Placement period of artificial retreats affects the number and demographic composition but not the body condition of skinks

William G. Batson[1*], Colin F. J. O'Donnell[2], Nicola J. Nelson[3] and Joanne M. Monks[4]

[1]Fenner School of Environment and Society, The Australian National University, Building 48 Linnaeus Way, Canberra, ACT 2601, Australia
[2]Science and Capability Group, Department of Conservation, Private Bag 4715, Christchurch Mail Centre, Christchurch 8140, New Zealand
[3]Allan Wilson Centre for Molecular Ecology and Evolution, School of Biological Sciences, Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand
[4]Science and Capability Group, Department of Conservation, PO Box 5244, Dunedin 9058, New Zealand
*Author for correspondence (Email: william.batson@anu.edu.au)

Abstract: Monitoring is important in conservation management, essential for assessing population trends, making decisions and allocating resources. Artificial retreats can offer a reliable, low impact and efficient method for monitoring cryptic herpetofauna. Methods for monitoring artificial retreats vary between different conservation management programmes in New Zealand, however, and a deeper understanding of the consequences of these variations would encourage greater standardisation and enable more reliable comparisons to be made across temporal and spatial scales. We investigate how placement period of artificial retreats affects population size indices and the body condition of common skinks (*Oligosoma polychroma*) in a grassland in Fiordland, New Zealand. We made 3987 skink sightings during 8250 visual checks and captured 638 skinks in 1200 physical searches of 400 artificial retreats during the summer of 2010/11. We observed more skinks under artificial retreats with a placement period of 2 years (permanent retreats) than under adjacent retreats in place for <2 months (temporary retreats). Placement period influenced the demographic composition of skinks occupying the artificial retreats, with a greater proportion of subadults and juveniles seen beneath temporary retreats and a greater proportion of adults occupying permanent retreats. Physical condition of the skinks occupying the retreats was not related to placement period. Our findings suggest that permanent placement of retreats is unlikely to increase survival or reproductive rates by increasing the body condition of individuals occupying retreats, but may result in competitive exclusion of juveniles and subadults by resident adults. We recommend temporary placement of retreats for assessing monitoring trends in skink populations in environments with moderate to high population densities, and permanent placement in areas of low population densities, due to the potential detection advantage. Our results emphasise the need for placement period to be considered when interpreting results from monitoring programmes using artificial retreats.

Keywords: artificial cover objects (ACOs); conservation; cover-boards; lizards; monitoring; New Zealand; *Oligosoma polychroma*; reptiles.

Introduction

Monitoring activities undertaken to ascertain the size or density of a population are essential for many aspects of population management and need to produce population indices that have a reliable linear relationship to the density of that population (Caughley 1977). However, the ability to produce reliable indices can be extremely challenging when monitoring cryptic herpetofauna, due to difficulties associated with detecting and catching individuals (Towns & Ferreira 2001; Hare et al. 2007). The use of artificial retreats (also known as artificial cover objects or cover-boards) has become popular for monitoring challenging populations of herpetofauna when traditional capture–mark–recapture methods are deemed inappropriate or overly demanding (Monti et al. 2000; Lettink et al. 2005; Hampton 2007; Wilson et al. 2007; Hoare et al. 2009). This popularity is largely derived from the method's potential to improve monitoring efficiency and facilitate standardised monitoring regimes (Godley 2012).

When used to monitor ectothermic species, artificial retreat monitoring operates primarily on the principle that individuals will be encouraged to occupy a retreat in order to obtain a benefit provided by the thermal properties of the structure (Thierry et al. 2009). Retreat occupancy, in turn, improves the likelihood that an observer will detect inhabiting individuals due to the increased density within the retreats, and because their location is more predictable compared with the occupancy of natural habitat features (Bell 2009). Artificial retreats can also facilitate a level of standardisation as observers can use a systematic approach to search retreats, and the retreats can be specifically designed (Godley 2012; O'Donnell & Hoare 2012).

