A trial wild-wild translocation of the critically endangered grand skink *Oligosoma grande* in Otago, New Zealand

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SUMMARY

The in situ management of the critically endangered grand skink *Oligosoma grande* currently hinges on the on-going health of a single large sub-population at Macraes Flat, Otago. Given its vulnerability, it was considered desirable to establish additional sub-populations to ensure the long-term survival of the species. A spatial meta-population simulation of grand skinks at Macraes Flat suggested that this could be facilitated by the translocation of grand skinks into areas of predator protected habitat. Areas identified by modelling as suitable translocation sites were ground-truthed by an experienced survey team in 2008. In October 2009 we began a translocation trial. We moved nineteen grand skinks from three locations to the translocation site. The founder population was made up of ten juveniles and nine sexually mature grand skinks. Seasonal estimation of persistence and abundance using a photographic re-sight methodology allowed the short- and medium-term performance of the translocation to be assessed. High initial persistence rates suggested immediate homing was not a factor of concern. After one year, all translocated juveniles had persisted, but only four of the original nine adults remained at the release site. While the loss of adults was to some extent offset by the birth of the young-of-the-year (total skinks start: $n = 19$, finish: $n = 20$) there was a moderate loss of ~ 10% in terms of the population's expected reproductive value. Overall, we viewed the outcome as favourable and on that basis undertook a follow up translocation.

BACKGROUND

Grand skinks (*Oligosoma grande*) are one of New Zealand's largest and most critically endangered lizards (Tocher 2003; Hitchmough et al. 2010). They are associated with deeply fractured schist rock outcrops (Towns 1985). Once found over much of central Otago, from Lake Hawea in the west to Macraes Flat in the east, they have declined to about 8% of their presumed former range (Whitaker & Loh 1995). The distribution of grand skinks is now reduced to relict populations in native tussock grasslands at the extreme east and west of their former range. Genetic evidence suggests that the current skink population is a fraction of its historic size (Berry & Gleeson 2005). Reardon et al. (2010) have implicated a suite of introduced predators: cats (*Felis catus*), stoats (*Mustela erminea*), ferrets (*Mustela furo*), weasels (*Mustela nivalis*) and hedgehogs (*Erinaceus europaeus*) in their current decline. In their three year management experiment Reardon et al. (2012) found that

predator eradication in mammal-proof fences or intensive control through trapping resulted in rapid population growth.

Currently, the largest wild population of grand skinks is spread across public conservation land and adjacent farmland on a ridge-top at Macraes Flat, Otago (likely numbering ~ 1300 animals). Predator trapping currently implemented at this site is suspected to be adequate for population stability but is insufficient to achieve population growth (Reardon et al. in 2012). Given this population's vulnerability it was considered desirable to have additional sub-populations to diversify risk.

In 2008 we undertook a spatial meta-population simulation (emulating 12,600 ha) to help us assess the long-term prospects of five potential management scenarios for grand skinks at Macraes Flat (DOC unpublished) These scenarios were: 1) no management, 2) the 2006 mammal-proof fencing and trapping networks
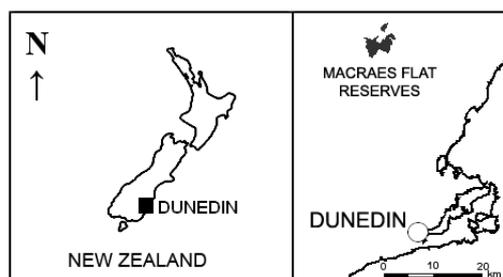
Figure 1. Location of the Macraes Flat reserve system, Otago, New Zealand

(sensu Reardon et al. 2012: core: 275 ha, peripheral: 1850 ha sensu), 3) an extended trapping network with existing mammal-proof fencing (core: 975 ha, peripheral 1675), 4) the extended trapping network with existing mammal-proof fencing with the annual translocation of low numbers of skinks (typically around 12 per year but fluctuating depending on the growth seen in the previous year) from mammal-proof fences to the vacant areas of protected habitat, and 5) two large mammal-proof fences (275 and 325 ha). We assessed each scenario using 506 spatially interlinked population projection matrices (Caswell 2001) over a 30 year time frame. These simulations suggested that scenario 4 would have the best potential recovery. This outcome was due in part to the otherwise low natural migration rates of grand skinks. Consequently, we hypothesised that meta-population recovery would be accelerated by the re-establishment of grand skinks into areas of protected vacant habitat. However, before there could be any possibility of such a conservation invention on a large scale, we would first need to establish that translocation of grand skinks was a viable technique.

