NEW ZEALAND JOURNAL OF ECOLOGY

RESEARCH

Evaluating translocation success using hard and soft release methods for an arboreal gecko, 8–11 years after translocation

Ellen D. Richardson[1]*, Alison Cree[1], Joanne M. Monks[1] and Stephanie S. Godfrey[1]

[1]Department of Zoology, University of Otago, P.O. Box 56, Dunedin 9054, Aotearoa New Zealand
*Author for correspondence (Email: 123ellenrichardson@gmail.com)

Published online: 23 October 2024

Abstract: Understanding the long-term implications of translocation methods is essential when refining best translocation practices for a species. High rates of movement and dispersal away from release sites have been key concerns when hard releasing lizards. A recent proliferation of research on translocation of New Zealand's endemic green geckos (*Naultinus* spp.) has confirmed that penning for at least four months promotes initial site fidelity. Using a standardised, staged framework previously applied to other species of New Zealand herpetofauna, we assessed the stage of translocation success for one hard release (n = 11) and two soft releases (n = 32 and 42) of jewelled geckos (*N. gemmeus*), 8–11 years following release into the fenced Orokonui Ecosanctuary. We conducted 75 visual surveys on sunny days when geckos were expected to be basking. Suitable jewelled gecko habitat within a c. 50 m radius of the release sites and habitat between sites was visually searched. Founders were identified through photo identification, and linear distance from release location was estimated. Eighty geckos were located (including 12 founders from across the three release cohorts). Stage 3 of translocation success (population growth) is suspected to have been reached at both the 2012 hard and soft release sites. The release method used had no detectable effect on the number of geckos found or the stage of translocation success reached 8–11 years since release. Contrary to the reported short-term failure of many hard release lizard translocations, including all hard releases of *Naultinus* species, our findings suggest that hard release may enable population establishment and potentially population growth as well. Understanding the drivers behind the establishment of a hard released population may enable further development and reduce the costs associated with the translocation of *Naultinus* species and other arboreal lizards with small home ranges.

Keywords: hard release, jewelled gecko, lizard, *Naultinus gemmeus*, soft release

Introduction

A translocation is the accidental or intentional human-mediated free-release of wild or captive living organisms from one area to another. Such movements are becoming an increasingly used conservation tool for global biodiversity conservation (IUCN/SSC 2013; Berger-Tal et al. 2020). Although it has been suggested that amphibian and reptile species may not be suitable for translocations following low success rates (Dodd & Seigel 1991; Reinert 1991), several successful amphibian and reptile translocations have since been reported when post-release monitoring accommodated the species' life history traits (for example, in Germano & Bishop 2009). Today, c. 87% of geckos endemic to Aotearoa New Zealand are classified by the New Zealand Threat Classification System (NZTCS) as 'Threatened' or 'At Risk', primarily due to predation by introduced mammals, habitat loss or fragmentation, and illegal collection (Hitchmough et al. 2016; Hitchmough et al. 2021). Subsequently, translocation to islands or fenced sanctuaries free of most or all introduced mammalian predators has become increasingly popular for New Zealand green geckos (*Naultinus* species; moko kākāriki). The need to assess translocation success is therefore essential to better inform and streamline future translocations, thus aiding the conservation of these threatened endemic species (Bubac et al. 2019).

To encourage the establishment of translocated populations, a soft release is used, whereby some form of transitional or staged release or provision of post-release care or support (including a transitional pen, supplementary food, water, or shelter) is provided; this may reduce the risk of competition for food, starvation, exposure, or predation following release (Cid et al. 2014; Tetzlaff, et al. 2019). In contrast, a hard release is where no post-release assistance is provided (Richardson et al. 2015; Tetzlaff et al. 2019). Throughout this paper, the soft release methods discussed involve penning a founder population within a defined area for a pre-determined period before release to the wider area. A frequent difficulty encountered during hard release translocations of reptiles is the potential for large initial dispersal of founders (Knox & Monks 2014; Bilby & Moseby 2023) and the effect this can have on translocation success (Resende et al. 2020). This issue has the greatest influence on the translocation success of species with small home ranges, as high rates of initial dispersal will likely reduce the incidence of mating once founders have

DOI: https://doi.org/10.20417/nzjecol.48.3573

established and impede the ability to monitor the success of the translocation (Knox & Monks 2014; Berger-Tal et al. 2020; Bilby & Moseby 2023).

A soft release strategy (of penning lizards prior to release), however, is known to reduce initial dispersal short-term (within at least the first 3 weeks following release) by encouraging the formation of stable territories within the release site (Knox & Monks 2014). Overseas, this outcome has been demonstrated for the St. Croix ground lizard *Ameiva polops* (when penned for 10 weeks; Fitzgerald et al. 2015; Angeli et al. 2018) and for the Texas horned lizard *Phrynosoma cornutum* (when penned for two weeks; DeGregorio et al. 2020). Within New Zealand, reduced dispersal has been seen for soft released Ngahere gecko *Mokopirirakau granulatus* (when penned for 10–31 months; Yee, et al. 2022) and several species of New Zealand green gecko including the jewelled gecko *Naultinus gemmeus* (when penned for four months and nine to ten months; Knox & Monks 2014; Monks, et al. 2017), the barking gecko *N. punctatus* (when penned for three months; Flynn-Plummer & Monks 2021), and the Auckland green gecko *N. elegans* (Scott 2016; Roger Wallace, Supporters of Tiritiri Matangi, pers. comm.).

To our knowledge, a total of 16 translocations of three species of New Zealand green geckos have been conducted throughout New Zealand: seven soft and nine hard releases (Knox & Monks 2014; Scott 2016; Knox et al. 2017; Flynn-Plummer & Monks 2021; Dale Shirtliff, Friends of Mana Island, pers. comm.; Roger Wallace, Supporters of Tiritiri Matangi, pers. comm.). None of the nine hard releases of green geckos have been considered successful, with negligible post-translocation resighting rates (of 0–1 geckos) and varying amounts of search effort invested (as reviewed by Knox & Monks 2014). Furthermore, research into the behavioural implications of different release methods on the post-release dispersal of founder individuals and population establishment is limited to short-term monitoring (from two weeks up to one year following the release; Sherley et al. 2010; Knox & Monks 2014; Knox et al. 2017; Flynn-Plummer & Monks 2021; Yee et al. 2022). The stage of translocation success detected following both hard and soft releases of green geckos has also been variable (Knox & Monks 2014).

The need for clearly specified criteria for success alongside long-term monitoring (for at least four years post-release) is becoming increasingly evident, especially to confirm translocation success of long-lived species with slow life histories (e.g. Bell & Herbert 2017; Bubac et al. 2019; Resende et al. 2020). Such criteria have, however, been inconsistent in the literature (Miller et al. 2014; Resende et al. 2020; Morris et al. 2021). Definitions historically used have often focused on single long-term outcomes such as population establishment (e.g. Teixeira et al. 2007), detecting a self-sustaining population (e.g. Fischer & Lindenmayer 2000), or persistence of the translocated population for a defined period (Short 2010). However, if such definitions are applied to translocations of long-lived species with slow life histories (including many of New Zealand's endemic reptiles), the first signs of success may not be detectable for decades.

To address this deficiency, Miller et al. (2014) developed a framework whereby translocation success is progressively assessed with the use of four standardised stages. These criteria take the species' life history and time since release into account, making it easier to compare translocation success among species and to better identify causes of translocation failure (Miller et al. 2014; Towns et al. 2016). The criteria are as follows. Stage 1: evidence for survival and growth of founder individuals; Stage 2: evidence of reproduction (excluding gravid females released); Stage 3: evidence for population growth, for example where the number of captures or resights is greater than the release propagule size (number of founders released) and there is evidence of reproduction by second-generation animals; and Stage 4: population viability, when the number of captures or resights per survey regularly exceeds the release propagule, and within which founder individuals make up a small proportion of captures and young individuals a large proportion.