Despite the numerous benefits associated with the use of artificial retreats to monitor herpetofauna, the indices produced can be susceptible to a range of biotic and abiotic factors that create variability and reduce the reliability of results. Previous research has identified that these factors can include placement period (Grant et al. 1992; Michael et al. 2004; Pike et al. 2008), retreat density (Reading 1997), retreat construction (Marsh & Goicochea 2003; Lettink & Cree 2007), retreat size (O'Donnell & Hoare 2012), monitoring frequency (Marsh & Goicochea

2003; Wilson et al. 2007), season (Reading 1997; Lettink & Cree 2007), time of day and environmental conditions (Hoare et al. 2009), height of surrounding vegetation (Chavel et al. 2012), and the ecological interactions within and between species (Downes & Shine 1998; Langkilde & Shine 2004; Lettink & Cree 2007). As artificial retreats can significantly alter microhabitat conditions (Thierry et al. 2009; Chavel et al. 2012) they may also affect biological and ecological processes that induce population-level effects by influencing survival and/or recruitment rates (Lettink & Cree 2007). This is based on the assumption that the relative quantities of stored fat can influence reproductive outputs in viviparous lizards (Doughty & Shine 1998). As with any monitoring method the causes of variability need to be carefully considered and accounted for when designing monitoring protocols and interpreting monitoring results.

In this study, we used a high density population of common skinks (*Oligosoma polychroma*) in a temperate grassland in Southern New Zealand to evaluate whether placement period of artificial retreats influences results of skink population monitoring. Specifically, we investigated (1) temporal trends in artificial retreat occupancy by skinks immediately following deployment of retreats; and (2) whether placement period (i.e. the length of time the retreat is left in position) influences the frequency, demographic composition and/or the body condition of skinks occupying retreats. Our primary objective was to establish whether placement period needs to be considered when designing artificial-retreat monitoring protocols and interpreting monitoring results for common skinks and similar species.

Our study was designed to build upon previous studies that have focused on the same population of common skinks with the common objective of developing site-specific monitoring protocols and to provide an operational case-study for other lizard monitoring programmes. To date, the findings of previous studies have indicated that the environmental conditions and timing (Hoare et al. 2009), retreat design (Hoare et al. 2009; O'Donnell & Hoare 2012), and vegetation (Hoare et al. 2009; Chavel et al. 2012) can all influence the population indices produced using artificial retreats on this population. The precision and accuracy of the indices have also been evaluated leading to the conclusion that the method appears to represent an appropriate monitoring approach for this population (Lettink et al. 2011).

Methods

Study area

The study was conducted within the Eglinton Valley in Fiordland, South Island, New Zealand (168°01′ E, 44°58′ S). The site consisted of a 1.5-km^2 area of flat valley floor comprising a mixture of native and exotic grasses and sparsely dispersed native shrubs (Chavel et al. 2012). The area experiences mean monthly maximum temperatures ranging from 7.5°C (June) to 21.5°C (February) (Hoare et al. 2009).

Study species

Common skinks are small (<79 mm snout-vent-length (SVL)) diurnal, heliothermic lizards that inhabit a wide range of environments including grasslands, sand dunes and rock piles (Jewell 2008). Common skinks occur at high densities throughout the study site with an estimated 3600–9200 skinks

per hectare (Lettink et al. 2011). Although the home range of the species has not been specifically investigated, we assume it to be close to 13.7 m^2 estimated for the closely related *Oligosoma maccanni* by Patterson (1985). The assumption of a small home range is also supported by the high population density at the study site.

Retreat design, field array and data collection

Each artificial retreat consisted of a single 670 × 420 mm sheet of corrugated composite roofing material (Onduline, distributed by Composite Insulation, Christchurch; http://www.onduline.co.nz/onduline.htm) placed on the ground. Vegetation beneath the retreats was first cut to c. 5 cm height, to aid in the detection of skinks. Onduline is light in weight and made of organic fibres saturated with bitumen, which retains heat and thus enables lizards to maintain an elevated body temperature relative to their natural surroundings (Lettink 2007; Hoare et al. 2009; Thierry et al. 2009). Previous research has demonstrated that lizards are attracted to Onduline retreats (Thierry et al. 2009) and that neither the colour of the upper surface of the retreat (red, brown and green were all used in this study, with black lower surfaces) nor the substrate beneath the retreat (grass or moss) influences their occupancy by common skinks (Hoare et al. 2009). The presence of artificial retreats substantially changes the characteristics of the vegetation beneath the retreats (Chavel et al. 2012), and it appears that the effect on vegetation is more substantial beneath the permanent retreats than under temporary retreats (WB pers. obs.).

Fieldwork was conducted over three 4-week periods during the summer of 2010/11 (Fig. 1). Within each sampling period, two methods were used to collect data. The 'sighting method' involved lifting artificial retreats and making visual observations of skinks beneath. The 'capture method' involved lifting the artificial retreats and capturing the skinks beneath.

