alternative to traditional capture techniques.

Mist nets have been used to capture gallinaceous species in conjunction with audio lures (Cink 1975, Lohr et al. 2011), pointing dogs (Skinner et al. 1998), radiotelemetry (Schladweiler and Mussehl 1969), and researchers directing the path of flushing birds (Silvy and Robel 1968, Campbell 1972, Browers and Connelly 1986). Schladweiler and Mussehl (1969) used a mist-netting technique to capture specific radio-marked individuals. Skinner et al. (1998) used a comparable technique to capture juvenile willow ptarmigan (*Lagopus lagopus*) over pointing dogs. Investigators knew the location of birds in both applications, and placed mist nets to intersect the predicted flushing direction, effec-

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tively targeting specific individuals for capture (i.e., targeted netting). Targeted netting for bobwhites is not new, but the relative convenience of mist nets has made it far more practical than early attempts with clap nets (Stoddard 1931: 441). Mist nets have been used to capture bobwhites, but investigators passively netted individuals attracted by an audio lure during the breeding season (Cink 1975, Lohr et al. 2011). Targeted mist-netting should be an effective way to capture bobwhites during the non-breeding season because of their gregarious behavior during this period and their relatively low and short flight trajectories (Kassinis and Guthery 1996). Coveys can be located and targeted for capture by following previously radio-marked individuals, using pointing dogs, or after incidental flushes.

We evaluated the effectiveness of targeted mist-netting to capture bobwhites during the non-breeding season on private lands in southwestern Ohio. Our objectives were to: (1) evaluate the efficacy of targeted netting to capture bobwhites; (2) compare body mass, age, and sex ratios of individuals captured with baited funnel traps and mist nets to test for potential capture-related biases; and (3) test for differences in post-capture survival of individuals captured with baited funnel traps and mist nets.

STUDY AREA

We worked on 4 private land sites in Highland and Brown counties in southwestern Ohio (centered at 39° 04′59”, 83° 39′10”). The sites were in the glaciated till plains physiographic region (Ohio Division of Geologic Survey 1998). The predominant land-use in the area was agriculture (39% row crops and 17% pasture/hay fields; Homer et al. 2004). Mean annual temperature was 11.1 °C and mean annual precipitation was 110.2 cm (NCDC 2011).

Habitat composition on the study sites was primarily row crop agriculture (55%) planted in soybeans and corn. Forests covered 13% of the study sites and were dominated by oak (*Quercus* spp.) and hickory (*Carya* spp.), although some bottomland forests were primarily ash (*Fraxinus* spp.) and black walnut (*Juglans nigra*). Early successional vegetation, including grasslands, old-fields, fencerows, and ditches covered 19% of the study area. Grasslands were generally dominated by fescue (*Festuca* spp.) or Indiangrass (*Sorghastrum nutans*). The most common shrub species used by bobwhites were blackberry (*Rubus allegheniensis*) and black raspberry (*R. occidentalis*).

METHODS

We captured bobwhites during 1 October-28 February 2009–2011 using baited funnel traps or targeted netting. Trapping, handling, and marking protocols were reviewed and approved by the Animal Care and Use Committee at Ohio State University (protocol # 2007A0228). We did not use nightlighting because of the proximity of study sites to areas where people unfamiliar with our research might have been alarmed by activity after sunset. Implementation of capture methods was non-random and opportunistic, dictated by expediency and necessity. We used both capture methods concurrently throughout the study period to maintain ≥ 1 radio-marked individuals in each known covey within the study sites.

Funnel traps were 30×40 x 45 cm and were baited with cracked corn. Traps were covered with burlap (Stoddard 1931: 443) to reduce trap-related injuries. We placed traps in areas where use by bobwhites was evident. We pre-baited trap sites with cracked corn for 1 week before traps were used. We positioned traps within cover and concealed them with vegetation to protect bobwhites from predators and weather. We checked traps ≥ 2 times per day after sunrise and at sunset. We documented trapping effort (i.e., trap-days) during the 2010–2011 field season.

