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TRANSLOCATION AS A POPULATION RESTORATION TECHNIQUE FOR NORTHERN BOBWHITES: A REVIEW AND SYNTHESIS

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ABSTRACT

Northern bobwhite (*Colinus virginianus*) abundance has declined precipitously for decades across much of the species range, to the point of widespread local, regional, and statewide extirpation. Because of successful translocations of other gallinaceous birds, bobwhite enthusiasts increasingly call for use of the approach. Consequently, the National Bobwhite Technical Committee (NBTC), on behalf of state agencies, requested a review and recommendation by the NBTC Science Subcommittee. Thus, our paper is co-authored by invited experts and includes reviews of peer-reviewed publications, manuscripts in these proceedings, state agency reports, experience by co-authors, and a survey of perspectives on translocations by state wildlife agency members of the NBTC. We discuss the state of science on key aspects of bobwhite conservation, offer best management practices (BMPs) for using translocation as a potential bobwhite restoration technique, and suggest ways to reduce uncertainty about implementation. We note that although conservationists

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operate on a relatively solid foundation of improving bobwhite abundance via increased quantity, connectivity, and quality of habitat, population restoration success to- date is relatively rare *and* unpredictable. Similarly, some past translocations have been unreliable with an abundance of failures and inadequate experimental designs. We conclude that because of major uncertainties regarding habitat, population phenomena (e.g., Allee effect) and restoration techniques, outcomes of translocations remain unpredictable; thus, future efforts must be a part of sound and rigorous peer-reviewed research. To improve scientific efforts, we recommend the following BMPs for future translocations: (1) target bobwhite abundance should be >800 post-translocation which will likely necessitate ≥ 600 ha of suitable and accessible habitat while a larger (e.g., >800 ha) area will be needed in areas with lower carrying capacity and when sites are highly fragmented or isolated, (2) personnel should identify and avoid stressors to bobwhites in all phases of the translocation process (i.e., capture, holding, transportation, and release), (3) source populations should be disease free and from similar environments and latitude; preferably from the nearest suitable source, (4) conspecifics should be present on recipient sites (5) birds should be released just before the breeding season (i.e., March or April), and (6) the translocation should incorporate robust short- and long-term bird (i.e., abundance and/or density) and habitat monitoring efforts (i.e., the Coordinated Implementation Program (CIP) of the National Bobwhite Conservation Initiative (NBCI)). In conclusion, we note that translocation of bobwhites is not a panacea for broad scale restoration of bobwhites; however, the technique should remain at the forefront of bobwhite science, taking into account knowledge of the species' life history and ecology, so that a practical and reliable solution can be developed. We recognize this paper is just the beginning of vigorous debate, testing of concepts, and on-the ground implementation of successful bobwhite conservation.

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Key words: Allee effect, *Colinus virginianus*, northern bobwhite, population restoration, reintroduction, restocking, translocation

INTRODUCTION

Northern bobwhites (*Colinus virginianus*) have experienced precipitous range-wide population declines averaging 3.28% annually since 1966 (Sauer et al. 2017) and has been attributed to myriad reasons including habitat loss, fragmentation, and degradation (Hernández et al. 2013). Despite conservation and restoration efforts (Dimmick et al. 2002, National Bobwhite Technical Committee 2012) populations continue to decline at alarming rates (Sauer et al. 2017). The fundamental objectives of most state agencies and the National Bobwhite Conservation Initiative (NBCI) are to achieve populations that can sustain a recreational harvest and persist in perpetuity. To this end, managing habitat has been the *modus operandi* with mixed success with very few published success stories (e.g., Morgan et al. 2017) and plenty of cries of frustration. The lack of success at large spatial scales has instigated the use of population restoration techniques (PRT) to re-establish self-sustaining populations. Population restoration techniques include reintroductions through translocation of wild bobwhites, restocking through translocations of wild bobwhites or artificially propagated birds, and on rare occasion conservation introductions (i.e., introduction bobwhites beyond their traditional range; Seddon 2010). It is important to establish definitions of these terms, as linguistic uncertainty exists in the bobwhite community. We will use Seddon's (2010) terminology because it facilitates consistency between bobwhite conservationists and other conservation communities. *Reintroduction* of bobwhites entails the release of bobwhites into an area that was once part of its range but has since been extirpated (IUCN/SSC 2013, Seddon 2010). Whereas *restocking*, reinforcement, supplementation, or augmentation (all synonyms) refers to the release of bobwhites into an existing population of bobwhites (Maguire and Serveen 1992, Seddon 2010). Lastly, *translocation* is the physical process of moving birds from source to donor site. Reintroductions and restocking efforts both require translocation and have been duplicated throughout the bobwhite range with varied outcomes. Additionally, success has been defined in a myriad of ways and an operational definition of success for bobwhite PRTs is needed.

The International Union for Conservation of Nature (IUCN) *Guidelines for the Re-Introduction of Galliformes for Conservation Purposes* recommends defining success in three phases, "the survival of founders, evidence of breeding by founders, and long-term persistence of the translocated population" (World Pheasant Association and IUCN/SSC Re-introduction Specialist Group 2009). Short-term goals may include survival of translocated bobwhites and successful production. Long-term goals would include the persistence and growth of the population, to the point that it becomes self-sustaining and could withstand hunter harvest without significant reduction to the population size. This long-term condition defines the ultimate success for bobwhite population restoration. However, an operational definition of success is needed.

Following the NBCI Coordinated Implementation Program (Morgan et al. 2016), if the population reaches the prescribed population goal in 10 years [i.e., 800 bird minimum *sensu* Guthery et al. (2000)] and stabilizes ($\lambda = 1$), the reintroduction or restocking effort would be considered an operational success. The necessity of PRT to achieve this operational success is conditional on population phenomenon (e.g., Allee effects; explained below) and the use of PRT in the absence of necessity to reach the critical threshold is beyond the scope of this manuscript (i.e., Allee effects in bobwhites is a hypothesis that needs to be tested). Operating under these premises, we offer a theoretical, empirical, and frankly expert opinion-based review of the literature such that PRT may be implemented, under current best management practices, knowing future research and monitoring will continue to improve these practices. This paper was crafted to meet a specific request by the National Bobwhite Technical Committee (NBTC), and was conducted under the leadership of the NBTC Science Subcommittee (National Bobwhite Technical Committee 2015). The choice to implement translocation or allow it ultimately belongs to the state agency per the Public Trust Doctrine. Our goal is to provide those decision makers the current science as to inform their decision.

