A review of reptile research and conservation management on Tiritiri Matangi Island, New Zealand

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Published online: 18 November 2013

Abstract: Tiritiri Matangi Island is one of the oldest community-driven island restoration projects in New Zealand. While great effort has been directed towards recovery of vegetation and avian communities since the 1980s, restoration of the island's reptile fauna has not been initiated until early 2000s. Tiritiri Matangi supports only three remnant reptile species, which is considerably low given the island's size and geographic location. In recognition of this and the importance of reptiles in ecosystem function, translocations of several reptile species have been undertaken. The translocations presented opportunities for integrating in-depth scientific studies in regard to applied conservation management of native reptiles with experimental approaches. This review summarises research efforts on Tiritiri Matangi to date, including post-graduate studies that have contributed to: (1) baseline information on resident species (*Oligosoma moco*, *O. aeneum*, *Woodworthia maculata*, *O. smithi* & *Naultinus elegans*); (2) understanding the importance of seabird co-habitation for *Sphenodon punctatus*; (3) post-release behaviours (dispersal and habitat selection) of *Hoplodactylus duvaucelii*; (4) body colour adaptation of *O. smithi* following translocation; (5) quantifying avian predation on lizard populations; and (6) measuring the short-term success of all translocations. Numerous research opportunities remain, either on existing populations or future translocations to the island. Emphasis has been placed on the involvement of public and local community volunteers in all reptile research. These groups are key stakeholders in the restoration of Tiritiri Matangi. Measurement of translocation success for New Zealand reptiles is dependent on long-term monitoring (> 10 years) and research, since these endemic reptiles exhibit distinctive characteristics such as slow maturity, low reproductive rates, and very high longevity. The process of restoration of a fully functioning New Zealand ecosystem is similarly slow, therefore, long-term study or monitoring will also enable assessment of the island's restoration outcome over time.

Keywords: island restoration; translocation; *Oligosoma*; *Woodworthia*; *Sphenodon punctatus*; *Hoplodactylus*; *Naultinus*; avian predation; monitoring

Introduction

The reptile fauna of New Zealand has suffered severe range contractions and dramatic reductions in abundance since the arrival of humans, c. 1000 years ago (Davidson 1984; Towns 1994; Craig et al. 2000). Once widespread throughout the country, many endemic species are now restricted to small, remnant, pseudo-endemic populations confined to predator-free offshore islands (Towns & Robb 1986; Daugherty et al. 1990; Towns & Daugherty 1994). Currently, over half of New Zealand's islands are legally protected and those that are ecologically significant (and therefore of high conservation value) are designated as Nature Reserves (Towns 1983). Introduced mammals have been eradicated from some of these island reserves and restrictions on public access ensures that the islands' biota, including reptiles, can survive and regenerate naturally (e.g. Mercury Islands (Towns 1991); Marotere Islands (Towns et al. 2007); and Little Barrier Island (Rayner et al. 2007; Bellingham et al. 2010)). As few of these important offshore islands offer opportunities for easy access to rare species, research efforts have been somewhat limited.

One exception is Tiritiri Matangi Island, an Open Scientific Reserve located approximately 4 km off the coast of the mainland Whangaparaoa Peninsula in the Hauraki Gulf (Fig. 1), which allows easy and frequent access for both the public and scientists. The island is historically important as one of the oldest community-driven island restoration projects in New Zealand. Removal of mammalian pests by 1993 and establishment of a community-driven replanting programme since the 1980s have resulted in extensive forest regeneration on the island (Drey et al. 1982; Mitchell 1985; Galbraith & Hayson 1994; Hawley 1997; Veitch 2002). Various faunal translocations to the island have led to establishment of new populations of threatened species (Galbraith & Hayson

