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MONITORING TRENDS IN SKINK SIGHTINGS FROM ARTIFICIAL RETREATS: INFLUENCES OF RETREAT DESIGN, PLACEMENT PERIOD, AND PREDATOR ABUNDANCE

COLIN F.J. O'DONNELL AND JOANNE M. HOARE

Research and Development Group, Department of Conservation, P.O. Box 11089, Sockburn, Christchurch 8443, New Zealand, e-mail: codonnell@doc.govt.nz and jhoare@doc.govt.nz

Abstract*.—Developing rigorous and repeatable techniques for monitoring a range of taxa is essential for evaluating responses to management. We investigated the use of artificial retreats made from a corrugated roofing material (Onduline) for monitoring Common Skinks (*Oligosoma polychroma*) over five years (2004–2009) in the Eglinton Valley, New Zealand. We addressed three questions: (1) how long does it take for skinks to use retreats; (2) which retreat design maximizes detection of skinks; and (3) do numbers of skinks detected co-vary with mammalian predator indices? We deployed four random transects, each comprising 11 retreats, in grassland habitat using four retreat designs of varying size and number of layers. We checked retreats for skinks at 1-month intervals primarily during summer months, and evaluated rodent and mustelid activity using quarterly footprint tracking records. We detected skinks under 30% of retreats one month after deployment and mean numbers of skinks peaked six months after deployment in the first year of sampling. Average rate of detection was proportional to retreat area and not related to the number of layers used. Skink counts from artificial retreats declined following heavy beech masting in autumn 2006 that increased predator activity, but recovered during the following summer as predator activity declined. Artificial retreats are a promising tool for monitoring skink populations and evaluating their responses to predator abundance and management.

Key Words.—artificial cover object; conservation; *Mustela*; *Mus; Nothofagus; Oligosoma polychroma*; populations; *Rattus*

INTRODUCTION

The maintenance of habitat and mitigation of threatening processes is a high priority for managers of threatened species worldwide and reliable monitoring techniques are crucial for evaluating the effectiveness of management. However, many species are inconspicuous and difficult to detect. Developing rigorous and repeatable techniques for monitoring such species is often problematic.

The New Zealand lizard fauna includes 100 taxa of which 62% are threatened or at risk (Hitchmough et al. 2010). Most lizard taxa are cryptic and few robust methods for measuring population trends exist (Hitchmough et al. 2010). Monitoring of lizards has been limited in New Zealand and usually involves non-standardized and informal searches undertaken by people with some expertize with lizards. Intensive and expensive mark-recapture techniques, often using pit-fall trapping, have been used successfully to monitor populations in some situations (e.g., Tocher 2006), while the use of simpler population indices is appealing, but largely untested (Lettink et al. 2011).

Worldwide, there has been interest in assessing the potential of artificial retreats (also known as artificial cover objects or coverboards) as simple sampling devices that enable calculating indices of relative abundance of herpetofauna. Recent research has focused on the potential of artificial retreats for sampling distribution, monitoring populations (Grant et al. 1992; Boughton et al. 2000; Scheffers et al. 2009), and for restoration of habitat (Webb and Shine 2000; Lettink 2007). Further work has focused on determining the best retreat designs for sampling different groups of herpetofauna (Arida and Bull 2008; Thierry et al. 2009; Scheffers et al. 2009) and optimizing the conditions under which sampling should occur (Hoare et al. 2009; Joppa et al. 2009). However, most research has focused on amphibians, and to a lesser extent, snakes (Monti et al. 2000; Houze and Chandler 2002; Joppa et al. 2009), and it is still uncertain how useful artificial retreats are for sampling or monitoring lizards.

In New Zealand, initial research on skinks has indicated that: (1) encounter rates under artificial retreats are correlated with density calculated from capture-mark-recapture pitfall trapping if counts are conducted under standardized conditions (Hoare et al. 2009; Lettink et al. 2011); (2) variability in skink encounter rates can be minimized if sampling is undertaken during optimal climatic conditions (Hoare et al. 2009); and (3) microhabitat at retreat sites can influence encounter rates (Chavel et al. 2012).