WORKING HYPOTHESIS FOR OPERATIONAL SUCCESS CRITERIA

Bobwhite populations can exhibit fast population growth rates in initial phases of restoration but still may take many years to reach the critical threshold. The 10-year condition is an assumption based on theory of population dynamics, some empirical data, and a few key assumptions that need to be tested. No population grows to infinity forever and should reach a stable equilibrium point. The simplest expression that creates a stable equilibrium population size is the logistic equation (Case 1999). The continuous logistic equation is defined as,

$$\frac{dN}{dt} = rN(\frac{K-N}{K})$$

where r is the intrinsic population growth rate, N is population size, and K is carrying capacity. Note, if $N = K$, the rate of change for the population ($\frac{dN}{dt}$) will become zero. Heuristically, this equation provides a starting point to determine how long it may take a reintroduced population or restocked population to reach the 800 bird critical threshold. If we assume that fall carrying capacity is 2.47 bird ha^{-1} and an 800 ha tract of land, then the stable population equilibrium is 1,946. Then how long it takes a population to get to that point is a function of N_0 (initial population size) and the intrinsic rate of growth (r). For reintroduced populations, N_0 is the number of birds initially translocated. If 0.35 birds ha^{-1} (average number translocated by Sisson et al. 2017) were reintroduced the N_0 is 287 birds. Using anecdotal and empirical growth rates (Morgan et al. 2017, Sisson et al. 2017; McConnell 2016) during the initial phases of restoration the population can take anywhere from 5 years ($r = 0.40$) to 16 years ($r = 0.10$; Figure 1). Obviously translocating more birds to increase N_0 could speed up the population reaching the critical 800-bird threshold, but the supply of wild bobwhites is limited and we are assuming survival and reproduction by translocated birds. This simple exercise also demonstrates the importance of long-term monitoring to determine success—determining failure or success after a few years is premature. An important caveat to consider is this mechanistic model does not take into consideration "black swan" events that cause unexpected population crashes (Anderson et al. 2017). Environmental stochasticity and severe weather events would cause the populations to take longer to reach the critical threshold or cause local extirpation (e.g., Errington 1933, Roseberry 1962, Burger et al. 1995, Wiley and Stricker 2017, this volume; and as discussed later in the paper). Nonetheless, this conceptual framework gives credence to the 10-year period for determining operational success and a working hypothesis as to how bobwhites may respond to PRT.

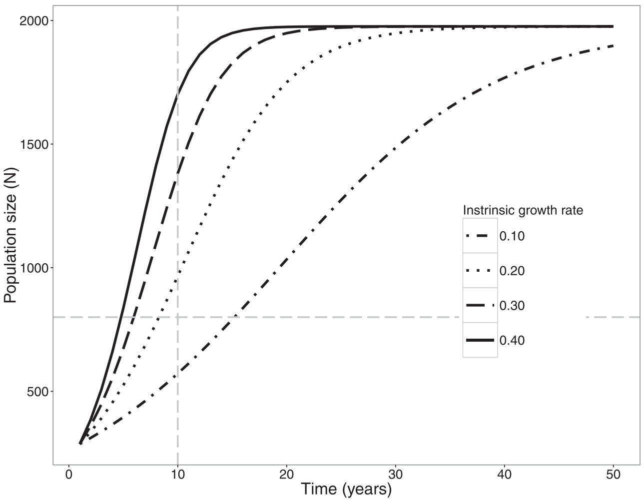

Fig. 1. Hypothesized response of northern bobwhite (*Colinus virginianus*) to reintroduction based on a continous logistic growth model with N_0 (initial population size) being 287 bobwhites in the spring (based on Sisson et al. 2017) and four possible intrinsic growth rates (based on Sisson et al. 2017 and McConnell et al., unpublished data). Carrying capacity was assumed to be 2.27 birds ha^{-1}. The vertical line at 10 years signifies the assumed expectation that success should be achieved by that time and the population monitored until then. The horizontal hashed-line represents the critical population threshold of 800 birds (Guthery et al. 2000) needed to determine success.

There are a few examples of successful, in the short-term, reintroductions in the bobwhite literature as discussed later in this review, but *reintroduction of bobwhites* has been unsuccessful (see below). Conversely, species establishment, reintroduction, and range expansion, have been notably successful for ptarmigan (*Lagopus* spp.), gray partridge (*Perdix perdix*), wild turkey (*Meleagris gallopavo*), and ring-necked pheasants (*Phasianus colchicus*) (Allen 1956, Griffith et al. 1989, Dickson 1992, Kimmel and Krueger 2007, Braun et al. 2011). As reviewed by Braun et al. (2011), all 12 species of grouse in North America have been translocated, with both success and failure. Successful movement from place-to-place of grouse and wild turkey was largely dependent on suitable unoccupied habitat. Braun et al. (2011) provided 15 recommendations for successful translocation of ptarmigan, and perhaps the most important, summing up all aspects of a well-executed translocation project, is the need to report results in a peer-reviewed publication. Similarly, Germano et al. (2015) concluded that translocations for many species fail to follow scientific best practices and are poorly documented, limiting learning, and improvement.

Much of the translocation parlance among bobwhite conservationists refers to restocking. Restocking, aims to augment a population to "avoid a critically low population size threshold... [to avoid] genetic or demographic collapse due to stochastic events (Seddon

2010)." The critical thresholds for bobwhites have not been empirically derived but Guthery et al. (2000) and Sands et al. (2012) provide guidance based on simulations (discussed more later). Restocking efforts via artificially propagated bobwhites are universally futile (e.g., Buechner 1950, Fies et al. 2000, Kinsey et al. 2012) and reviewing that literature is beyond the scope of this review. However, restocking bobwhites through the translocation of wild bobwhites has been successful in the short-term (Terhune et al. 2006b) and long-term (Terhune et al. 2010 and reevaluated 10 years later in Sisson et al. 2012). Of the many historical efforts to restock via translocations, a few recent studies have demonstrated success as indicated by survival and reproduction not less than that of resident birds (Jones 1999, Terhune et al. 2006b, 2010). A later translocation study also conducted in Georgia resulted in a 115% population increase on the treatment area (Terhune et al. 2010) which has been shown to stabilize at >1.25 birds per acre more than 13 years later (see Sisson et al. 2017 [this volume]). Furthermore, these studies demonstrate that *translocation* per se does not affect the survival of those birds (i.e., they survive the move quite well) under certain conditions being met as outlined in Terhune (2008) and Terhune et al. (2010). These case studies demonstrate that the survival, reproduction, site fidelity, and fecundity of translocated bobwhites are sufficient to allow short-term persistence (e.g., 2-5 years) and in one case long-term persistence (Terhune et al. 2010, Sisson et al. 2017 [this volume]). Many of these studies, did not have a control site (paired site without the addition of bobwhites), and where there was a control (see Terhune 2008 Terhune et al. 2010, Sisson et al. 2017 [this volume]) it cannot be said with certainty that restocking was necessary for the population to reach the critical thresholds (Guthery et al. 2000). Put another way, we cannot say for sure that the population would not have increased in the absence of translocation (Downey et al. 2017). However, this does not relegate the fact that translocation did not negatively affect bobwhite demographics and was potentially an impetus for more rapid population growth (Terhune 2008, Sisson et al. 2017 [this volume]). Stakeholders often want immediate results following habitat restoration efforts and restocking can provide, at least in the short-term, positive population responses and stakeholder satisfaction as well as encourage management on the premise they will receive wild birds through translocation (Sisson et al. 2017).