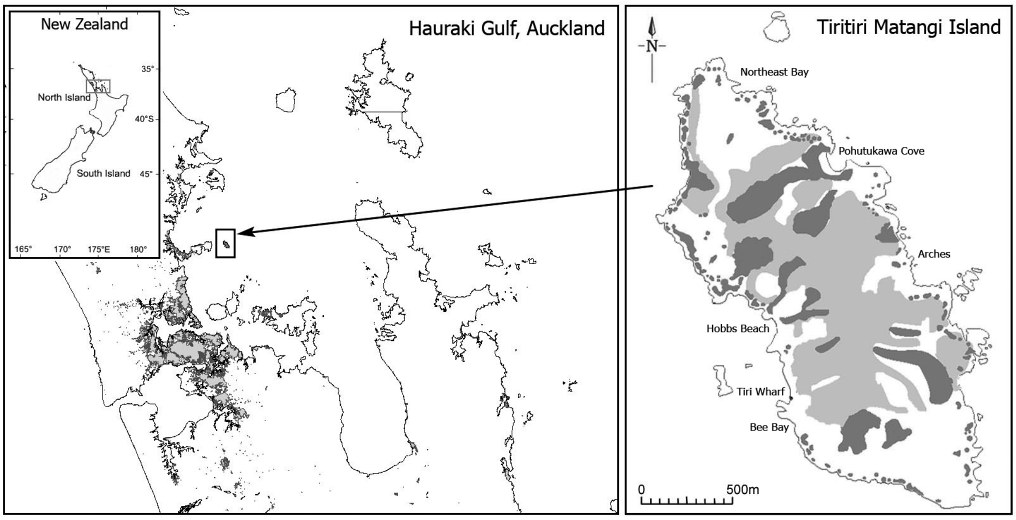

Figure 1. Location of Tiritiri Matangi Island in the Hauraki Gulf, Auckland, New Zealand.

1994), while associated scientific research projects have provided information on the biology, ecology and successional changes in vegetation (West 1980; Craig & Stewart 1988; Cashmore 1995), invertebrate (Green 2002; Clarke 2003), reptile (Habgood 2003; Ruffell 2005; van Winkel 2008; van Winkel & Ji 2012; Baling et al. 2013) and bird communities (e.g. Galbraith & Hayson 1994; Armstrong & Ewen 2001; Ortiz-Catedral & Brunton 2009).

The level of research for restoration of reptile communities on Tiritiri Matangi has been relatively low and has largely been overshadowed by studies on more charismatic avian taxa (e.g. Colbourne & Robertson 1997; Ryan & Jamieson 1998; Jones 2000; Brunton & Stamp 2007). Additionally, early restoration management of Tiritiri Matangi (Drey et al. 1982) did not take an ecosystem-wide approach and failed to recognise reptiles as important elements of the environment, and thus as candidates for translocation (with the exception of northern tuatara, *Sphenodon punctatus*). There has been an increase in support for and recognition of the role of reptiles within New Zealand ecosystems, including plant-animal interactions (Whitaker 1987; Lord & Marshall 2001; Wotton 2002; Smith 2009), predator-prey dynamics (Markwell 1998; Ball & Parrish 2005), and island nutrient cycling (Mulder & Keall 2001). This has prompted many restoration groups to focus their conservation initiatives on restoring and monitoring reptile communities (e.g. Ritchie 2000; Gardner-Gee et al. 2007).

The purpose of this paper is to describe the variety of projects that have been initiated for reptile conservation on Tiritiri Matangi, to discuss the scientific drivers behind population restoration efforts and the role of public involvement in the long-term monitoring of scientific programmes.

Baseline information on resident reptiles

Prior to planning the restoration of reptile communities for a given island, baseline knowledge of historical and current status of reptile populations needs to be assessed. Historically, there may have been at least six reptile species on Tiritiri Matangi, but only three species survive there today. These remnant species are the moko skink (*Oligosoma moco*), copper skink (*O. aeneum*) and common gecko (*Woodworthia maculata*). *Oligosoma moco* and *O. aeneum* are the most abundant species, and overlap in distribution across the island (Habgood 2003, Clarke 2003). Habgood's (2003) study estimated that population densities for both species were highest in the open grassland areas, followed by those in young mixed-species planting areas. These two skink species have benefited from the eradication of mammalian predators and they appear to be capable of maintaining high population densities despite the high abundance of avian predators that are present on the island (Habgood 2003).

A remnant population of *W. maculata* was detected relatively recently (2004) during routine biosecurity monitoring on the island. The discovery of gecko footprints in a rodent tracking tunnel initiated a survey on the eastern cliffs (The Arches) and confirmed the presence of this species. Another reptile survey in 2006 identified additional sites that extended the distribution of *W. maculata* along the eastern coast of the island (Ussher & Baling 2007). Periodic surveys of the population are conducted by Massey University to determine the population density and genetic structure. Initial results from a mark-recapture study indicate the *W. maculata* population size is larger than previously expected (W. Ji, unpub. data). This remnant population has persisted in the presence of introduced predators, particularly kiore (*Rattus exulans*), by surviving in the crevices of the coastal cliffs. However, the recovery rate of *W. maculata* seems to be slow, with the population still largely confined to coastal cliffs 11 years after all kiore were removed from the island.