Cost–benefit analysis has shown that trapping at Macraes Flat to protect the remaining populations of grand skinks and the syntopic Otago skink (*Oligosoma otagense*) is more cost efficient than mammal-proof fencing for areas greater than 10 ha (Hutcheon et al. 2011). Consequently, beginning in late 2008 the trapping network at Macraes Flat was extended (using the same suite of trap/bait combinations as Reardon et al. 2012) until it covered approximately 4500 ha with 800 active traps (positioned along the trap-lines at intervals of 100m). As a result of these actions, protection was given to areas of grand skink habitat that had not been protected from predators under the previous management regime (cf. Reardon et al. 2012).

The translocation sites used in the computer simulation were ground-truthed by an experienced lizard survey team in 2008. The survey team considered the merits of these candidate locations based on the ecological requirements of grand skinks: availability of lizard shelter (fissures, cracks and overhangs), flat basking areas, sunny ridge-top aspect and availability of fruiting vegetation (especially *Melicytus alpinus*). The operational requirements needed for the trial were the natural containment of outcrops (to provide a distinct search area), safety and accessibility (i.e. absence of bluffs and high promontories). From a candidate set of locations, a ridge top translocation site, consisting of a tight cluster of isolated rock outcrops was identified for our trial. This site was protected on three quadrants by multiple trap-lines and by a single trap-line on the south-eastern quadrant.

Although this site was well within their historic range, the area had no previous recorded instances of grand skinks. However, a solitary mature grand skink was encountered during an unrelated survey of the wider vicinity in December 2008, thus supporting the choice of the general area as a suitable translocation site.

The aims of our trial were threefold: 1) to establish whether the translocation site habitat was viable in the short- and medium term; 2) to identify whether juveniles or adults were the best cohorts to translocate; and 3) to ascertain improvements for future translocations.

ACTION

Study Site: The study centred upon a reserve system managed by the Department of Conservation (DOC) at Macraes Flat (45° 25' S, 170° 28' E) in eastern Otago (Figure 1). The wider area contains extensive Haast schist rock outcrops which form an obligate part of the grand skink habitat. Within the translocation area vegetation was a mosaic of introduced grassland, native tussock (*Chinochloa rigida, C. rubra*) and mixed shrublands (Bibby 1997) with kanuka (*Kuneza ericoides*) as the dominant woody species.

Source population: We planned to translocate 20 animals to a discrete cluster of outcrops on a gully ridge (total area 0.25 ha, nearest useable habitat 60 m away). From our experiences elsewhere in the reserve this number of founders was thought to be well within the carrying capacity of the translocation site. Source sites were all approximately 4 km from the translocation site – far greater than the 200 m required to overcome the homing effect in grand

skinks reported in Stanley (1998). Skinks were removed from three donor sites under one of two management regimes: 1) no predator management and likely to go extinct in the medium term (two sites), and 2) from within small mammal-proof exclosures where the extraction was part of a parallel carrying capacity experiment (one site).

We suspected that there may be ontogenetic differences with site fidelity. While grand skinks generally do not appear to migrate much over their lifetime, preliminary data suggested that adult grand skinks appear to show higher site fidelity than juveniles (DOC unpublished data). To exacerbate these possible differences, we split the founders between juveniles (young-of-the-year) and adults.

As grand skinks are believed to be promiscuous (Berry 2006) the limiting factor for population growth would be female availability. Currently, the only established technique for sexing mature *Oligosoma* skinks is by physical eversion of the hemipenes in males (Holmes & Cree 2006). A negative result would mean the skink is female or male with hemipenes that failed to evert. Consequently, because of the possibility of obtaining a false negative and a promiscuous mating system, it was decided to maintain an adult sex bias slightly in favour of presumed females.

Translocation day: Two teams of four people worked simultaneously on 5th October 2009 to capture the animals from the various donor sites. The day was fine and sunny but with a cooling breeze (Dunedin max temperature: 11°C). Although the aim was to catch 20 skinks the teams only managed 19 (ten juveniles, nine mature adults: five presumed female, four male). Captured animals were held in cloth bags within insulated containers cooled by frozen coolant pads. Palpation (Holmes & Cree 2006) indicated that at least two of the females examined were likely to be carrying embryos at the time of capture. Animals were then released randomly at rock crevices across the translocation site between 17:34 and 17:55 hrs which allowed the skinks some opportunity to find cover before night fall (Dunedin sunset: 1951 hrs). The majority of skinks were observed to make for shelter in crevices, however 3–4 larger animals remained within 10–20 cm of their immediate release position and basked.