Not all restocking efforts have been successful, but inferences from many of these efforts are limited because they are confounded in some way. Scott et al. (2013) investigated restocking by translocating wild bobwhites into fragmented landscapes. The effort was unsuccessful. Their results are unsurprising considering fragmentation at the ecoregion scale was the presumed cause of the low bobwhite abundance; therefore, any population restoration efforts without alleviating the cause of the original extirpation will have a high probability of failure. This incongruence between a conservation action (i.e., restocking) and the management implications derived from research is an impetus for this review. The scientific community needs to provide sound and rigorous experimental tests of reintroductions and restocking efforts. Moreover, reasons for doing PRT and constraints on using PRT are plentiful and need to be discussed in detail. Furthermore, there is a need to reduce the uncertainty regarding reintroductions and restocking such that past mistakes can be avoided. Pragmatically, several states are considering PRT as ways to restore bobwhite populations and need information to make an informed decision. Pennsylvania Game Commission was one of the first state agencies to declare statewide extirpation of bobwhite (NBCI 2015:46).

HISTORICAL TRANSLOCATION EFFORTS

State wildlife agencies have extensive experience translocating wildlife, and a review of select efforts for bobwhite follows. The list excludes results of studies where the focus was release of first-generation progeny (F1) (e.g., Roseberry et al. 1987, Fies et al. 2000). A non-exhaustive list of projects is listed in chronological order.

Wisconsin, public land, initiated in 1950. Kabat and Thompson (1963:127) reviewed a long history of translocation, across many areas, usually undertaken to remedy winter-caused population declines, perhaps local extirpation in some cases. They emphasized the decline of suitable habitat in the species' range and concluded translocation of wild bobwhite produced mixed results, including no reproduction, reproduction for 1-2 years, and dispersal toward existing native populations.

West Virginia, public land, initiated in 1990. Framed as a pilot study, in collaboration with a local chapter of Quail Unlimited, Inc., 63 bobwhites from Kansas were released, some with radio transmitters, into an area with 28 hectares of suitable habitat. A small fraction of the bobwhites could be found in 1992. Crum (1993) pointed out the habitat was less than optimal for bobwhites and recommended that further stocking in West Virginia not be attempted.

Indiana, public and private farmlands in northern Indiana, initiated in 1990. The impetus for translocation was to remedy winter-caused population declines, perhaps local extirpation in some cases. Local chapters of Quail Unlimited, Inc. provided extensive support. Osborne et al. (1993) suspected radio transmitters on released birds caused mortality, and subsequently Frawley (1999) used breeding season surveys to determine bobwhite population response. During 1993-1995, Indiana Division of Fish and Wildlife released 868 wild bobwhites on 44 sites widely distributed across northern Indiana, and subsequent call counts on control and release sites indicated elevated abundance for 2-3 years after translocation, but then a sharp decline, and eventually insignificant difference between control and release sites. Frawley (1999) concluded that longer-term monitoring was needed to determine if the observed short-term increased abundance on released sites is sustainable, and lacking any identification of individual released birds, could not conclude that birds existing in 1998 were the progeny of translocated bobwhites.

Texas, Rio Grande Plains ecological region, initiated in 1993. Perez at al. (2002) studied resident and translocated bobwhites and compared survival of radio-tagged birds. Translocated birds died at a higher rate, i.e., 50% loss in 47 days vs. 72 days for residents, and at 12 weeks, their survival was not significantly different.

Tennessee, private land, initiated in 1994. Jones (1999), collaborating with the Tennessee Wildlife Resources Agency, studied radio-tagged resident and translocated bobwhites and compared their survival and movements. During 2 years of research, population performance was similar between translocated and resident bobwhites. Jones (1999) concluded the limiting factor of the technique for large-scale restoration was the high cost of trapping bobwhites in Tennessee.

Ohio, public land, initiated in 1998. Wiley and Stricker (2017) report in detail on the history of Ohio Department of Natural Resources (ODNR) efforts in this proceedings. ODNR initiated a long-term statewide translocation effort to expedite population growth following population losses during severe winter weather. After years of poor success with release of first-generation progeny (F1), during 1998-2000 and 2005-2007, ODNR translocated 980 wild bobwhites from Kansas to five Ohio wildlife areas, and translocated wild bobwhite from Ohio sources. Based on population surveys during 1998—2012, Wiley and Stricker (2017) concluded populations had not increased.

Texas, Post Oak Savannah ecological region, initiated in 2004. Scott et al. (2013), collaborating with Texas Department of Parks and Wildlife, translocated 550 bobwhites to 2 sites during 2004–2006. Radio-tagged, translocated bobwhites had lower survival, nesting rates, and relative abundance, compared to residents. Scott et al. (2013) speculated that restoring bobwhite populations in fragmented landscapes with few remaining bobwhites might be impractical.

In addition to these published accounts of PRT, the NBCI Translocation Survey revealed unpublished translocation between state wildlife agencies since 1980. For example, Maryland provided bobwhites to Pennsylvania, Illinois twice provided bobwhites to New Jersey, Texas provided bobwhites to unidentified states, and Kansas provided bobwhites to Colorado. Colorado Parks and Wildlife currently recognizes establishment of these bobwhites near Trinidad, Colorado (accessed 20 February 2017). Moreover, unpublished translocation exchanges among private landowners to supplement hunting have occurred in the past. Whether the translocation was public or private, the motivation was often to provide increased hunting opportunity because of population growth from translocated bobwhites.

In summary, many of the state agency translocations were undertaken along the northern part of the species' range to remedy local population declines, in some cases local extirpation, caused by severe winter weather. A common catalyst for translocation was recreation, hunting or field trials, with state agencies being responsive to requests from hunting organizations and their concern about population declines, or lack of hunting opportunity. The effect of reintroduction and restocking on population abundance was in general neutral. Short-term site fidelity and reproduction were common, but long-term increases in bobwhite populations were lacking. In general, project study designs resulted in a substantial amount of uncertainty regarding efficacy of translocation. For example, control sites lacking any bobwhites were uncommon, and post-translocation bobwhite lineage was not traced to translocated bobwhites. The reason for low population sizes, even with sufficient habitat, likely determines the probability of translocation success.

REASONS FOR TRANSLOCATION

Biological and Ecological Reasons

Overcoming small population sizes. Remnant, isolated populations of bobwhites may not have the capacity to rebound even after the extrinsic factors causing their decline (e.g. severe winter weather, drought, etc. [Errington 1933, Roseberry 1962, 1989]) are no longer present. A demographic Allee effect, or positive density dependence, occurs when population vital rates decrease as a result of abundances below a minimum threshold and can manifest through a variety of processes (Deredec and Courchamp 2007, Armstrong and Wittmer 2011). Allee effects may influence bobwhite populations through several likely mechanisms. Decreased probability of locating a reproductive partner is the most commonly recognized mechanism causing Allee effects across all species (Deredec and Courchamp 2007) and may have implications for bobwhite reproduction if low densities preclude pair formation. Social prey species tend to be more vulnerable to predation at lower densities leading to lower survival (Gascoigne and Lipcius 2004, Armstrong and Wittmer 2011). Williams et al. (2003) identified optimal covey size in bobwhites to be approximately 11 birds. They observed lower survival, decreased group persistence rates, and higher movements for covey sizes below the optimal size (Williams et al. 2003). Additionally, bobwhite populations are known to exhibit large annual fluctuations (Lusk et al. 2007). Even weak Allee effects could have substantial impacts on populations where there is a large degree of stochasticity in annual vital rates (Dennis et al. 2016). Restocking wild bobwhites may eliminate the negative effects of low density if the number of individuals added to the population brings the total population above the minimum threshold (Guthery et al. 2000).