We used 61-mm mesh 4-shelf mist nets for targeted netting (AFO Mist Nets, Manomet, MA, USA). Each net measured 2.6 by 12 m and was suspended between 2, 3.05-m aluminum conduit poles (1.9-cm diam). We used homing or triangulation from short distances to locate coveys with previously radio-marked individuals (White and Garrott 1990). We identified the apparent location for coveys that did not contain radio-marked individuals using cues from pointing dogs and by visually marking the location of bobwhites that were flushed incidental to other research activities. Nets were erected near the anticipated covey location and positioned to intersect the most likely flight path of flushing bobwhites. We identified the most likely flight path based on characteristics of nearby cover, position of pointing dogs, and direction of investigator approach. We typically used 1–2 nets during each attempt, although up to 4 nets were used within expansive homogenous cover (e.g., grass fields) where flight direction was less predictable. Investigators flushed bobwhites toward the standing nets and extracted entangled birds. We defined netting attempts as events where ≥ 1 bobwhite was flushed after ≥ 1 mist net was fully deployed. We documented all netting attempts including date, method of bobwhite location, habitat type, number of bobwhites captured, and reasons for failure. We defined successful attempts as those that resulted in capture of ≥ 1 bobwhite.

We recorded age and sex of each bobwhite (Rosene 1969: 44–54), and weighed birds to the nearest gram. We leg-banded all captured bobwhites and radiomarked a subset of individuals weighing ≥ 165 g with pendant-style mortality-sensing radio transmitters (6.6 g; Advanced Telemetry Systems, Isanti, MN, USA). We released bobwhites at the capture site immediately after processing and marking. We located each radio-marked individual ≥ 6 times/week by homing or triangulation (White and Garrott 1990). We immediately located the transmitter after detecting a mortality signal and inferred the cause of mortality based on field signs at recovery sites or condition of the transmitter.

We used a Chi-square test to examine differences in age and sex ratios of individuals captured. We used a *t*-test to examine differences in body mass potentially

Table 1. Total number of targeted netting attempts on bobwhites and capture success rates by covey location method during October-February 2009–2011 in southwestern Ohio.

Location method	No. of attempts	Success rate (%)
Radiotelemetry	155	67.7
Pointing dog	30	76.7
Incidental contact	16	81.3

caused by consumption of bait after capture in funnel traps. We excluded individuals < 150 days of age based on molt of primary flight feathers (Rosene 1969) in body mass comparisons. We assumed potential influences associated with handling and radiomarking were equal between capture methods and tested for differences in post-capture survival between the 2 techniques. We used funnel traps and targeted mist-netting concurrently and assume captured individuals were exposed to the same natural mortality factors. We used the nest survival model in Program MARK to compare post-capture survival over a 21-day interval starting at the day of the initial capture. We assumed mortalities after a 21-day interval were unrelated to the initial capture. Abbott et al. (2005) detected differences in survival between 45 and 62 days but we assumed that such differences would be difficult to detect in our data set, because of the low survival observed in the population (Janke and Gates 2012).

We compared 8 models with age and temporal (i.e., year and time) effects (Holt et al. 2009). We used the most parsimonious baseline model to examine the influence of capture technique (netting or trapping) and linearly decreasing effects representing days since capture (DSC). The DSC covariates represented a decreasing linear trend from day of capture through 3, 7, 14, or 21 days. Day values represented a range of traditional censoring periods used in radiotelemetry studies to control for short-term acute effects of capture and handling (Holt et al. 2009). We developed a candidate model set that included a model for each DSC covariate alone, each DSC covariate with a capture technique effect, and their interaction. Interaction terms were used to test for differences in DSC influences between capture techniques. We compared models with Akaike's Information Criteria corrected for small sample sizes (AIC_c), and considered all models with $\Delta AIC_c < 2.0$ as having equivalent support (Burnham and Anderson 2002). We interpreted the influence of each parameter in the top

Table 2. Total number of targeted netting attempts on bobwhites and capture success rates by habitat type during October-February 2009–2011 in southwestern Ohio.

Habitat type	No. of attempts	Success rate (%)
Agricultural field	13	53.8
Grassland and old field	56	76.8
Woody ditch and fencerow	103	69.9
Woodlot	17	47.1
Unknown (not recorded)	12	91.7

Table 3. Sex and age distributions of bobwhites captured by targeted netting and baited funnel traps during October-February 2009–2011 in southwestern Ohio.

