Translocation and post-release monitoring techniques of Auckland green gecko (*Naultinus elegans elegans*) using a penned release

A thesis in partial fulfilment of the requirements for the degree of

Master of Science in

Conservation Biology,

Massey University, Auckland, New Zealand

Sarah Naomi Scott

2016

Juvenile green gecko “Jade”, posing for a photo, Hunua Ranges, New Zealand. Photograph by Harry Scott.

Abstract

A translocation of Auckland green gecko (*Naultinus elegans elegans)* using penned and hard releases is conducted during an emergency salvage in the Hunua Ranges, Auckland. The value of limiting individuals' movement post-translocation is discussed. Radio-telometry as a resourceful long-term monitoring technique is also discussed including limitations.. The population of 52 individuals were salvaged prior to deforestation of habitat as part of the mitigation process in human-wildlife conflict. Translocations are a major part of New Zealand's conservation strategies, and this event proved a unique opportunity to study post-release movements of Auckland green gecko (*Naultinus elegans elegans*).

To test whether penned releases have an effect on post-release movements, salvaged geckos were divided into two groups. One group of individuals was released as a penned release and one group as a non-penned (hard) release. Using radio-telemetry, information was collected on movement behaviours post-release. 100% minimum convex polygons and 95% kernel estimates were used to establish areas for each individual and compared between the two release groups. Due to the small sample sizes, statistical power was low and no statistically significant differences were found between penned and non-penned release groups in terms of movement post-release. However, exploratory data analysis shows some differences in range particularly in relation to distance from release (m). It seems that penned released geckos tend to stay within the area of their release site compared with non-penned released geckos. This could be an early indication of territory and home range establishment from founder individuals.

Multiple methods of monitoring post-translocation of green geckos as well as trapping and monitoring or mammalian predators within the area were carried out throughout the duration of the radio-telemetry aspect of the study. The benefits and limitations are discussed for each. Rat trapping in the release site area showed a trend with very low numbers caught (n=2) and high levels of mice prints throughout the general shrubland area. The presence of rat posion in the digestive tract of one rat caught during trapping leans towards successful pest control to date which is keeping numbers of rats at relatively low densities.

Using penned release methods during wildlife translocations can prove to be an expensive and long-term endeavour. The practical use of penning Auckland green gecko post-release is still yet to be accurately defined in this study. Using radio tracking techniques to monitor the translocated individuals' movement behaviours up to 4 weeks after release was successful. Using specific materials and harness designs that are the right 'fit' for the species is imperative as was shown with the unsuccessful use of the first design in this study. Transmitters allowed for the collection of detailed information of movement behaviours horizontal and vertical to be collected with ease. For cryptic, arboreal geckos this information would otherwise be difficult to attain if relying only on regular searching techniques such as spotlighting. Future translocations of gecko should consider using radio-telemetry to collect invaluable information for future translocation management decisions.

Permits and Authorisations

MUAEC Protocol 13/71
"Dispersal of Green Geckos Following Translocation"
Approved Thu 22/05/2014 3:25 p.m.

National Doc Permit number 37031-FAU, File number NHS-12-03
This National permit is for use by trained Tonkin and Taylor staff and covers capture, handling, and relocation of NZ lizards across the Auckland Region, including Hunua Quarry.

Acknowledgements

First and foremost, I would like to thank my supervisors Dianne Brunton and Manu Barry for their time and guidance over the past two years. Thank you Manu for your extensive herpetofauna knowledge and experience that has been invaluable to this study. As well as always having plenty of help in terms of theses and papers that could point me in the right directions. Thanks to Winstone Aggregates for providing the funding and means for this project, in particular Keith Barber, for your extensive help out in the field. Big thanks to all of the team at Tonkin & Taylor, Graham Ussher, Matt Baber, Duncan Law, Keiran Miller, Caleb Sjardin, and Megan Young for their support and extensive help not just with spotlighting but also sharing of knowledge, experience and enthusiasm during the early hours of the morning. Thank you to Carey Knox and Jo Monks for their correspondence with gecko harness design, their studies greatly influenced the process of this one. Thanks to Aaron Palmer for all your help in the field as well as technical help with field gear, help in the lab and with statistics using R. Thanks to Adam Smith for his extensive help with R and giving me the tools to progress my own knowledge. Thank you to all my volunteers- Esther, Bailey, Harry, Liam, Jill, Liz, Wesley, Kelsey, Anja, Mark, Mum and my two biggest helpers Dad and Carl who came out on multiple trips day, night, and weekends to help me get the work done at the quarry. Thanks to my amazing friends and colleagues from Massey, Monika, Natasha, Eli, Michael, Faline, Serena and Ewan for the weekly lunch dates, as well as their support through some, if not all of this journey. Special thanks to Faline for generously helping me with R in her spare time. Biggest thanks to my family for being such a great support during my time studying as it hasn't been easy. Last but not least, thank you to Carl, my partner,

number one volunteer, and biggest cheerleader and support particularly the last two and a half years of study. I don’t know what I would have done without you.

Contents

List of figures

List of plates

List of tables

List of Appendices

Chapter One

Introduction

1.1 **Introduction**

1.1.1 New Zealand Herpetofauna

Basic biological information such as habitat use and behaviour are crucial to manage and conserve native species. (J. M. Hoare, Melgren, & Chavel, 2012). There are currently over 80 species of reptile known in New Zealand, however for the majority there is a lack of basic biological information (Hare, Hoare, & Hitchmough, 2007; Romijn, Nelson, & Monks, 2013). The diversity of reptiles in New Zealand is high compared to other temperate areas in the world (Cree, 1994). However, almost half the herpetofauna are listed by the IUCN as endangered, threatened or rare (D. R. Towns & Daugherty, 1994). New Zealand reptiles have low annual reproductive output (Cree, 1994), which makes them susceptible to pressures such as predation and habitat loss (Baling et al., 2013). New Zealand geckos are classified into two genera of *Naultinus* and *Hoplodactylus* (Chambers, Boon, Buckley, & Hitchmough, 2001) with 7 and 22 described species respectively. Preliminary mitochondrial DNA sequencing suggest that as many as 20 additional species exist but have not been taxonomically classified (Nielsen, Bauer, Jackman, Hitchmough, & Daugherty, 2011). A unique feature of New Zealand geckos is that they are all viviparous (Cree, 1994). The high account in geckos is particularly unusual; aside from one gecko species in New Caledonia they are the only viviparous gecko species in the world (Chambers et al., 2001; Cree, 1994).

1.1.2 Distribution- Past and Present

Since the arrival of humans to New Zealand, there has been a dramatic effect on the native fauna. Over-exploitation, deforestation and introduced predators have all had devastating effects on the wildlife of New Zealand (D. R. Towns & Daugherty, 1994). There is evidence to suggest considerable range restrictions when comparing current distributions with sub-fossils of tuatara (*Sphenodon* spp.), Duvaucel’s gecko (*Hoplodactylus duvaucelii*) and Whitaker’s skink (*Oligosoma Whitakeri*) (Joanne M. Hoare, Pledger, Nelson, & Daugherty, 2007). New Zealand’s oldest known reptile, the tuatara were once abundant and widely spread throughout New Zealand, now primarily survive on off-shore islands (Daugherty, Patterson, & Hitchmough, 1994). This is a common occurrence as over 40% of New Zealand herpetofauna are restricted to or entirely on off-shore islands (Daugherty et al., 1994). Many species only survive the mainland due to their habitat choices of rocky crevices that suffice as refuges from predators (Daugherty et al., 1994).

1.1.3 Threats

During the 1800's new predators were introduced to New Zealand to herpetofauna that had only ever been exposed to predation from birds and other reptiles (D. R. Towns & Daugherty, 1994). This led to a lack of predator awareness, further aggravating the problem (Joanne M. Hoare, Pledger, Nelson, et al., 2007). Rodents in particular have caused world-wide extinctions, range restrictions, and decline of endemic fauna as they are very effective invaders (Joanne M. Hoare, Pledger, Nelson, et al., 2007). New Zealand reptiles are particularly susceptible due to their longevity and low reproductive rates (Joanne M. Hoare, Pledger, Nelson, et al., 2007).

Many species of geckos co-exist with rats however it cannot be confirmed whether this is because a) gecko recruitment is reduced by rats but sufficient for population survival, albeit at lower densities, or b) gecko populations are being driven to extinction by the predation of rats (Joanne M. Hoare, Pledger, Nelson, et al., 2007). In many off-shore island cases in New Zealand, it has been shown that post-eradication of rats, sightings of reptile species increase (Joanne M. Hoare, Pledger, Nelson, et al., 2007), as well as increases in densities and reproductive success (D. R. Towns & Daugherty, 1994). Co-existence of reptiles and rats is possible if the reptile species largely occupies a different habitat to rats or changes their behaviour in the presence of rats (Joanne M. Hoare, Pledger, Nelson, et al., 2007; D. R. Towns & Daugherty, 1994). For example, avoiding microhabitat of rodents that they would otherwise occupy in the absence of rodents.

1.1.4 Translocation

Many endangered species are threatened with habitat degradation, predation and changing climates. Translocation of populations to habitat that is at a lower risk from these factors has become a widely used conservation management technique (Ebrahimi & Bull, 2014; Miller, Bell, & Germano, 2014). New Zealand has many endangered wildlife that are actively managed through various translocations to both predator-free or predator-controlled off-shore islands, and mainland sanctuaries (Nelson, Keall, Brown, & Daugherty, 2002; Van Andel, McInnes, Tana, & French, 2016). The first conservation translocations in New Zealand were Richard Henry's as he tried to establish Kakapo and Kiwi on islands in the Dusty Sound (Armstong & McLean, 1995).

All translocations in New Zealand are done either directly by the Department of Conservation (DOC) or by local community groups under the guidance of DOC, and all translocations must follow DOC guidelines (Van Andel et al., 2016). The success of translocations depends on translocated individuals remaining in the area of release so a breeding population can be established (Ebrahimi & Bull, 2014; C. D. Knox & Monks, 2014). Translocation success also relies on the distribution of resources at the site and the numbers of individuals released. Releasing large numbers may increase the chance of some animals surviving to establish the population, however may create adverse effects as it increases the competition of resources and could force dispersal (Ebrahimi & Bull, 2014).

It is difficult to assess the success of a translocation and what exactly constitutes 'success' (Dodd & Seigel, 1991; Miller et al., 2014). Many follow the assumption that a translocation is a success if there is proof of a self-sustaining population. However, due to the longevity of many reptile species it can be many years before it is clear if the population is self-stained (Dodd & Seigel, 1991). To determine the success of populations, following translocation, requires long-term monitoring of the site and can be costly to conduct (Burton & Rivera-Milan, 2014; Miller et al., 2014). Failed or uncertain outcomes of translocations are less likely to be published than those considered successful (Miller et al., 2014). Results of translocations are also more likely to be published if the reason for research is conservation and research compared with mitigation translocations (Miller et al., 2014).

The two main methods of conserving *Naultinus* species are intensive pest control at mainland sites and translocations to off-shore islands (mammal-free) (Hare et al., 2007). The most common problems with reptile translocations is individuals dispersing after release (C. D. Knox & Monks, 2014). This can affect the success of the translocation as individuals may fail to find a suitable mate, or move to less suitable habitat (Ebrahimi & Bull, 2014).

Reptile translocations have received less attention to the likes of mammals and birds. Due to low success rates in the past, it has been suggested that reptiles are not suitable for translocation (Dodd & Seigel, 1991; Germano & Bishop, 2009; C. D. Knox & Monks, 2014). Although success rates have increased over the past decades, there has been suggestions that increasing site fidelity would result in even greater success (C. D. Knox & Monks, 2014). One type of release method is the ‘soft’ release which generally entails a period of confinement to limit dispersal, coupled with artificial retreats and/or food supplementation (Hardman & Moro, 2006). The other type of release most often used is the ‘hard’ release which consists of the immediate release of animals into the wild with no provisioning of any kind (Hardman & Moro, 2006).

Using an enclosure or barrier has also been shown to be an effective tool to prevent dispersal (C. D. Knox & Monks, 2014; McCoy, Osman, Hauch, Emerick, & Mushinsky, 2014). Generally, the longer the time spent in an enclosure, the higher the rate of survivorship, lower distance of dispersal from site, and release site fidelity increases (Attum, Otoum, Amr, & Tietjen, 2011). The dispersal away from the release site can result in higher individual mortality. Releasing animals just before periods of hibernation or low rates of activity can increase the success of the translocation as they are less likely to disperse during these times regardless (Attum et al., 2011).

1.1.5 Green gecko ecology

Green geckos (*Naultinus spp.*) are highly cryptic, arboreal, long-lived species that are found in various locations throughout New Zealand (Hare et al., 2007; Wilson & Cree, 2003). The genus *Naultinus* is one of only two genera within the family Diplodactylidae that are diurnal (Hare et al., 2007). Once widely spread through the country, the populations have suffered reductions due to habitat loss, predation and poaching. Due to the fragmented nature of the mainland populations it is likely there is very limited gene flow, further implicating the decline of the species (Hare et al., 2007). There is no data on longevity in wild populations of *Naultinus* species, however in captivity *N. manukanu* and *N.stellatus* live for 30 years and 47 years respectively (Hare et al., 2007). The cryptic nature of *Naultinus* species has meant there is little information known of their basic ecology making conservation management difficult (Hare et al., 2007; Jewell & McQueen, 2007). The lack of information is particularly scarce for mainland populations although there is evidence to suggest the species are declining. Certain wild populations of *Naultinus* have been studied for substantial time periods (Gartrell & Hare, 2005; Joanne M. Hoare, Pledger, & Nelson, 2007; Jewell & McQueen, 2007; Carey D. Knox, Alison, & Seddon, 2013).

Hare et al. (2007) used results from 25 years of research on Marlborough green gecko (*Naultinus manukanus*) on mammal-free Stephen’s Island to examine their ecology and behaviour. Methods included mark recapture, telemetry, population census and captive rearing juveniles. The green geckos on Stephen’s Island are the largest known population of *N.manukanus.* Coastal shrubs *Olearia paniculata* and *Ozothamnus leptophyllus* were frequented most often (Hare et al., 2007). However this habitat preference cannot be directly compared with mainland populations as *N.manukanus* populations are not always confined to coastal areas. The observed method of foraging was a sit and wait technique rather than actively seeking out food resources (Hare et al., 2007). The geckos that inhabit the island have a sex bias of 1:1.7 m:f (Hare et al., 2007). It was observed that during the day geckos were most likely found on the edge of foliage basking. Geckos used the full range of habitat from top of the foliage to the grasses at ground level. However, the ground was thought to be used more as a means to travel between shrubs rather than a preference of habitat (Hare et al., 2007).

Geckos were not found to use refuges during their inactive period unlike many other species (*Hoplodactylus*). Rather they appeared to be in the position they happened to be when the sun went down or retreated slightly into foliage (Hare et al., 2007). This may leave them exposed to nocturnal predators such as rats, cats and owls. Predation and the low reproductive output of this species leaves them in danger of further population decline (Carey D Knox, Cree, & Seddon, 2012). This is particularly true for mainland populations as many off-shore islands are mammal-free, thus eliminating the threat of introduced predators (Hare et al., 2007).

1.2 Aims

1. To assess the effectiveness of penned releases for the short-term establishment of a population of Auckland green gecko in the Hunua Ranges.

2. The second aim of this study was to investigate habitat use, movement patterns and increase our knowledge of behaviour and ecology of Auckland green geckos.

1.3 Thesis Structure

Chapter One- Introduction
A general introduction to New Zealand herpetofauna is discussed. Threats to geckos in New Zealand as well as translocation is reviewed. Green gecko ecology is introduced. The aims and thesis structure of this project are outlined.

Chapter Two- Study Site and Methods
The study site is introduced with history of resources and settlement. Detailed accounts of all methods used throughout this study are included in an overall methods chapter. However statistical analysis is tailored for each individual chapter. All chapters are interlinked in their information, thus a general methods chapter covering all methodology is included. However specific but brief methods are included at the commencement of each individual chapter; making a small degree of repetition inevitable.

Chapter Three- Translocation
The methods and results of the salvage effort are reported along with the results of the populations general dynamics and morphological significances. Appropriate graphical representation of data is presented.

Chapter Four- Radio-telemetry
The processes of the penned and hard release are discussed and the repercussion of results for both release groups. Limitations of harness designs and tracking methods are discussed. Results of tracking including minimum convex polygons and kernel estimates are produced along with appropriate graphical representation of data.

Chapter Five- Pest control and monitoring methods
Rationale for pest control is discussed and outcomes of six-week intensive pest control methods. Post-release monitoring methods that were tried and tested are discussed with reference to limitations as well as outcomes.

Chapter Six- Summary
Conclusions from the findings in this study, including the limitations. Recommendations for future research on Auckland green geckos including conservation management tools, with particular interest in translocation.

Chapter Two

Study Site and Methods

1.4 Study Site

1.4.1 Hunua Ranges

The Hunua Ranges covers approximately 96 square miles of forested land, south-east of Auckland between latitude 37º and 37º 20´ (Barton, 1972). To the east the ranges reach the Firth of Thames, the north the Tamaki Strait, to the south the Mangatangi River, and to the west the Wairoa River (Barton, 1972). The forest is made up of five main types: tawa-podocarp (*Beilschmiedia tawa; Podocarpus spp.)*; kauri (*Agathis australis*); hard beech (*Fuscospora truncate*); tanekaha (*Phyllocladus trichomanoides*) forest; taraire (*Beilschmiedia tarairi*); montane scrub above 2000 ft. in altitude; and some pockets of coastal forest found below 300 ft. altitude (Barton, 1972).

Before European settlement in the 1860s, there was a significant population of Maori in the lowland areas surrounding the ranges (Barton, 1972). Many introduced mammals were present in the ranges during the time of settlements such as pigs, goats, cattle, possums, cats, stoats, hares and rabbits (Barton, 1972). However, many of these species were successfully eradicated from the forest (Barton, 1972) with the exception of stock animals on private farm lands. The clearing of the forest began with the arrival of Europeans with much of the land considered too steep for farming burnt and felled (Barton, 1972).