Stages 1, 2, and 3 have been confirmed or were inferred to have been reached in translocations of lizards endemic to New Zealand including Duvaucel's gecko (*Hoplodactylus duvaucelii*) and several *Oligosoma* skink species (Towns et al. 2016). However, none of the 16 translocations of New Zealand green geckos (hard and soft releases) have achieved Stages 3 or 4 (population growth, or the establishment of a viable population; Flynn-Plummer & Monks 2021). This situation probably reflects not just the 'slow' life history of green geckos (e.g. 2–4 years to sexual maturity and a maximum of two live-born offspring per year; Cree & Hare 2016) but also the effort required to monitor these cryptic, arboreal species (with only systematic visual searches suitable for effective monitoring; Lettink & Monks 2016).

The jewelled gecko is one of the nine endemic species of New Zealand green gecko. The species is endemic to southern New Zealand (Chapple 2016) and ranked as At Risk, Declining under the New Zealand Threat Classification System (Hitchmough et al. 2021). It is a diurnal, viviparous (live-bearing), arboreal species with a low annual reproductive output (one to two neonates every one to two years) and a longevity of at least 12 years in the wild and potentially up to 40 years in captivity. Females reach sexual maturity at three years of age (Cree & Hare 2016). Adults are known to occupy a mean home range (± SE) of 31.1 ±7.5 m^2 (Knox et al. 2017), which can be larger for adult males (42.7 ±30.2 m^2; Schneyer 2002). This species can therefore be difficult to monitor, and long-term monitoring is essential to confirm the later stages of translocation success.

We conducted comprehensive visual surveys for jewelled geckos that were translocated to Orokonui Ecosanctuary (located c. 20 km north of Dunedin in southern New Zealand) across three separate sites: Site 1 (a soft release conducted in 2009) and Sites 2 and 3 (hard and soft releases conducted in 2012). Following these translocations, irregular and random day-surveys have been conducted every 1–2 years up to 2016 at Site 1 and up to 2018 at Sites 2 and 3. As a result, sanctuary-born geckos, new to the photo records, have been identified at all three sites (Mandy Tocher, facilitator of the 2009 translocation, and Carey Knox, a facilitator of the 2012 translocations, pers. comm.). With these sightings, all three sites at Orokonui have reached Stages 1 and 2 of the Miller et al. (2014) criteria for translocation success, regardless of the release method used (Table 4). Our study primarily aimed to determine the effect of the hard and soft release translocation methods on the stage of translocation success reached at all three release sites 8–11 years following translocation. We used the Miller et al. (2014) criteria for translocation success, in which the population structure of the sighted populations, number of founders sighted, and total number of sightings compared to the release propagule size were interpreted. We also compared the dispersal distances of hard and soft released founders to better inform us on the effects of the release method on long-term dispersal and, subsequently, population establishment.

With the knowledge that *N. gemmeus* is an arboreal gecko with a slow life history (Cree & Hare 2016), we developed four main predictions: (1) that the soft released founders would be sighted closer to their release locations than the hard released founders; (2) that evidence of recent reproduction (neonates/juveniles) would again be found at all three sites, as noted during earlier post-release surveys up to 2018. Assuming that penning provides better outcomes for translocation in this species long-term as well as following immediate release, we also predicted (3) that a greater proportion of the soft released founders would be resighted than hard released founders, and subsequently (4) that the 2009 and 2012 soft released populations detected would be close to or have reached Stage 3 of the Miller et al. (2014) criteria for translocation success (i.e. population growth), whereas the 2012 hard released population would not have reached this stage.

Methods

The study site, Orokonui Ecosanctuary, consists of a mammalian predator-resistant fence enclosing 307 hectares of primarily native, kānuka (*Kunzea ericoides*) dominated forest, shrubland, and rank grass, virtually free of introduced mammals. Mice (*Mus musculus*) remain within the ecosanctuary but are suppressed at the release sites through annual poison operations and routine trapping (Elton Smith, conservation manager at Orokonui Ecosanctuary, pers. comm.).

Jewelled geckos were first translocated in 2009 to Site 1 (with no prior occupancy known). For this soft release, geckos were held in seven pens (three to seven geckos per pen) ranging from 14–48 m^2 in size for 12 months (n = 32; Elton Smith & Mandy Tocher, facilitators of the 2009 translocation, pers. comm.). An additional three pens were used in the 2009 soft release, but these pens were placed c. 400 m from the other seven pens and held an additional five founders between them. The founder individuals and any signs of reproduction have not since been detected at the release site or surrounding area (Elton Smith, conservation manager at Orokonui Ecosanctuary, pers. comm.). These release sites were subsequently not visually searched in this study and not considered part of Site 1. The other two translocations were conducted in 2012 to Site 2 (a hard release across 206 m^2, n = 11) and Site 3 (a soft release where geckos were held in one pen, 655.5 m^2 in size, for nine months, n = 42; Knox & Monks 2014) (Table 1). The pens used for soft release were made from heavy-duty polythene plastic walls (0.3–0.5 m high) with a buried skirt and a 2 m wide strip of vegetation sufficiently cleared and trimmed so that geckos were unable to breach the pen (e.g. Monks et al. 2017). This form of soft release was used to minimise post-release dispersal (Knox & Monks 2014).

In addition to these three translocations, a fourth translocation (soft release) to the ecosanctuary occurred c. 50 m from Site 2 in October 2013 (11 months after the 2012 hard release at Site 2). After 11 days, a breach in the pen was noticed resulting in individuals prematurely moving into the wider ecosanctuary. With additional concerns about poaching due to site visibility, the decision to recapture and relocate the individuals to outside the ecosanctuary was made. Habitat was searched within a 100 m radius of the pen (c.75% of the search time spent in a 50 m radius); however, 10 of 15 individuals were unable to be resighted and therefore remained within the ecosanctuary (Knox et al. 2017; Carey Knox, a facilitator of the 2012 translocation, pers. comm.). Two of those ten geckos have since been resighted in 2014 (an adult male at the 2013 release site) and 2015 (an adult female within the 2012 hard release site). In our study, the 2013 release site and the accessible surrounding habitat were also regularly searched and considered part of Site 2.

Sightings of founders and ecosanctuary-born geckos have been made through annual surveys (consisting of 1–8 day-surveys every 1–2 years up to 2016 at Site 1 and up to 2018 at Sites 2 and 3). These sightings were made prior to our study in 2020/21; however, they were not incorporated into our assessment of translocation success. This was to avoid the confounding effects of the number of gravid (presumed pregnant) founders released, the variable time elapsed between release and when a new individual was sighted, and any mortality that may have occurred between previous sightings

Table 1. A summary of the three founding populations of jewelled geckos, *Naultinus gemmeus*, translocated to Orokonui Ecosanctuary (Otago, New Zealand) in 2009 (soft release to Site 1) and 2012 (hard release to Site 2 and soft release to Site 3). A-F = adult female, A-M = adult male, SA = subadult, N = neonate/juvenile, UC = unconfirmed, as the individuals were too young to be reliably sexed. The total number of sanctuary-born geckos identified during irregular surveys up to 2016 at Site 1 and up to 2018 at Sites 2 and 3 are provided. The number of sanctuary-born geckos identified prior to our study that were likely born from gravid founding females were estimated by taking into account the life-history stage and the year since release when first sighted. Information was gathered from Knox & Monks (2014) and pers. comm. with Mandy Tocher (2020) who conducted the 2009 translocation.

