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Animal reintroductions: An innovative assessment of survival

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ABSTRACT

Quantitative evaluations of reintroductions are infrequent and assessments of milestones reached *before* a project is completed, or abandoned due to lack of funding, are rare. However, such assessments, which are promoted in adaptive management frameworks, are critical. Quantification can provide defensible estimates of biological success, such as the number of survivors from a released cohort, with associated cost per animal. It is unlikely that the global issues of endangered wildlife and population declines will abate, therefore, assurance colonies and reintroductions are likely to become more common. If such endeavors are to be successful biologically or achieve adequate funding, implementation must be more rigorous and accountable. We use a novel application of a multistate, robust design capture–recapture model to estimate survival of reintroduced tadpoles through metamorphosis (i.e., the number of individuals emerging from the pond) and thereby provide a quantitative measure of effort and success for an "in progress" reintroduction of toads. Our data also suggest that tadpoles released at later developmental stages have an increased probability of survival and that eggs laid in the wild hatched at higher rates than eggs laid by captive toads. We illustrate how an interim assessment can identify problems, highlight successes, and provide information for use in adjusting the effort or implementing a Decision-Theoretic adaptive management strategy.

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1. Introduction

Over the last several decades, methodologies targeted specifically at species preservation have flourished. The family of tools termed relocation, repatriation, translocation, and reintroduction represent an approach to managing populations and species of concern that focus on moving individuals or groups of individuals from established populations (wild or captive) to historical or new habitat in response to threats ranging from habitat loss to population decline as a result of disease (Seigel and Dodd, 2002; Dodd, 2005). Despite ongoing use of this management tool (hereafter reintroduction), success is rare. Reintroduction efforts for birds, mammals, and fish are deemed successful less than 50% of the time (Griffiths et al., 1989; Harig and Fausch, 2002). Reintroduction efforts for amphibians and reptiles reflect similar results, for example, of 85 projects considered by Germano and Bishop (2008), 42% were considered successful. Griffiths and Pavajeau (2008) considered 58 projects that included reintroduction of amphibians and were able to assess 22 for success, of these; only 13 were considered highly successful. However, success can be defined on a continuum from survival of released individuals (low success, Griffiths and Pavajeau, 2008) to the establishment of a breeding population of adults and the presence of multiple age classes (high success, Griffiths and Pavajeau, 2008; Semlitsch, 2001; Dodd and Seigel, 1991) and because negative results are less likely to be published (Fanelli, 2012), the proportion of successful reintroductions is likely inflated.

Reintroduction efforts can have high stakes. Efforts are costly but may be critical to the persistence of the species. Endpoints can be elusive and typically, efforts suffer from lack of quantification and monitoring (Seigel and Dodd, 2002; Dodd, 2005; Field et al., 2007). Scenarios with high stakes, whether financial, or biological (i.e., the extinction of a species), call for accurate evaluations of reintroduction effort. Success depends on multiple factors, including habitat quality and the number of individuals that are released, and many of these attributes or characteristics can be quantified, allowing for an evaluation of effort. Despite this need, quantitative evaluations of reintroduction efforts are uncommon (but see Bell et al., 2004). Furthermore, reintroduction efforts provide an appropriate context (ongoing decisions and a high degree of uncertainty) within which managers can apply adaptive management methods (Runge, 2011). In particular, the Decision-Theoretic School (DTS) of adaptive management (Williams et al.,

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2007; Runge, 2011) uses formal tools for decision analysis but also incorporates predictive modeling (with ongoing updates from monitoring) and articulates levels of uncertainty. The identification of appropriate benchmarks to measure progress (Dodd, 2010) and a quantification of these elements prior to the completion of a reintroduction project offer an opportunity to assess and potentially re-direct conservation efforts. Information gleaned from incremental assessments can provide defensible estimates of biological success (e.g., survivorship of a release effort), identify potential cost savings (thereby increasing accountability), and importantly, provide insight into what "success" might look like in the particular situation.

Reintroduction is likely to be particularly important for conservation of amphibian species because of the increasing number of species brought from the wild into "assurance colonies" to protect them from acute threats such as disease that can presage likely extinction in the wild (e.g., Mendelson et al., 2006; Zippel et al., 2011). Such programs provide respite in the short term but maintenance of biodiversity in the long run requires returning animals to their native, or suitable new, habitat with subsequent successful natural reproduction.

Program initiation, implementation, and final outcomes are all topics that have been discussed thoroughly elsewhere (Dodd and Seigel, 1991; Denton et al., 1997; Griffiths and Pavajeau, 2008; Lukis, 2009). Instead, we focus here on measuring the progress of a reintroduction program, specifically survival of a particular life stage, using a novel application of the multi-state, robust design, capture–recapture model. Our focus on progress is unique; intermediate assessments of ongoing efforts are generally overlooked but can inform husbandry and colony maintenance, judge the short-term efficacy of release methods, determine the duration of efforts necessary before success is achieved, and importantly, refine plans for funding acquisition – all of which can provide foundational data for structured decision making and adaptive management strategies.