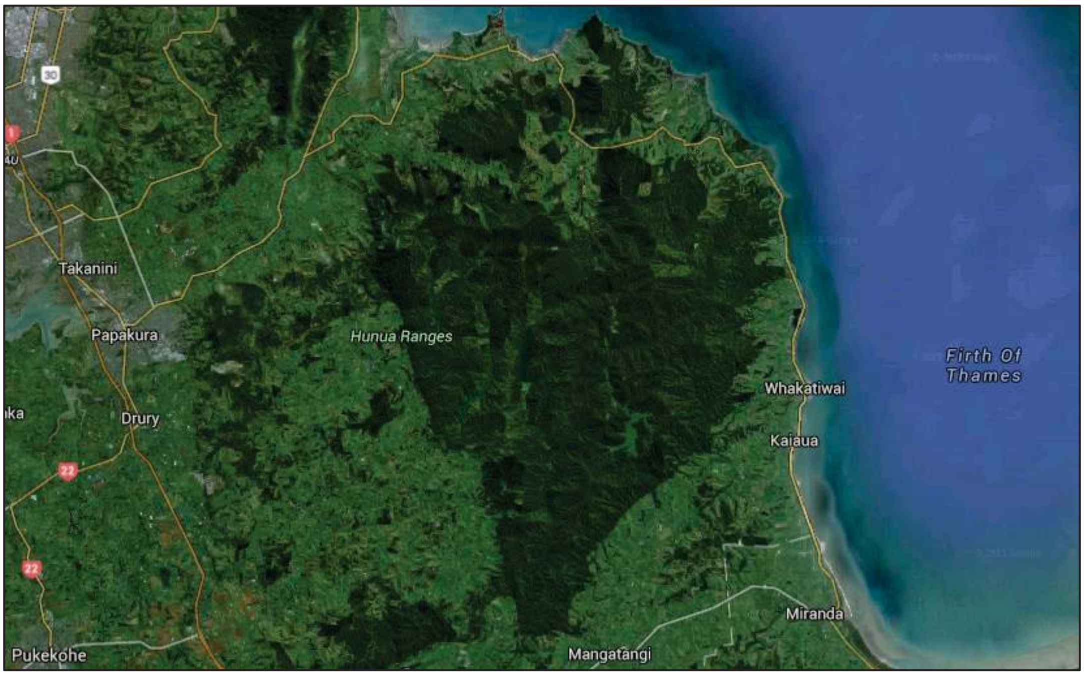


Figure 1. Satellite view of the Hunua Ranges South East of Auckland in relation to Auckland suburbs and the Firth of Thames.

1.5 Methodology

1.5.1 Establishment of study site

The study was carried out at two sites located in the Hunua Ranges, south-east of Auckland. All field work for this study was done at Winstone Aggregates quarry as part of a mitigation project that required the removal of Auckland green geckos (AGG). The translocation site was the area of forest that had been permitted to be felled for a new quarry pit where a substantial AGG population had been found during initial survey efforts. The release site (known as Hay-paddock) is also located on quarry property < 2km from the translocation site. The release site was chosen in 2007 by herpetologists from Tonkin & Taylor based on the location and regenerating forest structure that could sustain a growing gecko population. This was established, prior to the involvement of Massey for the 2014 translocation.

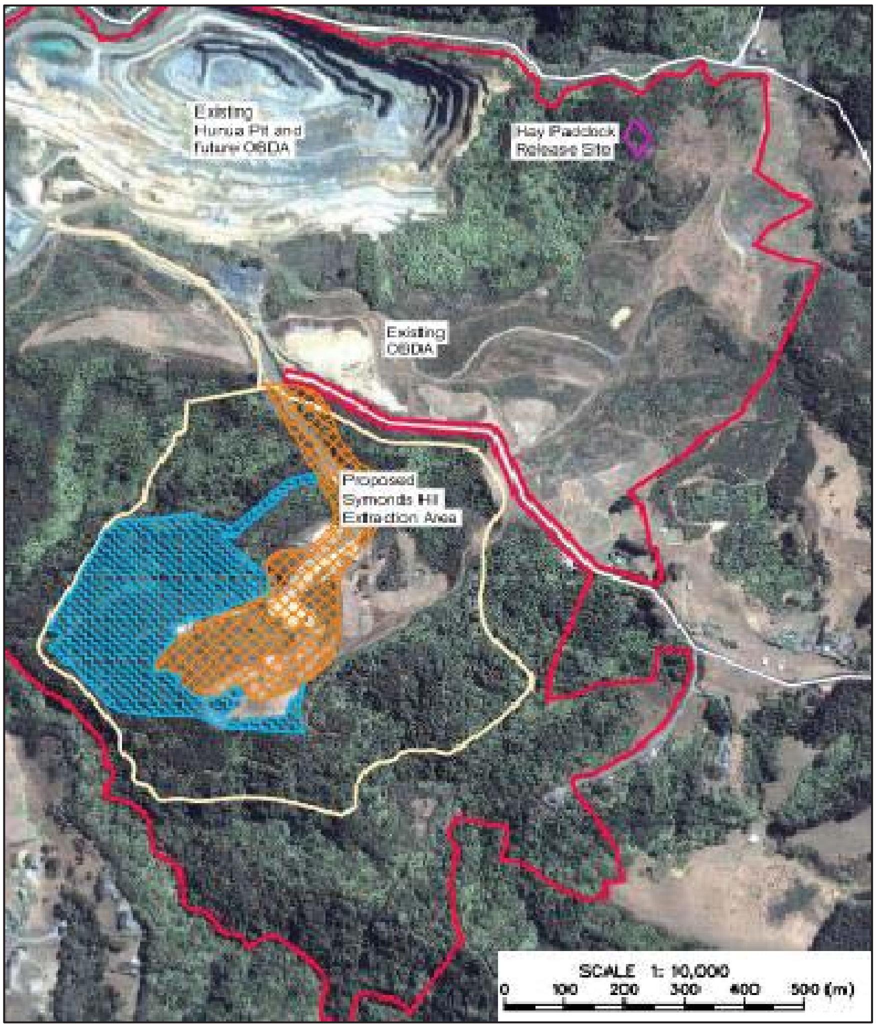


Figure 2. Aerial map of Winstone Aggregate Quarry. White outline indicates the proposed quarry pit; gecko search area is indicated by orange; second stage gecko search area indicated by blue; purple outline indicates the release site also known as Haypaddock.

This study set out to establish the effectiveness of a penned vs. hard release for Auckland green geckos. It has been shown in previous studies that using an enclosure for a pre-determined length of time to allow animals to habituate to the site improves translocation success (Attum et al., 2011; C. D. Knox & Monks, 2014). A small barrier was erected, made from black polythene plastic, 0.5m in height and approximately 1600m² to act as an enclosure for geckos released.

Plate 1.The 0.5m fence used to surround the penned release area as a barrier. Made from black plastic and positioned around the entire soft release area. All vegetation on both sides was cut away to prevent escape over the fence.

1.5.2 *Spotlighting and Translocation*

Night searches were conducted during the late summer-early autumn months of 2014. Each night between 2-8 searchers of various experience would search the outlined area for 3-8 hours. If a gecko was spotted the tree height, species, and height of gecko perch would be recorded (m). If possible to reach gecko, branches would be cut with a hand saw. Alternatively, the whole tree would be felled to capture the gecko. The time, date and G.P.S location was recorded and the gecko placed either in an aerated plastic container with foliage, or in a cotton capture bag with foliage. The geckos caught would then be translocated by vehicle to the release site at the end of the night.

The first calendar week of searching focused on edges of forest and interior bush. Following the first week, transect lines were cut throughout the focus area. Lines were cut 50m apart and 5m wide for the second week of searching. Each week, the lines were cut back each side to widen them so forest that was previously interior canopy would then be fresh edge to search. This method of cutting back continued until the last of the forest was felled following the last night of searching on March 31st 2014.

1.5.3 Handling and measuring procedures

Processing of geckos consisted of recording all morphological measurements. Using a digital pocket scale with a plastic cup to hold the gecko, weight (g) was recorded. A standard 30 cm ruler was used to record (mm) snout-vent-length (SVL), vent-tail-length (VTL), head width and tail width. Colouring and markings were noted including any scarring or injuries. If the gecko had a regenerated tail the length (mm) was recorded. Regenerated tails are those that have grown back after an individual drops its original tail as a defence against predators. Each gecko was given an I.D which was written on the underside of the gecko in xylene free permanent marker pen. Photos were taken of the dorsal surface of each gecko to document individual markings.

Plate 2. Auckland green gecko being weighed using a plastic cup and electronic weights during processing.

1.5.4 Transmitter attachment and release

Transmitters could not be more than 6% body weight of any gecko, hence many geckos were not suitable for transmitted release due to their size. Geckos that were not suitable for transmitters were released the same night of capture into the Hay-Paddock penned area. The release location of each individual was documented with GPS. Gravid (pregnant) females were also not used as they were not covered in the animal ethics of this study as they are already carrying significantly more body weight than usual. The majority (86%) of transmitted geckos being male.

Geckos suitable for transmitters were held on site in containment for up to 3 days until a reasonable number of geckos that were appropriate had been caught. Those held in enclosures were given fresh food (flies) and water every day. Due to this study only using a barrier as a means of 'soft' release, the term 'penned release' will be used in favour (C. D. Knox & Monks, 2014).

Initially a harness design was used that consisted of a green coloured stretch sports wrap bandage coupled with self-adhesive tape to attach transmitter to harness (Plate 3). This had previously been used by Massey University with Duvaucel's geckos (*Hoplodactylus duvaucelii*). After using the design on the initial geckos released with transmitters it was realised the design was not suitable for the much smaller green gecko due to their smaller size and more sensitive skin. It also did not have any self-adhesive attaching the harness to the body of the gecko and so had to be applied in such a way that the gecko could not wriggle free of the harness.

Plate 3. Auckland green gecko wearing the original harness design using non-adhesive green bandage material.

The second harness design comprised of a long strip of USL hypoallergenic self-adhesive tape 16cm long and 3mm wide following recommendations by Knox & Monks 2014 (Plate 4). The strip of tape was coloured green for camouflage with xylene free marker. The strip was then used in a 'backpack' style that went over each shoulder, crossed over on the chest then wrapped around and held in place the transmitter on the dorsal side of the gecko between the two shoulder blades. Geckos were handled for a maximum of 15 minutes throughout this study as per approved protocols by the Massey University Animal Ethics Committee. If any signs of stress were shown such as breathing heavily and/or panting then geckos were immediately put in a catching bag, plastic holding container or back into their enclosures. The transmitters used were R1614 (0.3g) with 15 ppm (45 day life) and R1612 (0.2g) with 15 ppm (22 day life). Mobility of gecko was checked for full range of movement prior to release. Geckos were then either released in the penned area of the Hay-paddock, or just outside the pen as a non-penned (hard) release.

Plate 4. Male Auckland green gecko wearing the second harness design made using self-adhesive hypo-allergenic sports tape coloured green with xylene free marker.

1.5.5 Tracking

Individuals were tracked up to three times on the first day of release every 3-4 hours. Geckos were then tracked every 1-3 days from then on with 3-4 hours between each track with up to four tracking points a day. With each location point tracked the date, time, GPS location, plant species, height of plant (m), and approximate height of gecko (m) were recorded for each individual. Weather conditions and approximate movement from last known point were also recorded.

Plate 5. Radio tracking of transmitter released Auckland green geckos (Naultinus elegans elegans).

At least one night of tracking was conducted for each individual. However, because *Naultinus* species are diurnal and no movement was observed during the nights tracked, no extra night tracks were deemed necessary. Tracking for each individual gecko was between 1 day to 4 weeks. This depended on the transmitter efficiency as in some cases the transmitter failed or the backpack fell off after only a few days. If possible, transmitters were changed when the current transmitter being worn had approximately 20% battery life remaining. The new transmitter frequency was recorded, and the gecko would be released back to the location of capture.

1.5.6 Subsequent Search Efforts

Geckos were left undisturbed from mid-winter in 2014 until January 2015. This was to give individuals enough time to settle and form territories. Subsequent night searching effort was done from January 2015 and is ongoing as part of the post translocation monitoring. A combination of night time spotlighting and day searches comprising 70 person hours were done in an effort to re-sight geckos. Any geckos that were found were measured and weighed for identification and indication of changes in body condition since release. The geckos that were re-captured were released with UV fluorescent powder covering the ventral side of the gecko in an attempt to track their short term movements.

Due to the low numbers being sighted during these initial searches of the release site, two methods were attempted to a) show geckos were in fact present using black trakka tracking tunnels in the trees and b) attempt to capture them using funnel traps baited with mashed banana and honey. Tracking tunnels were made out of clear plastic cups that had the bottoms cut off to create a tunnel. Tracking card paper was taped onto the inside with ink on both sides and a small cap in the centre filled with mashed banana and honey to entice geckos to walk through the tunnel.

The funnel traps baited with mashed banana and honey were first tested on captive green geckos to test if individuals could be lured into traps. A gecko was found within the trap in the first 24 hours of testing so field use went ahead. Funnel traps were placed at the release site in trees that were last known locations of individuals. Tunnels were made out of plastic piping and cut to 30 cm long with wire mesh at each end fashioned into the funnel shape. The mesh ensures geckos can go in but have difficulty getting out. Tunnels were baited with mashed banana and honey.

1.5.7 Pest Control

Winstone Aggregates has pest control measures in place around the quarry site including traps and baits. However, on one occasion during the search effort in 2015, rodent excrement was found inside the penned area on a funnel trap that was set for geckos. Because of this finding, intensive rat trapping around the penned area was done over a six-week period to increase the success of the establishing gecko population. Ten DOC 250 traps were set using peanut butter as bait. They were placed in areas where rodents would be likely to frequent such as along the fence line and forest lines (Figure 12). Traps were checked over three consecutive nights each week during the six-week period.

In conjunction with the rat traps, tracking tunnels baited with peanut butter were also set up in the area to establish the presence of predators that may not be caught in traps (Figure 12). All tracking cards were changed once a week and documented as to which tunnel on site the card came from. All prints found were examined and species identified by the prints.

Rodents that were trapped and killed were taken immediately to be frozen for preservation on site at Massey University. After the six-week period of trapping was complete, all rodents trapped were thawed and dissected. Each individual was identified in terms of species and sex where possible. Particular interest was paid to the intestinal tract to look for any signs of bait that had been eaten prior to the death of the animal as an interest of Winstone Aggregates following baiting in the area (Plate 6).

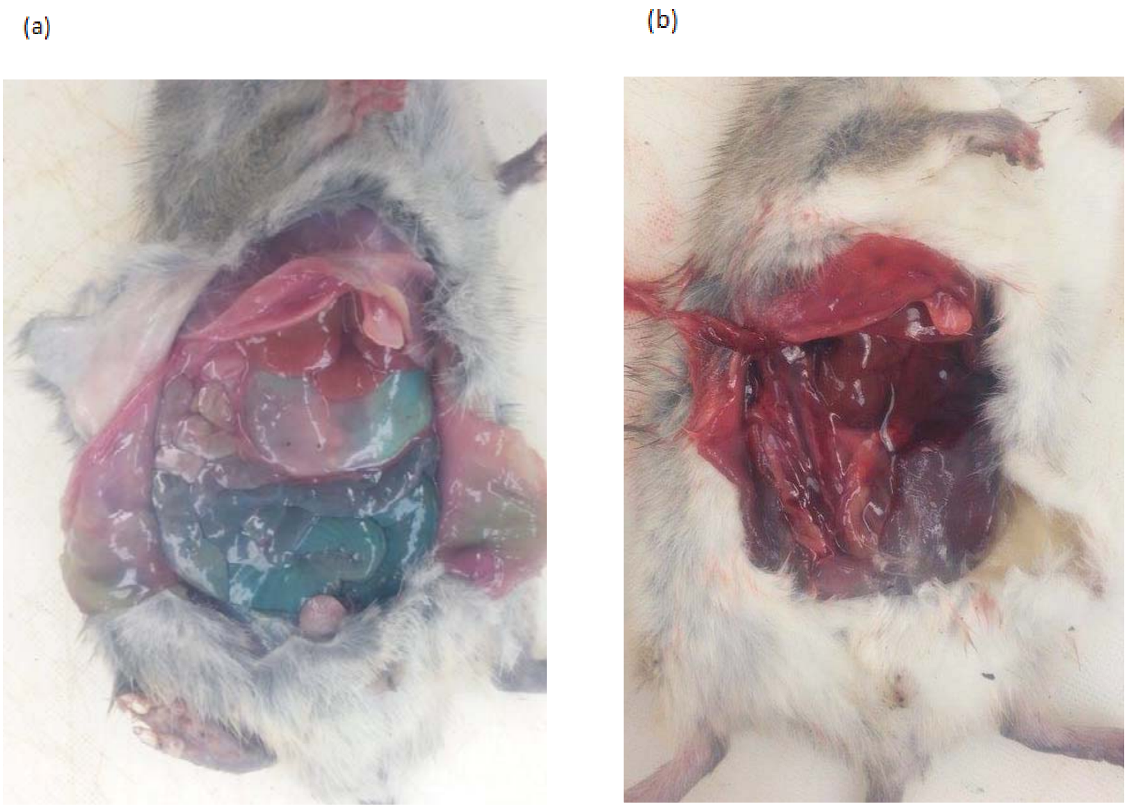


Plate 6. Comparison of intestinal colouration between two rats. (a) has ingested bait with abnormal colour, (b) normal colour of tract.

1.5.8 Relevant permits and authorisations

MUAEC Protocol 13/71
"Dispersal of Green Geckos Following Translocation"
Approved Thu 22/05/2014 3:25 p.m.

National Doc Permit number 37031-FAU, File number NHS-12-03
This National permit is for use by trained Tonkin and Taylor staff and covers capture, handling, and relocation of NZ lizards across the Auckland Region, including Hunua Quarry.

1.5.9 Statistical Analysis

Software packages used for the analyses in this thesis include R x64 3.2.2 as well as Ranges 9 v1.7, Microsoft Excel 2010, IMS SPSS Statistics 23.0. All statistical analyses were conducted using $p \leq 0.05$ as a level of significance. All tests conducted and respective outputs are detailed in the specific chapters.

Chapter Three

Translocation

1.6 Introduction

Translocation of animals is a common practice in conservation management (Attum et al., 2011; Baling et al., 2013; Besson & Cree, 2011; Griffith, Scott, Carpenter, & Reed, 1989). Moving a population of wild animals to a former range or habitat is done for many reasons including ecological restoration, moving to a less predator dense area, or in this case to move a population before deforestation of habitat (Griffith et al., 1989; McCoy et al., 2014). Translocations of reptiles have been known to have low success rates (Ewen, Soorae, & Canessa, 2014; McCoy et al., 2014; Miller et al., 2014; Nelson et al., 2002; Seddon, Strauss, & Innes, 2012). There are many factors that are involved in making a translocation successful but the main goals are generally the same; high survival rates of translocated individuals; settlement at the release site and the ongoing breeding and recruitment of the population (Parker, Dickens, Clarke, & Lovegrove, 2012).

Translocations of blue iguanas found that over a three year period, the population density was unchanged despite individuals being released between annual surveys (Burton & Rivera-Milan, 2014). Due to the lack of evidence for mortality within the study site, dispersal away from the release site is more likely the main factor in the unchanging densities. The results raise questions for reptile translocations whether containment in the study site should be included in translocation plans for a more successful outcome (Burton & Rivera-Milan, 2014).

To increase the chances of establishing a breeding population, important factors include the quality of habitat at the release site, number of individuals released, and on-going post-release monitoring programmes (McCoy et al., 2014). Monitoring however, can be exhaustive on resources and in some cases, exceed the duration for grants or other programs involved in the management (Burton & Rivera-Milan, 2014; David R. Towns & Ferreira, 2001). Distance sampling has been argued to be ineffective in some reptile cases where the method requires that all individuals present are available for detection (Burton & Rivera-Milan, 2014). In many cases, as with the cryptic green gecko species; this method is a problem as many if not the majority of individuals are not in plain sight. Mark-recapture has been shown to be more effective when dealing with species whose behaviour is not suited to distance sampling (Burton & Rivera-Milan, 2014). However, mark-recapture can be costly and is better suited to smaller study sites.