Predation by introduced mammals is one of the most significant threats to the long-term viability of many lizard populations in New Zealand (Towns and Daugherty 1994; Norbury 2001; Hoare et al. 2007). Thus, standardized and repeatable methods, such as the use of artificial retreats, are required to monitor responses of lizard populations to predator abundance and control. However, a number of issues still need to be explored, including understanding the best retreat size and design that maximizes detection of skinks, optimal placement (settling in) period for retreats, whether permanent placement of retreats is warranted, and whether monitoring protocols can be generalized across habitat types, geographic zones, and different lizard taxa.

The Eglinton Valley in New Zealand is the site of a long-term research program that is investigating effects of predation by introduced mammals on wildlife and responses of native species to experimental predator control (e.g., Dilks et al. 2003; Pryde et al. 2005; O'Donnell and Hoare 2011). Predator irruptions following periodic heavy seeding of southern beech (*Nothofagus* spp.) cause significant declines in reproductive output and survival of threatened native birds and bats every 4–6 years (Elliott 1996; O'Donnell and Phillipson 1996). The program aims to investigate the benefits of predator control on other native species groups, including lizards. The central aim of the present study and lizard research previously conducted in the Eglinton Valley (Hoare et al. 2009; Lettink et al. 2011; Chavel et al. 2012) is to examine issues associated with the use of artificial retreats for monitoring lizards and to develop rigorous monitoring protocols. Previous studies have not investigated optimal retreat design, nor looked at time to first use. In this study, we addressed three questions: (1) how long does it take for skinks to use artificial retreats; (2) how can we design retreats to maximize detection of skinks; and (3) do numbers of skinks detected using retreats co-vary with predator indices?

Materials and Methods

Study species.—We used Common Skinks, *Oligosoma polychroma*, to address our study questions. Common Skinks are small (to 79 mm snout-vent length), diurnal skinks that are avid sun baskers found in a range of habitat types including sand dunes, grasslands, wetlands, and rock piles (Jewell 2008). Common Skinks exist at high densities (3,600–9,200 skinks/ha; Lettink et al. 2011) at the Eglinton Valley study site.

Study site.—The Eglinton Valley is located in the northeastern corner of Fiordland National Park, on the South Island, New Zealand (168°01'E, 44°58'S). The valley covers approximately 8,000 ha and is one of the few extensive lowland areas of mixed southern beech forest in New Zealand. The valley is of glacial origin with steep sides and a flat floor, 0.5–1.5 km wide, at ca. 250–550 m ASL. Our study site was a 1.5 km^2 area of grassland, comprising mixed native and exotic grasses and some native shrubs, in the central valley. Mean maximum monthly air temperature ranges from 7.5° C (June) to 21.5° C (February).

Lizard sampling.—We established four 0.5 km transects randomly in grassland on the Eglinton Valley floor in November 2004 (Fig. 1). We placed 11 artificial retreats on un-trimmed grass at 50 m intervals on each transect (n = 44 retreats). Retreats consisted of sheets of Onduline (distributed by Composite Ltd., Christchurch, New Zealand), which is a lightweight corrugated roofing material manufactured from organic fibers saturated with bitumen (Available from http://www.onduline.co.nz [Accessed 10 April 2012]). It retains heat, thus enabling lizards to maintain an elevated body temperature relative to their natural surroundings (Lettink 2007; Thierry et al. 2009).

We deployed four retreat designs: 1 = single layer 28 × 40 cm; 2 = single layer 65 × 45 cm; 3 = double layer 65 × 45 cm with 10-mm spacers between layers; and 4 = single layer 95 × 65 cm. We checked retreats at 1-month intervals between October and February (five seasons, 2004–2009) and we recorded the number of Common Skinks seen under each retreat (n = 1,496 retreat checks). In addition to the October to February checks, we undertook counts in March, April, May, August, and September during the first year after deployment of retreats. We also recorded presence of other animals (e.g., House Mouse, *Mus musculus*) beneath retreats.