Issues of connectivity. Although bobwhites are generally recognized as the least mobile of gallinaceous bird species, dispersal can still play an important role in population dynamics through a rescue effect, the process where populations at low density are augmented by individuals from populations with higher densities (Brown and Kodric-Brown 1977, Townsend et al. 2003). Habitat fragmentation has long been recognized as the main driver of range-wide bobwhite declines (Hernández et al. 2013), and inhibits natural recolonization or augmentation of depleted populations by decreasing dispersal (Houde et al. 2015). When habitat fragmentation is high, the cost of dispersal (in terms of mortality) is also high because dispersers must traverse a matrix of unsuitable habitats (Terhune et al. 2010, Graves et al. 2014). Thus, natural recolonization rates may not be sufficient to restock isolated populations that have declined due to extrinsic factors such as winter weather or drought, or to re-establish populations following a habitat restoration. Restocking or reintroduction using translocation in this circumstance may serve as a viable tool for "artificial dispersal" or to enhance naturally occurring dispersal (Seddon 2010, Terhune et al. 2010, Houde et al. 2015). However, these fragmented populations are more susceptible to local extirpations; thus, translocations in these situations have a high probability of failure (Scott et al. 2013).

Perceptual Errors. Perceptual errors may present another limitation to bobwhite recolonization of restored habitats if cues are present that cause individuals to perceive the habitat as poor when in actuality it is good (Gilroy and Sutherland 2007). This may occur if there are anthropogenic cues or if the new habitat is sufficiently different from the source area habitat (Gilroy and Sutherland 2007). However, for social species such as bobwhites, the addition of conspecifics to the landscape may help to change those cues by signaling to dispersers that the habitat is suitable (Bayard and Elphick 2012, Andrews et al. 2015). Thus, the addition of bobwhites to a restored habitat where none currently exist may help to improve the colonization rates from naturally dispersing birds by improving the perception of habitat quality. However, translocated birds may also perceive habitat as inferior and disperse—leaving the site no better off before translocation.

Stakeholder-driven Motivations for Translocation

The desire to begin a wildlife translocation effort may be initiated by a private landowner, a non-governmental agency (NGOs), a government agency, or any number of stakeholders. A recent survey of authors of translocation efforts showed that most efforts were funded by federal (67%) and state governments (65%). Universities and local NGOs were cited as requesting or funding translocations at 53% and 34%, respectively (Brichieri-Colombi and Moehrenschlager 2016). All stakeholders must be well informed of the positives and potential negative effects of translocation efforts. Outside of biological obstacles to successful translocations, non-biological factors can also negatively influence programs. Public relation and education efforts can increase support by the public and governmental leaders (Reading et al. 1997). While state agencies operate under the Public Trust Doctrine to manage wildlife for the benefit of all people, the stakeholders served are an increasingly changing demographic. Manfredo et al. (2003) suggested that views toward wildlife have shifted from more utilitarian to protectionist. In this case, it may be difficult to convince stakeholders that it is necessary to increase populations of a species for the desired result of a huntable population. Other factors that may affect bobwhite population restoration efforts are the mandate to achieve quick results, financial, political agendas, and interest from the public as stakeholders. Bobwhite are a socio-economically important species. Bobwhites provide both consumptive and non-consumptive benefits with the former being the primary reason for their intentional management. However, the latter (non-consumptive) benefit is becoming more and more prominent in the face of precipitous range-wide decline, local and regional extirpations, and range contraction. For example, it is common vernacular of today for landowners to simply want to see or hear bobwhites again.

CONCERNS FOR TRANSLOCATION

Biological and Ecological Concerns

Genetic Implications of Translocations. Population restoration techniques should consider several factors prior to translocating animals in order to maximize reintroduction or restocking success and meet population goals. Because the translocation of wild animals can affect the genetic structure and make-up of species and populations, the genetic implications of translocation must be considered prior to translocation.

There are both genetic benefits and risks associated with PRT. Possible genetic benefits derived from translocation may include enhanced reproductive fitness, increased genetic variation, and improved adaptability of a population under environmental pressures (Weeks et al. 2011). Genetic risks of translocation include outbreeding depression (i.e., decreased reproductive fitness because distinct populations were attempted to be crossed), hybridization of related species, reduced genetic diversity, loss of historic genetic records, and the loss of a locally adapted population (Avise 2004, Weeks et al. 2011). Given the large number of genetic benefits and risks associated with translocation, it is important that managers weigh these genetic implications on a case-by-case basis prior to translocation. To assist managers in weighing these implications, Weeks et al. (2011) developed two tools (a decision tree and risk-assessment framework) to identify benefits and risks of translocation, assess and mitigate risks, and provide translocation guidance even when biological and genetic information for a species is lacking. We recommend managers use these tools when contemplating PRT as a management or conservation practice.

Fortunately, the bobwhite is an intensely studied species and thus information generally is available to guide translocation decisions. In the past, as many as 24 subspecies of northern bobwhite were described using male plumage and geographic distribution; however, currently 19–22 subspecies are acknowledged (Brennan et al. 2014, Madge and McGowan 2002, Williford et al. 2014, Williford et al. 2016). Recent mitochondrial DNA analysis found that the phylogeographic structure of bobwhites west of the Mississippi River was not consistent with the proposed subspecies distribution and more variation was found within populations than among populations (Williford et al. 2014). Therefore, it is suggested that many previously described bobwhite subspecies are not actually distinct taxonomic units (Williford et al. 2014); however, the Florida subspecies (*C. v. floridanus*) may be a distinct subspecies and likely should only be translocated within the peninsula of Florida (Eo et al. 2010).

The lack of genetic distinctness among subspecies is particularly surprising because physical differences such as plumage and patterns are apparent between subspecies (Williford et al. 2014). Even bobwhites in eastern and central United States that have more consistent plumage but vary in body size and colors (Williford et al. 2014). The physical variation (e.g. color, size, plumage pattern) between subspecies may be caused by adaptation to local or regional environments despite the fact that subspecies may not be genetically distinct populations (Williford et al. 2014). Thus, if bobwhites are locally adapted to their environment, then it is possible that bobwhite populations native to a region may be more fit to survive and reproduce in that region than bobwhites from a different region. For example, in the northern fringe of the bobwhite range where severe winter weather is common, size of bobwhites affects heat loss, and thus energy balance is an important factor to consider in the context of local environmental adaptation (reviewed by Burger et al. 2017, this volume). However, Hereford (2009), a comprehensive study of published research related to translocation, reported that the fitness costs associated with local adaptation are weak and not strong enough to prevent adaptation to multiple environments. This study did find that fitness costs associated with local adaptation were stronger when native environments differed greatly between populations and when a population adapted to an environment significantly different than its ancestor's environment.