Translocation	Release area	Penning time before release	Release propagule size	Founding Cohort Population Structure				Sanctuary-born individuals identified prior to this study (number of offspring likely born from gravid founders)
				A-F (gravid)	A-M	SA (F:M)	N (UC)	
2009 Soft release (Site 1)	7 pens: 14–48 m^2	12 months	32 (3–7 geckos per pen)	13 (13)	10	3 (2:1)	6	32 (12)
2012 Hard release (Site 2)	206 m^2	-	11	6 (0)	5	0	0	9 (9)
2012 Soft release (Site 3)	1 pen: 665 m^2	9 months	42	22 (19)	7	2 (2:0)	11	52 (23)

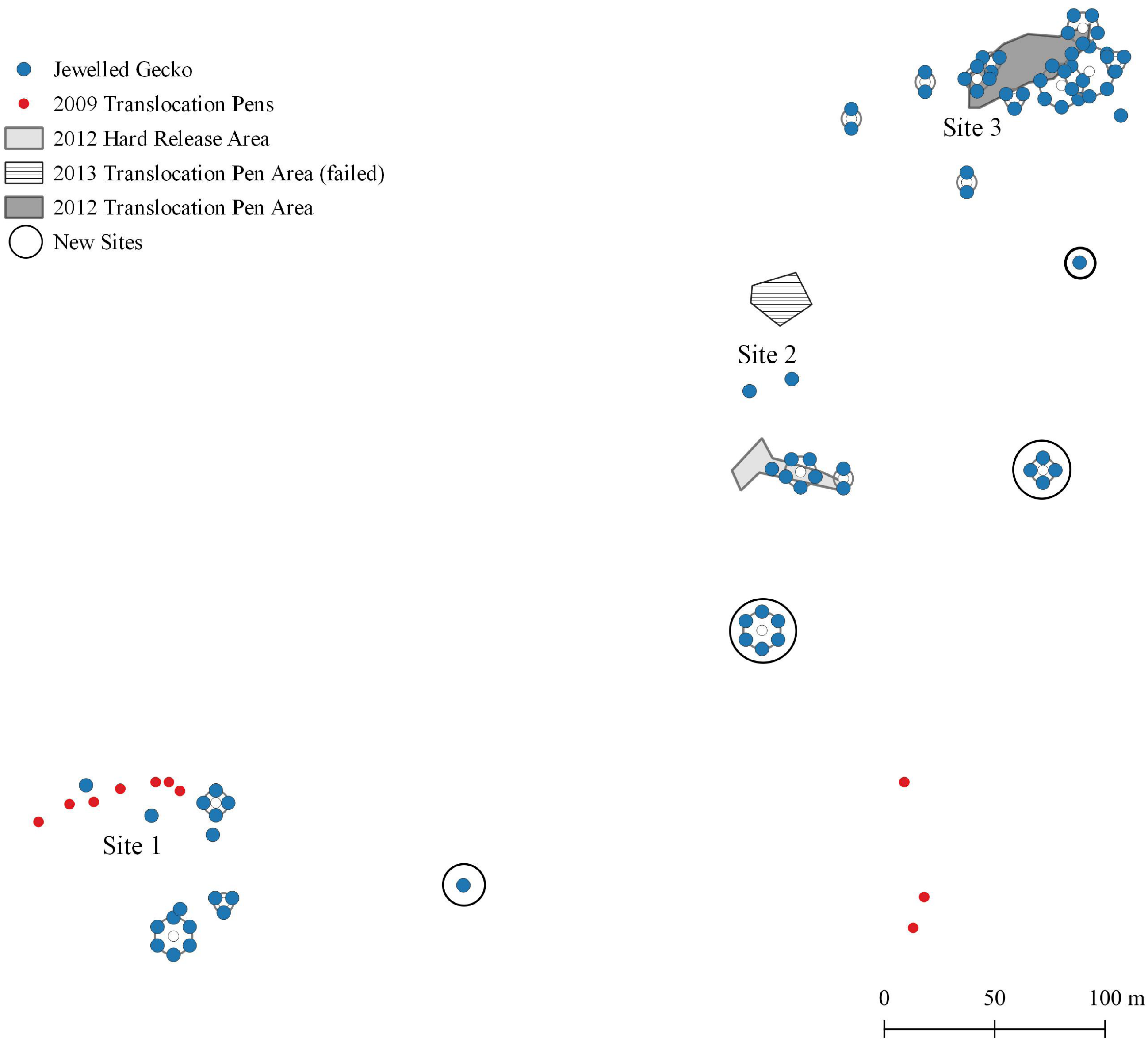

Figure 1. A map illustrating the distribution of jewelled geckos, *Naultinus gemmeus*, throughout Orokonui Ecosanctuary. Geckos were sighted between May 2020 and February 2021. Geckos first sighted within 5 m of one another are joined in a ring formation around a white circle which pinpoints the location of the first sightings. Pen and release areas ranged in size; Site 1 pens: from 14–48 m^2, Site 2 hard release area: 206 m^2, Site 3 pen area: 655.5 m^2. Sites include the hard release or penned areas and the suitable habitat within a c. 50 m radius of the release areas. The 2013 soft release failed due to a pen leak detected 11 days following release and poaching concerns. Despite attempts to relocate escaped founders, ten geckos were essentially hard released and thought to have dispersed into the wider ecosanctuary. Site 2 included both the 2012 hard release site and the 2013 penned area. The three 2009 release pens in between Sites 1 and 2 held only five geckos and previous surveys suggest the founder individuals have not remained in this area (Elton Smith, conservation manager at Orokonui Ecosanctuary, pers. comm.). The area surrounding these pens was subsequently not visually searched in this study and not considered part of Site 1. If a gecko was sighted >50 m from the hard release or pen boundaries, it was considered to be in a new site for jewelled geckos to occupy within the ecosanctuary.

and our study. With our study occurring 8–11 years following translocation, we could assume any individuals identified as new to the photo records to be the result of mating following release (and at least second-generation offspring). To be confident in this assumption, however, we also assume that all individuals born from pregnant founders were sighted and photo identified prior to our study, and therefore accounted for in the photo library.

Specific details on the location of gecko sightings and release sites are not provided due to concerns around potential poaching of this species. The spatial arrangement of the release sites and gecko sightings are, however, illustrated in Fig. 1. Site 3 was the largest site (c. 525 m from Site 1; Fig. 1) followed by Site 2 (c. 200 m between Sites 1 and 3) and Site 1 (Fig. 1). Mānuka (*Leptospermum scoparium*) and kānuka (*Kunzea ericoides*) trees and dense *Coprosma* shrubs dominated the vegetation at all sites. Approximately 38–50% of the habitat at each site was too dense or tall to be surveyed (Table 2). The habitat structure at Site 1 was taller than at the other sites, with densely grouped kānuka trees c. 7 m tall, compared to a maximum height of c. 4.5 m at Sites 2 and 3. Site 1 had also experienced the greatest habitat growth and change since the

Table 2. A summary of the effort invested (person hours spent) surveying across the area of accessible basking habitat across all sites. Site 1 = 2009 soft release, Site 2 = 2012 hard release, Site 3 = 2012 soft release. New sites were defined as an area > 50 m from the hard release or pen boundaries where a jewelled gecko was sighted. These sightings were made while walking between sites. Accessible area is an estimation of the area of vertical habitat edges that could be visually searched. This estimation does not include dense pockets of vegetation that were not visible to the searcher(s). The person hours spent surveying is an estimation and includes hours contributed by volunteers, fellow researchers, and members of Orokonui staff. The * represents an individual new to the sanctuary photo records that was found just outside the fence boundary. It was caught and released inside the ecosanctuary at the nearest release site (Site 1).

Sites	Total Site Area (m^2)	Accessible Area (m^2) that was surveyed	Person Hours Surveying (% of total search effort)	Total Sighted in this Study (and Release Propagule Size)
Site 1	5091	3365 (66%)	52 (14 %)	18* (32)
Site 2	6067	3737 (62%)	45 (12 %)	10 (11)
Site 3	4717	2384 (50%)	201 (54 %)	40 (42)
New Sites	–	5400	73 (20 %)	12
Totals	15 875	9486 (60% - excluding new sites)	371	80 (85)

translocation (Elton Smith, conservation manager at Orokonui Ecosanctuary, pers. comm.).

Between 14 June 2020 and 7 February 2021, we conducted 75 one-day surveys on sunny days when geckos were expected to be basking. The optimal basking time of geckos varied between seasons. Consequently, surveys were carried out between 1000–1500 New Zealand Standard Time (NZST) in early winter, 1100–1400 NZST by mid to late winter and from 0900 New Zealand Daylight Time (NZDT) onwards during spring and summer. The duration of each survey was subject to the weather throughout the day and the time available; however, the order of sites surveyed was rotated with each visit to eliminate any temporal bias in data collection. Surveys conducted between 14 June and 3 September 2020 focused on Site 3 only to source individuals suitable for the ecosanctuary's new outdoor enclosure (established December 2020). From 16 September 2020 to 7 February 2021, all three sites and the connecting suitable habitat were surveyed regularly.