Although initial checks preceded work that determined optimal environmental conditions for checking retreats (Hoare et al. 2009), we primarily checked retreats in optimal temperatures during warm or mild weather and when wind conditions were calm. We did not check retreats in the rain. We measured ambient temperature at weather stations at Knobs Flat, located 7 km north of the study site in an open grassland microhabitat, and at Walker Creek, 7 km south of the site in a clearing in the forest. We averaged temperature measurements across the two sites to provide a temperature estimate at the study site and included these estimates in the analyses (below).

Seedfall and predator sampling.—We monitored beech seedfall from March to May each year using the standardized New Zealand protocols (*sensu* Wardle 1984). We collected seeds in standard funnels (plastic 0.28-m diameter funnels; Gyro Plastics, Lower Hutt, New Zealand) placed along a random line transect (eight funnels, 1.25 m off the ground, 50 m apart, > 50 m away from a forest edge or 20 m away from a canopy gap). The transect was 4 km from the study area in forest representative of the Eglinton Valley. Seeds that fell into funnels collected in stockings fitted over the narrow ends of the funnels.

We measured relative abundance of introduced predators (rats, *Rattus* spp., House Mouse, and Stoats, *Mustela erminea*) using 15 standardized foot print tracking tunnel lines placed randomly in the study area (Gillies and Williams 2002). Each tunnel line consisted of 10 tunnels set at 50-m spacing. We operated tracking