The three other species that are either unconfirmed or considered extinct on Tiritiri Matangi are *S. punctatus*, shore skink (*O. smithi*) and Auckland green gecko (*Naultinus elegans*). Evidence for the past existence of *S. punctatus* on the island is derived from a single bone found in a midden site (pre-dating the apparent Maori settlement on the island) during excavations for wharf structures in the 1990s (R. Brassey, pers. comm.). Additionally, accounts by a lighthouse keeper of handling a live tuatara while stationed on the island in the early 1900s, adds further support for the historical presence of *S. punctatus* (J. Craig, pers. comm.).

Sightings of several *O. smithi* were reported on one of the beaches on the southern end of the island (Bee Bay, south of Wharf Beach) in 1975 (R. Hitchmough, pers. comm.). Lizard surveys undertaken in 2000 and 2006 failed to detect this species, despite live-trapping and hand-searching along the island's coastline (Ussher 2000; Ussher & Baling 2007). As a result, this species was declared locally extinct in 2006.

There have been unsubstantiated records of bright green geckos from several locations on Tiritiri Matangi, including Lighthouse Valley, Little Wattle Valley and Bush 1 (Rimmer 2004; P. Cashmore, pers. comm.; A. Rimmer, pers. comm.). However, there are no records (substantiated or otherwise) since these single sightings in the early 1900s. The lizard survey in 2000 failed to detect any geckos and Ussher (2000) concluded that any small remnant population of this species would have declined over the years to solitary individuals. A more extensive search for *N. elegans* over the summer season of 2007/08 (> 80 person search hours) reaffirmed the apparent absence of this species on the island (M. Baling, unpub. data).

Northern offshore islands of New Zealand are historically and currently known to support large numbers of reptile species (e.g. 10 species on 13 ha Middle Island, 9 species on 100 ha Stanley Island, 10 species on 138 ha Lady Alice Island, and 12 species on 1509 ha Motutapu Island; Whitaker 1978; Towns & Ballantine 1993), and most of these species often occur naturally at high densities (e.g. Towns 1996; Markwell 1997). Therefore, Tiritiri Matangi at 220 ha, could potentially have supported reptile diversity and densities similar to those other islands. The current fragmented distribution of reptiles at Tiritiri Matangi also suggests that several of the island's ecological niches are unoccupied. Based on the fauna of adjacent islands (Towns & Ballantine 1993; Miller et al. 1994; Towns et al. 2001; Towns et al. 2002), Tiritiri Matangi should be capable of supporting species such as *O. suteri* (egg-laying skink) in beach habitats; *Dactylocnemis pacificus* (Pacific gecko) and *Hoplodactylus duvaucelii* (Duvaucel's gecko) in forest edge habitats; and *O. ornatum* (ornate skink), *Mokopirirakau granulatus* (forest gecko), *S. punctatus* and *O. whitakeri* (Whitaker's skink) in forest habitats.

Scientific approach to translocations

Reptiles represent a large portion of the faunal biodiversity of New Zealand (Towns & Daugherty 1994), and therefore, are expected to have a strong influence on New Zealand ecosystems (Walls 1981; Whitaker 1987; Spencer et al. 1998; Lord & Marshall 2001; Payton et al. 2002). In the absence of reptiles (e.g. due to introduced mammalian predators), some ecological interactions can be supressed or lost (Whitaker 1973; Towns 2002; Hoare et al. 2007). Therefore, pest eradication alone may be insufficient to regenerate a functioning ecosystem if there are missing links in the biotic diversity of that island. This recognition has been an impetus for active conservation management via translocation.

Conservation translocation is a commonly used wildlife management tool. Individual organisms are intentionally transferred from one geographic location to another, where the primary objective is for species or ecosystem conservation benefit (IUCN 1987; IUCN/SSC 2013). This tool has been used for various reasons: 1) population restoration, via establishing populations within the species' native range from which it has disappeared (reintroductions) or for supplementing existing populations (reinforcement); and 2) conservation introduction of a species outside of its native range, to avoid population extinctions (assisted colonisation) or to perform an ecological function (ecological replacement) at the new site (Griffith et al. 1989; Armstrong & Seddon 2008; Seddon 2010; IUCN/SSC 2013). Translocations are driven by many goals and ambitions. In New Zealand, the primary objective of most conservation translocations is for establishment of new populations within the species' native range. Tiritiri Matangi has seen both reintroduction and reinforcement of reptiles. In this paper we are using the term 'translocation' to cover both types.