As with green geckos there is no technique that has been tested that successfully marks the animals long-term that does not either cause unnecessary harm to the animal or methods used are only temporary such as writing on their skin because they shed. Techniques used with other reptiles include blue iguanas which can have their nuchal crest pierced for an effective longer term marking that can incorporate using coloured beading on wire to identify an individual (Burton & Rivera-Milan, 2014).

1.7 Methodology

Night searches took place during February and March of 2014 at the Winstone Aggregates quarry. Searching was dependant on weather. For optimal search conditions, no rain and little wind is necessary. A total of 18 nights were completed with 2-8 searchers present each night. Spotlighting would only commence after the sun went down with a range between 3 and 8 hours of searching each night. The area of focus was searched along its edges as well as internally during the first three nights of search effort. After the initial nights of searching, transect lines were cut over the weekend approximately 50m apart and 5m wide throughout the search area consisting of 7 hectares. The following week, searching continued and included the new edges created by the cut transect lines. Transect lines continued to be expanded every weekend until all the forest was eventually felled. The number of nights searching took place each week ranged from 1 to 4 due to being heavily dependent on weather conditions. The data recorded for each gecko caught included height and species of tree (m), height of gecko (m), time, date and GPS of location.

Once geckos were caught they were kept in cotton catching bags or aerated plastic containers with foliage. Following the end of the nights' search, the geckos found would then be transported by vehicle to the release site known as Hay paddock. The basic body measurements were taken of each gecko including weight (g), snout-vent-length (mm), vent-tail-length (mm), head width (mm), tail width (mm) length of regenerated tail if applicable (mm); scars, markings and colourations as well as reproductive status i.e. gravid, non-gravid, juvenile, adult. After processing geckos were either released into the penned site or held in outdoor enclosures awaiting transmitter attachment and release.

1.7.1 *Statistical analysis*

Students t-tests were used to statistically analyse the morphometric differences in the data, particularly with focus on males vs. females. All test results given have used a $p \leq 0.05$ significant level. A table of search effort is presented including the number of search personnel, hours per nights and number of geckos caught for each of the 18 spotlighting night efforts. Boxplots are presented displaying medians and range comparatively with male and female weights (g). Boxplots of male and female snout-vent-lengths (mm) displaying medians and ranges are also presented. A table of morphometrics including means and standard errors (SE) is produced comparative of sex and reproductive status. A scatterplot of weight (g) and snout-vent-length (mm) correlations is also shown. All statistical analysis and plots for this chapter were produced using R 3.2.2.

1.8 Results

1.8.1 Translocated population

In total there were 52 geckos caught during the search period in early 2014. 17 juveniles, 20 adult females (13 gravid), and 14 adult males. Geckos were considered juvenile if their weight was <4g. Two of the 52 geckos translocated were of the yellow morph-type, one adult male and one juvenile. There were 7 geckos with either no tail due to recent tail loss or a regenerated tail (13%). Of those two were juveniles, three adult females and two adult males.

1.8.2 Search effort

484 hours in total were spent spotlighting over a period of 18 non-consecutive nights equating to 0.11 geckos per person per hour searched. All bar one gecko was found on the bush edge rather than interior bush (0.52%). A total of 52 hours were conducted in interior bush (no fresh edges cut or tracks) equating to 0.02 geckos caught per person per hour. The majority of time was focused on bush edge along tracks or newly cut transect lines (432 hours) equating to 0.12 geckos caught per person per hour. 5 geckos were found but not caught due to either evading capture attempts or being in a position that was too dangerous to attempt capture.

Table 1. Search effort from every night searched including search areas and number of geckos caught each night.

Date	Number of search personnel	Search Areas	No. of hours searching	No. of geckos caught	Search effort (person hours)
Feb-17	8	3 people searched interiors, 5 people searched edges and tracks.	5	5	40
Feb-18	6	2 people searched interiors, 4 people searched edges and tracks.	7.5	2	45
Feb-19	7	3 people searched interiors (including interior track), 4 people searched edges and tracks.	4.5	2	31.5
Feb-24	6	Cut and mulched tracks.	7.25	2	43.5
Feb-25	7	Cut and mulched tracks.	5.75	8	40.25
Feb-26	7	Cut and mulched tracks.	5.5	3	38.5
Mar-03	6	Cut and mulched tracks.	5.5	2	33
Mar-04	6	Cut and mulched tracks.	4.5	2	27
Mar-05	4	Cut and mulched tracks.	5	2	20
Mar-06	2	Searched interior untracked site.	4.25	1	8.5
Mar-10	4	All tracked area and edges.	7	1	28
Mar-11	4	All tracked area and edges.	6	2	24
Mar-12	3	Searched western side tracks and edges.	5.5	1	16.5
Mar-18	3	Searched new Haul Road tracks.	5.5	3	16.5
Mar-19	3	Searched new Haul Road tracks.	6.5	5	19.5
Mar-22	4	Searched new Haul Road tracks.	5.75	3	23
Mar-26	4	Searched new Haul Road tracks.	4	4	16
Mar-31	4	Searched new Haul Road tracks.	3.25	4	13

During the search effort no other species of gecko or skink were seen. All geckos caught were found on kānuka (*Kunzea ericoides*). All were found in the foliage at the top of the tree aside from one gecko found on the trunk of a kānuka tree.

1.8.3 Gecko morphometrics

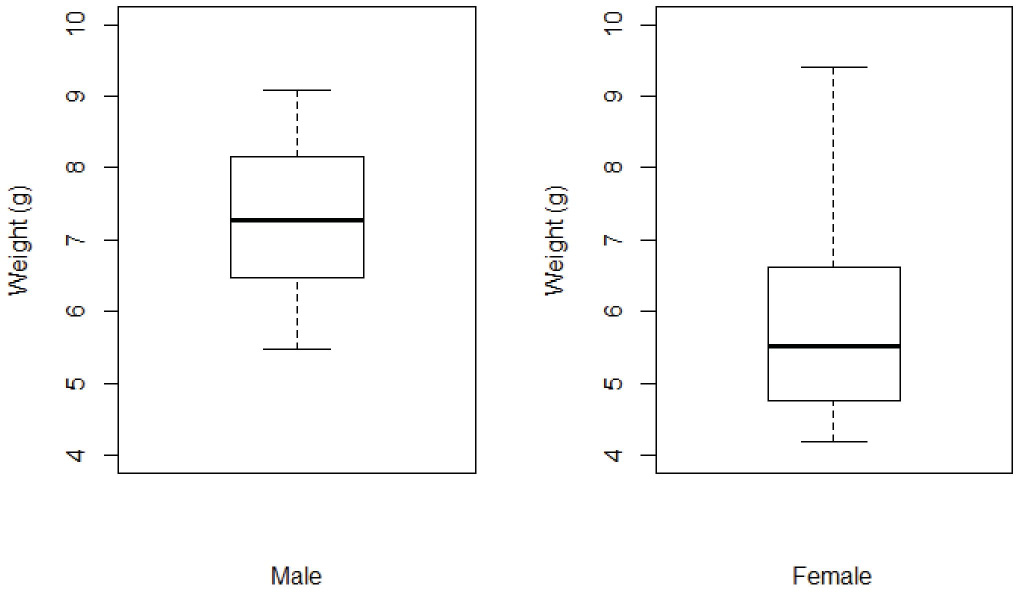


Figure 3. Male and female weight (g) of Auckland green geckos (*Naultinus elegans elegans)* shown comparatively as boxplots displaying medians and range.

Comparing the weight (g) of adult males and females, gravid females were excluded due to having extra body weight from carrying offspring. There was no significant difference between the weights of females and males (Student's t-test, $p=0.15$). The boxplots of the data (Figure 3) shows however the difference in variances between male and female weight, with females having a much larger range of weights than males.

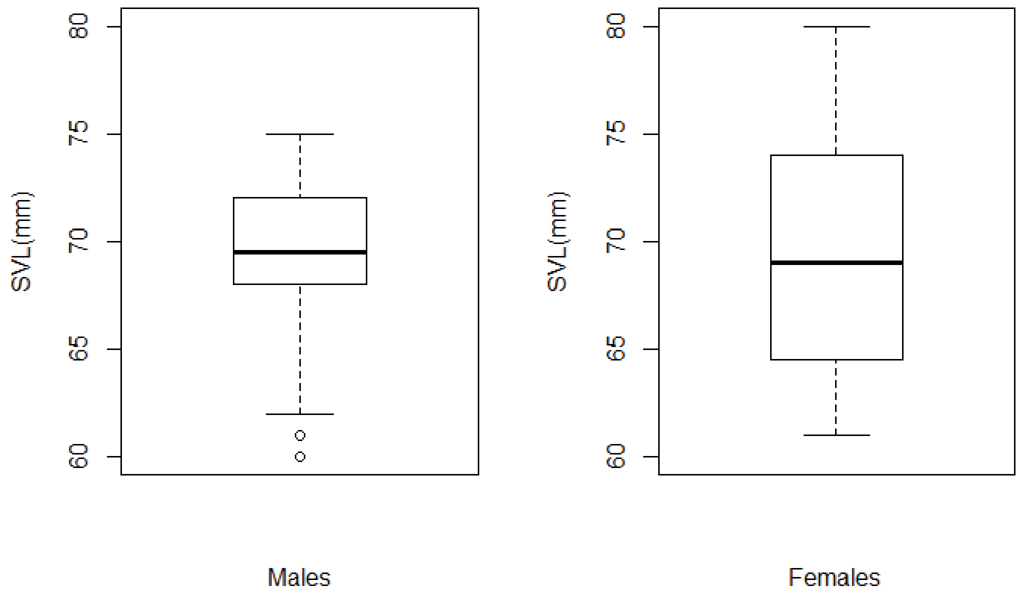


Figure 4. Male and female snout-vent-lengths (mm) of Auckland green geckos (*Naultinus elegans elegans*) expressed as boxplots displaying medians and range.

The snout-vent-length of adult males and females was not significantly different (Student's t-test, *p=0.64*). However, as with the comparison of weights, females have a larger variance of values than males (Figure 4). Males and females had similar averages for weight (g) and snout-vent-length (mm) but males had on average larger vent-tail-lengths than females; 86.12 mm and 80.13 mm respectively. More juveniles were caught then adult males or females alone. There were very little geckos caught within the weight range of 3.5g- 5g (n=2) making juveniles and adults easy to distinguish even without checking to see if juveniles could be sexed yet.

Table 2. Mean measurements and standard errors for all sex/reproductive status categories.

Sex/Repro status	Mean weight (g) ± SE	Mean SVL (mm) ± SE	Mean VTL (mm) ± SE	Mean tail width (mm) ± SE	Mean head width (mm) ± SE
Male	7.3 ± 0.29	68.7 ± 1.28	86.1 ± 2.82	5.9 ± 0.14	13.0 ± 0.19
Female (ALL)	8.3 ± 0.58	69.6 ± 1.33	80.1 ± 3.30	5.5 ± 0.23	13.2 ± 0.39
Female (Gravid)	9.4 ± 0.57	71.3 ± 1.21	84.7 ± 3.13	5.6 ± 0.31	13.6 ± 0.51
Female (Non-gravid)	6.0 ± 0.76	65.8 ± 2.91	70.3 ± 6.71	5.1 ± 0.27	12.3 ± 0.36
Juvenile	2.4 ± 0.12	48.2 ± 0.85	52.1 ± 4.39	3.4 ± 0.24	9.8 ± 0.20

Gravid females were significantly larger than non-gravid females (Students t-test, *p=0.004*). The smallest gravid female weighed in at just 5.25g and SVL of 76 mm and the largest at 11.92g with a SVL of 76 mm (Table 2). Females also had larger average snout-vent-length measurement when compared with males, 69.6mm and 68.7mm respectively (Table 2).

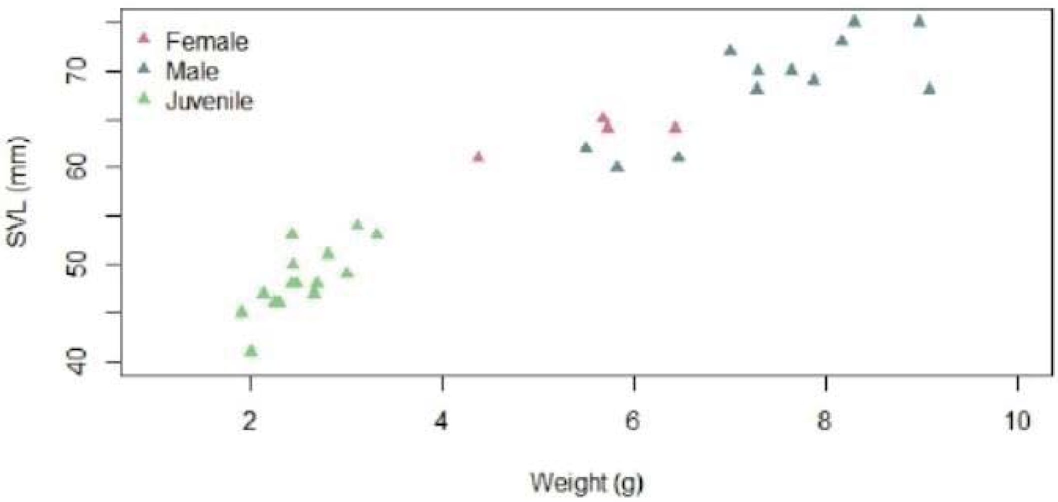


Figure 5. The correlation between weight (g) and snout-vent-length (mm). All gravid females were excluded from this analysis due to their weight being larger than normal. Animals with no tail or a regenerated tail were also excluded due to the impact it would have on weight.

There were statistically significant correlations between morphometrics. Weight (g) and snout-vent-length were strongly correlated (Pearson's, r= 0.96) (Figure 5). Gravid females and geckos with regenerated or no tails were excluded from the test. Snout-vent-length and vent-tail length also had extremely strong correlations (Pearson's, r= 0.95). Geckos with regenerated tails or no tails were excluded. Snout-vent-length (mm) and tail width (mm) had a slightly weaker correlation (Pearson's r= 0.802) including all individuals morphometrics in the test. Snout-vent-length (mm) and head width (mm) also had a slightly weaker correlation (Pearson's r= 0.856) including all individuals.

1.9 Discussion

1.9.1 Search effort, methodology and constraints

The number of geckos caught during this study (n=52) was greater than the previous on site during 2011 where 38 geckos were caught. Although 52 is a large number of geckos it is assumed that this is only a small portion of the total population that was in the search effort area. This is due to the fact that gecko catch numbers were not decreasing as time went on. Geckos were consistently being caught during the entire 18 non-consecutive night search.

Using the method of cutting transect lines through the area was established as a good method for spotlight searching from previous years of salvage at the quarry site. Searching along forest edge rather than interior gives the searcher a larger surface area of foliage to spotlight and is much easier to see geckos positioned on the edge than searching through interior bush. Although some interior search effort was conducted to test this theory, only one gecko was found using this method and as such the majority of the search effort was put into searching forest edge.

Cutting fresh edges was most likely a factor in the high number of animals caught as previous interior canopy would then be exposed for searching as forest edge. Although this method proved fruitful, because numbers never showed any signs of declining more time spent searching before each cut would have been beneficial. Due to time constraints a more flexible schedule was not possible. Spotlighting is also weather dependant; any rain or high winds make for less than effective searching and thus was also a constraint on time.

The capture rate of 0.11 geckos per person per hour searched was lower than that during the 2011 search of 0.26, however is similar to other search efforts in similar habitat in the region. The lower capture rate in 2014 could be a factor of less experienced searchers making up a large portion of the volunteers and man hours.

1.9.2 Habitat preference

Kānuka (*Kunzea ericoides*) was the only tree species that green geckos were found residing on. Kānuka makes up the majority of the canopy in the search area with a variety of sub-canopy species. Only one gecko was found on the trunk of a kānuka. This is in line with current data that Auckland green geckos are an arboreal species (C. D. Knox & Monks, 2014). Due to spotlighting happening at night no conclusions could be made about activity in relation to whether the species is strictly diurnal from the initial stages of the field work. Night searches are more effective for searching for green geckos in such large and established forests. The colour of their skin is much easier to spot under the light of a powerful torch than it is during the day with natural light.

1.9.3 Morphometrics

Males and females did not have significant differences in their weight or snout-vent-length. This could however be due to the small sample size in this instance as females had a larger range for both measurements. It is also difficult to decipher the gecko with the heaviest weight as the largest females were gravid so their weights cannot be directly compared with males. Males however did have larger mean values for vent-tail-lengths than females, 86.12 mm and 80.13 mm respectively. Although this has been seen in other species of gecko, the exact ecology reasoning behind males having larger tails is only speculated (Salvador, Martin, & López, 1995). One theory is that larger tail size is important for dominance position among males, therefore a larger tail means access to more females. Males and females could differ in their use of tails in terms of social structure as larger tails could be a factor with territorial males or the extra fat stores may be advantageous when searching for a mate. Overall there was no blatant evidence of sexual dimorphism within the Auckland green geckos found during this study.

The capture of such a high number of juveniles (n=19) is a good indicator that the founding population was breeding successfully and well established with a large range of sizes seen (1.34g-11.92g). Too many adults and few juveniles can show the presence of an aging population with little to no successful reproduction occurring. This could indicate factors such as high predation pressures, disease or illness, or low/declining population numbers affecting reproductive adults' ability to find a mate.

Gravid females were significantly larger than non-gravid females ($p=0.004$) which is to be expected due to the extra body weight they are carrying with offspring. Age could also be a factor as the non-gravid females tended to be smaller in size and possibly had yet to reach reproductive maturity. The time of year that the translocation took place (early months of 2014), meant that many females were gravid and would be giving birth to live offspring during the coming winter months. Translocating so many gravid females could give the founding population an advantage as the numbers would have grown with the addition of those unborn offspring, adding another generation to the population dynamic and a more diverse gene pool. The strong correlations between weight (g) and snout-vent-length (mm) (r= 0.96) and snout-vent-length (m) with vent-tail-length (mm), show the most reliable correlations using green gecko morphometrics to base body size from.

1.9.4 Measures of a successful translocation

Many reptile translocation fail, in part, due to a lack of clear criteria to warrant success or failure of goals set for the outcome of the translocation (Ewen et al., 2014; McCoy et al., 2014). McCoy et al, reviewed and adjusted six major criteria that should be considered to remedy these deficiencies. (1) develop clear goals and criteria for the achievement of the goals; (2) understand the species and the threats it faces at the donor site; (3) Ensure the quality of habitat at the release site; (4) long term monitoring; (5) test the approach employed and develop standardised techniques; (6) publish results, even if translocation fails (2014). During this study at least four of these criteria have been implemented. The goals for the translocation included: capturing as many geckos as possible to be released as the founding population; implementing a soft or penned release strategy shown to have slowed dispersal in other case studies; using telemetry to study the habitat preferences and behavioural patterns of those translocated to the release site; continue with long-term monitoring of the species to gauge the long term success of the population.

1.9.5 Population data

The donor site was known to have mammalian pests including possums (*Trichosurus vulpecula*), rats, and feral cats (*Felis catus)* as well as other pests such as mice, wasps and natural predators such as morepork (*Ninox novaeseelandiae)*. Despite this, the population was large and seemed to be surviving despite the presence of predators and pests. The evidence for this was firstly the large numbers that were caught during the translocation effort and numbers of those caught did not decline as time progressed. The majority of the females were gravid which indicated a healthy level of reproduction occurring as well as a substantial number of juveniles caught during the effort showing a healthy population age range.