Skink Monitoring Protocol:

Initial period: Cormack-Jolly-Seber analysis

Over the next 59 post- translocation days we assessed survival on six occasions (at intervals of 7–15 days) using a non invasive photographic re-sight methodology which accounted for variable detection probabilities (Table 1). For consistency, and to provide the best capture probabilities, photographic re-sight surveys were only carried out in warm sunny conditions with low wind strength (as in Roughton 2005). Surveyors attempted to photograph both lateral sides of all visible skinks with a preference for the nose to foreleg region which encompassed spots and curvilinear black and gold markings by which individuals could be easily distinguished (Reardon et al. 2012). The best left and right-hand side images of each individual were checked against a photographic library. The extensive photographic re-sight surveys of Reardon (2012) showed small changes in scale coloration were rare, thus we regard the probability of misidentification within such a limited sample size to be remote. There were no specific time limits for each survey although they typically took 1–1.5 hours. To minimise observer bias between sampling occasions, we alternated the starting position of surveyors within the translocation site. The nearest neighbouring outcrops which encircled the translocation site (60–220 m away) were also separately searched for the presence of any migrant grand skinks (resulting in a total search area of 5.7 ha).

Photographic re-sight data were analysed using the Cormack-Jolly-Seber model (CJS) in program MARK (version 5.1). The CJS model is an open population model meaning that the population is considered open to births, deaths and migration (Williams et al. 2002). We utilized the CJS for the initial two months because we were looking for any evidence of a sensitive period which may have been indicative of homing or an inadequacy in the translocation site. The model parameters of interest were apparent survival (φ) and detection probability (p). Simulated modelling suggested that the dataset would be too sparse to run a time-dependent general model, therefore reduced parameter models were based upon a model in which juvenile or adult cohorts (g) showed differences both in survival and detection probability: $\varphi(g)$ $p(g)$. The remaining three models considered were: cohort differences in survival but not in detectability $\varphi(g)$ $p(.)$, cohort differences in detectability but not in survival $\varphi(.)$ $p(g)$, and no cohort differences in either survival or detectability $\varphi(.)$ $p(.)$. An adjustment was made for a variance inflation factor ($\hat{C}$). Survival is presented as a survival probability across the entire 59 day period (Table 1).

Table 1. Model selection table for Cormack-Jolly-Seber photographic re-sight analysis with model specific survival (φ) and detection (p) probabilities for the 59 day initial monitoring period. Depending on the model, φ and p maybe shared between juvenile and adult cohorts.

| Model	AICc	Delta AICc	AICc Weight	Model Likelihood	Parameters	Deviance	Juvenile φ (95% CI)	Adult φ (95% CI)	Juvenile p (95% CI)	Adult p (95% CI)
$\varphi(.)\,p(g)$	102.943	0.00	0.52418	1.0000	3	35.282	0.88 (0.57 -0.97)		0.73 (0.57 - 0.85)	0.90 (0.76 - 0.96)
$\varphi(.)\,p(.)$	104.634	1.69	0.22511	0.4294	2	39.141	0.87 (0.56 - 0.97)		0.81 (0.71 - 0.89)	
$\varphi(g)\,p(g)$	105.171	2.23	0.17205	0.3282	4	35.280	0.88 (0.28 – 0.99)	0.89 (0.42 – 0.98)	0.73 (0.57 - 0.85)	0.90 (0.76 - 0.96)
$\varphi(g)\,p(.)$	106.737	3.79	0.07865	0.1500	3	39.075	0.85 (0.31 – 0.98)	0.89 (0.41 – 0.99)	0.81 (0.71 - 0.89)	
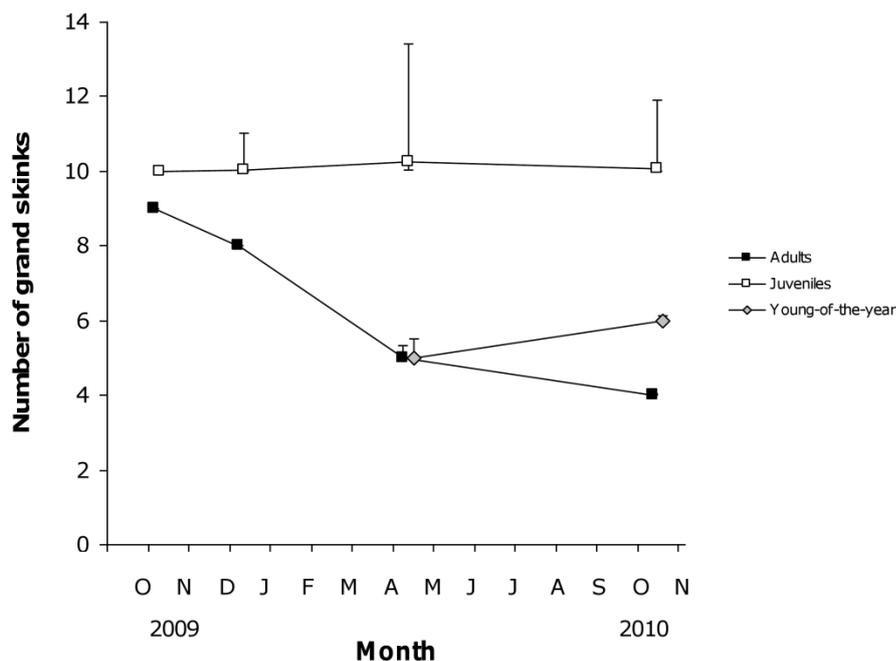
Figure 2. Changes in abundance of translocated grand skink cohorts through seasonal monitoring. Error bars represent 95% confidence intervals.