Suitable jewelled gecko habitat within a c. 50 m radius of the release sites and habitat between sites was visually searched. If a gecko was sighted >50 m from the hard release or pen boundaries, it was considered to be a new site. Only habitat edges were surveyed, meaning that c. 40% of the total suitable habitat across the sites was inaccessible or not visible (Table 2). Surveys covered c. 14 900 m^2 of accessible jewelled gecko habitat within Orokonui Ecosanctuary (c. 9500 m^2 across the three release sites and an additional c. 5400 m^2 of suitable habitat surveyed when travelling between sites, including the area of public paths walked). When first sighted, individuals were photographed using a Canon 800D camera with a Tamron 18–400 mm lens and identified using their unique natural patterns on the dorsal surface (Knox et al. 2013). The life-history stage of each gecko sighted was visually determined as a neonate/juvenile, subadult, or adult. When possible, a photo of the tail base was taken to determine the presence (male) or absence (female) of a hemipenial sac to identify the sex of individuals. Neonates/juveniles were unable to be sexed. As geckos were not handled, the reproductive state of females was unable to be confirmed via palpation. Instead, photos were analysed; females that appeared pregnant from the distension of the abdomen were categorised as "probably reproductive". When first sighted, the gecko's global positioning system (GPS) location was recorded with at least 5 m accuracy on a GARMIN GPSmap 60CSx using the New Zealand Transverse Mercator (NZTM) coordinate system, and mapped along with the GPS locations of the pen and hard release boundaries using the Quantum Geographic Information System).

A photo library was used containing the photos of the 89 originally released (and the additional 10 founders that could not be relocated following the 2013 release pen leak) and 93 ecosanctuary-born geckos sighted during annual surveys before our study (photos provided by Carey Knox). New photos were added to the library when new gecko individuals were sighted in this study. Each gecko sighted in our study was identified as an originally released (translocated in 2009 or 2012), previously sighted (but sanctuary-born prior to this study), or new gecko (sighted for the first time during this study) by visually matching the unique dorsal patterns with those in the photo library (Knox et al. 2013).

Data collected from Sites 2 and 3 (the 2012 hard and soft release sites) were included in comparisons of founder minimum dispersal distance. Only the minimum dispersal distances estimated for founders resighted from the 2012 soft release cohort were used to compare dispersal distances of males and females. This was to avoid the potential effect of release type on reported dispersal. Site 1 (the 2009 translocation) was not included in either to avoid the confounding effect of time since translocation. The minimum dispersal distances detected in this study (measured by the distance in metres between each gecko's first sighting in our study and its release location) were estimated in R (Package GeoDist; Padgham & Sumner 2020). The initial release locations for geckos from the 2009 and 2012 translocations, however, were not recorded. Instead, the GPS locations of where geckos were first sighted following pen removal in 2012 were used as a proxy for their release positions. The time frame within which these initial sightings following pen removal were made ranged from 1–4 weeks (for six of the founders sighted in our study) to 1–5 months (for three of the founders sighted in our study).

Results

We conducted 75 visual surveys totalling 371 person-hours (person-h) for jewelled geckos within Orokonui Ecosanctuary; however, 95% of the geckos sighted (76 of 80 geckos) were found within 54 searches (after 308 person-h of searching). On average, surveys lasted 3 h 35 min (range: 1 h 20 min–6 h). The greatest search effort went into Site 3 (2012 soft release site; 201 person-h), followed by suitable habitat in between sites (73 person-h), Site 1 (2009 soft release site; 52 person-h) and Site 2 (2012 hard release site; 45 person-h; Table 2). The search effort required per gecko sighting was higher in winter (mean ± SD; 2.7 ± 1.2 sightings per unit of effort, n = 26 day surveys) than in summer (1.5 ± 1.2, n = 35) and spring (1.1 ± 0.8, n = 14).

A total of 80 individual geckos were sighted during this study across all three translocation sites. Of these, 18 individuals were located at Site 1, 10 individuals at Site 2, and 40 individuals at Site 3, with an additional 12 individuals found across four new sites (Fig. 1). We invested a large search effort into Site 2 (2012 hard release site; 45 person-h); however, 90% of the total geckos found were sighted after 18.8 person-h. Similar numbers of female and male jewelled geckos were detected across all areas surveyed (21 females:24 males confirmed) and adults were most frequently observed, followed by neonates/juveniles, and then subadults (Fig. 2). Sixteen geckos were unable to be sexed, and the life-history stage of two geckos and the origin of 10 geckos were unable to be confirmed due to poor photo quality or the absence of photographic evidence. We identified 53 geckos as new to Orokonui's photo records; four were previously sighted geckos (but born within the ecosanctuary) and 12 geckos were founders, released with the founding cohorts in 2009 or 2012 (Fig. 3). An additional founder was resighted in 2021 and identified as an individual released as an adult (at least three years old) in 2009. With a previously reported longevity of at least 12 years old (Cree & Hare 2016), our observation suggests this gecko was at least 15 years old.

The mean minimum dispersal distance estimated for Site 3 founders was 36 m (±31 m SD, n = 9 founders), similar to the mean for Site 2 founders of 41 m (±27 m, n = 2); Table 3. A third founder resighted at Site 2 was originally released in the 2013 translocation (and unable to be recaptured and relocated following the pen leak), and had a minimum dispersal distance of 97.7 m. The mean minimum dispersal distance travelled by male founders resighted from the 2012 soft release was 47 m (±31 m, n = 5) and 22 m for the female founders resighted (±29 m, n = 4).

A youthful population was detected at Sites 1 and 3, with 41% and 53% of geckos respectively confirmed to be neonates/juveniles. In contrast, predominantly adults were detected at Site 2 (80% of geckos). No neonates/juveniles were detected at Site 2, although two subadults were found and two females were categorised as probably reproductive (in addition to two females at Site 1 and eight at Site 3). The two probably reproductive females at Site 2 were both identified as founders. However, two of the probably reproductive females from Site 1 and three from Site 3 were identified as new to the photo records. This provides evidence for reproduction from second generation individuals at both soft release sites, fulfilling one of the two criteria for Stage 3 of translocation success (Table 4). This is reported with the assumption that any adult geckos that we identified as new to the photo records were born from mating that occurred post-release (and therefore at least second-generation individuals), rather than born from a gravid founder (and just not sighted until our survey). Reproduction was also evident at three of the four new sites identified, with a probably reproductive female sighted at the new site closest to Site 3; two neonates and one subadult sighted at the new site between Sites 2 and 3; and then two neonates at one of the new sites between Sites 1 and 2 (locations illustrated in Fig. 1).

