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The importance of including survival release costs when assessing viability in reptile translocations

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ABSTRACT

Translocations to restore populations of endangered species are an important conservation tool, but a reliable diagnosis is needed to assess their success. We used capture-recapture modeling to analyze the adult apparent survival of released and resident tortoises in two translocation projects in Spain monitored for 14 and 29 years. We tested if long-term survival rates differ between released and resident individuals, if survival was lower during the phase of establishment (i.e. release cost), how long acclimation lasts and if increased density due to releases affects survival. We found lower survival of released tortoises during the phase of establishment (1 to 3 years) when residents were already present. After establishment, survival was very high and unaffected by density-dependence. Body condition before release was similar between recaptured and dead/missing tortoises, and did not predict establishment survival. Stochastic population viability analysis showed that success when releasing small numbers of individuals strongly depends upon adult long-term survival. Release of small second batches of tortoises was not sensitive to a growing population, regardless of its release timing. Our results highlight long-term survival as crucial in translocation projects of long-lived species, invalidating short-term (first year) survival assessment, when survival release cost does not match long-term survival. A release cost of different duration should be included in model estimation before modeling predictions. Releasing tortoises (for welfare of captive individuals or for mitigating human negative impacts) in an already established population is not recommended under most circumstances. Acclimation cost is followed by survival approaching wild counterparts. If this milestone is not achieved, the project needs to be carefully assessed to adopt other management options or should be stopped altogether.

1. Introduction

Translocations as conservation programs aim to restore wild populations of endangered animals, are considered to be an important tool for conservation and are used with increasing frequency (Seddon et al., 2012). In this work we follow the definitions proposed by the IUCN/SSC (2013) reintroduction guidelines. As initial key factors that need to be assessed in all translocation programs, Armstrong and Seddon (2008) identify that settlement, survival and reproduction of founders is required during the phase of population establishment. Once translocated individuals overcome the establishment phase, positive growth is necessary to the persistence of the population (Armstrong and Seddon, 2008) and their long-term viability. On the other hand, Miller et al. (2014) developed standardized criteria to determine success in translocation projects by the time elapsed since release, and proposed assessing survival and growth of released individuals as a first indicator of success. Survival is also a key parameter in demography and conservation biology and for long-lived species it requires long-term monitoring to obtain proper accurate estimates (Lebreton et al., 1992). Long-term monitoring of released marked animals by recapture (or resighting) is necessary to assess translocation projects (Sarrazin and Barbault, 1996; Miller et al., 2014) and allows for survival estimates by the well-developed mark-recapture methods (e.g. Lebreton et al., 1992; Williams et al., 2002).

Short-term reduction in demographic parameters after release has been called “release cost” by Sarrazin and Legendre (2000). Particularly related to survival parameter, several translocation projects have found a post-release negative impact on survival (i.e. a release cost) in vertebrates, that involves a high post-release mortality or a high permanent dispersal during the establishment phase, a period that can be defined as an acclimation or adaptation period. This short-term local survival of released animals is important to establish a population

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(Tavecchia et al., 2009), because if mortality (or dispersal) is high, founder animals cannot establish a population that persists over time. Several factors and circumstances have been identified and may affect negatively short-term local survival (hereafter release cost): age of individuals (Sarrazin and Legendre, 2000), sex (Bertolero and Oro, 2009), release method (Eastridge and Clark, 2001; Green et al., 2005; Mihoub et al., 2013), rearing conditions (Bright and Morris, 1994; Whiteside et al., 2015), long-distance dispersal (Le Gouar et al., 2012), and meteorological conditions (Hardouin et al., 2014). The length of the acclimation period, with significant release cost, can vary from few weeks (e.g. Maran et al., 2009; Hamilton et al., 2010) to one year in different long-lived species (e.g. Sarrazin et al., 1994; Bar-David et al., 2005; Le Gouar et al., 2008; Tuberville et al., 2008; Bertolero and Oro, 2009). To our knowledge, a longer acclimation period of up to two years has been reported only for immature griffon vultures *Gyps fulvus* (Sarrazin et al., 1994; Le Gouar et al., 2008).

Despite the fact that translocation projects have been used extensively in conservation programs involving reptiles and, in particular, chelonians, only two published translocation projects have estimated survival rates for periods longer than ten years with mark-recapture methods (Bertolero et al., 2007a; Tuberville et al., 2008). This may be due to the difficulties of carrying out long-term monitoring programs with long-lived species. On the other hand, very few projects have directly assessed if survival shows a release cost effect after release. Thus, only one year of release cost was found in Hermann's tortoise *Testudo hermanni* (Guyot and Clobert, 1997), in gopher tortoise *Gopherus polyphemus* (Tuberville et al., 2008) and in Mediterranean pond turtle *Mauremys leprosa* (Bertolero and Oro, 2009). However, other works failed to detect a one year release cost in Hermann's tortoise, in Agassiz's desert tortoise *Gopherus agassizii* and in European pond turtle *Emys orbicularis* (Bertolero et al., 2007a; Nussear et al., 2012; Canessa et al., 2016).