Artificial retreats were arranged in an array of eight paired transect lines (hereafter denoted as 'lines') with randomly located start points within the study site. Each line contained 25 artificial retreats 10 m apart with lines being at least 100 m apart. Eight permanent lines were established in January 2009, almost 2 years before we began this study; and these retreats remained in position until the completion of the study. For this study, we established a corresponding temporary line parallel to and 10 m away from each permanent line. The field array was designed to maintain a high level of independence between retreats as based on the small estimated home range of the species. The eight temporary lines were deployed 3 weeks before sampling in early summer and removed at the end of that period (Fig. 1). Temporary lines were then redeployed one day before the mid-summer sampling period and remained in place until the completion of our study (Fig. 1).

The 3-week non-observational period before sampling began in early summer was included to reduce disturbance caused by cutting the vegetation beneath the retreats prior to deployment. This non-observational period was not repeated for subsequent sampling periods because the vegetation beneath the retreats had not grown substantially. The height of vegetation was measured 0.5 m from each retreat to account for its effect on skink sightings (Chavel et al. 2012).

The sighting method was conducted during the first 3 weeks of each sampling period (Fig. 1). A single observer lifted each retreat and recorded the number of skinks observed beneath. Each skink was categorised into one of three demographic groups (adult, subadult or juvenile) according to size. The adult group was used as the default group when
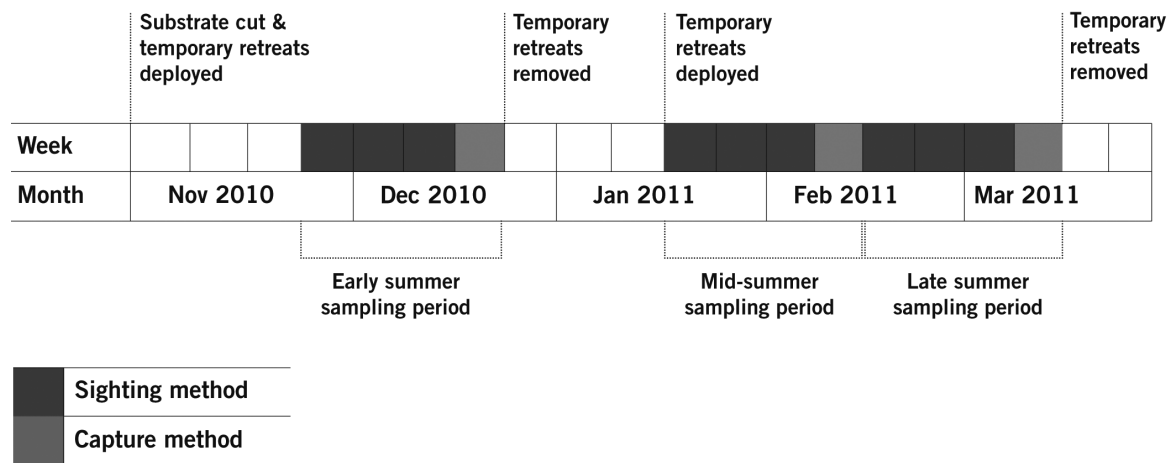
Figure 1. Timeline summarising the schedule and key events involved in monitoring common skinks (*Oligosoma polychroma*) using Onduline artificial retreats in the Eglinton grassland, Fiordland, during the summer of 2010/11.

a definitive categorisation was not possible (due to partial concealment or fleeing). As this method was designed to be as non-invasive as possible to reduce disturbance effects on subsequent observations, the habitat beneath the retreats was not deliberately disrupted, and retreats were not checked more than once a day (Lettink 2007). Sightings were made when ambient temperature was between 12° and 18°C, and monitoring during periods of heavy rain and between sunset and sunrise was avoided following the recommendations of Hoare et al. (2009). Retreats were returned to their previous position immediately following a check and each line was completed within 20 min. Paired permanent and temporary lines at each location were checked together as close in time as possible, and their order was randomised at each check. The order of locations was also varied to minimise any bias caused by the time of day.

The capture method was conducted during the week immediately following the completion of the sighting method within each sampling period (Fig. 1). Two observers worked together with one lifting the retreat and both attempting to capture the skinks by hand. Each retreat ($N = 400$) was checked using the capture method once during each sampling period. Capture sessions were conducted at 0700–1200 and 1800–2000 hours to avoid the hotter period of the day when capture success was reduced due to increased skink body temperature and, hence, mobility. During the capture sessions the habitat beneath the retreats was actively searched (including lifting grasses, mosses and rocks, and hand-searching of tunnels and crevices) in an attempt to locate all individuals. All individuals were returned to the point of capture once morphological assessments were completed.