Seasonal robust design analysis

Using the same photo-resight technique we monitored the population in December 2009, April 2010 and October 2010 (the periods consisted of five, three and four closed capture sessions respectively). We analyzed the photographic re-sight data using the robust design model with a Huggins closed population estimator in Program MARK (version 5.1). The robust design, while more labour intensive than a CJS approach, has the advantage of producing population estimates, but this method requires the assumption of population closure. Nine models were tested representing all permutations of survival (in the robust design denoted by S) and detectability (p) being influenced by time (t), cohort (g) or neither (.). Interactions (e.g. $p* t$ models) were not tested due to the sparseness of the data. Of the candidate model suite only the $S(t)$ $p(g)$ model failed to be estimable.

We ranked the candidate models in each analysis using model selection based on the corrected Akaike Information Criterion (AICc, an adjustment to AIC to account for bias due to small sample size), which was used to compute model weights to rank models (Burnham & Anderson 2001).

CONSEQUENCES

Analysis of the photo-resight data in program MARK using the CJS method indicated that approximately 88% of all animals likely survived and remained in the translocation area for the first 59 days and that cohort was not an immediate factor in survival (Table 1). All CJS models gave similar survival estimates regardless of whether cohort was considered as a factor. Indeed the similarities in deviance between the models with and without cohort as a factor in survival suggested that cohort, in relation to initial survival, was a pretending variable (sensu Anderson 2008) and thus its inclusion in the model was uninformative. There was, however, some support for cohort differences on detectability grounds with juveniles having a lower estimated detectability of 0.73 compared to that of 0.90 for adults (Table 1). The confidence intervals of these detectability estimates, however, were sufficiently wide to suggest that the difference may be less than definitive.

Of the robust design models (Table 2), the $S(g)$ $p(g)$ model had almost unanimous support (AICc 240.96, AICc weight 0.94, 6 parameters) indicating that cohort affected both survival and detectability over the year. The robust design

seasonal monitoring showed unequivocally that all the juveniles had persisted at the translocation site throughout the year (Figure 2). Such high survival and fidelity (persistence) was unexpected. By contrast, the number of adults declined at the site throughout the year with the largest drop occurring over the December–April period until just four adults remained (Figure 2). The top model in the robust design analysis confirmed that there were large differences in detectability between adults (p = 0.92, 95% CI: 0.82 – 0.96) and juveniles (p = 0.71, 95% CI: 0.62 – 0.78). This result backed up the inference from the CJS analysis and suggested that the difference in detection probability between cohorts needs to be accounted for as a standard modelling practice. In practical terms this means indices or estimators which do not address cohort detectability issues run the risk of producing erroneous results.

Whilst there were clear differences between cohorts in terms of persistence, grand skinks that were translocated were clearly capable of surviving at this site and individuals showed remarkable persistence in the first eight weeks. It was clear that whilst our sample size was small the encounter histories generated through the photographic re-sight method were nevertheless adequate for providing useful management information. The 100% survival rate of juveniles over the course of a full year was exceptional and

suggested that there is little risk associated with their translocation. Adults, on the other hand, appeared less persistent with five of these individuals disappearing throughout the year.