Diseases. Numerous macro- and micro-parasites can cause morbidity and mortality in bobwhites. Among some of more common pathogens are protozoon coccidea, *Salmonella* sp. bacteria, and avian influenza viruses. These are thoroughly reviewed by Peterson (2007). Managers need to have concern for diseases for two key reasons of equal importance. When transferring bobwhite from source populations to new areas, managers must avoid moving diseases into new areas where existing populations of bobwhite and other bird species could be jeopardized. Likewise, managers should avoid translocating bobwhite into high disease risk areas that could jeopardize translocated bobwhites. For example, areas where there are large numbers of backyard and industrial poultry (Garber et al. 2007, Madsen et al. 2013).

The U. S. Department of Agriculture (USDA), and state veterinarian offices have regulatory authority over movement of birds. This authority includes both in-state as well as out-of-state movement. The USDA and state veterinarians are concerned with movement of diseases that may cause morbidity and mortality in domestic bird flocks such as commercial poultry. These entities require defined testing of birds for certain diseases of concern to agriculture. Often testing is based on the testing standards for the National Poultry Improvement Plan (USDA Veterinary Services 2014). State veterinarians may define additional disease tests before accepting birds into their jurisdiction from out of state or movement between different locations within a state.

Planning for a bobwhite translocation should include the following considerations:

1) Consultation with state veterinarian and USDA Veterinary Services;
2) Obtaining the services of a veterinarian to provide necessary health inspections and to oversee collection of samples; and,
3) Arrangement of a properly certified laboratory to conduct tests.

Wild bird supply. Historic efforts to translocate wild bobwhite have been profuse and widespread, with records dating back to the 1700s, and including destinations such as the West Indies, Peru, Hawaii, Europe, New Zealand, etc., and many U.S. states (Long 1981). Although comprehensive verified data on the quantity of bobwhites translocated is difficult to determine, records from Texas show 3 contracts over a 2-year period in the 1930s for 10,000-18,000 wild bobwhites each, from Mexico to Texas, and that costs were increasing because of "the growing scarcity of quail in northern Mexico…trapping operations which now must be carried on deeper in the interior of the country" (Texas Game, Fish and Oyster Commission 1939). New Jersey has a record in 1899 of receiving 30,000 wild bobwhites from Oklahoma (Chanda et al. 2011). Several state agency coordinators report similar translocations of bobwhites from Mexico. Similarly, between 1990 and the present, bobwhite research studies amassed sample sizes in the 10s of thousands (e.g., Burger et al. 1995, Sisson et al. 2009, Ruzicka et al. 2016). Thus, in the context of possible limitations to translocation, capturing wild bobwhites *per se* appears unlikely assuming some source populations remain.

Despite the relative ease of capturing bobwhites, the long-term, widespread decline in bobwhite populations in the late 20th Century resulted in decreased supply of birds for translocations. Both the Ohio Department of Natural Resources, in 1993 (Wiley and Stricker 2017), and the Canadian Ontario Ministry of Natural Resources, in 1994 (James and Cannings 2003), reported that insufficient numbers of wild bobwhite among states delayed or ended translocation projects. However, some private landowners in a few states (e.g., Texas, Georgia, and Florida) have historically been willing to allow trespassing on their property to translocate birds. However, the birds themselves belong to all residents of that state and the state wildlife agency is entrusted to decide whether or not to allow translocation.

Management Constraints

The Lacey Act. Understanding state and federal laws concerning bobwhite translocation is essential to success of PRTs. While most states have general statutes prohibiting capture and possession of native wildlife, specific regulations governing capture and transport for translocations are not developed for the majority of states in the bobwhite range. Without such state-specific regulations, the legality of capture and translocation of native birds falls directly under the Lacey Act. First passed in 1900 the Lacy Act prohibits, among other things, "*import, export, transport, sell, receive, acquire, or purchase any fish or wildlife or plant taken, possessed, transported, or sold in violation of any law, treaty, or regulation of the United States or in violation of any Indian tribal law*" (Lacey Act 1900). If capture and possession of native wildlife is prohibited, then importing or exporting those animals would be illegal under the Lacy Act due to the method they were taken. Therefore, capturing and translocating birds within or across state boundaries is prohibited under the Lacey Act in the absence of state-specific statutes that permit capture and transport of native wildlife for translocation. We recommend states interested in PRT investigate the opportunity for drafting specific legislation regarding translocation.

State Agency Willingness. In autumn 2016, NBCI surveyed quail coordinators of the 25 state wildlife agency members of the National Bobwhite Technical Committee for information on bobwhite translocation. Based on 18 responses, 44% of coordinators (8 states) indicate potential ("very-likely," "somewhat-likely," or "neutral") for their state agency to be a source of wild bobwhites for translocation to other state agencies during the next 5 years. Affirmative responses were contingent on several factors, including existence of a biologically based evaluation of recipient site, publication of a national translocation guidance, and a positive trend in the donor state's quail population. At the time of the survey, quail populations were very high in the majority of states willing to donate bobwhites. Only two state agency quail coordinators indicated their agency is "very likely" to be a source of bobwhites, Kansas Department of Wildlife, Parks and Tourism, and Georgia Department of Natural Resources. Kansas has a long history, since the 1980s, of donating bobwhites, providing birds to state agencies in Colorado, Indiana, and Ohio.

The Georgia Department of Natural Resources Wildlife Resources Division is increasingly facilitating exchange of wild bobwhites between private landowners under their 2006 Game Management Policy Statement: Q-1 Quail Translocation (Sisson et al. 2012). Donations of Georgia bobwhites to private entities in Maryland, New Jersey, North Carolina, and South Carolina necessitated approval by state agencies in those states, following the Public Trust Doctrine. Under the Public Trust Doctrine, state wildlife agencies have jurisdiction over resident wildlife including wild bobwhite with the responsibility of managing the species to benefit all the state's citizens (Decker et al. 2015). Peterson et al. (2016) point out that interpretation of the merits of species conservation via privatization (e.g., translocation managed by private entities) has been constantly evolving. Following the Public Trust Doctrine, some coordinators answering the NBCI survey emphasized that translocation of bobwhites out of their state must provide a clear benefit to the citizens and hunters of that state. For example, a common practice among state agencies has been to exchange species, e.g., wild turkeys for river otters (*Lontra canadensis*). For bobwhite conservation, several coordinators expressed the opinion that the private lands model has the potential to play a key role in bobwhite conservation if protective measures are in place and the spatial scale is large enough to increase the probability of long-term population viability. Private lands could be the foundation of a state's bobwhite recovery, augmenting management, research and translocation that may be cost prohibitive to state agencies. Private land owners can provide large-scale habitat management, exemplary land stewardship, and conservation advocacy benefiting a suite of species, both fauna and flora. Moreover, bobwhites are no longer a priority for some state agencies, partly a result of declining numbers of small game hunters, e.g., the number of small game hunters declined 49% from 1975-2000 (Flather et al. 2009).