		Capture method	
		Targeted netting	Baited funnel traps
Sex	Male	132	136
	Female	104	106
	Unknown	21	11
Age	Adult	59	52
	Juvenile	191	200
	Unknown	7	1

models based on model-averaged coefficients and 95% confidence intervals.

RESULTS

We captured 257 individuals with targeted netting (137 in 2009-10 and 120 in 2010-11) and 253 individuals with baited funnel traps (105 in 2009-10 and 148 in 2010-11). A single successful netting attempt generally captured ≤ 4 birds, whereas a successful trap was capable of capturing as many as 18 in a single event. We captured 0.306 birds/trap-day in 484 trap-days during the 2010–2011 field season. We made 201 targeted-netting attempts of which 141 (70.1%) were successful. Success rates were similar among covey location methods (Table 1) and habitat types (Table 2). We incorrectly predicted flight path in 56.7% of all failed netting attempts for which reason for failure was recorded ($n = 30$). Flight in the predicted direction but over standing nets contributed to 36.7% of recorded failures. Other reasons for failure included bobwhites breaking through or striking the net without becoming entangled. There were no differences in age ($\chi^2 = 0.480$, df $= 1$, $P = 0.4884$) or sex ($\chi^2 = 0.001$, df $= 1$, $P = 0.973$) ratios of birds captured between the 2 techniques (Table 3). Mean body mass of bobwhites captured by targeted netting (mean $= 185.6$ g, 95% CI $=$ 183.5-187.6 g) was less than bobwhites caught in traps (mean $= 191.4$ g, 95% CI $= 188.7$-194.1 g; $P = 0.009$). Bobwhites or non-target passerines died in funnel traps in ≥ 8 events during the study period, all of which resulted from predation while in the trap. Trapped bobwhites occasionally sustained visible injuries (e.g., scalp lacerations) from striking the top of the trap. No bobwhites died during capture with mist nets although 2 (0.8%) were visibly injured by pointing dogs following entanglement in the net.

We included 259 individuals in the survival analysis (netting: $n = 153$, trapping: $n = 103$). The best fitting baseline model in the survival analysis represented an across year quadratic relationship with time (Table 4). The addition of DSC covariates improved the fit of the baseline model but models with a capture technique term were not competitive (Table 5). Model averaged coefficient for the technique term was $\beta_{net} = 0.002$ (95% CI $=$ –0.214, 0.219) and the odds ratio was 1.002 (95% CI $=$ 0.807, 1.244) indicating there was no difference in

Table 4. Baseline temporal models used to control for seasonal variation in survival of bobwhites captured with baited funnel traps and targeted mist-netting during October-February 2009–2011 in southwestern Ohio.

Model[a]	k^b	$AIC_c{}^b$	$\Delta AIC_c{}^b$	$w_i{}^b$
Across year quadratic time	3	624.28	0.000	0.385
Within year time	2	625.96	1.684	0.166
Null	1	626.39	2.111	0.134
Age	2	627.29	3.014	0.085
Across year time	2	627.43	3.148	0.080
Year + within year time	3	627.82	3.544	0.065
Year	2	628.28	4.005	0.052
Year + age	3	629.26	4.983	0.032

[a] Time = linear trend increasing from 1.

[b] k = number model parameters; AIC_c = Akaike's Information Criteria corrected for small sample sizes; ΔAIC_c = change in AIC_c from lowest model; w_i = Akaike's weight.

survival between the 2 techniques. The model with a 7-day acute influence had the most support ($w_i = 0.275$) and models including 14- and 21-day parameters had moderate support ($w_i = 0.183$ and $w_i = 0.108$ respectively; Table 5). The model averaged coefficient for the 7 DSC covariate was $\beta = -0.131$ (95% CI = –0.232, –0.029). The model averaged coefficient for the 14 DSC covariate was $\beta = -0.064$ (95% CI = –0.119, –0.001). The model averaged coefficient for the 21 DSC covariate was $\beta = -0.049$ (95% CI = –0.095, –0.002).