1.10 Summary and conclusion

No geckos were found to be in bad body condition and with the majority of females gravid it was a good insight into the condition of the population. The time constraints on the field work were unfortunate as the unforeseen extent of geckos being caught was underestimated prior to spotlight searches commencing. Had there been a more accurate data available on approximate population size, more time and planning could have resulted in larger numbers being translocated before the vegetation was cleared. The small sample size meant that much of the data analysis was exploratory with low statistical power and would need further investigation.

The small portion of the population that was caught had exemplary circumstances to give the best chance of a successful translocation in long terms of successful breeding and a large range of individuals at different ages and reproductive status. Fairly even numbers of adult males and females, a large portion of juveniles and the majority of females being gravid are all advantages for this translocation project. The only way to get a true picture of translocation success however is the long-term monitoring of the release population. Generally, the approximate life span of the species is considered sufficient. In this case Auckland green geckos have been known to live for 30 years in captivity thus this part of the process is only a small snapshot of the lifespan for this species.

Chapter Four

Radio Telemetry

1.11 Introduction

1.11.1 Translocation and dispersal

In a recent review, success of reptile and amphibian translocations were found to be twice that reported in an earlier review in 1991 (Germano & Bishop, 2009). However, reptile translocations that were motivated by human-wildlife conflict have a higher failure rate than translocations motivated by conservation (Germano & Bishop, 2009). The most commonly reported problems with mitigation translocations were homing and dispersal behaviours post-release and poor habitat at the release site (Germano & Bishop, 2009).

Dispersal after release is one of the main problems with translocations (Attum et al., 2011). Animals that are hard-released without any previous acclimatisation to the area, frequently undergo linear long distance dispersal; due to either homing behaviours or being unfamiliar with the release site (Attum et al., 2011). One method that may limit dispersal from the release site is a soft-release (Attum et al., 2011). This can be either release just prior to a period of hibernation or the use of an outdoor enclosure to restrict movement for a predetermined period of time (Attum et al., 2011). The longer the time spent in the soft-release enclosure, the less movement that is seen from the release site, the increased site fidelity and increased survivorship (Attum et al., 2011).

1.11.2 Monitoring methods

It is important to identify monitoring methods that are reliable for post-release management of species (Burton & Rivera-Milan, 2014). The IUCN highlights the importance of post-release monitoring methods of conservation translocations (Scott Jarvie et al., 2014). However, detection and monitoring of cryptic herpetofauna is difficult, and there are only limited reliable methods (S. Jarvie & Monks, 2014; Romijn et al., 2013). Because of this, 41% of New Zealand's lizards are 'Data poor' and 4% are considered 'Data deficient' due to their rare encounters (S. Jarvie & Monks, 2014). Some management methods can be resources extensive and may be strenuous on time. Having methods of monitoring for Auckland green geckos that are known to give reliable results would be a huge benefit to the future ecological studies involving the species and other closely related species. Methods such as distance sampling and repeated counts are common among a range of taxa (Burton & Rivera-Milan, 2014), however may not be appropriate for some herpetofauna particularly arboreal, cryptic geckos. Besides spotlighting, traps such as funnel traps and minnow traps have been used successfully in capturing small, arboreal geckos (Davis, Fleming, Craig, Grigg, & Hardy, 2008; S. Jarvie & Monks, 2014). Baiting and types of bait used is also important and depending on the species correlates to what bait would be applicable (Davis et al., 2008).

Radio-tracking is a technique that has been successfully used to provide data on locations, estimates of survival, habitat use and movement patterns, from which home range sizes and utilisation patterns can be explored (Harris et al., 1990; Scott Jarvie et al., 2014; Romijn et al., 2013). Habitat use studies are important in determining which habitats need to be protected in order to assist in wildlife conservation (Attum et al., 2011). Knowledge of macrohabitat is important to lessen the effects of fragmentation and habitat degradation; whereas microhabitat is important for determining the important structures needed within the broader scale (Attum et al., 2011).

1.11.3 Minimum convex polygons and kernel density estimates

Minimum convex polygons (MCP) are widely used technique when estimating species range (Burgman & Fox, 2003). They are used to assess trends in occupied habitat and are an important part in the assessment of conservation internationally (Burgman & Fox, 2003). The MCP is the smallest possible convex polygon that encompasses all the known locations of an individual (Hayne, 1949). Some species, particularly herpetofauna, are known to use the same area repeatedly over time; a concept called home range used to define animal movements that has been fundamental in ecological studies (Nilsen, Pedersen, & Linnell, 2008). However, using the MCP method has been called into question due to the unpredictable and bias nature (Nilsen et al., 2008). Kernel density estimates (KDE) have been found to be much more accurate in calculating home range estimates compared with the MCP method (Nilsen et al., 2008). Nonetheless, many studies have presented their findings using the MCP methods. This is mostly due to the fact that many studies, including older studies have used this method and thus inter-study comparisons can be made (Nilsen et al., 2008).

1.12 Methodology

1.12.1 Harness design

Geckos that were suitable for transmitter released were kept in enclosures within the penned area until there were enough to release at one time so that the full first day post release could be adequately recorded. The second harness design was used for the majority of the study. It consisted of a long piece of self-adhesive, hypoallergenic sports tape that was coloured in green with xylene free marker. It measured approximately 3mm wide and 16cm in length. The transmitter itself was positioned between the shoulder blades of the geckos whilst the tape was wrapped around in a backpack fashion to hold it in place. The harness wrapped over the first shoulder and diagonally across the chest, around the side of the gecko and straight over the end of the transmitter, around the side and back diagonally over the chest and over the opposite shoulder as pictured in Plate 4.

1.12.2 Release and tracking

Geckos were either released in the penned area of in the ‘un-penned’ area not far from the fence line. On the day of release, geckos were tracked up to three times every 3-4 hours. Geckos were then tracked every 1-4 days from then on with 3-4 hours between each track with up to four tracking points a day. With each location point tracked the date, time, G.P.S location, plant species, height of plant (m), and approximate height of gecko (m) were recorded for each individual. Weather conditions and approximate movement from last known point were also recorded. If possible, transmitters were changed when the current transmitter being worn had approximately 20% battery life remaining. The new transmitter frequency was recorded, and the gecko would be released back to the location it was found in.

1.12.3 Statistical analysis

Due to the small sample sizes of the penned (n=6) and non-penned groups (n=7), and the sample as a whole (n=13), non-parametric tests were used in the analysis of this data. Boxplots and comparative bar graphs displaying data from both release groups are displayed showing the medians and range of the data as well as the weekly distribution of movements. 100% minimum convex polygons and 95% kernel estimates are displayed along with Pearson's correlations between kernels and weight (g) and snout-vent-length (mm). 75% and 95% minimum convex polygons areas are also displayed in a table for comparative purposes with other studies. Individual geckos I.D with number of fixes per individual are also displayed in a table alongside SVL (mm), weight (g) and area estimates from both methods. All analyses were conducted using RANGES 9 v1.7 and Microsoft Excel 2016.

1.13 **Results**

Following the release of each gecko their movement patterns for tracked from anywhere from 2 to 56 days depending on time transmitters stayed attached for. Any geckos that were tracked for less than a week (n=1) have been kept out of all analysis as the number of fixes is too small and may give inaccuracies in the statistical analysis. On that basis only one gecko had to be excluded as it was tracked only two days due to harness failure. That left 13 geckos with transmitters, 6 in the penned release group and 7 in the non-penned release group.

There was no statistical difference of average weekly movement (m) between the penned and non-penned groups (Mann-Whitney U= 20, p= 0.94) using a two-tailed test. The range of data collected from both groups is shown relatively similar when plotted using a boxplot (Figure 6).

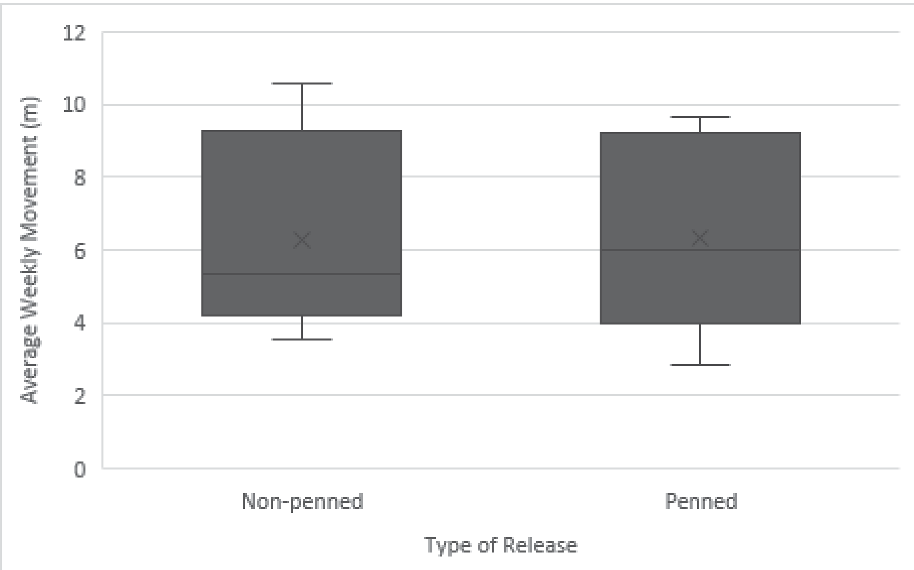


Figure 6. Comparative boxplots of Auckland green gecko (*Naultinus elegans elegans)* non-penned and penned release groups average weekly movements (m).

1.13.1 Average daily movements

The average daily movements were calculated by using any two fixes with an approximate 24 hour period allowed for movement between them for each gecko tracked. Weeks indicate the number of weeks since each individuals' release. As geckos were not released all in one event but staggered their calendar weeks' post-release are different from each other. The sixth week was excluded from the graph as only one gecko had points that could be used to calculate daily movement during their sixth week of tracking. That gecko was also identified as an extreme in the data analysis as an individual at the maximum end of the range for all movement data.

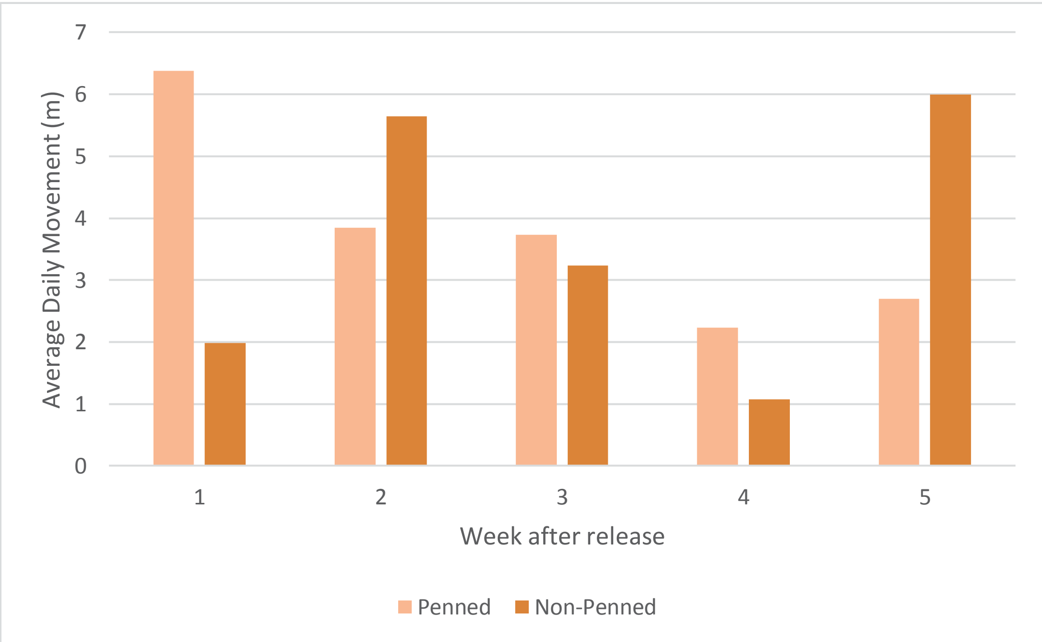


Figure 7. Graph of the two different release types for side by side comparison of average daily distance per week over for every week for five weeks' post-release.7

1.13.2 Movement in relation to release point

There was no statistical significance of final distance from release point (m) between the penned and non-penned groups (Mann-Whitney U=19, p=0.83) using a two-tailed test. However, from the boxplot in Figure 8, it is apparent that the non-penned group had a far more equal spread across all distances than the penned release group. This could indicate that although the average weekly movements are similar between the groups, the non-penned group are in fact moving further from the release point. Penned geckos although moving a lot stay within the general area of their release.

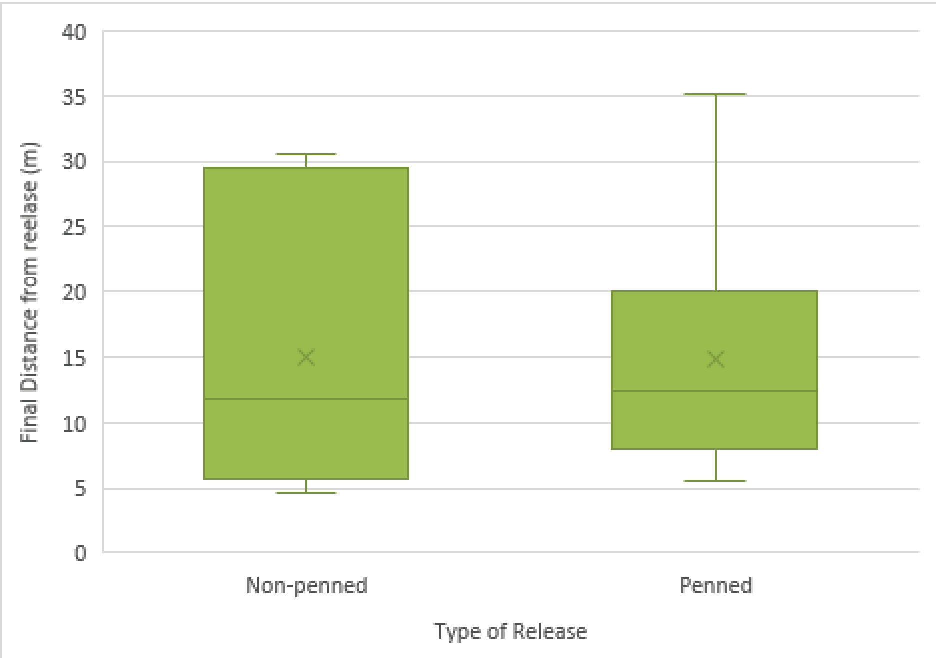


Figure 8. Boxplot of non-penned and penned release groups final distance from release point (m).

The average maximum distance from release site (m) was calculated for both penned and non-penned groups. Not all geckos were tracked for six weeks so not all geckos are included in each weeks' average in Figure 9. The largest distance away from release site at any one time was 35.18 metres by the largest adult male in the study

(I.D= MS) in the penned release. The smallest distance from release site at any one time was a mere 0.5 metres by a non-penned female (I.D=Flow).

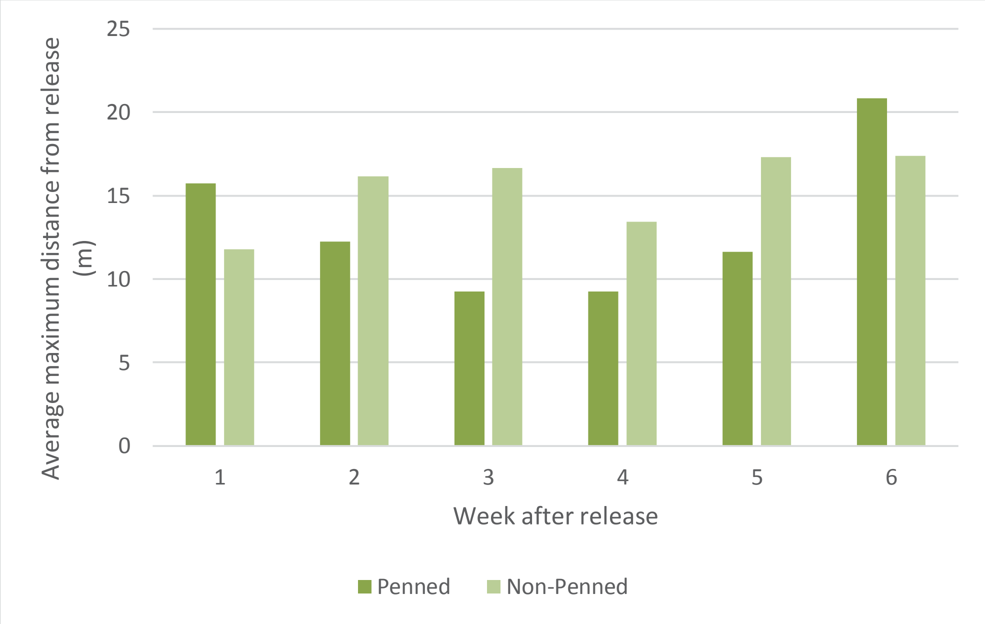


Figure 9. Comparative graph of penned and non-penned release groups' average maximum distances from release (m) shown in weeks' post-release.

The total distances travelled (m) over the tracking period of penned and non-penned released individuals irrelevant of direction of movement was found to be insignificant (Mann-Whitney U= 19, p=0.84) with a two tailed test at significance of $p \leq 0.05$. The average largest total distance moved for non-penned and penned were 114.68m (58.11m-192.54m) and 108.51 (23.92-186.89) respectively.

1.13.3 Habitat use

The average perch height (m) of all geckos was 1.73m and the average height (m) of trees occupied was 2.23m. The average perch height is within the top 30% of the average tree height. No geckos were found on trunks throughout the study except for one during the salvage effort. Transmitter signals were at times pointing towards geckos being in the grass which was necessary to move between patches of trees due to the immature nature of the vegetation. There was no significant difference in average perch height (m) between the penned and non-penned group (Mann-Whitney U= 10, p= 0.13) using a two tailed test. During tracking, geckos were found on Manuka (*Leptospermum scoparium*) 76.15% of the time, Gorse (*Ulex europaeus*) 12.47%, Mahoe (*Melicytus ramiflorus*) 8.67%, and any other species 2.71% which included species such as Karamu (*Coprosma robusta*), Kanuka (*Kunzea ericoides*) and Tarata (*Pittosporum eugenioides*).

1.13.4 Calculation of areas occupied

The minimum convex polygons at 75%, 95% and 100% were calculated for the penned and non-penned groups and tested for significant difference with two-tailed tests. There was no significant difference in the area size (m^2) between the penned and non-penned groups (Mann-Whitney U=19, p= 0.836) for the 75% MCP. Neither the 95% MCP or the 100% MCP had significant difference between the two groups (Mann-Whitney U= 20, p= 0.945, Mann-Whitney U= 19 p= 0.836) respectively. There was also no statistical significance of 95% Kernels between penned and non-penned groups (Mann-Whitney U= 20, p= 0.945).