Snout-vent-lengths were measured to the nearest millimetre using a clear plastic ruler, and weights (mass) were assessed to the nearest 0.1 g using a Pesola spring balance (10 g or 30 g). Captured individuals were categorised into age classes on the basis of their SVL (juvenile: SVL ≤ 39 mm; subadult: 40 mm ≤ SVL ≤ 44 mm; or adult: SVL ≥ 45 mm). The sex of adults was assessed using hemipene eversion, abdominal palpation and/or visual inspection (only for heavily gravid females). A measure of body condition was calculated for each skink using the equation log(mass)/log(SVL), which is an approach adopted in previous herpetological studies (e.g. Hoare et al. 2006).

Statistical methods

Statistical analyses were conducted in R (version 2.12.1; R Development Core Team 2010). In many instances, linear mixed-effects models were conducted using the 'lmer' function in R package 'lme4' to account for the repeated measures nature of the design. As the degrees of freedom cannot be calculated for linear mixed-models, *P*-values reported are based on estimated degrees of freedom. For models in which degrees of freedom could not be estimated, statistical significance ($P \leq 0.05$) was assumed when $t \geq |2.1|$ (the critical value for t_{18}) where degrees of freedom could reasonably be expected to exceed 18. Significance was confirmed using highest posterior density intervals for each fixed effect based on Markov Chain Monte Carlo sampling ($N = 1000$) with the probability set at 95%, but these density intervals are not presented here. Data were checked for normality prior to statistical testing.

The effects of using permanent versus temporary retreats on the demographic composition of observed skinks were assessed using sightings data collected 3+ weeks after deployment of temporary retreats (i.e. excluding data from the mid-summer sample in which temporary retreats had been deployed for less than 3 weeks). The total number of sightings per retreat was included as the response variable, placement period (temporary or permanent), life history stage (juvenile, sub-adult, adult) and their interactions as fixed effects, mean height of vegetation surrounding the retreat as a covariate, and retreat (nested within line) and sampling date as random effects. We assumed the temporary and permanent lines were independent and so our analysis treats the datasets as two distinct populations.

The temporal trends in occupancy of temporary retreats immediately following their deployment were investigated using data from the mid- and late-summer sampling periods. Our approach was to use piecewise linear regression to ascertain the change point (i.e. where skink sightings reached a peak or plateau after an initial acclimatisation period) (Vieth 1989). Number of skink sightings per retreat was included as the response variable and weeks since deployment as the predictor variable. A separate linear model was used to evaluate whether the relationships between sightings under permanent versus temporary retreats in each sampling session were consistent among lines. We included sightings under temporary lines as the response variable, and sightings under permanent lines in

the same sampling session, line number and their interaction as predictor variables.

Data collected from the capture method were used to investigate whether body condition ((log(mass)/log(SVL); as the response variable) of skinks was influenced by placement period of retreats for each of the four life-history stages (juvenile, subadult, adult female and adult male). For these analyses, we included placement period, life history stage and their interaction as fixed effects and retreat (nested within line) as a random effect. Using a subset of data including only adult females, we also investigated whether body condition of pregnant females was influenced by placement period of retreats.

Results

During our fieldwork we made 3987 skink sightings from 8250 retreat checks using the sighting method (mean = 0.48 skink sightings per retreat). The sightings comprised 3270 adults (82%), 601 subadults (15%) and 116 juveniles (3%). Excluding data from checks of temporary retreats with a placement period of less than 3 weeks (from the mid-summer sampling period; Fig. 1), a total of 3557 skink sightings were made from 6825 retreat checks (mean = 0.52 skink sightings per retreat check) comprising 2990 adults (84%), 463 subadults (13%) and 104 juveniles (3%) (Table 1).

The frequency of skink sightings was greater beneath permanent retreats (0.57 skinks per retreat) than beneath temporary retreats with a placement period of 3+ weeks (0.44 skinks per retreat) ($t_{390} = -5.62$, $P < 0.001$). The difference between placement periods was driven by the frequency of adult observations, with an average of 0.49 adult skinks observed per permanent retreat, and 0.35 adults per temporary retreat ($t_{390} = 13.84$, $P < 0.001$; Fig. 2). In contrast, the frequency of non-adults was similar beneath retreats with both placement periods (0.08 non-adults per retreat). Thus, the proportion of non-adults observed beneath retreats was significantly higher under temporary retreats ($t_{390} = 11.76$ and 12.33 respectively, $P < 0.001$; Fig. 2).