BEST MANAGEMENT PRACTICES FOR TRANSLOCATION SUCCESS

The decision to use PRTs is driven by stakeholders and agencies wanting to meet conservation objectives (e.g., state agency quail and biodiversity plans) under constraints of policies and laws. If PRT is considered as a management action to achieve those objectives, the best science should be used to inform its use. It should be instituted on a site-by-site basis, and decisions governing its implementation should take into account knowledge of the species' life history and ecology. This approach would ideally increase the efficacy of PRT and help to guide its role in conservation planning and management. The success of PRT is conditional on several key factors including sufficient habitat, minimizing stress during translocation, using the right source population, the presence of conspecifics, timing of the translocation in the bobwhite annual cycle, and releasing enough birds (Table 1).

Sufficient habitat. Guthery et al. (2000) suggests that to avoid local extinctions in the face of summer and winter extreme events about 800 birds in autumn is needed with 800-1,600 ha of habitat. Sands et al. (2012) extended this work and indicated that a greater amount of habitat is needed to sustain spatially-structured bobwhite populations in the presence of harvest where as much as 9,600 ha of habitat is needed with a 40% harvest rate. Thus, we do not recommend exploitation of newly reintroduced or restocked populations until the population has stabilized ($\lambda = 1$) and 800 birds. Terhune et al. (2010) recommended properties should be large (>600 ha) and contiguous to increase site fidelity and survival post-release where population colonization is limited due to isolation from source populations. To date, translocation to smaller sites (<600 ha) has not experimentally been tested and, as such, we do not recommend doing so (Terhune et al. 2010). The minimum habitat requirements of the NBCI Coordinated Implementation Program (Morgan et al. 2016, sidebar #1) follows Guthery et al. (2000) and Terhune et al. (2010), but relaxes requirements for 100% contiguous sufficient habitat in space and time. The NBCI minimal criteria allow for conservation in the context of an abundance of insufficient habitat in a focal

Table 1. The critical steps to assure reintroduction or restocking success.

1. Determine if translocation is necessary and appropriate via an initial assessment of habitat and bobwhite abundance (Figure 2);
2. Identify source site for wild bobwhites; utilize the decision tree and risk-assessment framework for Weeks et al. (2011) to identify benefits and risks of translocation, assess and mitigate risks, and provide translocation guidance even when biological and genetic information for a species is lacking;
3. Secure appropriate state permits (from source and recipient state) and identify disease testing requirements (from recipient state) and possible disease threats;
4. Capture wild bobwhites during mid-March to early-April using baited funnel traps (see Stoddard 1931), minimizing stressors such as handling and heat stress;
5. Upon capture, work up birds and record data (sex, age, weight, leg-band number, conduct health screening as stipulated in trap and transfer permit (e.g., extracting blood samples, gular swabbing);
6. Place birds into transport boxes (with air holes) in groups of ~11 individuals while trying to keep birds intact with original social groups; assure that the boxes don't let in light;
7. Transport birds immediately to release (recipient) site;
8. Release birds using a "hard-release[1]", during the daylight within 24 hours (preferably within 18 hours) of capture on the release site; and,
9. Monitor the population for 10 years to determine success (Figure 1).

[1] We recommended not holding the birds in a captive setting for acclimation (Parker et al. 2012). But birds should be released into cover and perhaps allowed to emerge from the transport box at their own will.

area, either because the land is primarily used for agriculture, or, management of plant succession (fire, mechanical removal of vegetation, etc.) renders areas insufficient for bobwhites for much of any one year. At this time, we recommend the following the minimum habitat area criterion as stipulated in Terhune et al. (2010), but we encourage future research to evaluate the sensitivity of landscape context and minimum habitat amount required to sustain viable population thresholds submitted via Guthery et al. (2000). The habitat is a means to get to >800 birds, thus, the habitat needed to sustain that population size is the targeted habitat area. We offer Terhune et al. (2010) and Guthery et al. (2000) as a minimum and a best management target, respectively.

Limiting Stress. Physiological stress is inevitable when moving birds to a new environment. Stress has been implicated as a major factor affecting wildlife translocations; however, by identifying and mitigating stress the translocation process can be improved (Letty et al. 2000, Teixeira et al. 2007, Chipman et al. 2008, Dickens et al. 2009, 2010).

Stress responses in translocated birds can be categorized as acute (short-term stress) or chronic (continuous stress). Acute stress includes a physiological response of adrenaline that signals increases in heart rate and blood flow to aid in a quick escape from threats (Parker et al. 2012). For example, evasion from a predator encounter would be considered the result of an acute stress response, which is beneficial to birds as a survival adaptation (Romero 2004). Alternatively, bobwhites are not evolutionarily adapted to manage chronic stress which can alter their physiology and compromise reproduction, immune responses, and metabolism; ultimately leading to death (McEwen 1998, Romero et al. 2009, Dickens et al. 2010). For example, wild birds held for long periods in captivity elicit a chronic stress response resulting in high mortality often observed after release (Armstrong and Seddon 2008).

Ultimately, the resultant pathology of stress is a factor of environmental vulnerability. For example, a lowered immune system leads to death by microbes and viruses, an altered predator response leads to predation, and altered reproduction could lead to a quick extirpation of bobwhites. While the categories of stressors are acute and chronic, Parker et al. (2012) identified 3 scenarios that elicit a stress response in wild animals: (1) lack of control, (2) unpredictability, and (3) novelty; all of which are introduced in the translocation process (Dickens et al. 2009). Thus, one goal of bobwhite translocations should be to identify and avoid stressors associated with all phases of the process (capture, holding, transportation, and release).

For example, Terhune et al. (2010) covered traps to minimize capture stress in bobwhites, and made great efforts to release all birds in less than 24 hours from time of capture. Abbott et al. (2005) found that injecting captured bobwhites with vitamin E and selenium increased their survival when translocated. Maho et al. (1992) found that any human handling of birds induced a stress response and suggested minimizing handling and processing time. Weiss (1968) and Dickens et al. (2009) suggested that a quick transition from capture to transport is vital as birds encounter stress from a myriad of changes in temperature, crowding, humidity, noise, light, etc. Holding pens are not recommended as they reduce the bird's ability to behave in a natural manner and should be avoided (Gelling 2010). When releasing translocated bobwhites, bird should be kept in familiar groups and released in environments similar to the capture site (temperature, humidity, structure, and nutrition). Additionally, any celebration or observation of releases should be done in a manner that to minimize stress and maximize animal welfare.

Using the right source. Prior to translocation, careful consideration regarding the source for translocated birds is necessary. However, source populations are often described inconsistently. For example, source populations, defined as the population from which birds were captured for translocation differs, in an ecological context, from source populations defined as the populations around a translocation site that could move into translocated sites. This distinction is critical as both could influence translocation success in different ways. For this section, we will refer to the population from which birds were trapped and translocated from as the source population and populations around the translocation site as neighboring populations. Few studies have experimentally evaluated the effect of source populations. We can glean anecdotal information from the literature but more research directly investigating the effect of source populations is needed. Troy et al. (2013) found source population had no influence on translocated mountain quail (*Oreortyx pictus*). However, Terhune et al. (2006*a*, 2006*b*) and Liu et al. (2000) found source population was important to success. Multiple mechanisms can influence the impact of source populations. For example, if site conditions of the source area differ considerably from the translocation area, the mechanism affecting success could be localized adaptations to habitat, weather, predator communities, populations of competitors for food and space, and interactions thereof. Therefore, the source population itself is not the mechanism, rather the bird's response to disparity in site conditions. Depending on geography, the further the source population from the translocation area, the greater the probability of differing site-specific adaptations, and therefore the greater the probability of failure. For example, translocation efforts in East Texas found that birds translocated from South Texas had lower survival rates than birds from another region of East Texas (<15 km away) (Lui et al. 2000). Similarly, Parsons et al. (2000) found that birds translocated from South Texas to East Texas were "inefficient in their ability to successfully nest, hatch eggs, and fledge chicks into the population. However, Downey et al. (2017) found weak evidence for an effect of distance on survival of translocated birds.