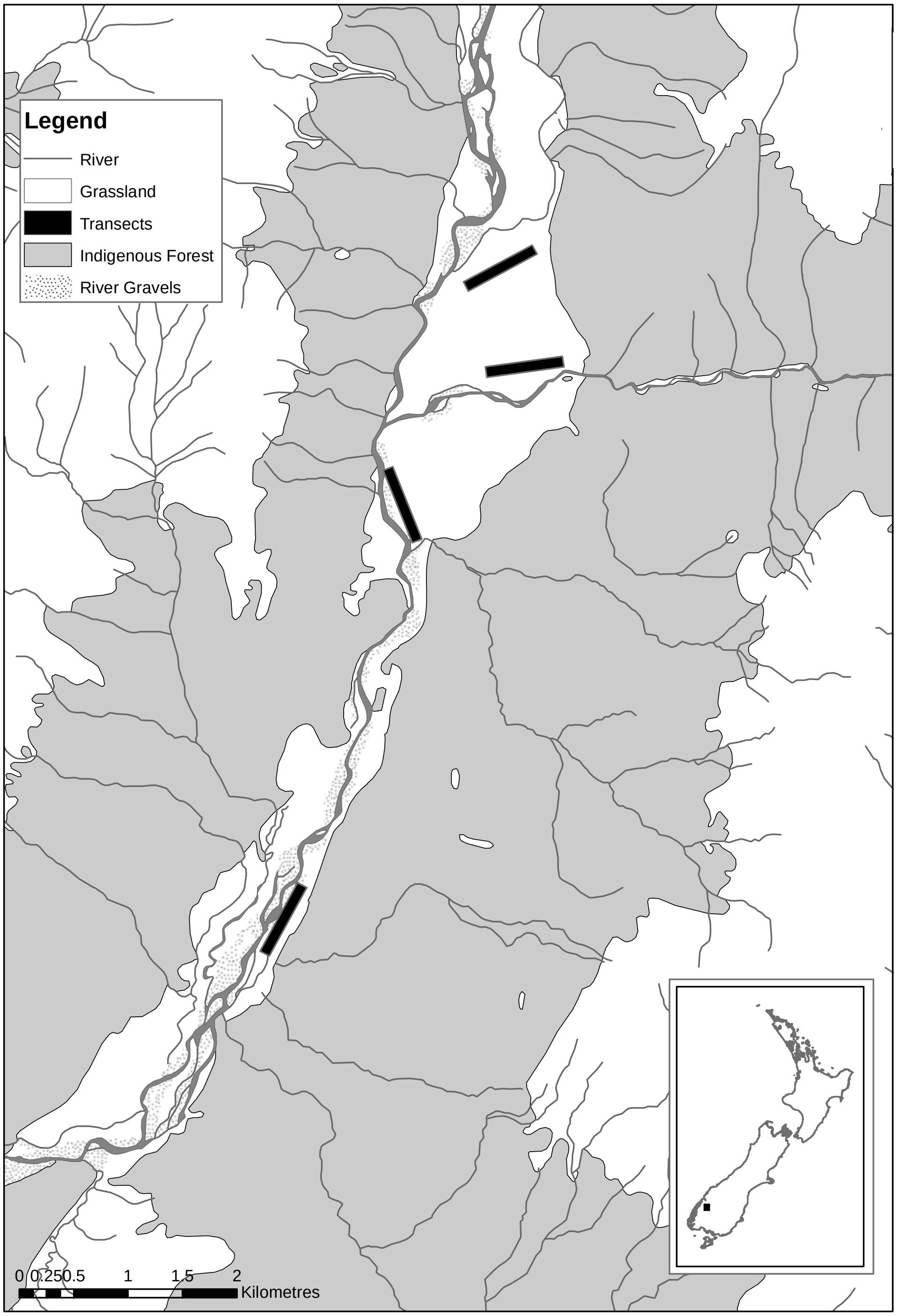

FIGURE 1. Location and layout of four lizard sampling transects in the Eglinton River Valley, Fiordland, New Zealand. Inset shows the location of the study area on South Island, New Zealand.

tunnels four times a year (February, May, August, and November) for one night each. We lured animals into the tunnel with a small piece of peanut butter; they walked across an inkpad, then brown paper, where they left footprints, which we subsequently counted and identified them to the species level. We treated lines as sampling units and summarized tracking rates as percentage of lines with footprints in each session.

Analyses.—We used a piecewise linear regression to investigate at what time, in the first 12 months after the deployment of retreats, skink sightings either peaked or reached an asymptote. We did not assume a break point, but allowed the model fitting procedure to identify the point at which a change in slope occurred. We investigated whether retreat design influenced number of skink sightings using Generalized Additive Mixed Effects Models (GAMMs). The GAMMs were necessary to account for the non-linear relationship between skink sightings and temperature (Hoare et al. 2009). We included the number of skink sightings (alternately uncorrected, then corrected, for retreat area) as the dependent variable and retreat design, transect and temperature at the time of sampling (as a smoothed term) as explanatory variables. We included retreat number as a random effect to account for the repeated measures nature of the study. We used the statistical program R (Version 2.12.1) for all analyses (R Development Core Team 2010). For tests we used $\alpha = 0.05$.

Five years of monitoring data that spanned only one predator irruption was insufficient to statistically test for any relationship between predator indices and skink sightings. We monitored predators quarterly, which allowed only three comparisons with skink counts per year (we did not monitor skinks through the winter months). Also, the time series was not long enough to account for either temporal dependence in observations or lag periods between predator irruptions and population-level effects on skinks. Instead, we explored the relationship graphically to generate hypotheses about how skink populations are affected by predator abundance to be tested in the future with a larger dataset.

RESULTS

We sighted 1,313 Common Skinks during 1,496 retreat checks (mean = 0.88 ± 0.03 SE skinks per retreat). We found no other lizard species using retreats. Skinks we observed beneath double-layered retreats (n = 374 skinks) were more frequently seen under the bottom layer (mean = 0.92 ± 0.07 SE skinks per retreat) than between the layers (mean = 0.42 ± 0.04 SE skinks per retreat; t = -6.30, df = 373, P < 0.001). We detected skinks under 30% of retreats after one month of deployment (the first retreat check). Skink sightings increased for the first six months from deployment in November 2004 and reached a peak in the mean number of skinks per retreat in April 2005 (t = 6.760, df = 437, P < 0.001, threshold α = 6.092; Fig. 2). By this time, 90% of retreats had been used by skinks.