Skink sightings increased rapidly over the initial 10 days following the deployment of temporary artificial retreats during the mid- and late-summer sampling periods (change point = 1.43 weeks, $t_{2422} = 8.83$, $P < 0.001$), after which they gradually decreased ($t_{2422} = -8.46$, $P < 0.001$; Fig. 3). Although the number of skinks observed varied among lines ($F_{7,91} = 4.61$, $P < 0.001$) and was higher under permanent than temporary retreats ($F_{1,91} = 124.45$, $P < 0.001$), we did not detect an interaction between placement period and line ($F_{7,91} = 1.21$, $P = 0.308$) indicating that the relationship between sightings beneath temporary and permanent retreats was consistent among the lines within the study site.

We captured 638 skinks from 1200 retreat checks using the capture method (0.53 skinks per retreat). The body condition was not related to the placement period of retreats for any life history stage of skinks ($P > 0.05$ for all; Fig. 4). Examining trends in adult females alone revealed the same pattern; although
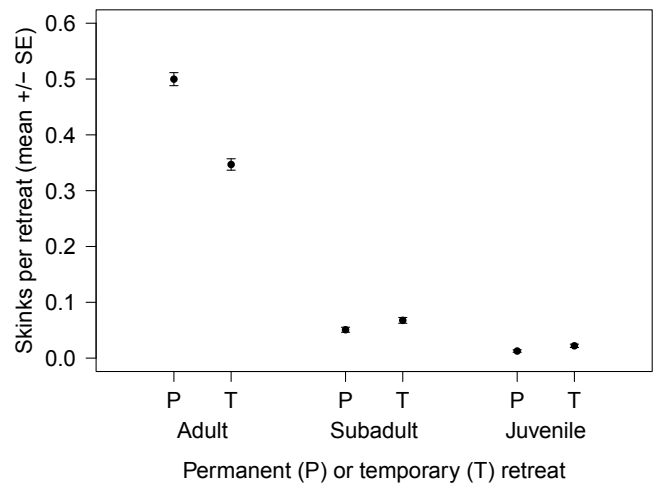

Figure 2. Sightings of common skinks (*Oligosoma polychroma*) under Onduline artificial retreats in place either permanently ('P'; 2 years) or temporarily ('T'; 3+ weeks) in the Eglinton grassland, Fiordland.

Table 1. Sightings and captures of common skinks (*Oligosoma polychroma*) occupying Onduline artificial retreats, summarised by demographics and sampling periods. Numbers in parentheses indicate the mean number of skinks seen or captured per retreat check. Data from permanent (in place for 2 years) and temporary retreats (in place for up to 6 weeks) are pooled.

| | Skink sampling period | | |
	Early summer	Mid-summer	Late summer
Sighting method			
Retreat checks	3350	2850	2050
Juveniles	68 (0.02)	22 (0.01)	26 (0.01)
Subadults	243 (0.07)	281 (0.1)	77 (0.04)
Adults	1639 (0.49)	976 (0.34)	665 (0.32)
Total skinks	1940 (0.58)	1279 (0.45)	768 (0.38)
Capture method			
Retreat checks	400	400	400
Juveniles	10 (0.03)	3 (0.01)	23 (0.06)
Sub-adults	13 (0.03)	15 (0.04)	31 (0.08)
Pregnant adult females	123 (0.31)	37 (0.09)	24 (0.06)
Non-pregnant adult females	13 (0.03)	63 (0.16)	79 (0.2)
Adult males	36 (0.1)	78 (0.2)	86 (0.22)
Escaped prior to sexing	2	1	1
Total skinks	197 (0.49)	197 (0.49)	244 (0.61)

body condition of pregnant females was higher than that of non-pregnant females ($t_{162} = 12.62$, $P < 0.001$), there was no detectable difference in body condition of pregnant females under permanent versus temporary retreats ($T_{162} = 0.62$, $P = 0.54$).

Discussion

Our results suggest that the placement period of artificial retreats affects the number and demographic composition of common skinks occupying artificial retreats, but not their body condition. We detected more skinks beneath permanently placed retreats, as well as a higher proportion of adults. In contrast, a greater proportion of subadults and juveniles were detected beneath temporarily placed retreats. We found that occupancy increased during the initial 10 days post-deployment, and there was a consistent relationship between the frequencies of sightings from permanent and temporary retreats among the locations of lines. This suggests that placement period may not affect

Figure 3. Sightings of common skinks (*Oligosoma polychroma*) under temporary Onduline artificial retreats in the Eglinton grassland, Fiordland, in the 6 weeks following deployment. Week numbers represent the number of whole weeks passed since retreat deployment.

the ability to compare population size indices among locations where placement periods are consistent.