Translocations are usually highly successful if approached in a strategic manner (e.g. when based on a good understanding of the biology and habitat requirements of the species), and when a research component is incorporated into the project (e.g. by using scientific or experimental design for monitoring success) (Towns et al. 1990; Armstrong et al. 1994; Frankham 1994; Armstrong & McLean 1995; Germano & Bishop 2009). A strategic or scientific approach to translocation and associated post-release monitoring will provide the best opportunity to measure success and to understand why translocations fail (e.g. unsuitable habitat quality, disease, predation, competition or homing behaviour; Armstrong et al. 1994; Germano & Bishop 2009). Lessons learnt can then be fed back into the species management strategy in an adaptive process, or be applied in any future translocation plans for the same island (Armstrong et al. 2007).

Translocations also offer the potential to conduct more in-depth research on a species or an ecological process that is otherwise rare or isolated (Parker 2008). A translocation can be designed where animals are released under specific experimental conditions to test particular hypotheses. Designing such experiments can be challenging, but they are an effective way to maximise the opportunity and success of translocation programmes over the long-term.

As part of the process of planning for successful restoration, problems that might arise from translocating new species of reptiles to Tiritiri Matangi need to be anticipated and addressed. Several initial topics of interest are: 1) inter-specific competition (the 'incumbent advantage' of resident species over introduced species); 2) ecological requirements of translocated species (habitat quality and selection, behavioural responses to transfer); and 3) avian predation (survival probability of the new species if introduced into high-density bird populated sites).

Population establishment and interspecific competition

The two resident skink species on Tiritiri Matangi Island, *O. moco* and *O. aeneum*, exist within similar habitat and locations, are both diurnal generalist foragers, and have similar reproductive ecologies (Habgood 2003). Concerns were raised regarding the difficulty a translocated lizard population might have when trying to establish in the presence of resident lizards. A resident species may have an advantage (e.g. by being abundant, and better at obtaining food resources) over immigrating non-resident species, especially where there is niche overlap between the two species (Massot et al. 1994).

Habgood (2003) undertook experimental field trials on *O. moco* and *O. aeneum* on Tiritiri Matangi, to determine potential effects of interactions between resident and immigrant species. This study was adapted from one of the research priorities set in the *Cyclodina* spp. Skink Recovery Plan (Towns 1999). Habgood's manipulation experiments showed that the resident species did not hold an incumbent advantage over a newly introduced species with regard to body condition, movement, habitat use or mortality rate; suggesting it is possible to establish new reptile species on Tiritiri Matangi. However, precaution still needs to be exercised. Habgood (2003) recommended that any new reptile species be released away from areas of high-density *O. moco* or *O. aeneum* populations (i.e. away from grasslands).

Table 1. The current status of reptile species resident (translocation and remnant populations) on Tiritiri Matangi Island, New Zealand.

Species	Translocation date	Number of founders	Source location	Reinforcement	Current status
Sphenodon punctatus	2003	60	Middle Island, Mercury Group	None planned	Breeding
Hoplodactylus duvaucelii	2006	19	Korapuki Island, Mercury Group	2013	Breeding
Woodworthia maculata	-	Remnant population	Tiritiri Matangi Island	None planned	Expanding
Oligosoma smithi	2006	30	Tawharanui Regional Park	2010	Breeding
Oligosoma aeneum	-	Remnant population	Tiritiri Matangi Island	-	Established
Oligosoma moco	-	Remnant population	Tiritiri Matangi Island	-	Established

Ecological requirements of founder populations

Northern tuatara translocation 2003

An understanding of species' ecological requirements is important for ensuring the success of a translocation because managers must be able to select suitable release sites to reduce the risk of failure (Griffith et al. 1989; Armstrong & McLean 1995; Meads 1995). However, the traditional approach of using remnant habitat to predict species' requirements may be misleading because associations may reflect historical (e.g. anthropogenic) events rather than a species' optimal requirements (Gray & Craig 1991; Jones 2000). Thus, it is important to test assumptions so a full range of release sites can be considered and the most suitable site(s) selected (Armstrong & McLean 1995; Ussher 2003).