We detected skinks under all retreat designs, with encounter rates ranging from 0.36 ± 0.03 SE skinks per retreat check under the smallest retreats to 1.66 ± 0.12 SE skinks per retreat check under the largest (Fig. 3A). We saw fewest skinks under the smallest retreat and most skinks under the double layer and the large single layer designs (Table 1; Fig. 3A). However, when we

TABLE 1. Results from Generalized Additive Mixed Effects Models investigating whether Common Skink (*Oligosoma polychroma*) sightings from the three larger retreats (designs 2–4) differed from those from the smallest retreat (design 1). Retreat designs: 1 = single layer 28 × 40 cm; 2 = single layer 65 × 45 cm; 3 = double layer 65 × 45 cm; and 4 = single layer 95 × 65 cm.

	Estimate	SE	*t* value	*P* value
Retreat design				
1	-0.035	0.318		
2	0.587	0.181	3.243	0.001
3	1.269	0.186	6.836	0.000
4	1.338	0.220	6.082	0.000
Retreat area (m^2)				
0.12	1.375	0.199		
0.29	0.079	0.107	0.744	0.457
0.59	0.193	0.115	1.671	0.095
0.62	0.216	0.143	1.508	0.132

corrected encounter rates for retreat area (skinks/m^2), encounter rates did not differ significantly among retreat designs (Table 1; Fig. 3B).

One beech masting event occurred during this study in 2006. During 2006, seedfall was 3,916 seeds/m^2 compared with 126 seeds/m^2 in 2005, 17 seeds/m^2 in 2007, and 285 seeds/m^2 in 2008. Rodent and mustelid numbers increased exponentially following the 2006 masting event and remained high during the following

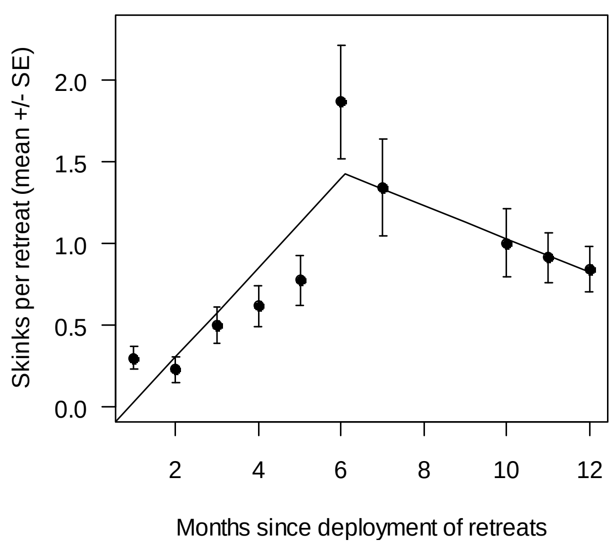

FIGURE 2. Mean number (± SE) of Common Skinks (*Oligosoma polychroma*) detected under artificial retreats (all retreat designs combined) in the Eglinton Valley, South Island, New Zealand during the first 12 months since deployment of retreats (November 2004 to October 2005). The solid line represents the fitted slopes of the piecewise linear regression model.