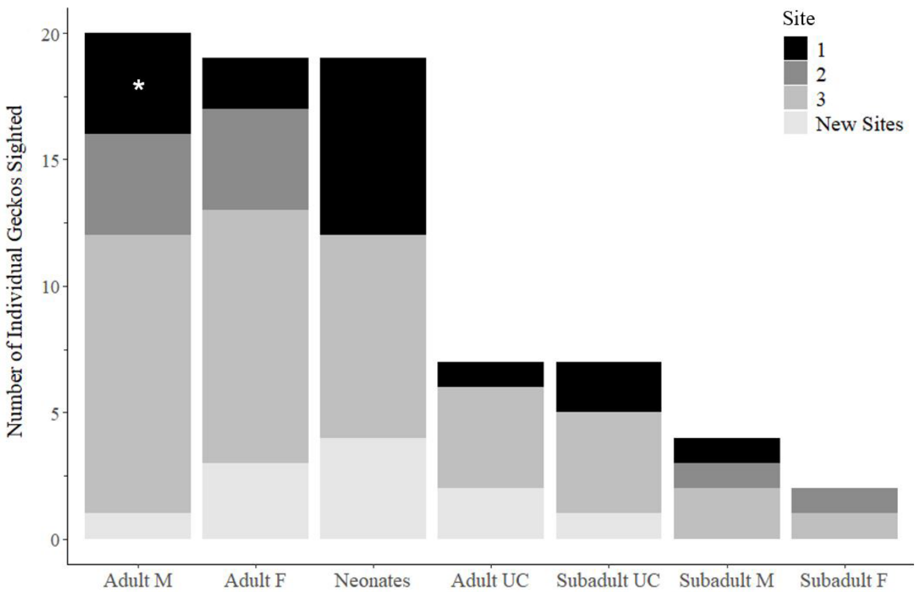

Figure 2. A summary of the population structure (sex and life-history stage) of each jewelled gecko population detected within Orokonui Ecosanctuary at all three release sites and the new sites (four sites combined) in 2020–2021. F = female, M = male, UC = sex is unconfirmed due to poor photo quality. Site 1 = 2009 soft release (n = 18), Site 2 = 2012 hard release (n = 10), Site 3 = 2012 soft release (n = 40). Both soft releases involved penning the founder cohort for 9–12 months prior to pen removal. If a gecko was sighted >50 m from the hard release or pen boundaries, it was considered to be in a new site for jewelled geckos to occupy within the ecosanctuary (n = 12). The * represents an individual that was found just outside the fence boundary. It was caught and released inside the ecosanctuary at the nearest release site (Site 1). Note: an additional two individuals were found in Sites 1 and at one of the new sites, but the sex and life-history stage were unable to be identified.

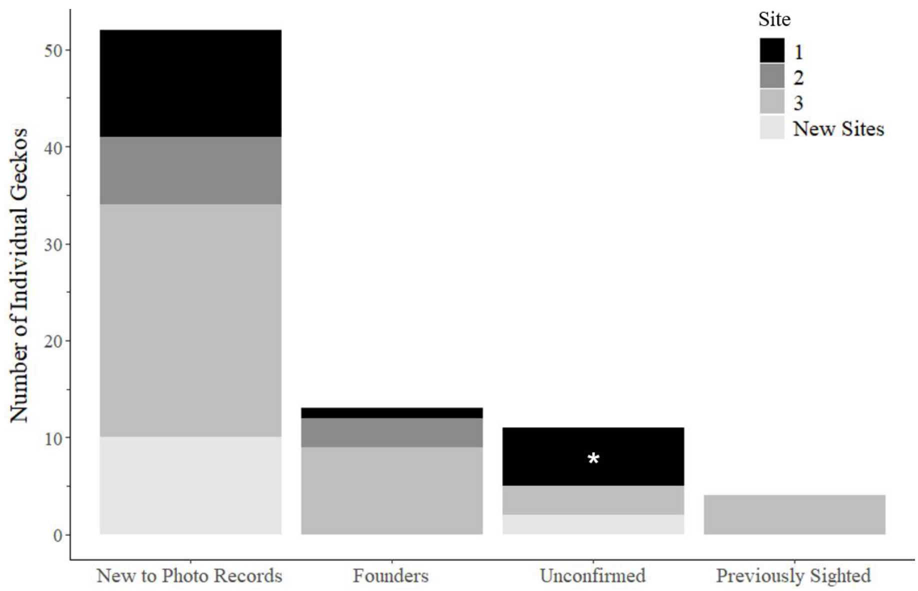

Figure 3. The identified origin of each jewelled gecko sighted within Orokonui Ecosanctuary at all three release sites and the new sites (four sites combined) in 2020–2021. UC = status is unconfirmed due to poor photo quality. Site 1 = 2009 soft release (n = 18), Site 2 = 2012 hard release (n = 10), Site 3 = 2012 soft release (n = 40). Both soft releases involved penning the founder cohort for 9–12 months prior to pen removal. If a gecko was sighted >50 m from the hard release or pen boundaries, it was considered to be in a new site for jewelled geckos to occupy within the ecosanctuary (n = 12). The * represents an individual that was found just outside the fence boundary. It was caught and released inside the ecosanctuary at the nearest release site (Site 1).

Table 3. The minimum dispersal distance of originally translocated jewelled geckos (*Naultinus gemmeus*) resighted within Orokonui Ecosanctuary between June 2020 and January 2021 (n = 13). Dispersal was calculated from the location where first sighted following release (rather than the exact release position, due to data unavailability) and where first sighted in this study.

Sex	Translocation	Date Translocated (or pen removed)	Date of first resighting following translocation	Date of first resighting between 2020–2021	Minimum Distance Travelled (m)
M	2009 pen	February 2009	April 2009	November 2020	31.6
F	2012 hard release	28 September 2012	November 2012	July 2020	21.8
F	Failed 2013 pen	8 October 2013 (into pen)	April 2015	October 2020	97.7
M	2012 hard release	28 September 2012	April 2013	January 2021	60.3
F	2012 pen	28 September 2012	March 2013	June 2020	64.6
F	2012 pen	28 September 2012	September 2012	July 2020	1.0
F	2012 pen	28 September 2012	October 2012	July 2020	6.1
F	2012 pen	28 September 2012	April 2015	October 2020	17.3
M	2012 pen	28 September 2012	October 2012	July 2020	14.4
M	2012 pen	28 September 2012	October 2012	July 2020	55.7
M	2012 pen	28 September 2012	September 2012	July 2020	15.3
M	2012 pen	28 September 2012	September 2012	August 2020	81.7
M	2012 pen	28 September 2012	September 2012	August 2020	68.4

Table 4. Stages of translocation success of jewelled geckos, *Naultinus gemmeus*, achieved at the three release sites within Orokonui Ecosanctuary. Site 1 = 2009 soft release, Site 2 = 2012 hard release, Site 3 = 2012 soft release. Table adapted from Miller et al., 2014.

Stages	Site 1	Site 2	Site 3
Date of pen removal or hard release	February 2009	September 2012	September 2012
Stage 1: Survival and growth of founders	✓	✓	✓
Stage 2: Evidence of reproduction (not from gravid females released)	✓ November 2011	✓ September 2013	✓ October 2013
Stage 3: Population growth (capture of more individuals than were released and evidence of breeding from the second generation)	15 more individuals new to this study needed to confirm	Likely reached in 2021: 2 individuals new to this study needed to confirm	Likely reached in 2021: 3 individuals new to this study needed to confirm
Stage 4: Viable population (consistently high number of resights, young animals regularly sighted or low probability of extinction)	Not yet detected	Not yet detected	Not yet detected

All sites largely comprised new individuals (≥ 60% of the population at each site). Previously seen geckos (during post-release monitoring up to 2018) were detected at Site 3 only. The proportion of founders resighted was similar between Site 2 (two out of 11 founders resighted; 18%, with an additional founder from the failed 2013 release sighted too) and Site 3 (nine out of 42 founders resighted; 21%), which differed to Site 1 (one out of 32 founders resighted; 3%; Fig. 3). Similarly, the proportion of geckos sighted compared to the release propagule size was similar for both Sites 2 and 3 (91% and 95%), but lower for Site 1 (57%).

Prior to our study, Stage 1 of translocation success (survival and growth of founders) had been reached at all three sites within the first year following release. Stage 2 was then confirmed within two years following release (Table 4). Furthermore, sanctuary-born geckos had been identified at all three sites: 32 geckos at Site 1, nine geckos at Site 2, and 52 geckos at Site 3 (Mandy Tocher, facilitator of the 2009 translocation, and Carey Knox, a facilitator of the 2012 translocations, pers. comm.). We can be confident that at least 12 of these geckos identified at Site 1, all nine from Site 2, and 23 at Site 3 were born from mating post-release as opposed to from gravid founders, as they were sighted as neonates/juveniles or subadults more than two years following translocation (Table 1).

With the populations sighted in this study alone, we cannot confirm that Sites 1, 2, or 3 have progressed to Stage 3 of translocation success (evidence of population growth; Table 4). Although reproduction from second-generation individuals was detected at Sites 1 and 3, the total number of individuals sighted did not exceed the founding cohort. To reach the third stage, these sites would require sightings of two (Site 2) and three (Site 3) individuals new to this study, whereas Site 1 would require 15 new individuals to be sighted. In addition, Site 2 requires evidence of reproduction from a sanctuary-born individual.