Since Tiritiri Matangi Island largely lacks ground-nesting seabirds, the northern tuatara, *S. punctatus* reintroduction in 2003 (Table 1) provided an opportunity to test the assumption that the presence of ground-nesting seabirds is a key factor in *S. punctatus* translocation success (Cree & Butler 1993; Gaze 2001). This is an important consideration because many islands proposed for *S. punctatus* restoration lack ground-nesting seabirds. All extant, stable *S. punctatus* populations coexist with large seabird colonies (Newman 1987; Cree et al. 1995). It has been suggested that co-habitation with seabirds may benefit *S. punctatus* in a number of ways: 1) through the provision of burrows (Ussher 1999; Ussher 2003), 2) because seabirds may increase the abundance of invertebrate prey (Walls 1978; Markwell 1998); and/or 3) through direct predation or scavenging of birds and eggs (Cartland et al. 1998; Blair et al. 2000). Alternatively, co-habitation may just reflect shared ecological pressures, e.g. habitation restriction because rats have confined both *S. punctatus* and seabirds to island refugia (Crook 1973; Cree & Butler 1993; Imber et al. 2000).

Ruffell (2005) aimed to test the hypothesis that burrow provision would increase *S. punctatus* translocation success by experimentally releasing *S. punctatus* into contrasting sites; with and without artificial burrows. There were no ground-nesting seabird burrows at the experimental sites. Results precluded this comparison, because *S. punctatus* failed to use the artificial burrows. Nevertheless, the release was still informative as to whether successful *S. punctatus* translocations could occur in the absence of extensive ground-nesting seabird colonies. A large proportion (38.3%) of the 60 founders were captured 150 days or more after release, and an even higher proportion (45%) of those were re-captured in a survey five years later (van Winkel & Habgood 2009). A 2-hour opportunistic survey by Ussher in 2012 resulted in four adults captures. All this indicates that the proportion of founders surviving on the island is likely to be very high. Body condition and length of all re-captured individuals increased post-translocation, both in 2003–2005 and summer 2007/08 (van Winkel & Habgood 2009). These results were consistent with those of other *S. punctatus* translocations, most of which found high survivorship and increases in body condition over time (Ussher 1999; Merrifield 2002; Nelson et al. 2002).

During 2005–2012, at least nine juveniles, one viable nest and three hatchlings were detected on the island. Gestation times and growth rates suggest that the juveniles were conceived prior to translocation whereas the hatchlings were conceived on Tiritiri Matangi (van Winkel & Habgood 2009). Although the absence of ground-nesting seabirds does not appear to affect the short-term translocation success of *S. punctatus* on Tiritiri Matangi (criteria for short-term translocation success of *S. punctatus* are stated in Cree & Butler (1993)), it is uncertain whether reproduction in the founder population is sufficient for long-term persistence of this species on the island. Further, in the absence of experimental controls, it is unclear whether the translocation would have been more successful (i.e. with higher survivorship, greater increases in body condition etc.) had ground-nesting seabirds been present at the release sites.

Duvaucel's gecko translocation 2006

Post-release behaviours may jeopardise translocation success if the occurrence of high frequency movements and large-scale dispersal from release sites reduce population density and consequently, expose the population to lower overall fitness or Allee effects (e.g. mate limitation, reduced population growth and expansion) (Dennis 1989; Nunney & Campbell 1993). Heightened activity levels may be energetically inefficient (Reinert & Rupert 1999) and extensive dispersal increases vulnerability to predation while individuals move through unfamiliar habitats (Sullivan et al. 2004). Both factors may reduce translocation success. Therefore, examining how a species responds to and utilises its new environment is important for management of the species and improving the design of future translocation projects (Germano 2006).

Nineteen adult Duvaucel's gecko, *H.duvaucelii* (10 females, 9 males), were captured on Korapuki Island (Mercury Island Group) and introduced to Tiritiri Matangi in December 2006 (Table 1) (van Winkel et al. 2010). van Winkel (2008) conducted intensive post-release monitoring of the geckos' movements and habitat preferences via radio-telemetry, and tested the detection efficiency of a range of monitoring techniques. Founders exhibited aberrant movements, often characterised by large-scale dispersal away from their release sites. This may reflect their unfamiliarity with the habitat and/or a drive to secure adequate resources. *Hoplodactylus duvaucelii* utilised habitat according to its availability on the island. However, these results may have been confounded by the founders' aberrant movements and unfamiliarity with novel environments.