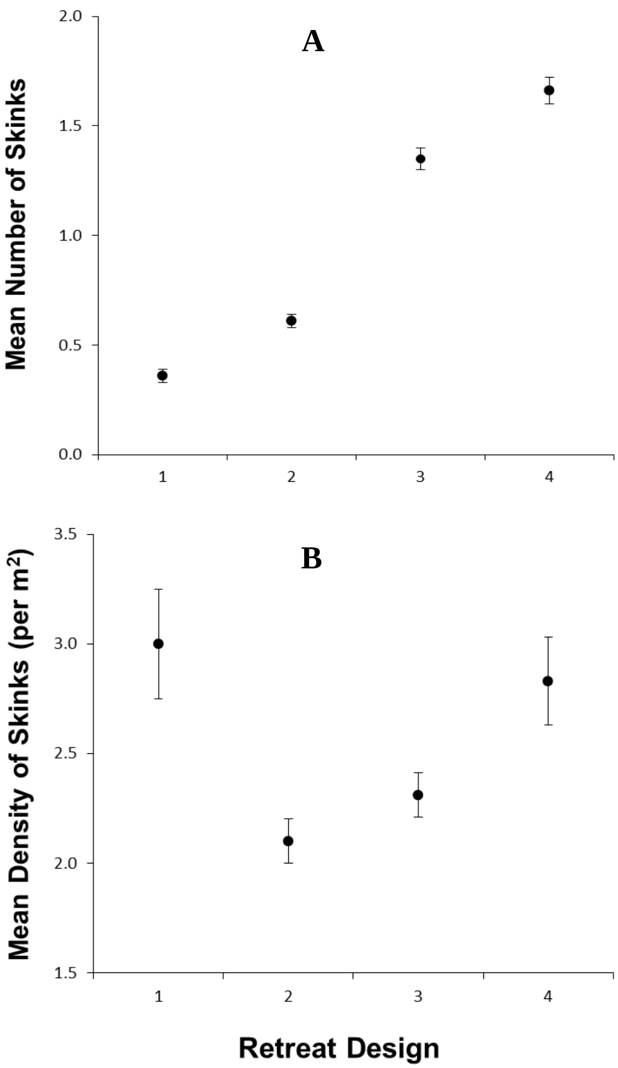

FIGURE 3. Mean number (± SE) of Common Skinks (*Oligosoma polychroma*) (A) per artificial retreat design (October 2004 to February 2009 combined) and (B) corrected for retreat surface area (skinks/m^2) where retreat design 1 = single layer 28 × 40 cm, 2 = single layer 65 × 45 cm, 3 = double layer 65 × 45 cm, and 4 = single layer 95 × 65 cm.

summer (Fig. 4). Of our 129 mouse sightings under artificial retreats during retreat checks, we detected 98% in the year following the 2006 seedfall and none in the 18 months of retreat checks prior to the mast or in the year following (2008). In addition, one of us (COD) recorded the presence of predator scats containing obvious lizard remains and partially eaten skinks during retreat checks. Of 23 observations of lizard remains in mustelid scats, 61% were in the year following the beech mast. Skink counts under retreats appeared to decline during the period that mice were seen using them and at the time when footprint-tracking indices for rats, mice, and stoats increased exponentially (Fig. 4). Skink encounters increased during the following summer once predator numbers had declined (Fig. 4).

DISCUSSION

Artificial retreats consisting of Onduline roofing material proved useful for detecting Common Skinks in cool-temperate grassland in the Eglinton Valley, as they have in two other habitat types and with different skink species (Lettink and Cree 2007; Wilson et al. 2007). A previous study in a markedly warmer environment in New Zealand showed that geckos displayed strong preferences for Onduline retreats over corrugated iron and concrete tiles (Lettink and Cree 2007). Skinks used all materials without apparent preferences. These results were supported by a laboratory-based study by Thierry et al. (2009) in which Common Geckos (*Woodworthia maculatus*) showed a significant preference for Onduline whether retreats were exposed to a radiant overhead heat source or not, whereas skinks did not display any preference among three types of retreat regardless of heating. Nevertheless, in the cool-temperate climate of our study area, Common Skinks used Onduline retreats significantly more often in an optimum temperature range of 13–18° C (Hoare et al. 2009).

Retreats were useful for detecting presence of skinks within one month of deployment and 90% had been occupied by six months. Researchers have speculated about what constitutes an appropriate placement period for artificial retreats to maximize encounter probabilities (Grant et al. 1992; Monti et al. 2000; Lettink 2007). Croak et al. (2010) found that the number of individual lizards using artificial rocks increased with time since deployment, and that all retreats having been used by either invertebrate, lizard, or snake species within 40 weeks of deployment. Our results suggest that a six-month placement period was sufficient for occupancy to reach equilibrium, a relatively short period compared to a two-year placement period used for Common Geckos (Lettink and Cree 2007). However, it seems unlikely that a placement period of less than six months would be useful for monitoring population trends.