Discussion

With 80 geckos sighted between 2020–2021 (including 12 founders from among the three release cohorts), we can confirm the establishment of jewelled gecko populations at all three hard and soft release sites 8–11 years following release. We have also identified an additional four new sites of jewelled gecko occupancy within Orokonui Ecosancatury (> 50 m from the hard release or pen boundaries). This includes the first reported re-sighting of hard released green geckos following release in New Zealand.

Unexpectedly, the mean minimum dispersal distances estimated in our study for Site 3 (soft released) founders were similar to the mean dispersal for Site 2 (hard released) founders (42.2 and 41 m respectively). This was a surprising result considering the effect penning had on reducing initial dispersal when monitored through telemetry and visual searches (Knox & Monks 2014). Upon initial release (into the pen) the soft released geckos were at a density of 27.3 m^2 adult $gecko^{-1}$ (n = 24). Three weeks after pen removal, these geckos covered a similar area, with 18 of 24 adults sighted inside the pen area and only one adult gecko sighted 3.5 m outside of the pen area. In contrast, the hard released geckos were released at a density of 22.9 m^2 adult $gecko^{-1}$ (n = 9), but by the end of the 3 week radio-tracking period, density had decreased to 99.7 m^2 adult $gecko^{-1}$ due to dispersal (Knox & Monks 2014).

Our ability to detect founder dispersal since 2009 and 2012, however, is severely limited by our study design. The initial increased rate of dispersal detected in hard released founders discussed above, and the significant time frame (of 8-11 years) between the three translocations and this study, highlights the potential for hyper-dispersal to have occurred. Hyper-dispersal describes when an individual moves a significant distance away from the translocation site, at which point it becomes isolated from the rest of the release cohort and is unlikely to contribute to population establishment (Bilby & Moseby 2023). While we did not detect any cases of hyper-dispersal in the 2012 hard released founders, our study may not have been able to detect them; in other words, we may have only been detecting the short-dispersing individuals that have remained at or close to the release site. In addition, only suitable habitat within a c. 50 m radius of each release site was visually searched, and few comprehensive surveys were conducted between the release sites. Therefore, any larger-distance exploratory behaviours of soft and hard released founders will not have been detectable.

Large dispersal distances have already been detected in *N. gemmeus* within Orokonui Ecosanctuary, as one sanctuary-born jewelled gecko was resighted four years later, 2.1 km from its previous location (Carey Knox, a facilitator of the 2012 translocations, pers. comm.). In addition, large movement between sites has been detected prior to our study as a male born at Site 3 in 2012 was recorded as an adult at Site 2 in 2016, and sighted again in the same area two years later. Such evidence suggests there may be additional geckos that have dispersed to other sites over the 8–11 years since release. We can therefore no longer treat the populations detected at the three release sites as independent. However, we also cannot know to what extent this mixing has contributed to the population size and structure we detected at each release site.

As stated in our second prediction, Stage 2 (evidence of recent reproduction) was detected at all three sites 8–11 years post-release (Table 4). However, contrary to our third prediction, the proportion of founders sighted in this study compared to the release cohort size was similar for both 2012 hard (18%) and soft (21%) releases. We therefore report the first hard release of an endemic green gecko species that may have resulted in population establishment at the release site. This result suggests that the release method used may not influence whether a population establishes in the long-term. This outcome is even more surprising in light of the reported failure of previous hard release translocations of green geckos, in which post-translocation resighting rates were negligible (0–1 geckos; as reviewed by Knox & Monks 2014). In our study, 90% of the geckos found at Site 2 (the 2012 hard release site) were sighted over 18.8 person-h of searching (within 18 of 49 searches). Our contrasting post-release sightings could therefore suggest that a much greater search effort is needed than has previously been invested in post-release monitoring of green gecko translocations (as reported in Knox & Monks 2014).

It is also interesting that we detected long-term population establishment and reproduction at all three sites despite their contrasting founding cohorts (Site 1: 2009 soft release, n = 32; Site 2: 2012 hard release, n = 11; Site 3: 2012 soft release, n = 42). Among several other key factors, the number of individuals released is a commonly reported driver behind translocation success or failure (Wren et al. 2023). There will be a threshold at which point the release cohort is too small to enable stages of translocation success, whether that is the result of the ease of finding breeding conspecifics or the effects of limited genetic diversity (Fischer & Lindenmayer 2000; Germano & Bishop

2009; Miller et al. 2009; Wren et al. 2023). These effects are particularly applicable to species with relatively small home ranges. If both suitable habitat and sufficient resources are available at the release site, a large founder cohort size could further encourage site fidelity for green geckos following a soft release (by reducing the effort required to find a mate). Despite a founding cohort of 11 individuals, the population detected at Site 2 has established and shown signs of population growth. However, movement and breeding between sites could have aided this establishment.

Variation in the time elapsed since translocation between the release sites may account for some of the observed patterns in population growth (namely number of founders sighted), as we do not know how old any of the adult founders were when translocated. Our study occurred 12 years following the 2009 translocation and the known lifespan of jewelled geckos in areas with low abundances of mammalian predators is at least 12 years old (Cree & Hare 2016). Although our study suggests this lifespan is likely higher than previously reported (with one gecko confirmed to be at least 15 years old), it is possible that more of the 2009 founders will have reached the end of their lifespan prior to our surveys (July 2020–February 2021) than the 2012 founders.

We also believe that differences in habitat structure, in addition to habitat growth experienced between sites, created a sighting bias towards sighting fewer geckos at Site 1. Sighting biases and challenges in detection are commonly encountered when conducting visual surveys of reptiles, largely due to the small body size, habitat preferences, and cryptic nature of these species (Siers et al. 2018; Boback et al. 2020; Shelton & Goldingay 2021). In dense and complex habitat, detection can be particularly challenging as it is easier for reptiles to move into undetectable areas. Furthermore, in long-term studies such as ours, habitat structure, foliage density, and leaf litter change over time (e.g. Rodda et al. 2015). Habitat immediately surrounding the release pens at Site 1 has become progressively dominated by tall mānuka trees, with the canopy reaching c. 7 m high (compared to a maximum height of c. 4.5 m at Sites 2 and 3). This dense foliage severely hindered our ability to locate geckos in that area. The growth of rank exotic grass is also likely to have increased mouse numbers. Although mouse control is carried out year-round at the release sites, they cannot be eliminated entirely. Nonetheless, the number of jewelled geckos detected in this study, and our ability to sight individuals of all life-history stages regularly at 8-11 years following translocation, suggest that the impact of mice on the jewelled gecko populations is not of concern (Elton Smith, conservation manager at Orokonui Ecosanctuary, pers. comm.).

In addition, visual searches were only able to focus on the edges of vegetation, which often formed the perimeter of dense and inaccessible habitat; therefore (and particularly at Site 1), geckos basking higher than the observer could see, or in dense pockets of vegetation, may have been missed (availability bias; Boback et al. 2020). The total number of individual geckos sighted is also likely to be under-represented, as neonates/juveniles and subadults, being smaller, with often smaller home range sizes and daily movements, are more likely to be missed (a problem reported for dubious dtellas *Gehyra dubia* and inland snake-eyed skinks *Cryptoblepharus australis*; Nordberg & Schwarzkopf 2015).

Contrary to our fourth prediction, we are unable to confirm Stage 3 of translocation success at any of the translocation sites. To confirm this stage, we need to detect 15 more individuals new to the study at Site 1, two more individuals at Site 2 and three more at Site 3. Furthermore, evidence of reproduction from a sanctuary-born individual at Site 2 is required.

With awareness of the sighting bias discussed, and knowledge of sanctuary-born individuals sighted prior to our study however, it is highly likely that both Sites 2 and 3 have already reached Stage 3 of translocation success (population growth; Miller et al. 2014) regardless of the release method used.