Founder survivorship of *H. duvaucelii* was high. No mortality was recorded 12 months post-release. A total of 22% (n = 6) of all recaptured individuals increased in body condition, while the detection of island-born juveniles (from gravid female founders) with high body condition scores provided evidence of successful recruitment and acquisition of resources (i.e. food, shelter) by the juveniles. In addition, *H. duvaucelii* monitoring in 2009 detected seven individuals: two adult males, two gravid females and three subadults (W. Ji, unpub. data). These results are promising for population establishment of *H. duvaucelii* on Tiritiri Matangi. A population reinforcement of 90 geckos was undertaken in 2013 by Massey University, to strengthen this establishment and increase population viability (i.e. genetic diversity).

Shore skink translocation 2006

Shore skinks, *O. smithi*, are widely distributed along the coastlines of the northern North Island and its offshore islands (Towns et al. 2002; Hare et al. 2008; Chapple et al. 2009). This species' body colouration is highly variable across its geographical range and between habitats (e.g. light colour morphology at white sandy beaches vs. dark colouration at rocky beaches). Such variation in body colours may represent an ecological adaptation to the different habitat types for camouflage (Brown & Thorpe 1991; Bauwens & Castilla 1998; Stuart-Fox et al. 2004). In frequently disturbed and heterogeneous sites such as coastal habitats, the ability of a prey species to change colour (behaviourally or genetically through evolution) according to its environment can be important to avoid predation. The reintroduction of *O. smithi* to Tiritiri Matangi (Baling et al. 2010) presented an opportunity to assess the ability of these lizards to adapt and blend into new habitat types. This may be important when considering future translocations, especially if selection of source populations with phenotypic traits relevant to the release sites can influence the probability of predation and hence founder survival.

A selection of light and dark-coloured *O. smithi* were collected from mixed habitats (light-coloured sand and vegetation) at Tawharanui Regional Park, Auckland, and were translocated to a beach with dark-coloured sand, vegetation and rocky habitats at Tiritiri Matangi (Table 1). The translocated population was monitored every three months for a year and a half, following release (2006–2008). The founder population established successfully, with an overall capture rate of 2.42 skinks/100 trap nights (TN) and a maximum of 8.00/100 TN in February 2008. Initial results showed high capture rates of dark-coloured individuals. No light-coloured *O. smithi* including those in juvenile stages, were found in any of the habitat types by 2007 (M. Baling, unpub. data). It is unknown whether individuals physiologically changed to darker colours or whether all the light-coloured animals failed to survive (e.g. through predation). There was no direct evidence of avian predation on *O. smithi*, however, New Zealand kingfishers (*Todiramphus sanctus vagans*) are abundant at the release site.

Island-born *O. smithi* found yearly in 2007 to 2009 indicated successful breeding and juvenile survival on the island, despite heavy storms and high tides during winters in all three years (M. Baling, unpub. data). There was no apparent aggression or competition between translocated and resident species (*O. moco* and *O. aeneum*), despite slight overlap in habitat use among all three species. Observations of founder and island-born juvenile survival of the *O. smithi* population in 2009 confirms the short-term success of this translocation. This population seems capable of adapting to new habitat types, with apparent rapid colour changes at the population level (either by natural selection or individual physical change).

Avian predation

Predation is a significant component of population dynamics, trophic level and community ecology (Poulin et al. 2001) because it plays a vital role in regulating populations and maintaining balance in ecosystem processes (Martín & López 1996; Zug et al. 2001). Predator-prey relationships typically evolve within natural communities, where prey populations are generally robust enough to withstand the pressures from natural predators (Bodini 1991). Translocated populations, which generally consist of a limited number of individuals due to 'harvest' restrictions based on source population size (Chau 2000; Pullin 2002; Begon et al. 2006; Dimond & Armstrong 2007), may not be as enduring as an abundant population of resident species. A translocated population with low founder population size will be susceptible to stochastic events and other biotic factors such as predation; where all can have a significant impact on the outcome of the translocation (Griffith et al. 1989; Saunders 1994; Armstrong & McLean 1995; Wolf et al. 1996).