We are unaware of any other studies that have compared encounter rates of skinks under retreats of different sizes. All retreat designs were successful in attracting skinks and all were used routinely over the duration of the study. We saw skinks more frequently under the bottom layer of double-layer retreats than the space between the two layers. It is possible that the bottom layers of double retreats had better insulation than single retreats. However, there were no more skinks overall using this design compared to the others when results were corrected for area. Therefore, our results support the notion that single layer retreats are adequate for sampling skinks (Lettink 2007; Lettink and Cree 2007).

Our results demonstrate that a range of designs and sizes of retreats can be used to detect lizards, suggesting that practitioners have flexibility in choosing retreat

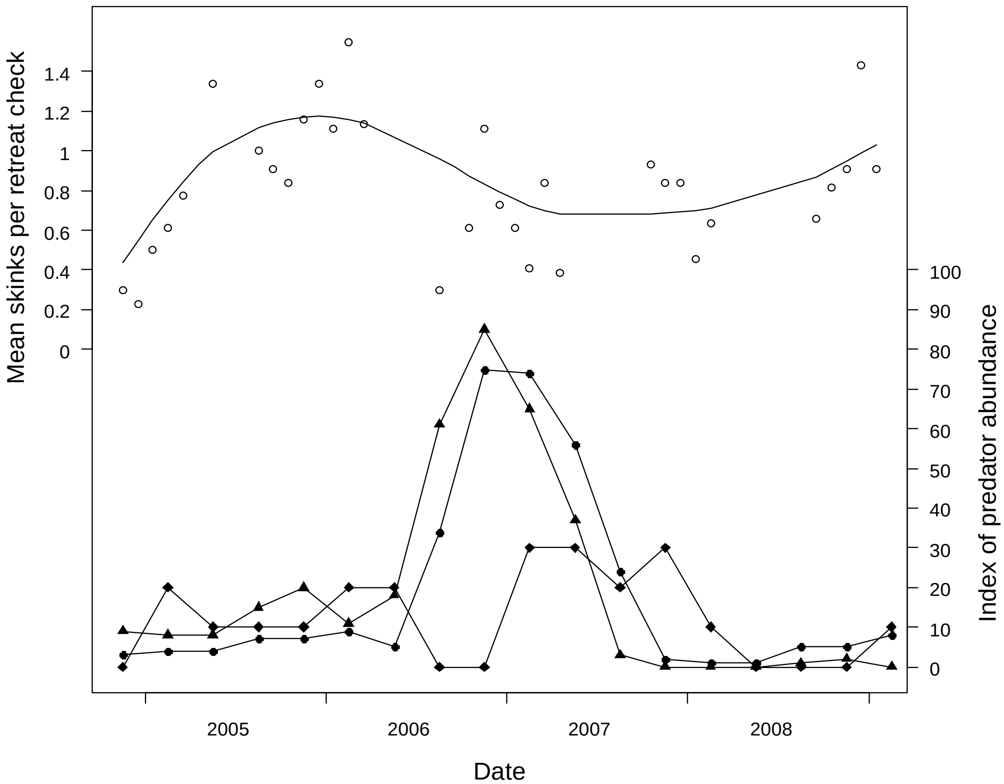

FIGURE 4. Mean number of Common Skinks (*Oligosoma polychroma*) detected per retreat check (o) with a cubic smoothing spline line fitted to the data compared with an index of predator abundance (% foot print tracking rate where ● = rats, ▲= mice, ♦ =stoats).

designs for lizard monitoring studies. If the objective of a study is to undertake an inventory, choosing a large retreat size is likely to maximize encounters and increase the probability of detecting rarer lizard species. Conversely, for longer term monitoring of relatively numerous lizards, using smaller retreat sizes may enable sampling of sufficient individuals to allow a meaningful index of relative abundance to be developed (Lettink et al. 2011). In addition, smaller retreats are far more practical to transport and deploy, especially in relatively remote field sites. However, territorial behavior in skinks could make the use of small retreats less desirable if retreat occupancy reaches an asymptote beyond which increased abundance in skinks is not reflected by encounters beneath artificial retreats (Langkilde et al. 2003). Because Common Skinks are thought to be territorial (Patterson 1984) and we found that skink encounters were proportional to retreat surface area, we cannot exclude this possibility.