We found that the total number of skink sightings was higher beneath permanent retreats than temporary retreats. This result is consistent with Grant et al. (1992) who found herpetofauna encounters were higher under artificial retreats with a placement period exceeding one year relative to retreats with a placement period of less than 2 months. Similarly, Michael et al. (2004) found that the abundance of three reptilian species was significantly greater under artificial retreats with a placement period of 15 years compared with artificial retreats with a placement period of less than a year.

Retreat occupancy is presumably dependent on retreat discovery and can be expected to increase temporally. This expectation is supported by the rapid increase in retreat occupancy during the initial 10 days following the deployment of the temporary retreats in our study (Fig. 2). The identified change point is in contrast to the findings of O'Donnell and Hoare (2012), who checked retreats at monthly intervals and found that retreat occupancy in the same population as assessed in our study increased from deployment until the placement period exceeded 6 months. This contradiction suggests that temporal trends in retreat occupancy may be influenced by the monitoring intervals used. The higher encounter rate under permanent retreats could also result from a temporally increasing direct or indirect effect of the retreats themselves (Monti et al. 2000). The most likely mechanism for such an effect is via additional food resources for skinks in the form of insect larvae (prey) using the retreats (Grant et al. 1992). However, our lack of detection of any difference in body condition between skinks captured under permanent versus temporary retreats suggests that food availability is not correlated with placement period, or, that any variation in the resources is insufficient to affect body condition.

We found that the proportion of adults was higher under permanent retreats relative to temporary retreats, whereas the proportions of subadults and juveniles were higher under temporary retreats relative to permanent retreats. The difference in demographic occupancy most likely reflects age-dependent territorial and dispersal behaviours. The high proportion of non-adults found occupying temporary retreats may be driven by higher dispersal rates during early demographic stages, as displayed by red-backed salamander (*Plethodon cinereus*;
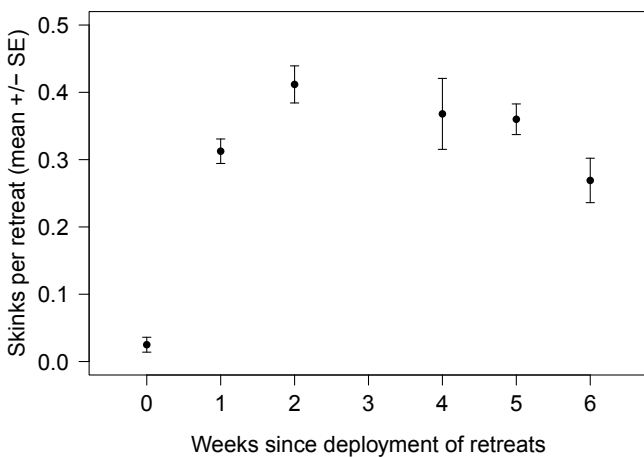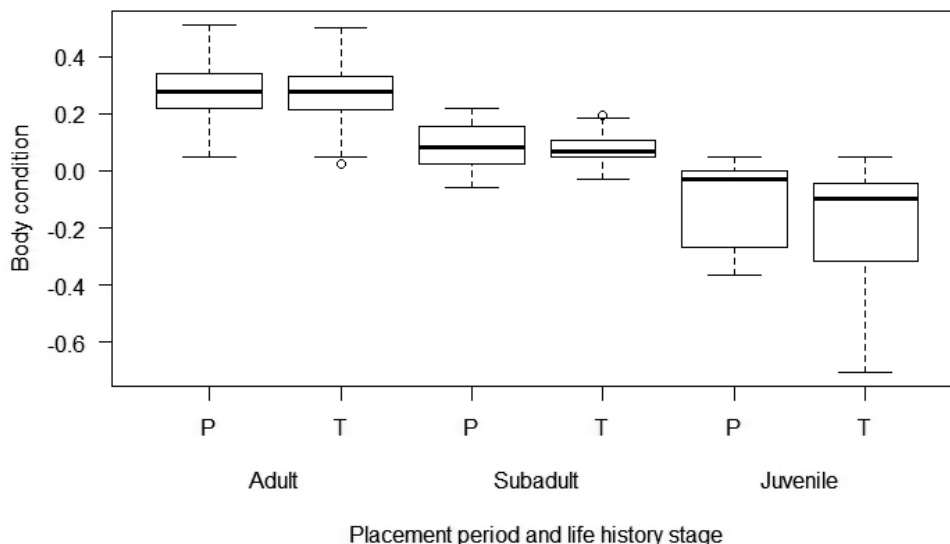

Figure 4. Body condition (log(mass)/ log(SVL)) of demographic groups of common skinks (*Oligosoma polychroma*) captured under permanent ('P'; 2 years) and temporary ('T'; 3+ weeks) Onduline artificial retreats in the Eglinton grassland, Fiordland.