DISCUSSION

Targeted netting was a versatile technique that we used effectively in situations where traditional bobwhite capture techniques were ineffective or not feasible. The high ranking of the DSC covariate models and the negative coefficients illustrates there was a short-term effect of capture, handling, or radiomarking in this study but odds ratio near 1 showed there was no difference in post-capture survival among the 2 capture techniques. Low ranking of the models with a technique by days since capture (DSC) interaction term also demonstrated the influence of capture was consistent among the 2 techniques. There was a short-term influence of capture and handling, but there were no significant differences in post-capture survival of bobwhites captured by targeted netting or in baited funnel traps. Targeted netting was unbiased in capture rates of age or sex classes. Targeted netting may have advantages over trapping in some situations because it provides a more accurate estimate of individual body mass (not biased by bait consumption) and can be used to quickly target specific individuals.

Targeted netting exploits the flushing behavior and flight characteristics of bobwhites. The tendency for bobwhites to remain motionless within concealing cover when approached allowed time to place nets near their position. The average maximum height of bobwhite flight is fairly low (2.4 m; Kassinis and Guthery 1996); Schorger (1946) observed that bobwhites in flight are generally incapable of avoiding objects with unnatural dimensions. The flight path of a flushing covey was typically through pathways free of obstruction in the direction opposite the position of a pointing dog or approaching investigator. Flight was often toward patches of dense vegetation in areas with patchy or fragmented cover and parallel to nearby woody cover (e.g., fence-rows, woodlot edges). The generally predictable nature of bobwhite flushing directions coupled with their low and straight flight trajectories made targeting netting effective in areas with linear features. Flight path was generally less predictable within homogenous cover (e.g., grasslands).

The most common reason for failed net attempts, flight away or to the side of nets, was due in part to incorrect predictions of flight path or inability to place nets in the most likely flight path due to physical

Table 5. Ranking for candidate model set with factors affecting post-capture survival of northern bobwhites captured with baited funnel traps and targeted netting during October-February 2009–2011 in southwestern Ohio.

Model[a]	k^b	$AIC_c{}^b$	$\Delta AIC_c{}^b$	$w_i{}^b$
TT + 7 DSC	4	619.87	0.000	0.275
TT + 14 DSC	4	620.68	0.807	0.183
TT + 21 DSC	4	621.75	1.873	0.108
TT + Technique+ 7 DSC	5	621.86	1.989	0.102
TT + Technique + 14 DSC	5	622.67	2.796	0.068
TT + 3 DSC	4	622.70	2.826	0.067
TT + Technique + 21 DSC	5	623.73	3.860	0.040
TT + Technique+ 7 DSC + Technique x 7 DSC	6	623.86	3.992	0.037
TT	3	624.28	4.407	0.030
TT + Technique + 14 DSC + Technique x 14 DSC	6	624.39	4.520	0.029
TT + Technique + 3 DSC	5	624.68	4.808	0.025
TT + Technique + 21 DSC + Technique x 21 DSC	6	625.52	5.646	0.016
TT + Technique	4	626.25	6.378	0.011
TT + Technique + 3 DSC + Technique x 3 DSC	6	626.64	6.771	0.009

[a] TT = baseline temporal model; DSC = days since capture.

[b] k = number model parameters; AIC_c = Akaike's Information Criteria corrected for small sample sizes; ΔAIC_c = change in AIC_c from lowest model; w_i = Akaike's weight.

obstructions. Flight over nets generally occurred within relatively tall, homogenous cover (e.g., woodlots) that forced bobwhites to flush more vertically to avoid obstructions. We could have used additional nets or taller net poles to address these situations but these alterations may have resulted in decreased placement efficiency. Our success rates were fairly high for all covey location methods and across different habitat types. Success rates with pointing dogs and incidental contact were higher than for radiotelemetry. Our definition of a net attempt excluded some causes of failure that were more common with attempts with pointing dogs or incidental flushes, which likely artificially inflated success rates. We were more likely to flush bobwhites before nets were deployed during capture attempts with pointing dogs or after incidental flushes than when using radiotelemetry. We occasionally failed to locate and flush any bobwhites after net deployment for all methods except radiotelemetry.

One of the primary benefits of targeted netting was the ability to capture bobwhites immediately after their location was known. A single experienced investigator could deploy a net within 5-20 m of bobwhites with relative ease in 2–3 min. We typically kept nets in field vehicles, furled and rolled on net poles, during daily activities and carried rolled nets while actively searching for coveys. This allowed us to take advantage of opportunities when unmarked coveys were encountered (i.e., dog pointing, incidental contact). Additionally, we could attempt targeted netting at different locations on several sites throughout the day, effectively spreading out capture effort. The area in which a single investigator could actively use funnel traps was restricted to that which could be quickly covered during trap checks and limited to only 1 site/day because of the distance between sites in our study ($\geq$ 7 km). The time-window for a trap check at sunset was particularly narrow because traps needed to be checked sufficiently late in the evening that bobwhites were unlikely to be captured afterward, yet sufficiently early that exposure of trapped bobwhites to nocturnal predators was minimized. Releasing captured bobwhites after sunset may predispose them to predation (Palmer and Wellendorf 2007).