Table 3. Medians (m^2) + Range (min-max) for MCP 75%, MCP 95%, MCP 100% and 95% Kernels for penned and non-penned groups and number of individuals in each group.

Release Type	**Number of individuals (n)**	**MCP 75% (m^2) Median (min-max)**	**MCP 95% (m^2) Median (min-max)**	**MCP 100% (m^2) Median (min-max)**	**95% Kernels (m^2) Median (min-max)**
Penned	6	239.80 (144.02-342.76)	320.15 (186.52-1218.73)	357.81 (186.52-1385.11)	129.06 (67.14-372.71)
Non-penned	7	211.44 (165.19-575.13)	278.32 (200-927.36)	506.77 (202.17-9996.05)	142.77 (65.35-327.87)

The 100% MCP and 95% kernel estimates for each gecko tracked varied significantly except one gecko (MC) whose two area estimates were very close (64.58 and 65.35 respectively). Kernel estimates are thought to be less bias and unpredictable in estimating area size within species, so were used to test correlations of body size (Nilsen et al., 2008). No strong correlation was found between snout-vent-length and 95% kernel estimate (Pearson's correlation r= 0.0229) nor for weight and 95% kernel estimate (Pearson's correlation r= 0.2755), indicating that increased size does not correlate to increase area. Both correlations present very week positive correlations.

Table 4. Each individual gecko tracked in both release groups with SVL (mm), Weight (g) and both 100% MCP and 95% Kernel estimates (m^2).

Gecko ID	Release Type	Sex	No. of fixes	SVL (mm)	Weight (g)	100% MCP (m^2)	Kernel estimate (m^2) [fixed, 95%]
Flow	Non-penned	Female	27	64	5.3	410.15	80.12
M18	Non-penned	Male	22	60	5.8	660.63	142.77
M4	Non-penned	Male	41	68	9.08	983.42	327.87
MB	Non-penned	Male	29	71	7.15	372.05	71.9
MC	Non-penned	Male	27	70	7.65	64.58	65.35
MY	Non-penned	Male	26	62	5.48	763.95	231.49
MZ	Non-penned	Male	31	69	7.88	1131.48	245.76
FT	Penned	Female	10	64	6.62	279.65	155.23
M1	Penned	Male	15	73	8.16	376.55	67.14
M17	Penned	Male	37	75	8.97	428.5	101.8
M30	Penned	Male	19	70	7.28	519.33	102.89
MS	Penned	Male	46	75	8.3	1601.43	372.71
Albert	Penned	Male	41	61	6.48	793.57	166.54

The minimum convex polygons overlap within the two groups substantially. The two females (one penned, one non-penned) are two of the smallest areas among their groups. Due to the very small sample size nothing conclusive can be asserted however it is possible that females have smaller home ranges due to the fact males are more territorial and are more likely to be actively seeking mates. Within each group there is a large range of area sizes; the smallest penned area for 100% MCP was 186.52m² and the largest being 138.11m². The 100% MCP calculated areas for non-penned are much larger with a minimum of 506.77m² and maximum of 9996.05m². These numbers are vastly different to the calculated minimum and maximum for the 95% kernels (67.14m²-372.71m² and 65.35m²-327.87m² respectively).

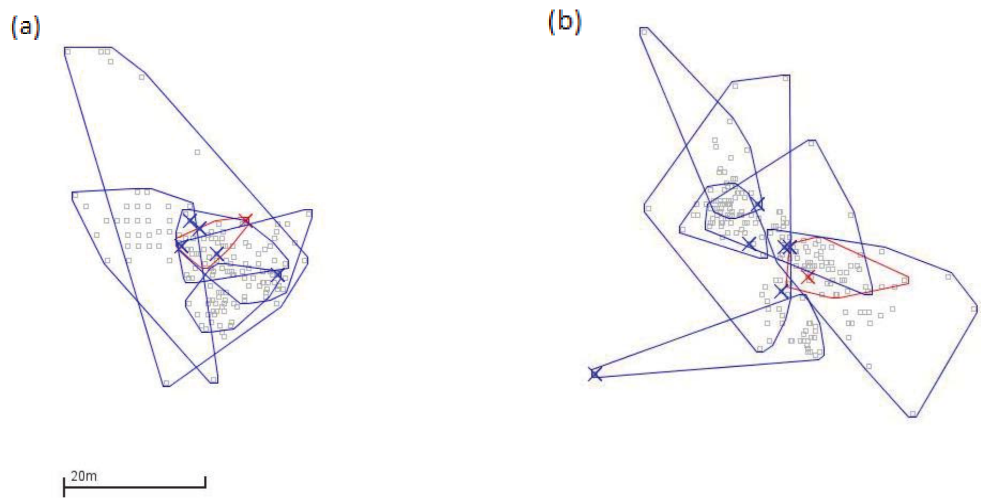


Figure 9. 100% MCP (a) penned geckos, (b) non-penned geckos. Sex is distinguished by colour: males in blue, females in red. Release points shown with an X within each polygon.

The 95% Kernel estimate areas are far denser than the 100% MCPs for both the penned and non-penned groups. As shown in Figure 10, not all location points are included in the outlined areas. Kernel estimates allow us to quantify intensity of habitat use rather than encompassing all known locations. The kernel estimates show the areas in which you are most likely to find each particular individual within it's 'home-range'. The largest 95% kernel estimate was 327.87m² (male, i.d= M4) for the non-penned group and the smallest being 71.9m² (male, i.d= MB). The largest area from the penned group was also the overall largest area from both groups was 372.71m² (male, i.d.= MS) and the smallest 67.14m² (male, i.d= M1). The gecko MS, as well as having the largest 95% kernel estimate was the only gecko from the penned group to have two separate areas indicated in Figure 10. This was partly due to the fact this gecko did in fact manage to escape the penned area due to overgrown vegetation being close enough to the fence.

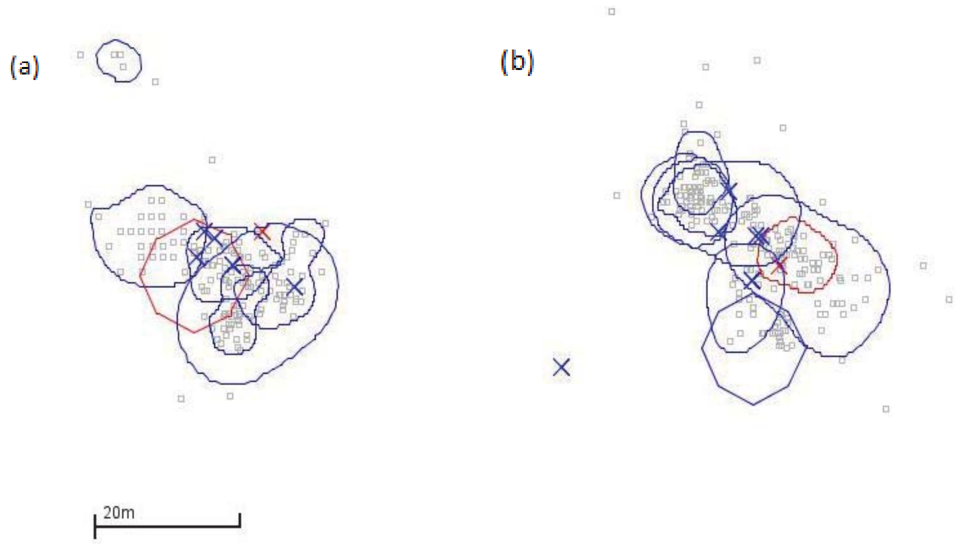


Figure 10. 95% Kernel estimates of (a) penned and (b) non-penned release groups. Differentiated by sex; males in blue, females in red. Release points shown using X.

1.14 Discussion

1.14.1 Harness design and transmitter attachment

The original harness design using a non-adhesive sports tape was not suitable for this species of gecko due to their size and excess amount of skin. The material of the first design was much heavier and required more time to attach to geckos as well as having problems with being too restrictive and only a small likelihood of coming off without intervention. It was important that the design be able to fall off after a period of time with shedding without the need for human intervention in case of transmitter failure (which it did in many cases) and not risk the welfare of the gecko if finding them became extremely difficult. It was also shown to give one gecko small blister like spots on the shoulder blades after being on for over a week and after heavy rainfall. The material did not hold its' shape after rain now it's textures, becoming tighter and rubbing on the skin of the gecko. The gecko found with the small wounds was treated and released with no transmitter.

The second harness design was based off that used with jewelled geckos in Otago with a very similar study design (C. D. Knox & Monks, 2014). The new material used was a self-adhesive sports type that was hypo-allergenic and lighter in weight making it a more breathable material than that previously used. The self-adhesive design was also much easier to apply by a single person than the first design which required two people, one to hold the gecko and one to attach the harness. The two types of transmitters R1614 (0.3g) with 15 ppm (45 day life) and R1612 (0.2g) with 15 ppm (22 day life), were changed when there was approximately 20% battery life left to avoid losing geckos with transmitters attached. However, as the weather turned colder, transmitters began to fail much earlier than expected, and because of this most of the transmitters were not taken off. It is hoped that the second design would fall off eventually as has been seen in other *Naultinus* studies (Monks, J., pers. comm.). In three instances the transmitter with harness was found, fallen off a gecko. The first to fall off was of the original design, hence no adhesive so it may not have been tight enough. The second instance was the second harness design and the transmitter was found still attached to the harness after heavy rainfall. The final instance just the transmitter alone was found, likely to have slipped out from the harness due to rain.

The transmitters had issues with entangling geckos due to the long antenna that protrudes out the back. In two instances geckos were found to be caught in branches by the antenna. To remedy this, the antenna was cut shorter when attached, this however significantly impacted on the strength of the signal given off and received on the receiver. This meant that if geckos had moved a large distance since their last known location, the receiver was much less likely to pick up the direction of the signal due to the large distance between the transmitter and receiver. Hence, finding the geckos became increasingly difficult when transmitters where modified. This problem was most likely heightened by the type of habitat. Mānuka trees tend to have large clumps of seed pods that make entanglement easy compared with mature kānuka (like that at the donor site) that have a higher foliage to seed pod ratio than immature manuka. The area also had patches of gorse that were not only tall in height but wide as well, creating a prickly matrix that made entanglement easier.

1.14.2 Habitat use

The habitat of the release site was quite unique in the fact that the vegetation in the area was still very young and would not be considered mature for many years to come. The vegetation in which Auckland green geckos are found naturally, involves large, mature vegetative canopy, generally kānuka (*Kunzea ericoides)* that is for the most part interconnected with no 'islands' of trees. The habitat use of the translocated population in the young manuka is then not directly comparable to the majority of wild and other translocated populations that are released to prehistoric ranges. However, it is interesting to note that the geckos were often found to be at ground level (although not sighted due to the long grass, but indicated by the location of the strongest transmitter signal). This shows they adapted to their new environment and although faced with 'islands' of trees in the area, they still persisted to move between those islands. These results show that translocating this species to vegetation such as that in this study, does not hinder their dispersal behaviours post-release into a new environment. It is possible that due to geckos moving down to ground level they are at risk of predation from a larger range of potential predators and competitors such as skinks, mice and other species that are less likely to climb than species such as the ship rat or possum. However, the only death during the four-month period of tracking was one male gecko that was part of the penned release group. The death was concluded as 'unexplained' in the pathology report. No other deaths were seen within the tracked individuals either due to predation or any other factors. This indicates that immature vegetation can sustain a population of green geckos. This could be an important factor with future translocations as relocating green geckos could occur earlier in ecosystem restoration projects than what is current practice.

1.14.3 Penned vs. Non-penned

The small sample size of the groups and lack of females in both meant that statistical power was relatively low and significant comparisons between the sexes could not be drawn (females n=2; 1 penned and one non-penned). Although there was no statistically significant difference in the average weekly movement (m) between the two groups the movement in relation to the release site shows that they are moving differently. Although the penned release geckos moved it seems, just as much as non-penned geckos, they tended to move in closer proximity to their release site rather than in a dispersal movement pattern. This is a good indication that penned release geckos may be quicker to settle and possibly males to set up territories as they have a limited area to disperse in. Compare this with the non-penned group, they can move large distances without restraint so they can move further and further away from the release site, and further from other geckos.

This dispersal is detrimental to the success of the translocation. If a gecko's initial reaction post-release is to move in straight lines with no restrictions rather than exploring the general area within close proximity to their release point, then their chances of coming into contact with others from the study becomes less and less likely (C. D. Knox & Monks, 2014). Initial searches of the area prior to translocation showed no signs of any pre-established population so it is likely that the translocated individuals make up most, if not all of the local green gecko population. This in turn means it is vital for the translocated individuals to stay within proximity of each other for an established breeding population to form. Although not statistically significant, the largest distances travelled in total and the range (m) was slightly larger in non-penned than penned geckos; 114.68m² with a range of 58.11m²-192.54m²; 108.51m² with a range of 23.92m²-186.87m² respectively. If translocated geckos disperse away from the site it may result in reduced founder numbers, decrease the genetic diversity within the population and increase the risk of extinction (C. D. Knox & Monks, 2014).

If more geckos had been found during re-capture efforts, then this theory could be truly tested by taking away any physical barriers and tracking the movement behaviours of individuals from the penned and non-penned groups for comparisons. However, this was not possible due to the very small number of geckos re-captured (n=2) and failure to identify those individuals from the translocated population. Within the study that this was based from, penning prior to release decreased movement away from the release site and females from the penned group were found to be gravid in the next season whereas females in the non-penned group were not (C. D. Knox & Monks, 2014).

1.14.4 Movement patterns after release

From the graph in Figure 9, the penned release group gradually reduces the distance from the release point after an initial spike in movement away from the release point. However, they do spike back up again in week 6. Week 6 however, is only the average of two geckos who were still being tracked at that time, both of which had high levels of movement throughout the study compared with the average of the group as a whole. It is likely then that if all geckos had been tracked for six full weeks there may not be such a spike in the average distance from release. Alternatively, it could be due to other factors that may change behaviour such as the changing of seasons from late summer/autumn into winter, mating, male territoriality, food resources.

1.14.5 Minimum convex polygons and kernel estimates

For the purposes of this study, both MCP and the more robust KDE methods have been used. 100% MCP was used as eliminating the outermost locations with a 95% MCP has been shown to lack any biological basis (White & Garrott, 2012). However, for the purpose of comparing results with other studies, 95% MCP and 75% MCP have also been explored. MCP is a linkage estimator that calculates the smallest convex polygon that includes all known locations of a tracked individual (Hayne, 1949). Kernel density estimate produce a distribution that estimates the likelihood of finding an individual at any particular location within its home range (Worton, 1989). It has also been shown to be robust against small sample sizes so is appropriate for this study (Börger et al., 2006). 95% kernels have been used as they are the most often used as the probability of 100% is extremely unlikely (Seaman & Powell, 1996).

Due to the nature of the study being a translocation of animals from a donor site, the areas calculated using these two methods cannot specifically be called home ranges. Tracking was simultaneous with the release of individuals before the animals had time to acclimatise to the new habitat, so animals have no yet established home ranges. For this purpose, they have been referred to simply as areas occupied over the period of tracking. The average area estimates from the 95% kernels are very similar between penned and non-penned groups, 161.05m^2 and 166.47m^2 respectively. There was no statistical significance between size of area occupied (95% kernel estimates) and SVL (mm) or weight (g). The statistical power for this is low due to the very low sample sizes however, it indicated that for this species, the size of the individual has very little to do with distances moved. This could be tested using geckos that have already been established in their habitat for a significant period of time, thus should have home-ranges and territories they regularly occupy. Using 95% kernel estimates to investigate the influence these parameters have on an already established population would be more reliable results to base conservation management on. The fact that this study only had two females (one from each release group) meant that no significant statistical tests would give any reliable results on whether males and females have differences in their movement patterns. Males and females could have different home range sizes as well as less overlap between competing males but more overlap between a single male and multiple females and/or juveniles. Researching whether males' movement behaviours change with the seasons due for breeding reasons would also be advantageous information that would help with future translocations and management of the species.

1.15 Summary and conclusion

Using radio telemetry to study herpetofauna is a useful and easy method for looking at basic biological information including habitat preferences and behaviour. Particularly with cryptic species such as the Auckland green gecko, the use of transmitters to track and locate individuals was invaluable in allowing particular individuals to be closely monitored. The chances of finding exact individuals on a day to day basis, particularly during daylight hours, would be difficult with this species.

The second harness design used was a great fit for this species as they have more delicate skin compared with other New Zealand species such as the Duvaucel's gecko. Using self-adhesive tape made the attachment of transmitters much easier to do with one person and was a more appropriate weight than the first design. No adverse effects were seen on any of the geckos sporting the second design.

Using a penned release to restrict dispersal behaviour post-release has been shown in other cases of *Naultinus* species to be successful (C. D. Knox & Monks, 2014). Unfortunately, during this study, lack of time and resources meant that this could not be confidently explored with informative results. Sample size was a particularly limiting factor with only two females being used with transmitters. This was due to the timing in the season when the majority of females were gravid and already carrying extra amounts of weight to carry offspring. However, this factor is also a positive for the population structure to have a new generation already being born at the site post-translocation. If adult females had not been gravid, the sample size of the study would have more than doubled as more females were caught during translocation than males. More studies like this, using the penned release method need to be completed fully to extract useful information for the future of gecko translocations in New Zealand and worldwide.

Chapter Five

Pest control and monitoring methods

1.16 Introduction

Rodents are abundant and are a diverse group (Cunningham & Moors, 1983). The mammalian order Rodentia includes many species such as rats, squirrels, guinea pigs and porcupines (Cunningham & Moors, 1983). Rats (*Rattus spp.*) are considered to be the most successful invasive mammals having reached around 90% of the world's islands (David R Towns, Atkinson, & Daugherty, 2006). New Zealand has four introduced species of rodent including the Kiore (*Rattus exulans*), also known as the Polynesian rat, the back rat and the Maori rat (Cunningham & Moors, 1983; Hasler, Klette, & Agnew, 2004; David R Towns et al., 2006). This species was introduced by early Polynesian settlers and was well established throughout the country by the time Europeans arrived in New Zealand (Cunningham & Moors, 1983).

The Norway rat (*Rattus norvegicus*), also known as the brown rat, was introduced late in the 18th century (Cunningham & Moors, 1983). The Ship rat (*Rattus rattus*), also known as the bush rat, black rat, roof rat and blue rat, was introduced to the North Island during the 1860s and the South Island during the 1890s (Cunningham & Moors, 1983). The Ship rat is abundant and found in most habitat types throughout New Zealand including some off-shore islands (Christie, MacKenzie, Greene, & Sim, 2015; Cunningham & Moors, 1983). The last rodent is the house mouse (*Mus musculus*) or field mouse, which was introduced in the 1830s to the North Island and later in the 1850s to the South Island (Cunningham & Moors, 1983). The species is found in almost all types of habitats and is very common throughout the country including off-shore islands (Cunningham & Moors, 1983).

All rodents have the famous single pair of front teeth in the upper and lower jaws used for gnawing (Cunningham & Moors, 1983). The incisor teeth grow throughout the duration of the rodents life and can only be worn down by gnawing (Cunningham & Moors, 1983). The rodents present in New Zealand prey on native species and have been known to cause extinctions and population declines (Baling et al., 2013; Christie et al., 2015; Cunningham & Moors, 1983; Getzlaff, Sievwright, Hickey-Elliott, & Armstrong, 2013; Newman, 1994; David R Towns et al., 2006).

