



Habitat suitability for conservation translocation: The importance of considering camouflage in cryptic species



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ABSTRACT

Habitat suitability is a critical aspect for the successful establishment of a translocated population. Past studies have identified multiple factors that contribute to habitat suitability, including resource availability, presence of invasive species, landscape connectivity and climate. However, visual camouflage – coloration that conceals individuals from predators or prey – is another important ecological requirement that has been largely overlooked. We provide a case study to illustrate how color patterns of a prey species can change from that of the source site following translocation. Shore skinks (*Oligosoma smithi*) were moved from a coastal sand dune ecosystem to an offshore island beach that differed in substrate and color. Within one year following release, the translocated population's color pattern variation had reduced to mostly one pattern type. The high match in color patterns between the skinks and release site (including a new substrate type) may have contributed to the observed color pattern shift. This reduced variation in color pattern implies that not all founders survived, potentially decreasing the genetic diversity in the population. Our study highlights the importance of considering a species' camouflage requirements when selecting habitat for release, not only to maximize founder survival and establishment success, but also to maintain phenotypic and genotypic diversity in the long-term.

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1. Introduction

In conservation translocations, habitat suitability is of critical importance for the successful establishment of a population (Germano and Bishop, 2008; Wolf et al., 1998). A suitable, good quality habitat promotes survival and breeding of a newly founded population. In contrast, poor habitat quality at release sites has been shown to incur significant post-translocation losses; for example, 16%–50% of failed cases are associated with poor habitat quality (Brichieri-Colombi and Moehrenschrager, 2016; Germano and Bishop, 2008; Moehrenschrager et al., 2013; Wolf et al., 1996). However, what constitutes habitat quality, and the specific reasons of translocation failure, are often unclear (Ewen and Armstrong, 2007; Fischer and Lindenmayer, 2000; Wolf et al., 1996). Therefore, identifying the ultimate causes for translocation failure due to a 'poor quality' site can be challenging.

Factors that determine habitat suitability or 'quality' are species-specific (Ewen et al., 2014). Selecting suitable habitat will depend on understanding the critical ecological requirements for the species in question, as well as the species function within the ecosystem or food web. Previous studies have looked at habitat or landscape

characteristics that fit species' requirements for foraging, refuge use, egg-laying sites (Castilla and Swallow, 1995; Ebrahimi and Bull, 2012; Ortiz-Catedral and Brunton, 2009), dispersal or other behaviors (Armstrong and Ford, 2015; Gobiel and Villard, 2008; Parlato and Armstrong, 2013; Richardson et al., 2015; Stamps and Swaisgood, 2007), effect of invasive or anthropogenic threats (e.g., removal of introduced predators, or isolation from the public; Atkinson, 2002; Moseby et al., 2015; Norbury et al., 2014; Towns, 2011; Towns et al., 1997), and climatic differences between sites (e.g., climate change, Fordham et al., 2012; Schwartz and Martin, 2013). In addition to the above, for some species the need for camouflage may be critical for survival, either to avoid predators or to successfully capture prey. The efficacy of visual camouflage is often dependent on the matching of the animal's body color to its immediate background (Merilaita and Stevens, 2011; Stevens and Merilaita, 2011a). Therefore, a potential mismatch between the animals and their new environment may increase their conspicuousness to predators or prey.

Three main factors influence effective background-matching in cryptic animals (Houston et al., 2007; Merilaita et al., 2001): 1) phenotypic plasticity and genetic variation of the focal species (e.g., Bergstrom et al., 2012; Cortesi et al., 2015; Morgans and Ord, 2013; Rosenblum, 2005; Tyrie et al., 2015; Westley et al., 2013); 2) the abundance and species composition of predators or prey (e.g., Defrize et al., 2010; Llandres et al., 2011; Rohwer and Paulson, 1987; Stankowich and Coss, 2007;

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Théry et al., 2004; Troscianko et al., 2013); and 3) the color, structure and complexity of the habitat (e.g., Kekäläinen et al., 2010; Nafus et al., 2016; Nafus et al., 2015). Because each factor influences an animal's conspicuousness across time and space, any change in these factors due to translocation could impact the population at different levels. For example, a population that mismatches with their release site can have lower establishment of founders through reduced individual fitness (inability to hide from predators or to capture prey). Lower founder size will affect recruitment rate, and the phenotypic and genotypic diversity of the translocated population (Armstrong and Wittmer, 2011; Forsman, 2014; Miller et al., 2009; Thrimawithana et al., 2013).

How significant a problem can ineffective camouflage be on the outcome of conservation translocations? We cannot currently assess this quantitatively for human-mediated translocations due to a lack of relevant data from the translocation outcomes, although the potential effects of human-induced disturbances on threatened-species' camouflage was raised within a recent literature review (Delhey and Peters, 2016). Nevertheless, a few studies have highlighted the potential effect of camouflage on the fitness of translocated species. One study on Atlantic salmon (*Salmo salar*) translocated for economic purposes showed a significant decrease in individual survival and higher predation scars on salmon at mismatched background sites (Donnelly and Whoriskey, 1993). The authors noted the importance of color-matching to minimize likelihood of individual loss to predators. Additionally, experimental and field studies on desert tortoises (*Gopherus agassizii*) found that the availability of rocks at a site contributed to reduced predator detection and lowered the dispersal of juveniles from the release site, thereby increasing individual fitness of the tortoises (Nafus et al., 2016; Nafus et al., 2015). Authors emphasized the importance of linking habitat to camouflage behavior (i.e., individual fitness) when selecting suitable habitat for species conservation management.