Ousterhout & Liebgold 2010). Alternatively, the transition to adult-dominated occupation of retreats may result from adults establishing territories that encompass the retreats and excluding smaller individuals (Lettink & Cree 2007). If this mechanism is apparent then the plateau in detection rates and the transition to an adult-dominated population could represent an interaction between the competitive exclusion of non-adults and a saturation point for the number of individuals inhabiting a retreat. Another plausible explanation is that the increased abundance of adults occupying permanent retreats results in an increased proportion of non-adults in the surrounding area, which are more likely to discover and inhabit the temporary retreats. However, we assume that this effect is likely to be moderated by the area's high population density, and the small home range of the species. A behavioural explanation for the temporal increase in retreat occupancy could be the influence of spatial learning, in which an individual increases its use of an environmental feature because of compounding positive experiences, such as successfully escaping predation or accessing resources (Paulissen 2008).

Lettink and Cree (2007) propose that artificial retreats could artificially boost localised populations via subtle effects on population parameters (e.g. survival and recruitment). Although this study was not designed to detect or evaluate such biological responses to the establishment of artificial retreats, we did not find that placement period influenced the body condition of any of the demographic groups. This finding is important, as any influence induced by the presence of retreats that affects reproduction or survival could potentially overinflate population indices deduced from monitoring efforts (Lettink 2007). Our conclusion that the long-term placement of artificial retreats does not increase survival is consistent with the conclusions of Lettink et al. (2010), who found that the presence of artificial retreats did not increase the survival probability for *Oligosoma maccanni* in coastal dune habitats.

Research to date suggests that, with methodological developments based on scientific testing of assumptions and practices, artificial retreat monitoring can become an increasingly robust tool for monitoring cryptic terrestrial reptiles, particularly in temperate areas (Lettink 2007; Hoare et al. 2009; Thierry et al. 2009; Chavel et al. 2012; O'Donnell & Hoare 2012). Our findings indicate that placement period needs to be accounted for when designing monitoring regimes and interpreting monitoring results. We recommend temporary placement of artificial retreats where practical, because of the apparent competitive exclusion of smaller individuals under permanent retreats. However, permanent placement may be preferable for monitoring low density populations or rare species due to potential to increase encounter rates. As the relative encounter rates under permanent and temporary retreats were consistent between locations within our study site, we suggest that with consistent methodology within monitoring programmes, reliable population indices can be obtained for adult skinks irrespective of placement period.

Acknowledgements

References

Bell TP 2009. A novel technique for monitoring highly cryptic lizard species in forests. Herpetological Conservation and Biology 4: 415–425.

Caughley G 1977. Analysis of vertebrate populations. New York, USA, John Wiley. 234 p.

Chavel EE, Hoare JM, Batson WG, O'Donnell CFJ 2012. The effect of microhabitat on skink sightings beneath artificial retreats. New Zealand Journal of Zoology 39: 71–75.

Doughty P, Shine R 1998. Reproductive energy allocation and long-term energy stores in a viviparous lizard (*Eulamprus tympanum*). Ecology 79: 1073–1083.

Downes S, Shine R 1998. Heat, safety or solitude? Using habitat selection experiments to identify a lizard's priorities. Animal Behaviour 55: 1387–1396.

Godley JS 2012. Sampling with artificial cover. In: McDiarmid RW, Foster MS, Guyer C, Gibbons JW, Chernoff N eds Reptile biodiversity: Standard methods for inventory and monitoring. Berkeley, USA, University of California Press. Pp. 249–255.

Grant BW, Tucker AD, Lovich JE, Mills AM, Dixon PM, Gibbons JW 1992. The use of coverboards in estimating patterns of reptile and amphibian biodiversity. In: McCullough DR, Barrett RH eds Wildlife 2001: Populations. New York, USA, Elsevier. Pp. 379–403.

Hampton P 2007. A comparison of the success of artificial cover types for capturing amphibians and reptiles. Amphibia-Reptilia 28: 433–437.

Hare KM, Hoare JM, Hitchmough RA 2007. Investigating natural population dynamics of *Naultinus manukanus* to inform conservation management of New Zealand's cryptic diurnal geckos. Journal of Herpetology 41: 81–93.