In response to declines and extinctions of New Zealand species, eradicating pests where possible is favourable (Getzlaff et al., 2013; David R Towns et al., 2006). Removal has progressed from large species such as cattle and goats, to the more complex removals of rodents (Baling et al., 2013; David R Towns et al., 2006). Eradications tend to be more environmentally and economically sensible then long term population monitoring (David R Towns et al., 2006). However, eradications can also cause wide scale collateral damage, can be expensive, and can cause unwanted backlash from the public (David R Towns et al., 2006). Eradication of introduced species can allow for declining native species to recover and re-establish in areas of local extinction (Baling et al., 2013; David R Towns et al., 2006).

Beech forests in the South Island of New Zealand have periods of mass seed crop production seasons known as ‘masting’ (David R Towns et al., 2006). Masting events cause massive increases in the number of mammalian predators such as rats, mice and stoats due to the influx of the food resource (Christie et al., 2015; David R Towns et al., 2006). In 1999 and 2000 the beech trees had two masting seasons in a row creating rat densities never before seen (David R Towns et al., 2006). The explosive number of rats had devastating effects on the yellowheads and orange-fronted parakeets (*Cyanoramphus malherbi*) with local extinctions in some areas (David R Towns et al., 2006).

Eradication of rats has also shown to benefit plant and invertebrate species (David R Towns et al., 2006). Effects of Norway rats on forest plants were studied on Breaksea Island. Results showed that nine species of trees and shrubs showed higher seedling numbers after rat eradication (David R Towns et al., 2006). Three species of cockroach, two of carabid beetles, a species of large centipedes and many other invertebrates were recorded for the first time also following rat eradication from the island (David R Towns et al., 2006). On Korapuki Island a 30-fold increase in skinks (*Oligosoma smithi*) was seen after the eradication of Pacific rats (David R Towns et al., 2006). Sightings of the common gecko (*Hoplodactylus maculatus*) increased 28-fold over a 15 year period free of rats (David R Towns et al., 2006).

1.16.1 Recapture methods

Capturing cryptic, arboreal and fast moving reptiles is difficult and many methods have been used in attempt to capture them (Davis et al., 2008). Methods include hand-captures, sticky traps, fishing with baited lines, pitfall traps, noosing and confining geckos with barriers (Davis et al., 2008; Fitzgerald, 2012; Rolfe & McKenzie, 2000). However with many species, these technique do not yield high results, and in the case of sticky traps, cause unnecessarily high death rates (Davis et al., 2008). Funnel traps have been successfully used in captive populations of reptiles including geckos, dragons and snakes (Thompson & Thompson, 2007). Baiting them however is disputed as they tend to attract ants which can attack reptiles caught in the traps. Baiting however, increases the chance of capture when time is a restricting factor (Davis et al., 2008). Reptiles caught in funnel traps are also susceptible to heat stress and thus traps need to be checked and cleared earlier in the day to prevent any heat related deaths (Thompson & Thompson, 2007).

1.16.2 Short term monitoring techniques

Fluorescent powder has been used as a short term monitoring method on many animals including reptiles (Mellor, Beausoleil, & Stafford, 2004). This method is most useful for nocturnal animals as the animal and the trail can be seen at night time under UV light. The trail can last up to a few nights after initial dusting of the animal and is an easy and cost effective way to track movement patterns (Mellor et al., 2004). It allows for identification and tracking during night hours which is when spotlighting for green geckos occurs. It is useful for gathering information on habitat use and movement patterns (Mellor et al., 2004). The main disadvantage to the temporary method is that it only lasts a few nights and is subject to rain and vegetation cover (Mellor et al., 2004).

1.17 **Methodology**

1.17.1 Recapture effort

Once geckos had been inside the penned release area for at least 9 months, searching of the area was conducted in an effort to recapture each of the transmitter released individuals and possibly non-tracked individuals. Over 70 day searches and night spotlighting searches were conducted at the release site.

Due to the low catch rate of geckos in the release site, two methods were introduced to try and increase that rate. Firstly, tracking tunnels were erected in the foliage of trees where green geckos tend to be found. They were baited with mashed banana and had a tracking card with ink on both sides to imprint the footprints of any gecko that walked though.

When the tracking tunnels were not successful in picking up on the presence of any geckos a second strategy was adopted. Funnel traps were made using plastic plumbing piping and wire mesh. The ends were bent inside the trap with only a small hole so geckos could enter but exiting would be made difficult. These traps were laid out in the foliage of trees and baited with the same style mashed banana as the tracking tunnels. Traps were set and left for up to 24 hours. However, on the third time checking the traps, mammalian excrement thought to be that of a rodent was found on one of the traps. This indicated that we were possibly attracting predators to traps that we were hoping to catch geckos in. This was then aborted as soon as excrement was found so as not to unnecessarily harm any geckos that may be present by inviting predators to climb the trees in search of banana.

1.17.2 Tracking tunnels and trapping

Rat trapping was then conducted at the release site along with black trakka tunnels to pick up prints of any predators present in the area. In total there were ten 250 DoC traps set within and surrounding the penned area. Traps were set around the edge of the fence on the inside and out as well as along natural edges that rodents were expected to use as a thoroughfare. Thirteen tracking tunnels were set up in the same manor covering the penned area and the surrounds (Figure 12).

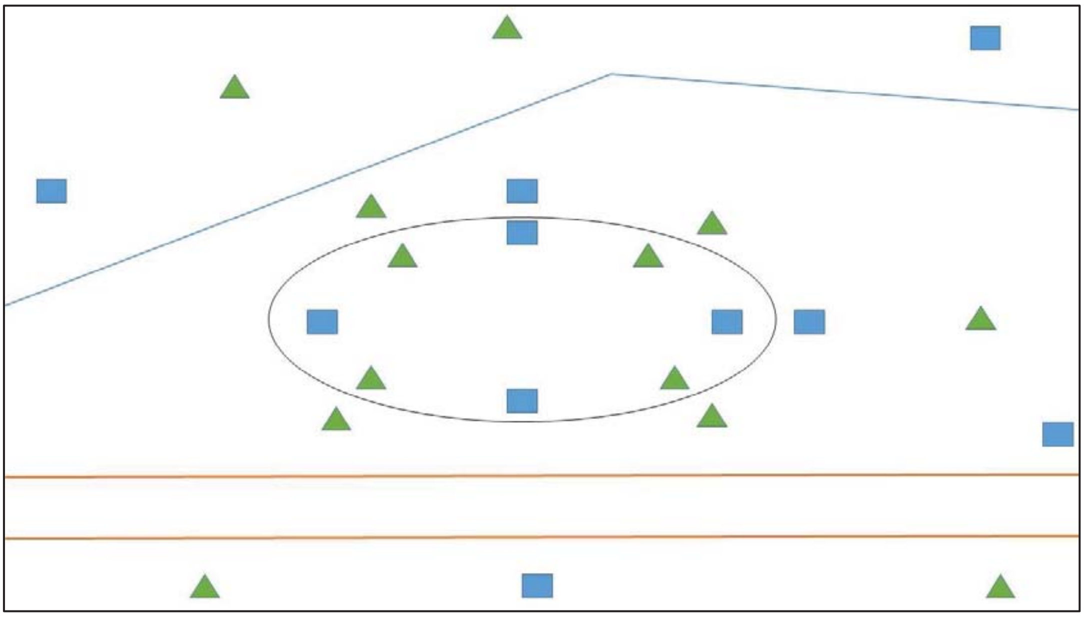


Figure 12. Diagram of approximate positioning of release site. The penned area (black oval), traps set (blue rectangles), tracking tunnels (green triangles), vehicle access way (double orange lines), forested area (above blue lines).

Traps and tunnels were set up in a range of microhabitats including, forested areas (above the blue lines shown in Figure 12), grass (below orange lines on side of access way in Figure 12, and shrubbery (all other areas of release site). All traps and tunnels were baited with peanut butter (as it is known to attract rats) (Hasler et al., 2004) and checked once a week. All cards in tracking tunnels were changed and any traps set off were reset and peanut butter was replaced in all traps and tunnels.

1.18 Results

1.18.1 Gecko recapture

Only three geckos were seen during the efforts to recapture released individuals. Two adult males were caught and one juvenile managed to escape capture by diving down into the grass after being spotted. All three geckos were found within the first night of searching. The two adult males were processed and found to be in good general body condition. Once processed, they were released back to the location they were found. Neither of these geckos could be identified from records of released individuals.

Both adults caught and re-released had UV fluorescent powder spread on the ventral surface in an attempt to show their movement after being re-released. Using a UV torch, the trail they left when moving between leaves, branches and trees was only apparent for one gecko. This trail was found the consecutive night after the capture and release of the individual. The trail however was only very short showing the geckos movement from one tree to another intertwined tree and then stopped as the powder did not last long on the body. The gecko was subsequently spotted that consecutive night after release but then never seen again. Following the first night of spotlighting and the capture and re-release of two geckos, no further sightings were recorded.

1.18.2 Recapture methods

Due to the lack of geckos caught during the researching effort a few extra methods were adopted to try and show the presence of geckos as well as physically capture them for processing and identification. The tracking tunnels proved unfruitful with no tracks being recorded despite them being ‘active’ for multiple consecutive weeks. Secondly, funnel traps were used in an attempt to capture geckos. This was aborted due to the finding of rodent excrement on one of the traps. The geckos found in the initial recapture efforts were also released with UV fluorescent powder covering the ventral surface of the gecko in an attempt to track short term movement.

1.18.3 Trapping

In total two rats and one mouse were caught during the six consecutive weeks of trapping. The sex of the mouse (*Mus musculus*) was unidentified. The rats caught were both ship rats (*Rattus rattus*), one male and one female based on location found and colourations (Cunningham & Moors, 1983). The male was of the ‘rattus’ colour variation of black with a grey belly. The female rat was of the ‘frugivorous’ brown black colour variation with a cream coloured belly (Cunningham & Moors, 1983).

Plate 7. Open contents of male rats' (*Rattus rattus*) stomach contents showing large amounts of recently eaten poisonous bait.

Both rats were caught in the same trap that was positioned on the outside of the penned area along the forested areas edge. The first rat was caught on the 4th night of trapping, the second on the 10th night of trapping and the mouse on the 15th night. All rodents caught were kept frozen and dissected at a later date to inspect stomach contents. The male rat was found to have very recently ingested poisonous bait that is set by Winstone around the penned area.

(a) (b)

Plate 8. (a) picture dorsal surface of male Ship rat (*Rattus rattus*) colour morph 'rattus', (b) dorsal surface of female rat (*Rattus rattus)* colour morph 'frugivorous'.

An index of abundance can be calculated and expressed as captures/100 trap nights by accounting for nights that the traps were set off or a rodent was caught and correcting for the number of trap nights (Cunningham & Moors, 1983). Subtracting half a night for each on the assumption that each will have been sprung for an average of half the night. In the calculation from this study 10 traps were set for a total of 18 nights. There were 3 captures and no sprung, empty traps.

10 traps set for 18 nights = 10 x 18

= 180 total trap nights

Trap nights lost = ½ (captures + sprung, empty traps)

= (3 + 0) x ½

= 1.5 trap nights lost

Corrected number of trap nights = Total trap nights – trap nights lost

= 180 – 1.5

= 178.5

$$\text{Index of abundance} = \frac{\text{Captures x 100}}{\text{Corrected trap nights}}$$

$$= \frac{3 \times 100}{178.5}$$

= 1.68 captures/100 trap nights

The index of abundance for the rat trapping for this study was 1.68 captures/100 trap nights. There were no nights of traps being set off without a capture and captures were only made on three occasions. That makes a total of 1.5 trap nights lost due to capture.

(a) (b)

Plate 9. (a) ventral surface of male Ship rat (Rattus rattus) colour morph 'rattus', (b) ventral surface of female Ship rat (Rattus rattus), colour morph 'frugivorous'.

1.18.4 Tracking tunnels

All tracking cards were covered in a variety of prints. Particularly within the shrubbery of the penned area. Table shows the total number of tracking cards that prints of certain species were found on. By far the most frequently occurring animal prints found were from mice (*Mus musculus*) shown in Plate 10 (Agnew, 2009), found on just over 80% of the tracking cards collected. Far behind mice were weta (31%), closely followed by rats with 28.2% (*Rattus rattus*), then skinks (*Lampropholis delicate)* (22.5%) and lastly possum with just 14.1% (*Trichosurus vulpecula*), print shown in Plate 11 (Agnew, 2009). All tracking cards had unidentifiable tracks due to either the sheer amount of tracks that were present, hence a lot of overlapping, or due to an incomplete print being transferred.

Plate 10. Tracking card covered with mice prints (Mus musculus) less than 10mm with the characteristic three dots from the front of the foot and 2-3 from the back of the foot.

All tracking cards had peanut butter sitting within the centre of the ink to attract rats. This bait seems to be successful in attracting mice as well as many other insects and animals. It is possible that some of the unidentified prints are that of other insects such as beetles that we have not been able to clearly identify. The main point of the tunnels was to detect predators so was successful despite the lack of rodents caught in traps.

Table 5. Results of tracking cards collected over a six-week period simultaneously with rat trapping.

	Mouse	Rat	Possum	Skink	Weta	Unidentified
Totals	57	20	10	16	22	71
Percent of total	80.30%	28.20%	14.10%	22.50%	31%	100%

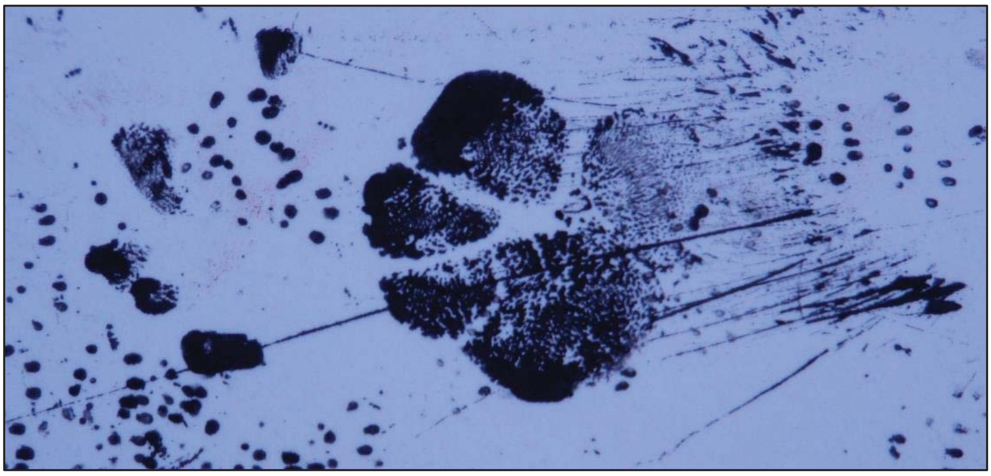


Plate 11. Tracking card with possum (*Trichosurus vulpecula*) print surrounded by mice prints (*Mus musculus*). Possum print shows the main pads of the foot and toe pads. Mice prints show the 3 front toes and two back marks from foot pads.

1.19 Discussion

1.19.1 Recapture

The reason for re-capture of geckos was to firstly assess their general condition to that recorded the previous year upon their release; and secondly to track their new movement patterns after removing the 0.5m fence that had been erected to limit dispersal up until this time. Ideally this would have given a good indication of whether the population was surviving in the habitat that had been chosen and whether or not the penned release had any effects on dispersal.

The lack of geckos found during re-capture hindered the second part of the study in trying to determine whether a penned release lowered dispersal rates. After the first night re-captures and two geckos being processed, no further geckos were sighted or caught either by spotlighting, hand searches during daytime and night time hours or funnel trapping. This begs the question of whether geckos were in fact present just not seen. The vegetation grew substantially over the time period when the area was not disturbed. So much so that some grass vegetation grew high enough without being cut back that it is possible geckos could have escaped the penned area, like-wise geckos on the outside could get in. It is hard to believe however that all geckos including those born after release due to the high number of gravid females included in the founding population, could have all escaped or worse yet died.

Geckos that were tracked during the initial stages of the study were followed for up to six weeks and during that time only one gecko died of causes unknown and no individuals were seen to be in poor body condition either from malnutrition or attempted predator attacks. The likelihood of a new factor being introduced without our knowledge between this time and our return for re-capture is highly unlikely. The most likely explanation is that geckos are present however due to their cryptic nature and the rapid vegetation growth in the area they are just not detected.

.

1.19.2 Tracking methods

The UV florescent powder has been used in other instances particularly with amphibians and reptiles (Furman, Scheffers, & Paszkowski, 2011; Rittenhouse, Altnether, & Semlitsch, 2006). It is used to track the pathway the individual takes to get from point A to point B. When tracking animals', you only know their current location and where that position is in relation to their last known location but not the path they took to get there. It is not necessarily the most direct path and being able to record whether geckos used the ground to move between trees would be helpful information in future translocations and research. The powder was useful for one of the two geckos re-captured and released. One however dropped into the grass upon release as a quick escape and due to the long grass no trail could be followed. The other however was observed the next night where the position the gecko was released under a UV torch, showed up a fluorescent coloured trail leading down one tree along low hanging branches and up another tree less than a metre away. The trail led to the second sighting of this individual however there was no need to recapture the gecko.

The following night of searching it was obvious the powder had all worn off as the trail finished around the position the gecko was last seen. This proves the powder can be effective when using for short term tracking movement patterns e.g. 24-48 hours however longer than that the powder does not last. Recapturing geckos every day or two is not beneficial as you are repeatedly interrupting the natural behaviour of the animal and any movements followed may be influenced by the repeated handling. Using a substance such as oil to mix with the powder could benefit the its longevity of the powder on the body of the gecko.

1.19.3 Tracking tunnels in trees

As with many species, searching through vegetation by day and spotlighting by night may fail to detect the species of interest particularly when the densities are low (Watts, Thornburrow, Green, & Agnew, 2008). This may explain the lack of gecko prints in this study and it does not necessarily mean that geckos were not present. It is possible they just do not use the tunnels for one reason or another due to the bait that was used or the materials used in their making. Using tracking tunnels in trees has been used to detect New Zealand's giant weta the wetapunga (*D. heteracantha*) an arboreal forest-dwelling species (Watts et al., 2008). In this study prints from this species surprisingly showed up more in the tracking tunnels on the ground. They also had more success with tunnels in the trees that were baited with peanut butter rather than left unbaited (Watts et al., 2008). Other types of tunnels need to be tested as well as baits in captive and wild populations of arboreal geckos to test the methods of using them above ground and whether or not it is a successful technique for some species.

1.19.4 Attempted captures using funnel traps

Although the funnel traps were shown to work with a captive gecko as well as dragons, snacks and other small reptiles (Thompson & Thompson, 2007), the finding of rodent excrement prevented thorough testing of this method in the wild population. The tunnels were only open for 24 hours before the discovery so the method was not given time to be robustly tested. The risk of attracting predators to the traps where geckos may have been caught was seen to be too large a risk on the newly released population so traps were disabled and not used again. It may have been successful had bait not been used to attract reptiles as it attracts other animals that can be predate on geckos caught (Thompson & Thompson, 2007). However, due to time constraints bait was used in an attempt to increase chances of capture.