In the present work, we aim to analyze short-term (i.e. release cost) and long-term survival to assess the long-term persistence and management alternatives in two independent translocation projects carried out on Hermann's tortoise in Spain. Each project has an annual monitoring program (Ebro Delta, 29-year data set and Minorca, 14-year data set). Studying two long-term projects allowed us to have a spatial replication, rarely possible when working with threatened long-lived species (see also Canessa et al., 2016). Also, it allowed us to monitor a temporal variation in one project (Ebro Delta), because batches of tortoises were released in the same place on two different occasions 10 years apart. And finally, we were able to compare survival rates between released and resident tortoises in the same places and conditions (see *Translocation projects*). Previous survival results in the population of the Ebro Delta (Bertolero, 2002; Bertolero et al., 2007a; Fernández-Chacón et al., 2011) with subsets of the present data set allowed us to hypothesize that: 1) survival of released captive tortoises is always lower than that of resident or wild-born tortoises, 2) after release, tortoises show a release cost in survival independent of the presence or density of conspecifics; this release cost can be longer than one year (suggested by Fig. 2 in Bertolero et al., 2007a), 3) negative density-dependence differently affects survival of released and resident tortoises, and 4) during the phase of establishment, body condition of surviving tortoises is better than that of tortoises that die or disperse permanently. Then, we built stochastic population models to assess how the survival rates of released tortoises and the number of released individuals can determine the long-term persistence of the reintroduced populations.

2. Material & methods

2.1. Study species

Hermann's tortoises *T. h. hermanni* is a Mediterranean species with a few scattered populations that live in Spain, France and Italy. The main conservation threats are habitat loss (including wildfires and agricultural transformation; Couturier et al., 2014), poaching for the pet trade and the increased numbers of predators (carnivores and wild boars *Sus scrofa*), and high rates of nest predation (Vilardell et al., 2012). The species was listed as *endangered* (European Reptile and Amphibian Specialist Group, 1996) 20 years ago but more recently proposed as *vulnerable* (Bertolero et al., 2011). However, this change is not motivated by a recovery of the species but a better knowledge of the remaining populations. In particular, Spanish populations show a contrasting scenario, with a highly endangered continental population in l'Albera (NE Catalonia) and good populations in Minorca and Majorca (Balearic Islands; Bertolero, 2014a). To increase the number of continental populations in Spain, seven reintroduction projects have been carried out since 1987 with different results: one with a persistent population, two that failed and the rest without enough information to assess their success or failure in the long-term.

2.2. Translocation projects

We analyze long-term survival in two translocation projects of Hermann's tortoise in Spain. The first one is a reintroduction project that started in 1987 in the Ebro Delta Natural Park (thereafter Ebro Delta), where a total of 66 tortoises were released in two batches (named G1 and G2) separated 10 years apart for conservation purposes in the Punta de la Banya Reserve (Table 1; for more details see Bertolero et al., 2007a). Both batches were of captive animals, although for most individuals the exact time in captivity was unknown. Before the first release, the host site lacked any established population of Hermann's tortoise, although the site lies within the historical range of the species (Bertolero and Martínez-Vilalta, 1994). The reserve is a peninsula legally and effectively protected from humans (restricted access) and safe from fire. The released tortoises inhabit a dune habitat covered with psammophilous and halophilous vegetation. The two batches of tortoises were released in the same dune complex isolated from other dunes by an episodically flooded sand desert plain with no vegetation (dunes are isolated patches with non-suitable habitat connecting them). Released tortoises and their descendants reproduced regularly (Bertolero et al., 2007b) and the population growth rate using stochastic models was estimated at $\lambda = 1.055$ for the period 2010–2099 (Fernández-Chacón et al., 2011). This reintroduction project has been followed annually from 1988 to 2015, and each year all parts of the release dune (11.1 ha) and surrounding dunes (see Fig. 1 in Bertolero et al., 2007a) were explored, most of the time by one observer, and since 2011 with the help of a trained dog.

The second translocation project was a reinforcement carried out by an NGO at Alfurí in Minorca Island (Balearic Islands; thereafter Minorca), where 48 adults were released in spring 2003 (March and April; Table 1). However, this action aimed to release tortoises that have been delivered by people to an animal rescue center and not to recover the local population (density of resident tortoises was unknown at the time of release). Most released tortoises likely come from captivity (Pons-Sabater et al., 2011). The habitat is a hill system with holm oak (*Quercus ilex*) and pine (*Pinus halepensis*) forests that extend more or less continuously for nearly 5 km^2 in the north coast of Minorca surrounded by cereal crop fields, grazing lands and the sea. This site is

Table 1
Number and release date of adult Hermann's tortoises released at the Ebro Delta Natural Park and Minorca island (F = females, M = males).

Population	Batch	Date	Release	Group name
Ebro Delta	Batch 1 (G1)	September 1987	17 F + 7 M	G1_87
	Batch 1 (G1)	May to August 1988	11 F + 9 M	G1_88
	Batch 2 (G2)	March 1997	5 F + 6 M	G2_97
	Batch 2 (G2)	September 1998	6 F + 5 M	G2_98
Minorca	–	March and April 2003	28 F + 20 M	R