We therefore report the first hard release of an endemic green gecko species that may have resulted in population establishment and population growth at the release site. The fact that Site 2 reached stages 1 and 2 of translocation success (prior to this study), and the likelihood that Stage 3 of population growth has now been reached, suggests that the release method used may not influence whether a population establishes in the long-term. However, we emphasise caution in interpreting this result considering the soft and hard release sites can no longer be considered truly independent of one another. We cannot exclude the possibility that the soft release geckos, their progeny or the 2013 founders that could not be relocated, may have contributed towards the population establishment we detected at Site 2. We can however be confident that the hard-release method enabled Stage 1 (founder survival and growth) and Stage 2 (reproduction outside of gravid founders) of translocation success, as these stages were detected within a timeframe where dispersal from neighbouring sites was unlikely (one year) and the 2013 pen leak had not yet occurred.

For such cryptic species, detection rates are often low, and it is rare that the number of individuals sighted represents the number of individuals present within a population (Thompson 2013). This challenge highlights the need for the Miller et al. (2014) criteria to account for such cryptic taxa. To accommodate such species, and those where founders can be identified, we suggest that a population abundance estimate that exceeds the release propagule size should also be considered as viable evidence that Stage 3 (population growth) has been reached (as used in Bell & Herbert 2017). We also note that using the Miller et al. (2014) criterion to confirm Stage 4 of translocation success (defined as finding evidence of population viability, in which the number of captures or resights per survey is required to regularly exceed the release propagule), is limited. For example, if the carrying capacity at the release site is close to or less than the number of founders released, then the population may still be viable and self-sustaining. The rate of population growth, however, will be restricted by the number of individuals that the release site is able to support.

Despite our inability to confirm Stage 3 of translocation success for any of the sites studied, several benefits of penning New Zealand native arboreal geckos prior to release to a site with few or no mammalian predators are evident from previous studies. There are several examples showing that penning for at least four months significantly reduced subsequent dispersal in the short-term (Knox & Monks 2014; Knox et al. 2017; Flynn-Plummer & Monks 2021; Yee et al. 2022). A reduction in initial dispersal following release (depending on the season), may result in greater recruitment and population growth rate at the translocation site in the year after release. Short-term site fidelity will also aid initial monitoring following the release, which will likely assist in determining when Stages 1 and 2 (evidence of survival, growth, and reproduction of founders) of translocation success are reached (Miller et al. 2014). Our study indicates that this short-term site fidelity can also be detected long-term for some translocations.

Nonetheless, a soft release that involves penning has considerable costs. Excluding labour, pen construction costs a minimum of c. NZ$1000 for materials (Carey Knox, a facilitator of the 2012 translocations, pers. comm.; Dale Shirtliff, Friends of Mana Island, pers. comm.) but will increase with pen size e.g. up to c. NZ$1800 for a 1200 m^2 pen (Roger Wallace & Malcolm de Raat, Supporters of Tiritiri Matangi, pers. comm.). The total time required (often with a team of four to five people) to construct and remove the pen(s) can be as low as two to four days (Carey Knox, a facilitator of the 2012 translocations, pers. comm.; Dale Shirtliff, Friends of Mana Island, pers. comm.), but is dependent on the pen size, terrain covered, and whether planting or weed removal is required. Under these more intensive circumstances, construction of the pen(s) has taken up to 2 weeks (Roger Wallace & Malcolm de Raat, Supporters of Tiritiri Matangi, pers. comm.). Costs can also accumulate if transport is difficult (e.g. the soft release of barking geckos to Mana Island involved NZ$1100 boating travel costs per weekend; Dale Shirtliff, Friends of Mana Island, pers. comm.). An additional disadvantage associated with pens is the unwanted attention that a pen can attract (e.g. from illegal collectors, possibly increasing the poaching risk).

Considering the costs involved with penning alongside the findings of our study, we stress the importance of further investigating what may enable a hard released green gecko population to establish at sites where introduced mammalian predators (except mice) are excluded. As part of this, we recommend investigating the role that physiological stress responses to capture and transport (e.g. elevated plasma corticosterone as reported in tuatara (*Sphenodon punctatus*); Anderson et al. 2015) may have on increasing activity and therefore initial dispersal (e.g. Belliure & Clobert 2004).

Historically, hard releasing lizards, in particular New Zealand green geckos, has resulted in no detectable founder survival, reproduction, or population establishment, likely due to high initial dispersal (Knox & Monks 2014; Resende et al. 2020; Bilby & Moseby 2023). Consequently, penning has become an adopted form of soft release to reduce post-release lizard dispersal at least in the short-term (Knox & Monks 2014; Fitzgerald et al. 2015; Scott 2016; Monks et al. 2017; Angeli et al. 2018; DeGregorio et al. 2020; Flynn-Plummer & Monks 2021; Yee et al. 2022). We report the first hard release of a *Naultinus* spp. that may have resulted in population establishment at the release site. Of even more interest, the population detected at Site 2 (2012 hard release site) is very close to Stage 3 of translocation success (population growth; Miller et al. 2014) eight years following hard release. Our findings suggest that penning New Zealand green geckos for at least four months may not dictate whether a population establishes at the release site in the long-term. We do, however, acknowledge that the degree to which our findings can be extended is limited due to the lack of replication our study design allowed and the possibility that progeny from soft release individuals, in addition to founders from the 2013 pen leak, could have contributed to the population establishment we detected at Site 2. Additional research comparing the long-term outcomes from soft versus hard releases at other gecko translocation sites is essential to improve our understanding.

With the potential to reduce the costs associated with penning, we recommend investigating factors that encourage the establishment of a hard released green gecko population. Of particular interest is whether a short-term elevation of corticosterone concentration contributes to dispersal of hard released geckos and, if so, over what time frame. This information could be used to strengthen the best practice for the translocation of *Naultinus* spp. and may be applicable to translocation protocols for other arboreal lizards with small home ranges and daily travel distances.

Acknowledgements

We thank Kāti Huirapa Rūnaka ki Puketeraki, Te Rūnanga o Ōtākou, Otago Natural History Trust, and the Orokonui Knowledge Group for supporting this research. We are incredibly grateful to the New Zealand Federation of Graduate Women for the Brenda Shore Award. This fully supported the purchase of equipment used including the Canon camera and Tamron lens. Thank you to the staff at Orokonui Ecosanctuary, especially Elton Smith and Kelly Gough, in addition to those who participated in visual surveys. Thank you to Phil Seddon and Carey Knox for valuable editing suggestions, and to Mandy Tocher and Carey Knox for advice and access to Orokonui's translocation reports and photo library.

Additional Information and Declarations

Author Contributions: All authors involved conceived the idea and developed the methodology. ER collected the data and wrote the manuscript alongside editorial contributions from AC, JM, and SG, and assistance with data analysis from SG and JM.

Funding: The New Zealand Federation of Graduate Women awarded a Brenda Shore Award to ER, which fully supported the purchase of the Canon camera and Tamron lens.

Data and Code Availability: The data and code from this article are not openly available online.

Ethics: Not applicable as all data were collected through non-invasive methods (visual searches of habitat only).

Conflicts of Interest: There are no financial, professional, or personal conflicts of interest that we can identify.

References

Anderson LE, Cree A, Towns DR, Nelson NJ 2015. Moving house: long-term dynamics of corticosterone secretion are unaltered in translocated populations of a rare reptile (the tuatara, *Sphenodon punctatus*). Conservation Physiology 3(1): cov014.

Angeli NF, Lundgren IF, Pollock CG, Hillis-Starr ZM, Fitzgerald LA 2018. Dispersal and population state of an endangered island lizard following a conservation translocation. Ecological Applications 28: 336–347.

Bell TP, Herbert SM 2017. Establishment of a self-sustaining population of a long-lived, slow-breeding gecko species (Diplodactylidae: *Hoplodactylus duvaucelii*) evident 15 years after translocation. Journal of Herpetology 51: 37–46.

Belliure J, Clobert J 2004. Behavioral sensitivity to corticosterone in juveniles of the wall lizard, *Podarcis muralis*. Physiology & Behavior 81: 121–127.