1.19.5 Trapping and tracking tunnels on the ground

In New Zealand, snap trapping and tracking tunnels are the two most commonly used methods to estimate relative density and abundance or rodent species (Brown, Moller, Innes, & Alterio, 1996; Pickerell, O'Donnell, Wilson, & Seddon, 2014). After seeing the results of the tracking tunnel cards it is apparent that mice seem to far out way the numbers of other mammalian pests in the area like rats and possum. This could explain the results of catching such low numbers of rats (n=2) during the six weeks of trapping. These results are in agreement with the general theory that the presence of Ship rats reduces the rate at which mice use traps and tracking tunnels (Brown et al., 1996). Considering the low rate of Ship rats caught, could be a highlighting factor in the incredibly high numbers of mice prints. The DoC 250 traps used are generally not set off my mice as they are too small, however one mouse was caught (Pickerell et al., 2014). There could have been a number of mice that navigated to the bait without setting off the traps. Both rats were caught along the forest edge outside the penned area whilst the mouse was caught in a grassy shrub-land area. This is consistent with other findings that mice tend to have higher densities in shrub areas compared to rats and conversely, rats have higher densities in forested areas compared with mice (Brown et al., 1996; Christie et al., 2015). Considering the release site is made up of immature trees, shrub-land and a high amount of ground cover, it is much more suited to mice that ship rats (Brown et al., 1996). As time goes on and the vegetation at the site changes with less ground cover the numbers of mice may decrease as the habitat becomes more rat specific. Possum prints were only found in the forested areas outside of the penned area. They are another predator that may become more prevalent in the release site as the vegetation changes. However, the low numbers are a positive sign that rodent control is successful in the area. It has been found that control of mammalian predators within an intense trapping focus on localised sites can enable local populations of skink to recover from low numbers, largely due to predation (Reardon et al., 2012).

1.19.6 Caught rodent results

Both rats were Ship rats (*Rattus rattus*) which is to be expected due to the location of the site. Kiore (*Rattus exulans*) and the Norway rat (*Rattus norvegicus*) are found in far fewer locations compared to the Ship rat, the most abundant and widespread rat on the mainland (Cunningham & Moors, 1983). The female was not pregnant at the time it was trapped and the stomach contents appeared to consist of a mix of insects and plant matter. The males stomach contents however contained a substantial amount of poisonous bait that is laid out in the area by Winstone. This is a good sign that the bait is effective in attracting rats. Ship rats pose the most threat to green geckos as they are good climbers and can easily climb trees into the arboreal gecko habitat.

1.20 Summary and conclusion

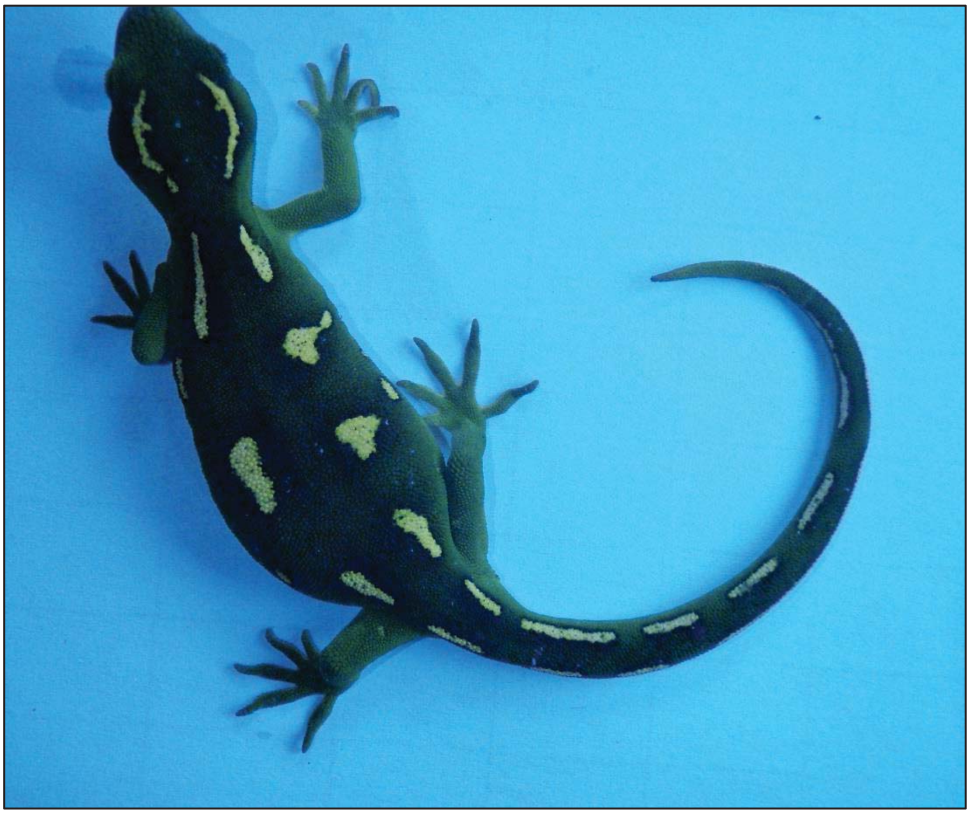
This study showed the difficulty in gathering important biological information for highly cryptic herpetofauna species. Auckland green geckos are notoriously difficult to find particularly due to their colour and habitat. The efforts to recapture geckos following months at the release site was extensive with very little pay off. The methods used in addition to spot lighting (funnel traps and tracking tunnels) are likely to have been unsuccessful due to the low numbers at the release site compared to what an established population structure may look like. Because this information is not known for this species it is only speculation as to why the methods failed to detect or capture any of the geckos presumed present at the site. More studies need to be done to determine whether these methods are suitable for green geckos. It is possible they would work well in higher densities but are not suitable for situations such as this study where the numbers are low.

The rodent excrement found in one of the funnel traps resulting in a six week stint of rat trapping is likely to be from a house mouse rather than a ship rat. The tracking tunnels used simultaneously with the trapping effort show that mice are abundant within the study site. The area has lots of prime mouse habitat with long grass and shrubbery covering a substantial part of the area between patches of Manuka. The current vegetation at the release site is favoured by mice rather than rats who prefer more mature forest. The extremely low numbers of rats caught (n=2) and the fact that one of those rats had recently ingested rat poison laid as pest control, is a good indicator that the current methods of lowering rat numbers are working. Controlling the predator populations particularly ship rats who are great climbers and can have devastating effects on wildlife is a very important part of ongoing conservation management of this translocated population. Low predator numbers give the founding members of the population time to establish a breeding population and build up the population over time. Green geckos are a long-lived species who have been known to live for decades in captivity need long-term management to successfully stop the slow decline of the total population of the species, and ensure they increase and return to historic ranges.

There is a tendency for conservation efforts in New Zealand to be focused on translocations to islands rather than mainland (Reardon et al., 2012; Saunders & Norton, 2001). Mainland based conservation approached are thought to be important in educating people and empowering stakeholder involvement (Saunders & Norton, 2001). The continuation of mainland focused research growth will benefit those species that can be excluded from island translocations where no equivalent habitat can be found on islands (Reardon et al., 2012).

Chapter Six

Conclusions and Recommendations



1.21 Overview

This study was in many ways, a pilot study concerning translocation and monitoring techniques of Auckland green geckos (*Naultinus elegans elegans*). Very little is published on *Naultinus* gecko, but the Auckland green gecko has particularly small literature concerning basic ecology and behaviours. Herpetofauna in general are less studied in comparisons to other taxa such as birds and marine mammals in New Zealand. Because green geckos are not the most endangered compared to species such as Duvaucel's gecko (*Hoplodactylus duvauceli)*, they have had limited time and funding go towards their conservation.

Basic ecological information such as population structure, behavioural patterns, and habitat use, are desperately needed for future management including translocations. Discussing best practice methods for monitoring and always updating and trialing novel methods is also a must to be able to effectively manage the species. Translocations are a huge part of New Zealand's conservation management particularly when it comes to island management and ecosystem restoration projects around the country (Gartrell & Hare, 2005). Although populations on pest free islands are beneficial for the longevity of the species as a whole, mainland conservation efforts have been left behind due to far higher costs involved with on-going pest control and species management.

Dispersal after release on islands does not have the same effect on the founder populations as it does in mainland translocated populations. Discovering the best methods for cryptic arboreal gecko mainland translocations and subsequent monitoring is imperative for the development of conservation management in New Zealand. Reducing the species population to small island populations is detrimental to the long term survival of the species by reducing gene flow as well as creating problems such as lack of predator aversion if populations are then moved back to the mainland.

1.21.1 Penning prior to release

Using a barrier of some sort to limit dispersal after release is likely to be a useful tool in the future of herpetofauna and other taxa translocations in the future. Although methods such as the penned release in this study raise the cost of the operation, it saves money in the end by helping those populations to become established and breeding that they may not have been otherwise. Although this study was unable to show true results of the penned release due to insufficient time and funding, it does not signify that this method is not useful. Other studies have shown lowered dispersal post release by using a penned of other form of barrier when released (C. D. Knox & Monks, 2014). Unfortunately, although the number of total geckos caught during salvage was quite large (n=52), the number of juveniles and gravid females made up a substantial portion of that number.

Had the time of year been different then the majority of females could have been used when they are not already carrying extra body weight. However, due to this project arising due to human-wildlife conflict, the timing was not flexible in terms of salvage and translocation. Although the timing was a negative for testing the penned vs. non-penned release questions, it was a positive for translocating so many extra geckos as unborn offspring to the site, further increasing chances of establishing a population with larger numbers. If in fact, penning prior to release does lower dispersal, then all the geckos released in the penned area including all the individuals not fit for transmitters will then be more likely to stay in the area and form territories and home ranges. Because of low numbers, when comparing penned and non-penned release groups in the statistical analysis, only non-parametric tests could be used. No results comparing the two groups were statistically significant in terms of distances moved, however the various data displayed in graphs gives us a picture of possibly significant patterns. With the right number of individuals under the same test conditions, the question of whether penned release really does lower dispersal for Auckland green geckos can be properly addressed.

1.21.2 *Transmitter use*

Green geckos in this study have shown great resilience with transmitter use and are well fit for having transmitters attached when using the appropriate materials which will vary between species. The length of time harness' can be attached without any adverse effects has yet to be tested. In this study most geckos were tracked for around three weeks before transmitters failed or harness' fell off. Although an expensive method, using transmitters are well worth it when it comes to a species as cryptic as green geckos. During the entire course of tracking individuals with transmitters, only 2 non-tracked geckos were seen in the area despite the fact that over 50 geckos had been released there. This highlights the incredible difficulty in finding green geckos without the help of technology.

1.21.3 *Post-release monitoring*

This study unexpectedly took a new component when the release site was searched during many man hours with very little sightings of geckos. In an attempt to (a) show geckos were in fact present and (b) possibly capture some, tracking tunnels and funnels traps were used. Although three geckos had been seen (two adult males and one juvenile) and two were captured (both adult males), tracking tunnels were used to try and assess which areas had the higher numbers so that funnel traps could be placed accordingly. When tracking tunnels failed to show up any gecko tracks (despite the fact that geckos were in fact present as they had been seen and captured), funnel traps were placed in trees where geckos had been sighted during the recapture efforts but also in trees where geckos had been known to habituate during the tracking period the previous year. Unfortunately, due to pests being able to access the traps and posing a threat to any geckos that were caught, all traps were disabled and discontinued use.

1.21.4 *Pest Control*

The trapping and tracking tunnels to capture and identify predators in the area (particularly rats) was also an unexpected component of this study. Pest control had including traps and baits had been used in the area for a substantial time prior to the geckos being released there during the 2014 translocation. This in turn meant that pest control was not a main focus or concern when translocation and tracking took place. However, the discovery of rodent excrement in a funnel trap, threatened to undermine the translocated population, so trapping and tunnels were set to make sure the gecko population had the best chance of success. Considering only two rats were caught over six weeks, and one of those having a full stomach of rat poison indicated the rat numbers were not a huge problem in the area, and that baiting was working. Although ship rats ranges have been shown to differ during different seasons, being smallest during winter (Dowding & Murphy, 1994); the same time as trapping was carried out. However, the number of mice prints on the tracking cards laid in tunnels was quite substantial and may need addressing in the future. Due to the type of habitat being favoured by mice with the long grass and shrubbery, it is ideal conditions for populations to flourish. Pest management targeting mice may be necessary as mice are known to predate on native reptiles. The results of tracking geckos after release, and the fact that many were using the ground and grass cover to move between patches of trees increases their likelihood to be predated by mice.

1.21.5 Moving forward

The future of monitoring of this population in the Hunua Ranges is integral for the outcome of the translocation. Due to the longevity of the species, the parameters needed to assess the success of the translocation are yet to come. It is hoped that with the ongoing monitoring and involvement of Tonkin and Taylor, the population structure and establishment will be monitored in the years to come. More research needs to be put in to New Zealand's cryptic, arboreal gecko species if penning prior to release is going to be rigorously tried and tested with the possibility of becoming standard practice for future translocations of geckos and many other species who could also benefit from lowered levels of dispersal. More focus on mainland populations is needed for these existing pockets of geckos to continue to survive and flourish. More translocations will most likely be needed in the future considering the extensive growth of Auckland cities infrastructure. Translocations due to human-wildlife conflict may become more prevalent and standard practices that can be implemented into species management plans, particularly concerning translocations is needing attention. It is hoped that if strong evidence is published in favour of penning prior to release, that it may be implemented in many more translocations of geckos to come, particularly mainland populations.

References

Agnew, W. (2009). What made these tracks? A guide to assist in interpreting the tracks of small mammals, lizards and insects.

Armstong, D. P., & McLean, I. G. (1995). New Zealand translocations: theory and practice. *Pacific conservation biology*, *2*(1), 39-54.

Attum, O., Otoum, M., Amr, Z., & Tietjen, B. (2011). Movement patterns and habitat use of soft-released translocated spur-thighed tortoises, Testudo graeca. *European Journal of Wildlife Research*, *57*(2), 251-258. doi:10.1007/s10344-010-0419-4

Baling, M., van Winkel, D., Habgood, M. R. N., Ruffell, J., Ji, W., & Ussher, G. (2013). A review of reptile research and conservation management on Tiritiri Matangi Island, New Zealand. *New Zealand Journal of Ecology, 37*(3), 272-281.

Barton, I. (1972). On the vegetation of the Hunua Ranges, Auckland. *New Zealand Journal of Botany*, *10*(1), 8-26.

Besson, A., & Cree, A. (2011). Integrating physiology into conservation: an approach to help guide translocations of a rare reptile in a warming environment. *Animal Conservation*, *14*(1), 28-37.

Börger, L., Franconi, N., De Michele, G., Gantz, A., Meschi, F., Manica, A., . . . Coulson, T. (2006). Effects of sampling regime on the mean and variance of home range size estimates. *Journal of Animal Ecology*, *75*(6), 1393-1405.

Brown, K. P., Moller, H., Innes, J., & Alterio, N. (1996). Calibration of tunnel tracking rates to estimate relative abundance of ship rats (Rattus rattus) and mice (Mus musculus) in a New Zealand forest. *New Zealand Journal of Ecology*, *20*(2), 271-275.

Burgman, M. A., & Fox, J. C. (2003). Bias in species range estimates from minimum convex polygons: implications for conservation and options for improved planning. *Animal Conservation, 6*(01), 19-28.

Burton, F. J., & Rivera-Milan, F. F. (2014). Monitoring a population of translocated Grand Cayman blue iguanas: assessing the accuracy and precision of distance sampling and repeated counts. *Animal Conservation, 17*, 40-47. doi:10.1111/acv.12148

Chambers, G. K., Boon, W. M., Buckley, T. R., & Hitchmough, R. A. (2001). Using molecular methods to understand the Gondwanan affinities of the New Zealand biota: three case studies. *Australian Journal of Botany, 49*(3), 377-387. doi:http://dx.doi.org/10.1071/BT00021

Christie, J. E., MacKenzie, D. I., Greene, T. C., & Sim, J. L. (2015). Using passive detection devices to monitor occupancy of ship rats (Rattus rattus) in New Zealand temperate rainforest. *New Zealand Journal of Ecology, 39*(1), 79-86.

Cree, A. (1994). Low annual reproductive output in female reptiles from New Zealand. *New Zealand Journal of Zoology, 21*(4), 351-372. doi:10.1080/03014223.1994.9518005

Cunningham, D. M., & Moors, P. (1983). *A guide to the identification and collection of New Zealand rodents*: NZ Wildlife Service.

Daugherty, C. H., Patterson, G., & Hitchmough, R. (1994). Taxonomic and conservation review of the New Zealand herpetofauna. *New Zealand Journal of Zoology, 21*(4), 317-323.

Davis, C., Fleming, P., Craig, M., Grigg, A., & Hardy, G. (2008). A funnel trap for capture of small arboreal reptiles. *Amphibia-Reptilia, 29*(3), 413-423.

Dodd, C. K., Jr., & Seigel, R. A. (1991). Relocation, Repatriation, and Translocation of Amphibians and Reptiles: Are They Conservation Strategies That Work? *Herpetologica, 47*(3), 336-350. doi:10.2307/3892626

Dowding, J. E., & Murphy, E. C. (1994). Ecology of ship rats (Rattus rattus) in a kauri (Agathis australis) forest in Northland, New Zealand. *New Zealand Journal of Ecology*, 19-27.

Ebrahimi, M., & Bull, C. M. (2014). Resources and their distribution can influence social behaviour at translocation sites: Lessons from a lizard. *Applied Animal Behaviour Science, 156*(0), 94-104. doi:http://dx.doi.org/10.1016/j.applanim.2014.04.013

Ewen, J. G., Soorae, P. S., & Canessa, S. (2014). Reintroduction objectives, decisions and outcomes: global perspectives from the herpetofauna. *Animal Conservation, 17*, 74-81. doi:10.1111/acv.12146

Fitzgerald, L. (2012). Finding and capturing reptiles. *Reptile biodiversity: standard methods for inventory and monitoring, RW McDiarmid, MS Foster, C. Guyer, JW Gibbons y N. Chernoff (eds.). University of California Press, Los Ángeles*, 77-80.

Furman, B. L., Scheffers, B. R., & Paszkowski, C. A. (2011). The use of fluorescent powdered pigments as a tracking technique for snakes. *Herpetological Conservation and Biology, 6*(3), 473-478.

Gartrell, B. D., & Hare, K. M. (2005). Mycotic dermatitis with digital gangrene and osteomyelitis, and protozoal intestinal parasitism in Marlborough green geckos (Naultinus manukanus). *New Zealand Veterinary Journal, 53*(5), 363-367. doi:10.1080/00480169.2005.36577

Germano, J. M., & Bishop, P. J. (2009). Suitability of Amphibians and Reptiles for Translocation. *Conservation Biology, 23*(1), 7-15. doi:10.1111/j.1523-1739.2008.01123.x

Getzlaff, C. L., Sievwright, K. A., Hickey-Elliott, A. B., & Armstrong, D. P. (2013). Predator indices from artificial nests and tracking tunnels: do they tell the same story? *New Zealand Journal of Ecology, 37*(2), 232-239.