Tiritiri Matangi, although free from mammalian predators, supports high numbers of native birds known to prey upon lizards (Haw & Clout 1999; Reid 2007). Even a small loss of individual lizards via the predatory effects of birds can be a large proportional loss to a small founder population and thereby, reduces the probability of population establishment. van Winkel & Ji (2012) examined the potential impacts of avian predation on small translocated lizard populations by quantifying the rate of native bird predation on Tiritiri Matangi's lizard fauna. The diets of a number of potential bird predators on the island were examined by analysing regurgitated pellets, stomach contents and nest materials, and by opportunistic observations of direct predation on lizards.

Kingfishers appear to be major predators of lizards on Tiritiri Matangi. A significant proportion (88%) of regurgitated pellets contained remains of skinks (van Winkel & Ji 2012). No lizard remains were recorded from any other bird species sampled during this study. This is contrary to past literature that reported a variety of avian species preying on lizards (Marples 1942; Oliver 1955; Carroll 1966; Ramsay & Watt 1971; Whitaker 1991; Ball & Parrish 2005; O'Donnell & Hoare 2009) and suggested that many bird species opportunistically prey on lizards. Even opportunistic predation via by-catch may still be enough to affect a small founder population of K-strategist species (i.e. those slow to reach maturity, with low reproductive rates). This strategy is characteristic of many of New Zealand's native and endangered lizard species (Towns 1991).

Future reptile conservation and management

Further reptile research

To date, research on Tiritiri Matangi Island's reptiles has only scratched the surface and further questions derived from previous research still remain unanswered. For example, is there a niche overlap in the dietary requirements of *O. moco* and *O. aeneum?* Niche overlap might create resource competition between these two species (Habgood 2003) or with other translocated species such as *O. smithi*. Additionally, any level of intra- or inter-specific competition between resident and translocated populations may affect the island's invertebrate communities. Despite the high abundance of invertebrates on the island (Clarke 2003), would this assemblage be able to withstand the increasing predation pressures from both reptile and avian biota? As for the avian populations on the island, to what extent will they respond to new prey (reptile) species, or potentially another resource competitor?

The influence of ecological restoration processes on remnant species populations also needs to be monitored. Habgood (2003) questioned the potential negative effect of the large-scale tree planting revegetation scheme on resident skink species. Over time, vegetation change will reduce open habitats and consequently, may contract the range and abundance of resident species that prefer these habitat types (Timmins 1990; Neill 1997). Approximately 40% of the island's area has been retained as grassland, and this supports high densities of *O. moco* and *O. aeneum*. These habitats have so far proven resilient to successional change (see other papers in this edition), however, this is no guarantee that such habitats will be maintained naturally or through active management in the long term. So in what percentages and over which areas will grasslands need to be maintained to sustain these lizard communities? As for the rest of the island, the progression towards mature coastal broad-leaved forest will create new habitat types for forest-dwelling reptiles (Habgood 2003). Will translocations of species that utilise those habitats be feasible when these new habitats are available? Or can species traditionally associated with climax forest and seabird communities elsewhere also survive and establish in the grassland and shrubland successional plant communities on the island?

Population size of founder and remnant species have been shown to be important in population persistence (Vucetich & Waite 2001; Briskie & Mackintosh 2004; Jamieson et al. 2006; Miller et al. 2009). However, currently there is no baseline information on genetic diversity of either the translocated or resident species, so how population genetics will affect their fitness and consequent long-term success is uncertain. There have been two reinforcements of the translocated populations (*H. duvaucelii* and *O. smithi*) to increase their effective population sizes on Tiritiri Matangi (Table 1). Despite the current lack in knowledge of the species' population genetic structures, these reinforcements will increase genetic diversity by having large founder population sizes and should improve the chances of population establishment.

Long-term monitoring should be a standard requirement for New Zealand reptile management. *Sphenodon punctatus* and other large New Zealand lizards, such as *H. duvaucelii,* are K-strategists (Cree 1994; Bannock et al. 1999) and will exhibit slow responses to ecological changes, including translocation outcomes. For example, the current evidence of juvenile *S. punctatus* recruitment on Tiritiri Matangi only represents the first generation offspring from founders (van Winkel & Habgood 2009). An indicator of translocation success is the confirmation of second-generation offspring, and so in the case of *S. punctatus,* this may take up to another 20 years to confirm (Seddon 2009). Another example is the monitoring of the endangered *O. whitakeri* (Whitaker's skink) that went for over nine years before there was significant evidence of population expansion on Korapuki Island (Towns & Ferreira 2001). Population expansion for many endemic New Zealand lizard species has been predicted to be less than 10% per year (Towns & Daugherty 1994). In other words, the duration of long-term monitoring to detect success of a population's establishment and its eventual sustainability should depend on the life history characteristics of the reptile species itself (Dodd Jr & Seigel 1991), rather than human or funding-based timelines.