Berger-Tal O, Blumstein DT, Swaisgood RR 2020. Conservation translocations: a review of common difficulties and promising directions. Animal Conservation

23: 121–131.
Bilby J, Moseby K 2023. Review of hyperdispersal in wildlife translocations. Conservation Biology 38(1): e14083.
Boback SM, Nafus MG, Yackel Adams AA, Reed RN 2020. Use of visual surveys and radiotelemetry reveals sources of detection bias for a cryptic snake at low densities. Ecosphere 11(1): e03000.
Bubac CM, Johnson AC, Fox JA & Cullingham CI 2019. Conservation translocations and post-release monitoring: identifying trends in failures, biases, and challenges from around the world. Biological Conservation 238: 108239.
Chapple DG 2016. (ed.) New Zealand Lizards. Springer International Publishing. 375 p.
Cid B, Figueira L, de T e Mello AF, Pires AS, Fernandez FAS 2014. Short-term success in the reintroduction of the red-humped agouti *Dasyprocta leporina*, an important seed disperser, in a Brazilian Atlantic Forest reserve. Tropical Conservation Science 7(4): 796–810.
Cree A, Hare KM 2016. Reproduction and life history of New Zealand lizards. In Chapple, DG 2016. (ed.) New Zealand Lizards. Cham, Switzerland, Springer International Publishing. Pp. 169–206.
DeGregorio B, Moody R, Myers H 2020. Soft release translocation of Texas horned lizards (*Phrynosoma cornutum*) on an urban military installation in Oklahoma, United States. Animals 10(8): 1358.
Dodd Jr CK, Seigel RA 1991. Relocation, repatriation, and translocation of amphibians and reptiles: are they conservation strategies that work? Herpetologica 47(3): 336–350.
Fischer J, Lindenmayer DB 2000. An assessment of the published results of animal relocations. Biological Conservation 96: 1–11.
Fitzgerald LA, Treglia ML, Angeli N, Hibbitts TJ, Leavitt DJ, Subalusky AL, Lundgren I, Hillis-Starr Z 2015. Determinants of successful establishment and post-translocation dispersal of a new population of the critically endangered St. Croix ground lizard (*Ameiva polops*). Restoration Ecology 23(6): 776–786.
Flynn-Plummer TP, Monks JM 2021. Penned release reduces area use by translocated barking geckos (*Naultinus punctatus*). New Zealand Journal of Ecology 45: 3432.
Germano JM, Bishop PJ 2009. Suitability of amphibians and reptiles for translocation. Conservation Biology 23: 7–15.
Hitchmough RA, Adams LK, Reardon JT, Monks JM 2016. Current challenges and future directions in lizard conservation in New Zealand. Journal of the Royal Society of New Zealand 46: 29–39.
Hitchmough R, Barr BP, Knox C, Lettink M, Monks JM, Patterson GB, Reardon JT, van Winkel D, Rolfe J, Pascale M 2021. Conservation status of New Zealand reptiles, 2021. Wellington, New Zealand Department of Conservation. 15 p.
IUCN/SSC 2013. Guidelines for reintroductions and other conservation translocations. Version 1.0. Gland, Switzerland, IUCN Species Survival Commission. 57 p.
Knox CD, Cree A, Seddon PJ 2013. Accurate identification of individual geckos (*Naultinus gemmeus*) through dorsal pattern differentiation. New Zealand Journal of Ecology 37: 60–66.
Knox CD, Monks JM 2014. Penning prior to release decreases post-translocation dispersal of jewelled geckos. Animal Conservation 17: 18–26.
Knox CD, Jarvie S, Easton LJ, Monks JM 2017. Soft release, but not cool winter temperatures, reduces post-translocation dispersal of jewelled geckos. Journal of Herpetology 51: 490–496.
Lettink M, Monks JM 2016. Survey and monitoring methods for New Zealand lizards. Journal of the Royal Society of New Zealand 46: 16–28.
Miller KA, Bell TP, Germano JM 2014. Understanding publication bias in reintroduction biology by assessing translocations of New Zealand's herpetofauna. Conservation Biology 28: 1045–1056.
Miller KA, Nelson NJ, Smith HG, Moore JA 2009. How do reproductive skew and founder group size affect genetic diversity in reintroduced populations? Molecular Ecology 18: 3792–3802.
Monks J, Knox C, Sidaway K 2017. Best practice techniques for the translocation of green geckos (*Naultinus* spp.). Wellington, New Zealand Department of Conservation. 8 p.
Morris SD, Brook BW, Moseby KE, Johnson CN 2021. Factors affecting success of conservation translocations of terrestrial vertebrates: a global systematic review. Global Ecology and Conservation 28: e01630.
Nordberg EJ, Schwarzkopf L 2015. Arboreal cover boards: using artificial bark to sample cryptic arboreal lizards. Herpetologica 71(4): 268–273.
Padgham M, Sumner MD 2020. Geodist: fast, dependency-free geodesic distance calculations. R package version 0.0.4.
Reinert HK 1991. Translocation as a conservation strategy for amphibians and reptiles: some comments, concerns, and observations. Herpetologica 47(3): 357–363.
Resende PS, Viana Junior AB, Young RJ, Azevedo CSD 2020. A global review of animal translocation programs. Animal Biodiversity and Conservation 43(2): 221–232.
Richardson K, Castro IC, Brunton DH, Armstrong DP 2015. Not so soft? Delayed release reduces long-term survival in a passerine reintroduction. Oryx 49(3): 535–541.
Rodda GH, Dean-Bradley K, Campbell EW, Fritts TH, Lardner B, Adams AAY, Reed RN 2015. Stability of detectability over 17 years at a single site and other lizard detection comparisons from Guam. Journal of Herpetology 49(4): 513–521.
Schneyer N 2002. Effects of avian predation and habitat degradation on the population dynamics of the jewelled gecko (*Naultinus gemmeus*) from the Every Scientific Reserve, Otago Peninsula, New Zealand. Unpublished MSc thesis, University of Otago, Dunedin, New Zealand.
Scott SN 2016. Translocation and post-release monitoring techniques of Auckland green gecko (*Naultinus elegans elegans*) using a penned release. Unpublished MSc thesis, Massey University, Auckland, New Zealand.
Shelton MB, Goldingay RL 2021. Comparative survey techniques for a cryptic Australian snake (*Hoplocephalus bitorquatus*). Australian Journal of Zoology 68(2): 68–75.
Sherley GH, Stringer IAN, Parrish GR 2010. Summary of native bat, reptile, amphibian and terrestrial invertebrate translocations in New Zealand. Wellington, New Zealand Department of Conservation. 303 p.
Short J 2010. The characteristics and success of vertebrate translocations within Australia 2009. Canberra, Australia, Australian Government Department of Agriculture, Fisheries and Forestry. 97 p.
Siers SR, Yackel Adams AA, Reed RN 2018. Behavioral differences following ingestion of large meals and consequences for management of a harmful invasive snake: a field experiment. Ecology and Evolution 8(20):

10075–10093.
Teixeira CP, De Azevedo CS, Mendl M, Cipreste CF, Young RJ 2007. Revisiting translocation and reintroduction programmes: the importance of considering stress. Animal Behaviour 73: 1–13.
Tetzlaff SJ, Sperry JH, DeGregorio BA 2019. Effects of antipredator training, environmental enrichment, and soft release on wildlife translocations: a review and meta-analysis. Biological Conservation 236: 324–331.
Thompson W 2013. Sampling rare or elusive species: concepts, designs, and techniques for estimating population parameters. Washington, Island Press. 400 p.
Towns DR, Miller KA, Nelson NJ, Chapple DG 2016. Can translocations to islands reduce extinction risk for reptiles? Case studies from New Zealand. Biological Conservation 204: 120–127.
Wren S, Bishop PJ, Beauchamp AJ, Bell BD, Bell E, Cisternas J, Dewhurst P, Easton L, Gibson R, Haigh A, Tocher M, Germano JM 2023. A review of New Zealand native frog translocations: lessons learned and future priorities. New Zealand Journal of Ecology 47(2): 3538.
Yee GE, Monks JM, Bell T 2022. Spatial patterns and habitat use of penned and hard released arboreal geckos translocated to an offshore island free of introduced mammals. New Zealand Journal of Ecology 46(2): 3477.

Received: 1 July 2023; Accepted 19 February 2024
Editorial board member: Isabel Castro