Intermediate assessment of reintroduction success (i.e., progress) could address any life stage between release and breeding age and may focus on a variety of questions specific to the situation and the natural history of the target species. For example, an informative question might be: How many of the released tadpoles survive to metamorphosis? An answer to this question provides data to use in calculating the cost of the introduction as well as an indication of the robustness of the tadpoles which may inform husbandry efforts. Moreover, these short-term results can inform, temper, and revise the time frame needed to meet long-term reintroduction goals. For example,understanding survival at each life stage can inform one of the most common questions in conservation biology and reintroduction activities; namely, how many released animals are required to provide the founding genetic material needed to capture most of the available genetic diversity and avoid the genetic pitfalls of small populations (e.g., Jamieson and Lacy, 2012; Zeisset and Beebee, 2012; Deredec and Courchamp, 2007; Soule and Wilcox, 1980).

Assessing a reintroduction effort is different in focus from typical monitoring exercises because information beyond occurrence and abundance is needed. Rigorous methods to quantitatively assess amphibian reintroductions are sparse and untested particularly in high elevation, sub-alpine environments. We present results from an ongoing reintroduction effort of Boreal Toads (*Anaxyrus* [*Bufo*] *boreas*) in such an environment in Rocky Mountain National Park, Colorado (Fig. 1) to illustrate how intermediate results can inform next steps. We (1) describe initial site selection; (2) quantify survival in eggs collected from the wild versus those produced in captivity; and (3) quantify survival to metamorphosis (i.e., over summer survival) of released tadpoles using removal sampling.

2. Materials and methods

2.1. Study species

Boreal Toads are an endangered species in Colorado and have been petitioned for federal listing (Greenwald et al., 2011). They are also considered one of the top 10 most vulnerable amphibians and reptiles in the U.S. (Giese, 2013). The Boreal Toad is one of only four extant amphibian species in Rocky Mountain National Park (RMNP, northeastern Colorado) (Corn et al., 1997). These toads belong to the *A. boreas* species group but the toads in the southern Rocky Mountains likely represent a different subspecies (Goebel et al., 2008). Boreal Toads are significantly less prevalent in RMNP than they were 20 years ago and notable declines have been documented even in the park's healthiest metapopulation (Corn et al., 1997; Muths et al., 2003; Scherer et al., 2005). Boreal Toads return to their natal site to breed when 3–5 years old; they are a long-lived species (12 + years, Hammerson, 1999), and data suggest that males can contribute to the breeding population for 10 or more years but that females frequently skip breeding opportunities (Muths et al., 2010; Muths and Scherer, 2011).

2.2. Site selection and disease surveillance

The reintroduction of Boreal Toads to sites in RMNP began in 2004 with a paper assessment of 23 candidate sites selected from locations in the park where Boreal Toads were reported historically but were currently unoccupied by toads (Corn et al., 1997, Unpublished RMNP files). Sites were ranked according to criteria established by the Boreal Toad Recovery Team (Loeffler, 2001; National Park Service, 2008) to determine suitability of sites for reintroduction. Criteria included habitat assessment (Holland et al., 2006), minimum distance from extant populations (to reduce potential disease transmission from migrants, but this became a moot point), disease status, predator (i.e., fish) presence, and logistical feasibility of accomplishing a reintroduction and maintaining adequate monitoring efforts. Repeated visual encounter surveys (e.g., Heyer et al., 1994; Dodd, 2010) were used to determine occupancy of the sites by toads and other amphibians.

All candidate sites were fishless; eight sites were rejected because of presence of, or proximity to, existing Boreal Toad populations. Two sites were rejected because the elevation, while within the range reported for Boreal Toads, was deemed too high for consistent reproduction; one site was rejected due to high use by visitors; and another was rejected because it was likely positive for disease. The remaining 11 sites were surveyed over three years (2004, 2005, and 2006) and three candidate sites were chosen for final assessments, undertaken in 2006. Basic water chemistry data, similar to those collected by Corn et al. (1997), were collected for the short-list of sites. Water chemistry, particularly pH may affect amphibian presence and reproductive success, (e.g., Barth and Wilson, 2010). Red Mountain was selected as the reintroduction site and tadpole releases began in the summer of 2007 (Table 1).

Disease was also a consideration in site selection and various methods were employed to determine the disease state of the candidate and selected sites prior to reintroduction. The amphibian chytrid fungus (*Batrachochytrium dendrobatidis*, Bd) is an amphibian disease that has played a role in the decline of Boreal Toad populations in Colorado (Carey et al., 2006) and RMNP (Muths et al., 2003). Amphibians were largely lacking at the three final candidate sites, but eight swab samples from Boreal Chorus Frogs (*Pseudacris maculata*) were collected using standard methods (Livo, 2004) and tested for the presence of Bd using non-quantitative PCR (Annis et al., 2004). Similar to the efforts of Fellers et al. (2007) to determine if threats persisted that led to earlier extirpations Mountain Yellow-legged frogs in Yosemite, we released 7 adult boreal toads