Public participation

Public involvement in the restoration of Tiritiri Matangi has been a critical feature of the island's conservation success. Long-term research and monitoring programmes of biota on the island are also likely to benefit greatly from public involvement (Galbraith & Hayson 1994; Parker 2008). Research and monitoring can be costly in both labour and time. Experience to date shows that the public contributes to research and monitoring by providing voluntary labour to collect data and to generate funds. This is done mostly through the public community group: Supporters of Tiritiri Matangi Incorporated (SoTM). Most long-term funding grants for research are awarded to projects that are of public interest and therefore, incorporating public participation or presentations are powerful strategies to ensure the success of a project (Galbraith & Hayson 1994; Towns et al. 2001). However, the public approach also has its downside; e.g. purely theoretical studies may have less chance of attracting research funding because it is difficult to identify the tangible conservation or public interest outcomes for the island.

There is currently a long-term monitoring scheme for all translocated reptile species on Tiritiri Matangi. This monitoring scheme aims to confirm self-sustaining populations for all translocated species by obtaining periodic field records of population abundance, distribution and breeding. Information gathered from this scheme can also be used to guide future management. The collaboration between the SoTM and reptile researchers from Massey University includes the provision of training and leadership responsibilities to SoTM volunteers so they can conduct methodical reptile surveys. This sense of joint ownership in managing reptile monitoring projects will bring together the knowledge and efforts of the scientists and volunteers. In doing so, it provides a method for collecting essential information that will be well informed and can be relayed to the public via SoTM volunteers.

Participation in research and monitoring projects will also give the public a sense of realistic approaches and timelines for conservation work. Quite often, only successful translocations are reported by the media and consequently, this tends to portray translocation as a very effective conservation strategy. Experience elsewhere indicates this creates unrealistic expectations of translocation outcomes, leading the public to expect it to be employed more often in the future as a quick fix to ecological problems (Craig & Veitch 1990; Dodd Jr & Seigel 1991; Reinnert 1991). The public need to be made aware that many translocations do fail and hard work over long periods of time is required to achieve translocation success. Collaboration between scientists and conservation volunteer groups like SoTM will be one of the key solutions that will deliver this information to the rest of the New Zealand public.

Conclusion

Current research on Tiritiri Matangi Island has increased the baseline knowledge of reptile populations and their role in the island's ecological processes. Many opportunities are still available for research to be conducted on this accessible island. There should be a continued emphasis on experimental, research-based approaches for any future reptile conservation translocations. Finally, conservation efforts should not only focus on ecologically significant offshore islands (Craig & Veitch 1990). The development, restoration and protection of highly-modified environments (usually considered of low biological value), as was the case for Tiritiri Matangi, not only provide opportunities for threatened species recovery without expense or risk to the original population, but also offer community groups and the general public the chance to be directly involved in reptile conservation.

Acknowledgement

We would like to thank Supporters of Tiritiri Matangi Inc. (especially Simon and Morag Fordham, and Mary-Ann Rowland), New Zealand Department of Conservation (especially past and current rangers Dave Jenkins, Jennifer Haslam, Ian Price, Ray and Barbara Walter), the University of Auckland and Massey University (especially Dianne Brunton) for their continued long-term support of reptile research on Tiritiri Matangi. Research and translocations were funded by the Supporters of Tiritiri Matangi Inc. Research Fund (*S. punctatus*, *H. duvaucelii*, *O. smithi*, *N. elegans*, *W. maculata*, *O. moco* and *O. aeneum*), Massey University (*O. smithi* and *H. duvaucelii*), Auckland Regional Council (*O. smithi* and *H. duvaucelii*), J S Watson Conservation Trust (*O. smithi*), Auckland Zoo (*S. punctatus*) and SRARNZ Herpetological Research Awards (*H. duvaucelii*). Research projects were approved by the University of Auckland and Massey University Animal Ethics Committees, Department of Conservation, and Auckland Regional Council.

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