Griffith, B., Scott, J. M., Carpenter, J. W., & Reed, C. (1989). Translocation as a Species Conservation Tool: Status and Strategy. *Science, 245*(4917), 477-480. doi:10.1126/science.245.4917.477

Hardman, B., & Moro, D. (2006). Optimising reintroduction success by delayed dispersal: Is the release protocol important for hare-wallabies? *Biological Conservation, 128*(3), 403-411. doi:http://dx.doi.org/10.1016/j.biocon.2005.10.006

Hare, K. M., Hoare, J. M., & Hitchmough, R. A. (2007). Investigating Natural Population Dynamics of Naultinus Manukanus to Inform Conservation Management of New Zealand's Cryptic Diurnal Geckos. *Journal of Herpetology, 41*(1), 81-93. doi:10.1670/0022-1511(2007)41[81:inpdon]2.0.co;2

Harris, S., Cresswell, W., Forde, P., Trewhella, W., Woollard, T., & Wray, S. (1990). Home- range analysis using radio- tracking data–a review of problems and techniques particularly as applied to the study of mammals. *Mammal review, 20*(2- 3), 97-123.

Hasler, N., Klette, R., & Agnew, W. (2004). *Footprint recognition of rodents and insects*. Retrieved from

Hayne, D. W. (1949). Calculation of size of home range. *Journal of mammalogy, 30*(1), 1-18.

Hoare, J. M., Melgren, P., & Chavel, E. E. (2012). Habitat use by southern forest geckos (Mokopirirakau 'Southern Forest') in the Catlins, Southland. *New Zealand Journal of Zoology, 40*(2), 129-136. doi:10.1080/03014223.2012.707663

Hoare, J. M., Pledger, S., & Nelson, N. J. (2007). Chemical discrimination of food, conspecifics and predators by apparently visually-oriented diurnal geckos, Naultinus Manukanus. *Herpetologica, 63*(2), 184-192. doi:10.1655/0018-0831(2007)63[184:CDOFCA]2.0.CO;2

Hoare, J. M., Pledger, S., Nelson, N. J., & Daugherty, C. H. (2007). Avoiding aliens: Behavioural plasticity in habitat use enables large, nocturnal geckos to survive Pacific rat invasions. *Biological Conservation, 136*(4), 510-519. doi:http://dx.doi.org/10.1016/j.biocon.2006.12.022

Jarvie, S., & Monks, J. M. (2014). Step on it: can footprints from tracking tunnels be used to identify lizard species? *New Zealand Journal of Zoology, 41*(3), 210-217. doi:10.1080/03014223.2014.911753

Jarvie, S., Ramirez, E. A., Dolia, J., Adolph, S. C., Seddon, P. J., & Cree, A. (2014). Attaching Radio Transmitters Does Not Affect Mass, Growth, or Dispersal of Translocated Juvenile Tuatara (Sphenodon punctatus). *Herpetological Review, 45*(3), 417-421.

Jewell, T., & McQueen, S. (2007). *Habitat characteristics of jewelled gecko (Naultinus gemmeus) sites in dry parts of Otago*: Science and Technical Pub., Department of Conservation.

Knox, C. D., Alison, C., & Seddon, P. J. (2013). Accurate identification of individual geckos (Naultinus gemmeus) through dorsal pattern differentiation. *New Zealand Journal of Ecology, 37*(1), 60-66. doi:10.2307/24060758

Knox, C. D., Cree, A., & Seddon, P. J. (2012). Direct and indirect effects of grazing by introduced mammals on a native, arboreal gecko (Naultinus gemmeus). *Journal of Herpetology, 46*(2), 145-152.

Knox, C. D., & Monks, J. M. (2014). Penning prior to release decreases post-translocation dispersal of jewelled geckos. *Animal Conservation, 17*, 18-26. doi:10.1111/acv.12149

McCoy, E. D., Osman, N., Hauch, B., Emerick, A., & Mushinsky, H. R. (2014). Increasing the chance of successful translocation of a threatened lizard. *Animal Conservation, 17*, 56-64. doi:10.1111/acv.12145

Mellor, D. J., Beausoleil, N. J., & Stafford, K. J. (2004). *Marking amphibians, reptiles and marine mammals: animal welfare, practicalities and public perceptions in New Zealand*: Department of Conservation Wellington.

Miller, K. A., Bell, T. P., & Germano, J. M. (2014). Understanding Publication Bias in Reintroduction Biology by Assessing Translocations of New Zealand's Herpetofauna. *Conservation Biology, 28*(4), 1045-1056. doi:10.1111/cobi.12254

Nelson, N. J., Keall, S. N., Brown, D., & Daugherty, C. H. (2002). Establishing a New Wild Population of Tuatara (Sphenodon guntheri). *Conservation Biology*, *16*(4), 887-894. doi:10.1046/j.1523-1739.2002.00381.x

Newman, D. G. (1994). Effects of a mouse, Mus musculus, eradication programme and habitat change on lizard populations of Mana Island, New Zealand, with special reference to McGregor's skink, Cyclodina macgregori. *New Zealand Journal of Zoology*, *21*(4), 443-456.

Nielsen, S. V., Bauer, A. M., Jackman, T. R., Hitchmough, R. A., & Daugherty, C. H. (2011). New Zealand geckos (Diplodactylidae): Cryptic diversity in a post-Gondwanan lineage with trans-Tasman affinities. *Molecular Phylogenetics and Evolution, 59*(1), 1-22. doi:http://dx.doi.org/10.1016/j.ympev.2010.12.007

Nilsen, E. B., Pedersen, S., & Linnell, J. D. (2008). Can minimum convex polygon home ranges be used to draw biologically meaningful conclusions? *Ecological research, 23*(3), 635-639.

Parker, K. A., Dickens, M. J., Clarke, R. H., & Lovegrove, T. G. (2012). The theory and practice of catching, holding, moving and releasing animals. *Reintroduction Biology: integrating science and management*, 105-137.

Pickerell, G. A., O'Donnell, C. F. J., Wilson, D. J., & Seddon, P. J. (2014). How can we detect introduced mammalian predators in non-forest habitats? A comparison of techniques. *New Zealand Journal of Ecology, 38*(1), 86-102.

Reardon, J. T., Whitmore, N., Holmes, K. M., Judd, L. M., Hutcheon, A. D., Norbury, G., & Mackenzie, D. I. (2012). Predator control allows critically endangered lizards to recover on mainland New Zealand. *New Zealand Journal of Ecology, 36*(2), 141-150.

Rittenhouse, T. A., Altnether, T. T., & Semlitsch, R. D. (2006). Fluorescent powder pigments as a harmless tracking method for Ambystomatids and Ranids. *Herpetological Review, 37*(2), 188.

Rolfe, J., & McKenzie, N. (2000). Comparison of methods used to capture herpetofauna: an example from the Carnarvon Basin. *Records of the Western Australian Museum, 61*(sSuppl).

Romijn, R. L., Nelson, N. J., & Monks, J. M. (2013). Forest geckos (Mokopirirakau 'Southern North Island') display diurno-nocturnal activity and are not reliant on retreats. *New Zealand Journal of Zoology, 41*(2), 103-113. doi:10.1080/03014223.2013.860041

Salvador, A., Martin, J., & López, P. (1995). Tail loss reduces home range size and access to females in male lizards, Psammodromus algirus. *Behavioral Ecology, 6*(4), 382-387. doi:10.1093/beheco/6.4.382

Saunders, A., & Norton, D. (2001). Ecological restoration at mainland islands in New Zealand. *Biological Conservation, 99*(1), 109-119.

Seaman, D. E., & Powell, R. A. (1996). An evaluation of the accuracy of kernel density estimators for home range analysis. *Ecology, 77*(7), 2075-2085.

Seddon, P. J., Strauss, W. M., & Innes, J. (2012). Animal translocations: what are they and why do we do them. *Reintroduction Biology: integrating science and management*, 1-32.

Thompson, G. G., & Thompson, S. A. (2007). Usefulness of funnel traps in catching small reptiles and mammals, with comments on the effectiveness of the alternatives. *Wildlife Research, 34*(6), 491-497.

Towns, D. R., Atkinson, I. A., & Daugherty, C. H. (2006). Have the harmful effects of introduced rats on islands been exaggerated? *Biological Invasions, 8*(4), 863-891.

Towns, D. R., & Daugherty, C. H. (1994). Patterns of range contractions and extinctions in the New Zealand herpetofauna following human colonisation.

New Zealand Journal of Zoology, 21(4), 325-339. doi:10.1080/03014223.1994.9518003

Towns, D. R., & Ferreira, S. M. (2001). Conservation of New Zealand lizards (Lacertilia: Scincidae) by translocation of small populations. *Biological Conservation, 98*(2), 211-222. doi:http://dx.doi.org/10.1016/S0006-3207(00)00156-7

Van Andel, M., McInnes, K., Tana, T., & French, N. P. (2016). Network analysis of wildlife translocations in New Zealand. *New Zealand Veterinary Journal, 64*(3), 169-173. doi:10.1080/00480169.2015.1110065

Watts, C. H., Thornburrow, D., Green, C. J., & Agnew, W. R. (2008). Tracking tunnels: a novel method for detecting a threatened New Zealand giant weta (Orthoptera: Anostostomatidae). *New Zealand Journal of Ecology*, 92-97.

White, G. C., & Garrott, R. A. (2012). *Analysis of wildlife radio-tracking data*: Elsevier.

Wilson, J. L., & Cree, A. (2003). Extended gestation with late-autumn births in a cool-climate viviparous gecko from southern New Zealand (Reptilia: Naultinus gemmeus). *Austral Ecology, 28*(3), 339-348. doi:10.1046/j.1442-9993.2003.01293.x

Worton, B. J. (1989). Kernel methods for estimating the utilization distribution in home- range studies. *Ecology, 70*(1), 164-168.

Appendices

Appendix I. Table of number of fixes, final distance from release (m), average weekly movement (m), total distance travelled (m) and average perch height (m) for all geckos tracked for longer than a week.

Release	I.D	Number of fixes	Final distance from release (m)	Average Weekly movement (m)	Total Distance travelled	Average Perch Height (m)
Non-penned	Flow	27	4.63	5.31	105.96	1.78
Non-penned	M18	22	30.56	5.59	58.11	1.7
Non-penned	M4	41	10.34	10.57	192.54	1.92
Non-penned	MB	29	5.68	5.37	91.92	1.91
Non-penned	MC	27	12.21	3.55	117.05	1.58
Non-penned	MY	26	11.85	4.17	112.12	2.15
Non-penned	MZ	31	29.51	9.26	125.12	2.15
Penned	FT	10	8.77	2.83	23.92	1.69
Penned	M1	15	10.55	6.5	56.54	0.97
Penned	M17	37	5.54	5.51	146.13	1.71
Penned	M30	19	14.22	9.66	68.28	1.72
Penned	MS	46	35.18	9.06	186.89	1.23
Penned	Albert	41	14.93	4.39	169.29	2

Appendix II. Pathology report from Massey University for deceased gecko M30.

Institute of Veterinary, Animal and Biomedical Sciences

PATHOLOGY REPORT

Submitter's Ref.:	Date Sent: 17/04/2014	Accession No.: **50779**

TO: Sarah Scott
Massey University - Albany
Auckland

Species: Reptile (1)	Sex: Male	Age: Adult	Breed: Auckland Green Ge
ID: M30	At Risk:	Affected:	Dead: 1
Owner:		Prev. Accn.:	Type: Post Mortem

HISTORY
Submitted by Sarah Scott from Massey University Albany.
Auckland Green Gecko Adult Male ID M30
Last weight 6.95 grams
Found dead in tree, hanging from transmitter antena on 21/03/14 at 3pm. Loaction Hunua Ranges, wild population translocation. Individual had been translocated on 26/02/14 from an area on site of the Windstone Agregates Quarry in the Hunua Ranges. Was translocated to another are on site <1km away. When released on the 03/03/14 had 0.3g transmitter attached with backpack desing that did not exceed 0.15g
This backpack was replaced on 18/03/14, the last time M30 was seen before being found dead a few days later. Because of this I think it may be stress that has caused the death. The body had been frozen from the day it was found and has been then placed in formalin.

GROSS FINDINGS
Arrived in formalin jar.

HISTOPATHOLOGY
Bearing in mind the autolytic artifact, sections of heart, lung, liver, kidney, testis and gastrointestinal tract show no obvious abnormalities.

DIAGNOSIS
Uncertain cause of death

COMMENTS
There was no obvious indication of an infectious/inflammatory process. Unfortunately freezing and thawing does result in some damage to the tissues so a more disease subtle process may not be picked up.

File Nos.:

Students:

Date: Pathologist: S A Hunter

Copy to:

Appendix III. Table of raw data, all collected measurements for every gecko caught during spotlighing efforts in 2014. Gecko I.Ds' and morphometrics along with any distinct markings or scars.

Capture Date	I.D	Sex	wt (g)	svl (mm)	vtl (mm)	regen (mm)	tail width (mm)	head width (mm)	scars/bitemarks/reprostate/notes
17/02/2014	J16	M	1.9	45	53	Full	3	8	No bitemarks, some markings on tail
17/02/2014	F16	F	11.5	74	87	Full	6.5	14	Gravid
17/02/2014	J17	M	3	49	53	Full	4	10	Bitemark on tail, markings
17/02/2014	M16	M	7	72	94	Full	5	13	Markings on tail, right lower lip scar
18/02/2014	F17	F	10.5	76	98	Full	7	14	Abraisions right lower lip, scar left chest, gravid
18/02/2014	J18	M	2	41	52	Full	3	9	Pink mark under chin, marking round front left eye
19/02/2014	F18	F	5.25	62	79	Full	4.5	12	Circular scar between eyes, gravid, scar damage between stripes on head
19/02/2014	J19	F	2.25	46	59	Full	3	10	No scar
24/02/2014	J20	M	2.13	47	57	Full	3	9	In process of shedding
24/02/2014	J21	M	2.44	50	56	Full	4	10	Scar by right eye
25/02/2014	M17	M	8.97	75	93.5	Full	6	14	Bite marks on tail, possible regen tail tip, scars on head between eyes, left toe scar, rear right missing
25/02/2014	F19	F	11.23	71	89	Full	7	13	Gravid, slight scar on head, scarring under chin
25/02/2014	M18	M	5.8	60	76	Full	5	12	Left hand pinky dead (later fell off), cream pattern along body, wound on left of tail
25/02/2014	J22	F	2.43	48	56.5	Full	4	10	Yellow strip along eyes and shoulder
25/02/2014	F2	F	9.91	74	54	45	4	13	Gravid, tiny scar left eye
25/02/2014	J23	?	2.29	46	61	Full	4	10	Scars on tail, yellow pattern stripes
25/02/2014	J24	F	2.47	48	60	Full	4	10	Wound under right lip that has a lump
26/02/2014	M30	M	7.28	70	88	Full	6	13	Scar under chin, scar on lower back and left side of belly. Yellow with cream markings
26/02/2014	F20	F	4.2	61	70	Full	4	11	Scar back of head and right eye
3/03/2014	J99	F	3.31	53	59.2	Full	4	11	No scars, little cream dot pattern
3/03/2014	F99	F	11.92	76	95	Full	7	15	Gravid, funny scar under right lip
4/03/2014	M2	M	7.26	68	93	Full	6	13	No bitemarks, in process of shedding
4/03/2014	F3	F	7.96	69	91	Full	5	12.5	No bitemarks, gravid, dirty yellow splotch pattern

5/03/2014	J1	?	2.65	47	57	Full	4	10	Yellow colouration with cream markings
5/03/2014	M1	M	8.16	73	92	Full	6	12	Cream splotch pattern
6/03/2014	J2	M	3.1	54	63	Full	4	11	Small yellow splotch pattern, no pattern on head
10/03/2014	F4	F	7.45	68	87.5	Full	4	12	Gravid, bruised under chin, scar on right shoulder, lump right lower jaw, sting-like spot on tail, scarring on tail
11/03/2014	Martha	F	9.34	68	80	Full	5	13	Gravid, scuff mark on tip of nose, no bitemarks, yellow splotch ,markings
11/03/2014	Albert	M	6.48	61	79	Full	6	12.5	Process of shedding, plain green
12/03/2014	FT	F	6.62	64	82	Full	5	13	Yellow pattern on head and tail, large pink wound on tail, nicked tail, scrap left side of head, dull scales
12/03/2014	Gertrude	F	9.4	80	81	73	6	13.5	Plain green, large pink wound on tail, crater scar under chin
18/03/2014	M4	M	9.08	68	100	Full	6	14	Dull green with light black dots, line scar on belly, tiny scar dots on head
18/03/2014	JX	?	1.34	43	6	0	3	8	Yellow splotch markings, scar on body, lost tail, oldish wound, not clean cut, wounds on back and right leg
18/03/2014	FX	F	6.99	68	74	Full	5	13	Gravid, bright green with yellow stripe and splotch pattern, tiny scar under left bottom lip, wasp sting on tail
18/03/2014	MX	M	6.27	68	75	71	6	13	Dark green bright contrast with cream spots with black outlines, silver scars on back, yellow snout, kink at tip of tail
19/03/2014	FA	F	8.22	72	86.5	Full	6	13	Gravid? Scar on left front foot and right back leg, two pink dots right tail and back left toe
19/03/2014	FB	F	5.73	65	77	Full	5	12	Gravid? Very bright green, no scarring, GC
19/03/2014	MC	M	7.65	70	86	Full	7	13	Little head, yellow stripe pattern, scuff on nose
19/03/2014	MB	M	7.15	71	64	55	6	13.5	Shedding in process, wasp sting on tail, pink dot on back foot, dullish green with yellow snout

22/03/2014	FC	F	11.25	71	90	Full	6	19	Gravid, faded gold stripe on head, bright gold stripe on tail
23/03/2014	JA	?	2.42	53	63.5	Full	3.5	10	Bright green, cream stripes with black outline, faded pink marking under chin
23/03/2014	Flow	F	5.3	64	73.5	Full	5.5	12	Bright green, few sliver dots on body, wasp sting back left leg, small scar under right chin, long scar on left side
26/03/2014	FZ	F	10.45	78	90	Full	6	13	Gravid, plain green, few silver scars on body and tail, purple tinge on bottom of feet
26/03/2014	MZ	M	7.88	69	86	Full	6	14	Scar on tail, pale green with pale stripe pattern
26/03/2014	FD	F	4.76	61	38	31.5	5	12	Bright green, pink dot on nose and right back leg, scar on tail and under chin
26/03/2014	MY	M	5.48	62	78	Full	5	12	Faded light green, shedding skin on head
31/03/2014	JS	F	2.26	50	4	0	0	10	Dark green, yellow stripe pattern with black outline, fresh tail drop, left eye cloudy with blood pots around eye ball, very docile, two scars on body
31/03/2014	JT	M	2.8	51	64	Full	3.5	10	Double yellow stripe on head, but plain pale green body, wound left side of tail, tiny scar under right eye
31/03/2014	MS	M	8.3	75	101	Full	6	13	Bright green with yellow splotted markings
9/05/2014	JJ	F	2.7	48	62	Full	4	10	Bright green no markings, scar right bottom jaw