Use of baited funnel traps is a well-established and effective capture technique for bobwhites, but we found it incompatible with landowner concerns in certain situations. Landowner acceptance is an important consideration when planning and conducting research on private land (Hilty and Merenlender 2003). Studies of recreational access on private lands indicate negative experiences (i.e., disruptive behavior, property damage) and protectionist attitudes (i.e., exclusive hunting rights, anti-hunting beliefs) were primary reasons for access to be denied (Stoddard and Day 1969, Brown 1974, Brown et al. 1984). Parallel concerns were expressed by several cooperating landowners in our study regarding the frequency and duration of investigator presence on their properties. Specific concerns included possible negative effects of investigator presence during hunting seasons. Hilty and Merenlender (2003) suggested landowners may be more accepting of experimental designs requiring only infrequent or brief visits to their property. Frequent trap checks, particularly during the hunting season, increased the likelihood of disturbing hunting or other recreational activities. Netting however, was used effectively throughout the day, allowing for more flexibility in our presence on a particular property. Properties could be avoided when hunters were present and accessed when the chances of disturbing hunters were relatively low.

Bait provided for trapping may have biased body mass estimates and may also have lingering effects on behavior or survival. We observed that coveys with radio-marked birds concentrated activities around bait piles during pre-baiting and trapping periods, which may have temporarily biased movements or survival (Robel and Kemp 1997, Townsend et al. 1999, Haines et al. 2004). Targeted netting captured individuals *in situ* and resulted in a quick release into the cover in which quail were found immediately prior to capture.

We found targeted mist-netting has applications outside the non-breeding season, when traditional capture techniques are generally less efficient (Wellendorf et al. 2002). We used targeted netting during summer to capture calling males, individuals paired with radio-marked bobwhites, and fledged young associated with a brooding adult (M. R. Liberati, personal communication). Capturing post-fledging young before separation from brooding adults may merit additional research because of the challenges presented in studying bobwhite chick survival (Roseberry and Klimstra 1984). Smith et al. (2003) used a wire fence erected around roosting radio-marked adults tending a brood in which some or all chicks were captured in 87% of capture attempts. This technique can be effective, but it requires that chicks can not fly (1–12 days post hatch) whereas we used targeted netting to capture flying chicks $\geq$12 days of age with a radio-marked adult. This technique could potentially provide an additional recapture period for capture-mark-recapture studies that use both chick-capture techniques. We found the smaller chicks were more capable of passing through the 61-mm mesh nets, and recommend that future investigations experiment with smaller mesh to capture chicks.

MANAGEMENT IMPLICATIONS

Targeted mist-netting is an effective alternative to traditional capture techniques, particularly when landowners place constraints on research activities, specific individuals are to be targeted, accurate measurements of body mass are required, or when traditional techniques are otherwise not feasible. Mist nets are highly portable and can be effective in all seasons. Researchers can quickly capture individuals from multiple coveys within a relatively short period of time using targeted netting in conjunction with well-trained pointing dogs or radiotelemetry. Targeted netting may also provide an effective capture technique for bobwhite chicks after they are able to fly. Investigators could use targeted netting concurrently with baited funnel traps or other capture techniques to optimize capture, particularly if their objective is to quickly capture as many individuals as possible.

ACKNOWLEDGMENTS

Funding was provided by Federal Aid in Wildlife Restoration (W-134-P, Wildlife Management in Ohio) administered jointly by the U.S. Fish and Wildlife Service and the Ohio Division of Wildlife. We thank B. M. Graves, L. D. Jenkins, C. J. Grimm, J. M. Jordan, M. R. Liberati, G. E. Fee, and B. T. Adams for assistance with collection of field data. We also appreciate the cooperation of > 50 landowners for permission to capture and monitor bobwhites on their properties.

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