Here, we present a case study that illustrates how color pattern, and therefore the degree of background-matching of a population, can change post-translocation without population management. We quantified color pattern variation and background-matching of a cryptic prey species before and after translocation. We also observed the degree of matching of the population when released to a site that included novel substrates. Our case study shows that color pattern of a translocated population can significantly differ from the source, even within one generation, and highlights the potential significance of camouflage on the phenotypic diversity of a translocated population.

2. Materials and methods

2.1. Study species and study sites

The shore skink (*Oligosoma smithi*) is a New Zealand endemic (national conservation status: Not Threatened, Hitchmough et al., 2013) with a relatively wide geographic distribution, inhabiting the northern half of the North Island. This species is present in diverse coastal habitats, from sand dunes, sandy, rocky pebbles or boulder beaches to vegetated cliffs on the mainland and offshore islands (Towns et al., 2002). There is extensive color pattern variation in this species among populations, with island populations having less variation overall compared to the mainland (McCallum and Harker, 1982; Towns, 1972). It is not known if color patterns of shore skink are genetically determined. Within their coastal habitat, shore skinks are found close to high tide mark of the coastline to >1 km inland; (Towns, 1975). Their home range and dispersal behavior is unknown, but because of the small size of the skinks (i.e., adult snout-vent length, SVL = 50–70 mm), we expect movement to be small. Similar to other New Zealand native reptile species, natural predators for shore skinks are birds (van Winkel and Ji, 2012), and populations are also affected by introduced mammals such as cats, rats, hedgehogs and mice (Jones et al., 2005; Lettink and Cree, 2006; Norbury et al., 2014; Wedding, 2007). Some populations are able to persist in non-predator controlled sites (M. Baling personal

observation; Towns, 1996). As part of a conservation effort to restore reptile diversity at an island reserve in the Auckland region (Baling et al., 2013), shore skinks were translocated from the nearest mainland population.

We sourced skinks from Tāwharanui Regional Park (hereafter 'Tāwharanui'), a 550 ha peninsula protected by predator-proof fencing erected in 2004. All introduced mammal species were eradicated following an aerial drop of poison in the park except for three species (house mice *Mus musculus*, European rabbits *Oryctolagus cuniculus* and European hedgehogs *Erinaceus europaeus*, Maitland, 2011). As a consequence, the population size of the resident shore skinks increased dramatically. The park also has a mixture of introduced (e.g., Australian magpie *Cracticus tibicen*, common myna *Acridotheres tristis*) and native (e.g., pukeko *Porphyrio melanotus*, sacred kingfisher *Todiramphus sanctus*) predatory birds. In 2006, we collected 40 skinks (14 males and 26 females) from a coastal sand dune system that had a gradient of light-colored sand at the foreshore to 100% vegetation cover at the back of the dunes. Nine out of the 26 females were recorded gravid at the time of capture. We captured skinks using an existing pitfall trap grid at the site, and also hand-searches by public volunteers, and staff and students of Massey University.

We then released these 40 shore skinks to Tiritiri Matangi Island Scientific Reserve (hereafter 'Tiri') in the Hauraki Gulf, Auckland (Baling et al., 2010). Tiri is a 220 ha public community-led island restoration that has had a highly successful history of translocation of threatened endemic birds, and more recently, reptiles (Baling et al., 2013; Galbraith and Cooper, 2013; Parker, 2013). The island is free of introduced mammals (Graham and Veitch, 2002), and has high densities of bird species, including known native predators of lizards (e.g., sacred kingfisher and morepork *Ninox novaeseelandiae*, van Winkel and Ji, 2012). The island had three extant resident reptile species, two skinks and one gecko (Baling et al., 2013). Shore skinks were recorded in the 1970's but subsequent surveys failed to detect their presence, and so the species was declared locally extinct (Baling et al., 2013).

Shore skinks were released on a small north-facing beach comprised of areas of dark-colored sand at the west and a mix of small and boulder rocks on the east part of the beach. Where the sand and rocks met (in the mid-section of the beach), there was accumulated driftwood and seaweed. Both substrates were mainly bare at the front of beach (with some seaweed and driftwood), and had varying levels of vegetation cover at the back. Vegetation consisted of exotic grasses, followed by thicker bush and trees towards the back of the beach. There were two other resident species present at the site: copper (*Oligosoma aeneum*) and moko skinks (*O. moco*), both are known to co-exist with shore skinks at other sites (Towns, 1972; Towns et al., 2002).

2.2. Population surveys

Between February 2007 and March 2008, we monitored populations at Tāwharanui and Tiri every three months. At Tāwharanui, we used three existing pitfall trap grids set at the sand dunes by a previous study (Wedding, 2007; Wedding et al., 2010). The grids were spaced 75 m and 120 m apart along the coastline, with each grid containing 40 4 L-sized plastic pitfall traps spaced every 20 m × 25 m, for a total of 120 traps for all three grids. At Tiri, we set up two 6 × 3 grids within the sand and rock sections of the beach. The grids had alternating pitfall traps and artificial refuges, spaced c. 5 m apart. These two grids were connected to a line of six pitfall traps in the middle of the beach, where the sand and rock met. For both sites we baited pitfall traps with fish-based cat food, and checked all traps and refuges every 24 h for three trap-nights at Tāwharanui and six trap-nights at Tiri for each survey. We temporarily marked all captured skinks with a xylene-free pen to avoid individual resampling during each survey. After processing, individuals were released at their point of capture.

During surveys, we took standardized digital photographs of the dorsal side of skinks and habitat backgrounds (1 × 1 m) where the

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