Consideration of latitude, Bergmann's Rule (Bergman 1847) and thermoregulation would prevent illogical selection of source populations due to disparity between body size of bobwhites, which range from ca. 160 g toward the south and 200 g toward the north. *If* energy balance is a limiting factor for bobwhites toward the north, birds from the southern extreme of the bobwhite range are illogical candidates for source populations to birds being translocated to the northern periphery of the range (Burger et al. 2017, this volume). Translocated birds lacking the genetic framework to adapt to conditions outside of their evolutionary roadmap are unlikely to adapt to conditions of which they have never been exposed. When local populations are completely extirpated, reintroduction via translocation can introduce demographic and genetic bottlenecks (Jamieson et al. 2007). Gregory et al. (2012) argued that genetic diversity of the source population was the ultimate factor of success with Evermann's Rock Ptarmigan (*Lagopus, muta evermanni*). Bobwhite translocations in areas of extirpation will be increasingly susceptible to genetic bottlenecks. Therefore, understanding the genetic diversity of source populations is important for translocation success. Furthermore, the expansion of bobwhite habitat around areas of translocation will reduce the probabilities of genetic bottlenecks.

Presence of conspecifics. Successful restoration efforts via translocation should occur prior to populations levels vulnerable to extirpation from stochastic events (Baxter et al. 2008). Recent bobwhite translocations with a positive population response were conducted where populations existed (Terhune et al. 2006*a*, 2006*b*, 2010). In each of these scenarios, bobwhite populations at the translocation site were at low densities (<1 bird per 3 ha), but not extinct. Scott et al. (2013), however, attempted translocation to area of central Texas that had been extirpated and the closest neighboring populations was 95 km away. The resulting unsuccessful translocation may have been due to the limited number of conspecifics at the translocation site and the fragmentation of the landscape. The importance of conspecifics in bobwhite translocation cannot be overstated. For example, Jones et al. (1999) observed 95% integration of translocated bobwhites into resident coveys that likely increased success of translocation. The exact density at which bobwhite populations should respond positively to translocation is not known and is likely site specific. The range of densities at which bobwhite will respond positively to PRT is unknown, but likely larger than range at which they cannot respond to translocation. In other words, a threshold density, below which augmentation via translocation is ineffective likely exists. At such a threshold, the Allee effect could render translocation efforts ineffective.

Releasing enough birds. Whereas release of translocated birds in coveys (8-12 birds) prior to the breeding season has become standard protocol (Terhune et al. 2006*a*, 2006*b*, 2010, Scott et al. 2013, Downey et al. 2017), and optimal covey size in bobwhites has been found to be approximately 11 birds (Williams et al. 2003), the density of released birds needed to produce a measurable translocation success is not known. Currently, no studies report the number of released birds relative to the translocation study area or target area (i.e., release density). This metric could influence success rates and efficiency of translocation efforts. Release density should theoretically vary with habitat type, quality, patch size, degree of fragmentation, historic density, distance to neighboring populations, density of neighboring populations, and management goals. However, this factor has not been evaluated and therefore, remains an unknown source of variation in translocation programs.

Spatial and temporal aspects of translocations. One-time translocations are common in the literature (Jones 1999, Liu et al. 2000, Scott et al. 2013), and a couple multi-year examples of failure (Frawley 1999, Wiley and Stricker 2017, this volume) that lack detailed measurement of bobwhites or habitat. Current descriptions regarding the spatial extent of release locations are vague and inconsistent. For example, Terhune et al. (2010) released birds at random locations within a stratified sample scheme, whereas Scott et al. (2013) used a uniformly distributed grid approach. However, the distances between translocated coveys is not reported. Considering the role of conspecific attraction in bird behavior (Ward and Schlossber 2004, Ahlering et al. 2006), proximity of release groups relative to release density could influence translocation success.

Time of year. Given adequate habitat management and a valid source of wild bobwhites, translocating individuals 3–4 weeks prior to the breeding season (during March) to provide ample time to acclimate to their new surroundings, but not longer than 3–4 weeks prior to breeding season to reduce mortality is important to success (Terhune et al. 2006b, Terhune et al. 2010).

REDUCING UNCERTAINTY ABOUT TRANSLOCATION SUCCESS

Assessment and Monitoring

Understanding the limits of translocation as a population recovery tool is inextricably dependent on sufficient evaluation and monitoring under varying scenarios. The range of approaches varies considerably among the published literature but does provide a rough roadmap for future studies. However, many questions remain unanswered regarding various logistical considerations associated with both pre- and post-translocation. While protocols exist for methodology of capture, banding, and tracking translocated bobwhites, a lack of consensus exists regarding multiple factors associated with the release process and how to evaluate outcomes. Terhune et al. (2006*a*) identified three mechanisms that largely influence translocation success: the source of the birds, the timing (season) of translocation, and the habitat conditions at the translocation site. These guidelines have served bobwhite translocation research in that subsequent translocation research has addressed these mechanisms but to varying degrees. However, the highly variable outcomes of bobwhite translocation efforts in the last two decades (Jones 1999, Liu et al. 2000, Terhune et al. 2006*a*, 2006*b*, 2010, Scott et al. 2013, Downey et al. 2017, Wiley and Stricker 2017, this volume) indicate that additional mechanisms warrant investigation (e.g., soft- vs. hard-release strategies) while existing mechanisms require further discussion. Before translocation efforts begin, decisions regarding population monitoring, source of birds, timing of translocation, release density and frequency, and release site must be made. Careful evaluation and assessment of these factors will increase efficiency and future successes of translocation efforts. Once translocation has been conducted continued monitoring and of survival, movement, production, health, and genetic quality must be conducted to evaluate factors that influence success.

Population Monitoring. —Restoration can only be evaluated with systematic, scientifically-based monitoring. Measuring translocation requires sufficient estimates of abundance pre-and post-translocation. Even when populations are low prior to translocation, effort must be made to adequately assess population trend (increasing, decreasing, stable) and size. Multi-year monitoring is important pre-translocation to determine population trajectory and therefore, implement translocation prior to extirpation (Griffith et al. 1989, Downey et al. 2017). Pre-translocation monitoring will also provide baseline indices to evaluate the outcome and interpret the magnitude of response of translocation efforts. Fall covey-counts and whistling male counts will both provide beneficial data to aid in evaluating translocation outcomes. Fall covey counts will also provide data on known locations of remnant coveys that could inform future translocation sites to increase probability of conspecific interaction. In situations where the goal of translocation is to augment existing, suppressed populations, data on body condition, survival, and reproductive metrics will be useful for evaluating translocation outcome (success/failure), but also to assess additional adverse (e.g., disease) or beneficial (e.g., increase in clutch size, body weight, nesting effort, etc.) effects that cannot be captured with passive monitoring techniques (e.g., covey counts). Maintaining a sample of banded and telemetered birds will provide the opportunity to capture subtle changes in populations that traditional monitoring could overlook.