There is the possibility that the density of adults at the translocation site may have exceeded carrying capacity. Indeed, during the breeding season in autumn fights were observed between mature males. We speculate that some adults may have left the area permanently as a result of such altercations or alternatively were subject to adult biased predation by residual predators. Regardless, no adult grand skinks were ever found in wider surveys (~500m radius) of the translocation area conducted in December 2010. The appearance of young-of-the-year in late summer/autumn, suggested some of the remaining females had given birth to healthy offspring and this to some extent offset the loss of adult animals.

Although there was an increase from 19 to 20 skinks over a period of a year at the translocation site, the reproductive potential of the population likely diminished due to the lower number of sexually mature animals present. This loss can be quantified to some extent through the use of a population projection matrix (Caswell 2001) based on the survival estimates from this study and surrogate values for missing life stages obtained from other grand skink monitoring sites

Table 2. Model selection table for Robust design photographic re-sight for the seasonal closed capture monitoring period.

Model	AICc	Delta AICc	AICc Weight	Model Likelihood	Parameters	Deviance
$S(g)\,p(g)$	240.957	0.00	0.94001	1.0000	6	286.479
$S(.)\,p(g)$	246.664	5.71	0.05417	0.0576	4	296.436
$S(g)\,p(.)$	252.214	11.26	0.00338	0.0036	4	301.986
$S(g)\,p(t)$	253.993	13.04	0.00139	0.0015	6	299.515
$S(t)\,p(t)$	255.415	14.46	0.00068	0.0007	14	282.938
$S(.)\,p(.)$	257.986	17.03	0.00019	0.0002	2	311.914
$S(t)\,p(.)$	259.282	18.32	0.00010	0.0001	5	306.941
$S(.)\,p(t)$	259.684	18.73	0.00008	0.00001	4	309.456

(DOC unpublished data). An analysis of the remaining animals, in terms of reproductive value as young-of-the-year equivalents derived from the left eigenvectors (Caswell 2001) from such a population projection matrix, indicated that there was a decline in reproductive value of ~10% over the course of the year (start: 23.18, finish: 20.81) (Table 3). So although there was a numerical gain in terms of the numbers of skinks present, there was a net loss in terms of the population's expected reproductive value.

In view of these findings, it was decided to translocate another 14 skinks on 22nd October 2010 (seven juveniles and seven adults including four gravid females) to an adjacent rock outcrop (90 m distant) to accelerate the potential establishment of a self-sustaining population. The average survival rate of a juvenile only cohort would have to exceed 0.76 for three consecutive years in order to match the number of sexually mature adults that would be expected to remain one year after direct translocation (given our observed adult persistence rate was 0.44). Whilst all juvenile animals in our study survived, Reardon et al. (2012) found survival rates for grand skinks at the core of the Macraes Flat trapping network averaged 0.69 – 0.72. Such survival rates suggest that sole reliance on juveniles in a translocation setting would require larger numbers of translocants, and given that more than three years are required to reach maturity, the onset of population growth would be delayed. Consequently, we concluded that a pragmatic strategy for the establishment of a resident adult cohort was to use a mix of cohorts in initial translocations.

During the 2010 translocation, we implemented improvements identified from our initial translocation. During the 2009 translocation day

3–4 skinks remained within 10–20 cm of their immediate release position and basked. It was thought that these skinks may have become too cool from the duration spent in the holding containers (which for some animals would have been approaching seven hours). Consequently in 2010 coolant pads were removed an hour prior to release to ensure that animals were not too cold upon release. Additionally, the skinks were released at the translocation site two hours earlier (~1530 hrs) so that they had better opportunity to find refuge before night fall (Dunedin sunset: 2014 hrs). This new translocation site was an outcrop set amongst large areas of contiguous rock which interconnected with an extensive bluff system which we hoped would decrease the magnitude of competitive interactions. However, we were aware that the structure of this rock habitat would make it more difficult to survey and hence obtain accurate survival and abundance estimates.

After our 2010 translocation, it was considered that the translocated population should undergo no further augmentation until it was firmly established by annual monitoring that the level of predator trapping in the surrounding area was sufficient to allow population growth. In the longer-term, DOC intends to continue to monitor this population on an annual basis and we look with interest towards the breeding of the first natal generation expected sometime around 2013–14.

Table 3. Reproductive value as young-of-the-year (YOY) equivalents: at the start of the translocation and one year later

Age (years)	Reproductive value (YOY equivalent)	No. of skinks start	No. of skinks after 1 year	YOY equivalents start	YOY equivalents after 1 year
0-1	1	10	6	10	6
1-2	0.895	0	10	0	8.95
2-3	1.145	0	0	0	0
3+	1.464	9	4	13.18	5.86
TOTAL		19	20	23.18	20.81

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