Hoare JM, Pledger S, Keall SN, Nelson NJ, Mitchell NJ, Daugherty CH 2006. Conservation implications of a long-term decline in body condition of the Brothers Island tuatara (*Sphenodon guntheri*). Animal Conservation 9: 456–462.

Hoare JM, O'Donnell CFJ, Westbrooke I, Hodapp D, Lettink M 2009. Optimising the sampling of skinks using artificial retreats based on weather conditions and time of day. Applied Herpetology 6: 379–390.

Jewell T 2008. A photographic guide to reptiles & amphibians of New Zealand. Auckland, New Holland. 143 p.

Langkilde T, Shine R 2004. Competing for crevices: interspecific conflict influences retreat-site selection in montane lizards. Oecologia 140: 684–691.

Lettink M 2007. Adding to nature: Can artificial retreats to monitor and restore lizard populations? PhD thesis, University of Otago, Dunedin, New Zealand. 190 p.

Lettink M, Cree A 2007. Relative use of three types of artificial retreats by terrestrial lizards in grazed coastal shrubland, New Zealand. Applied Herpetology 4: 227–243.

Lettink M, Cree A, Seddon PJ, Norbury G 2005. Pitfall traps versus artificial cover objects: a comparison of methods and preferences in a mark-recapture study of New Zealand lizards. New Zealand Journal of Zoology 32: 225–226.

Lettink M, Norbury G, Cree A, Seddon PJ, Duncan RP, Schwarz

CJ 2010. Removal of introduced predators, but not artificial refuge supplementation, increases skink survival in coastal duneland. Biological Conservation 143: 72–77.

Lettink M, O'Donnell CFJ, Hoare JM 2011. Accuracy and precision of skink counts from artifical reteats. New Zealand of Ecology 35: 236–246.

Marsh DM, Goicochea MA 2003. Monitoring terrestrial salamanders: Biases caused by intense sampling and choice of cover objects. Journal of Herpetology 37: 460–466.

Michael DR, Lunt ID, Robinson WA 2004. Enhancing fauna habitat in grazed native grasslands and woodlands: use of artificially placed log refuges by fauna. Wildlife Research 31: 65–71.

Monti L, Hunter M Jr, Witham J 2000. An evaluation of the artificial cover object (ACO) method for monitoring populations of redback salamander *Plethodon cinereus*. Journal of Herpetology 34: 624–629.

O'Donnell CFJ, Hoare JM 2012. Monitoring trends in skink sightings from artificial retreats: Influences of retreat design, placement period, and predator abundance. Herpetological Conservation and Biology 7: 58–66.

Ousterhout BH, Liebgold EB 2010. Dispersal versus site tenacity of adult and juvenile red-backed salamanders (*Plethodon cinereus*). Herpetologica 66: 269–275.

Patterson GB 1985. The ecology and taxonomy of the common skink *Leiolopisma nigriplantare maccanni* in tussock grasslands in Otago. PhD thesis, University of Otago, Dunedin, New Zealand. 217 p. http://hdl.handle.net/10523/124.

Paulissen MA 2008. Spatial learning in little brown skink, *Scincella lateralis*: the importance of experience. Animal Behaviour 76: 135–141.

Pike DA, Peterman KS, Mejeur RS, Green MD, Nelson KD, Exum JH 2008. Sampling techniques and methods for determining the spatial distribution of sand skinks (*Plestiodon reynoldsi*). Florida Scientist 71: 93–104.

R Development Core Team 2010. R: A language and environment for statistical computing. Vienna, Austria, R Foundation for Statistical Computing. http://www.R-project.org/.

Reading CJ 1997. A proposed standard method for surveying reptiles on dry lowland heath. Journal of Applied Ecology 34: 1057–1069.

Thierry A, Lettink M, Besson AA, Cree A 2009. Thermal properties of artificial refuges and their implications for retreat-site selection in lizards. Applied Herpetology 6: 307–326.

Towns DR, Ferreira SM 2001. Conservation of New Zealand lizards (Lacertilia: Scincidae) by translocation of small populations. Biological Conservation 98: 211–222.

Vieth E 1989. Fitting piecewise linear regression functions to biological responses. Journal of Applied Physiology 67: 390–396.

Wilson DJ, Mulvey RL, Clark RD 2007. Sampling skinks and geckos in artificial cover objects in a dry mixed grassland-shrubland with mammalian predator control. New Zealand Journal of Ecology 31: 169–185.