After translocation, intensive passive (e.g., covey counts) and active (e.g., radio telemetry) monitoring are required to fully assess the outcome of translocation. In addition to traditional metrics gained from radio telemetry (i.e., survival and reproductive measures) data on movement and emigration out of the target area are needed to understand how translocated birds respond to the new environment. Research on differences in survival, reproduction, and movement of translocated birds is highly variable (Liu et al. 2002, Terhune et al. 2006*a,b*, 2010, Downey et al. 2017). Movement out of the translocation area could be a function of both the distance travelled from the source population, poor habitat on the release site, lack of conspecifics, and/or the disparity in habitat conditions between source and translocation areas. Therefore, intensive monitoring is necessary to adequately assess birds' response to translocation. Continuation of whistling male and fall covey counts, after translocation will provide a comparison of pre- and post-translocation population indices that will aid in determining the magnitude of population response to translocation. Population monitoring should continue for a minimum of 10 years, following the NBCI Coordinated Implementation Program (Morgan et al. 2016), to determine the establishment and persistence of the population.

Future Research Directions

Translocation to judiciously restore and augment bobwhite populations can only achieve large-scale success if we continue to use sound science to inform decision making. Therefore, more research is needed to evaluate a range of issues regarding multiple steps in the translocation process. For example, research that explicitly and experimentally evaluates the influence of source populations on translocation success must be conducted with considerations for local adaptations to habitat types, environmental stressors, and predator communities. Similarly, the genetic consequences of source populations from translocations has yet to be investigated. Measures of survival and reproduction are sufficient to evaluate the short-term effects of translocation, but the long-term impacts on evolutionary consequences will need to be evaluated in the future (Gregory et al. 2012). Research to determine the population thresholds below which translocations can succeed will be vital to prioritizing a population or area's candidacy for translocation and optimizing resource allocation. The importance of implementing translocations while populations can numerically respond is crucial to the success of translocation as a restoration tool (Griffith et al. 1989). Research that experimentally investigates varying release densities relative to habitat type, quality, patch size, degree of fragmentation, historic density, distance to neighboring populations, density of neighboring populations, and management goals will allow managers to optimize translocation efforts across diverse landscapes. Similarly, temporal and spatial distribution of release sites relative to release density will facilitate strategic translocation efforts thereby minimizing cost and time. Collectively, these research areas will add to the existing literature and provide a guiding framework for future translocation efforts.

Regardless of much needed further research, the implementation of reintroduction and restocking in the future fundamentally boils down to the question of these techniques causing population recovery. Said another way, would the population have recovered without the use of translocation? Translocation may not be the most effective use of limited resources (considering birds have some intrinsic value). In either case, sound experimental design is needed to continue to refine reintroduction science. Learning comes at a cost because more sites and control sites will be needed—these are sites that restoration could have occurred on if learning was not an objective. We operate under the assumption that sites for population restoration cannot be identified at random because of the limited number of landscapes suitable for restoration. Thus, a Before-After-Control-Impact (BACI) design is likely the most feasible design to determine causality. The control sites should be areas with sufficient habitat (>800 ha) that do not receive translocated birds. The treated sites should have sufficient habitat and receive translocated birds. Sufficient habitat can be measured using the Coordinated Implementation Plan Habitat Assessment (Morgan et al. 2016). Treatment and control sites should be replicated. The number of replicates will depend on the site-to-site variability and the effect size. The effect size (increase in population as a result of the treatment) could be large, if it exists, making the number of replicates needed relatively small. We recommend monitoring annually for 10 years post-translocation to evaluate long-term success (Figure 1) following the Coordinated Implementation Plan's monitoring protocol (Morgan et al. 2016). We strongly urge those interested in future translocation efforts to collaborate with scientists on design and implementation to optimize success while sufficiently monitoring and documenting for continued learning.

SUMMARY AND CONCLUSIONS

Bobwhite conservationists need to know what tools are effective at meeting population objectives. Population restoration techniques—restocking and reintroduction—even after multiple decades of research have a cloud of uncertainy around them making definitive conclusions difficult. Unfortunately, this uncertainty is mostly due to experimental designs that do not allow for isolating the cause of failures or successes. In the examples of failure, habitat was likely not sufficient or at the least the area was insufficient to support a growing population of birds thus creating the "pouring down the sink phenomenon (sensu Pulliam 1988)" (Seddon 2010); however, it can't be ruled out that the translocation itself failed. The successful examples illustrate that translocated birds' survival and reproduction is comparable to their resident counterparts. However, it does not permit a definitive conclusion that translocation was the cause for population response given experimental controls were lacking in most studies to date (excluding Terhune 2008, a restocking experiment). Nonetheless, these successes provide enough evidence for the benefits of translocation that warrants the continued practice and exploration of restocking populations in areas of sufficient habitat to meet population goals but under certain criteria (Figure 1). The sufficient habitat criteria should be applied as a stringent criteria for potential PRT projects and any deviation from this criteria should be treated as experimental and done so under the guise of research not management. Even under this criteria the success of PRT is not guaranteed considering our current uncertainty regarding knowledge of bobwhite habitat and other looming factors contributing to population declines. Furthermore, even populations of respectable size (>800 birds) in sufficient habitat are subject to local exinction due to environmental stochasticity which is exacerbated in fragmented landscapes (Anderson et al. 2017). Potential reintroduction projects, in particular, should consider the quantity of birds translocated. Assuming habitat is sufficient and a low density population, immigration of other wild bobwhites into the site is limited, making any rescue effect unlikely; therefore, the translocation itself must get the population over any critical population threshold (i.e., 800 birds). Uncustomarily, again assuming habitat is sufficient and population goals have not been met, a plausible approach is to wait a few years to see if the population responds without PRT (Figure 2). However, this "wait and see" approach is not without risk. For example, if a small population exists in sufficient habitat, waiting a few years could allow the population to continue to decline with possible local extinction. An inherent, often forgotten risk in PRT projects, is the consequences to the donor site, thus, any removal of birds from donor sites should be treated similar to harvest and the minimim bird criteria (800 birds) should be applied to donor sites too—don't rob Peter to pay Paul.

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Wild Birds Present	Habitat Sufficient: Yes	Habitat Sufficient: No
Yes	Restocking through translocation or wait longer.	Manage habitat
No	Reintroduction through translocation or wait longer.	Manage habitat

Fig. 2. Conceptual decision matrix for determining what type of translocation effort should be implemented (restocking or reintroduction) and if it should be implemented conditional on the amount of habitat. The decision assumes that the population is below the target for the entity; otherwise, continued management under the status quo is warranted.

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