The impacts of introduced mammalian predators on lizard populations in New Zealand (e.g., Daugherty et al. 1993; Towns and Daugherty 1994; Norbury 2001; Hoare et al. 2007) and on other wildlife species within the Eglinton Valley (e.g., Elliott et al. 1996; O'Donnell et al. 1996; Dilks et al. 2003; Pryde et al. 2005; O'Donnell and Hoare 2011) are well documented. Furthermore, there is a well-known relationship between heavy seeding of beech in autumn in temperate New Zealand forests that leads to increases in populations of introduced mammalian predators during the following summer, with subsequent impacts on forest bird and bat populations (e.g., King 1983; O'Donnell and Phillipson 1996; Pryde et al. 2005; Innes et al. 2010). However, we have not come across any evidence to suggest that this phenomenon also impacts lizard populations in and around southern beech forests. We could not discount the possibility that Common Skinks simply avoided using retreats when numbers of predators were high. In laboratory studies, lizards avoid using retreats occupied by predators after detecting them using scent (Downes and Shine 1998; Robert and Thompson 2007). However, in our study area we observed a peak in predator scats and partially eaten skinks on or under retreats that coincided with high predator (rodent and mustelid) numbers. Other studies in New Zealand support the notion that predation by introduced mammals causes population declines (Towns 1992; Newman 1994; Miskelly 1997; Hoare et al. 2007). Therefore, based on the preliminary results of this study, we hypothesize that population declines in lizards, similar to those documented for forest birds in the study area, coincide with predator irruptions (Elliott et al. 1996; O'Donnell et al. 1996).

We recommend that longer-term monitoring studies that sample across multiple predator irruption years are initiated to evaluate the effects of beech masting and predator-prey cycles on lizard populations. Ideally, a better design for specifically testing this question would involve treatment-non-treatment designs. However, this approach is not possible at the Eglinton Valley long-term research site, where there is only one skink grassland and predator control is undertaken on a valley-wide scale. Common Skink populations are likely to recover from predation pressure much faster than most New Zealand forest birds (Heather and Robertson 2000) because of their greater productivity (1–10 young per litter; Jewell 2008).

Uncertainty remains about the usefulness of artificial retreats for long-term monitoring, largely because a range of factors influence detectability and the relationship between detectability and density is still unclear (Monti et al. 2000). However, this is likely also true of other, more established, sampling techniques such as pit-fall trapping. Encounter rates of Common Skinks under retreats in the Eglinton Valley are correlated with density calculated from capture-mark-recapture pit-fall trapping if sampling is done under optimal conditions (Hoare et al. 2009; Lettink et al. 2011), which suggests that artificial retreats provide a promising tool for monitoring skink abundance. Results from this short-term study imply that population-level effects of predator abundance on lizards may be detected using artificial retreats if the monitoring time series were longer. Monitoring using artificial retreats may ultimately enable testing of whether predator control methods are effective at either reducing impacts of predators or restoring skink populations. Testing for these relationships is challenging, partly because the time series needs to be long enough to encompass multiple predator irruption events and account for both temporal dependence in observations and explore anticipated lag periods between the peak in predator irruptions and population level effects on native species (Elliott 1996).

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COLIN F. J. O’DONNELL is a scientist working in the Threatened Species Science Team, Department of Conservation in New Zealand. He gained a Ph.D. from the University of Otago in Dunedin, which focused on the ecology of rainforest bats. He oversees a number of research programs that assess the long-term costs and benefits of control of introduced mammalian pests for threatened species, particularly birds, bats, and lizards, in forests and wetlands in New Zealand. (Photographed by Jo Hoare)

JOANNE (JO) M. HOARE is an ecologist currently working for the Department of Conservation in Christchurch, New Zealand. She gained a Ph.D. from Victoria University of Wellington, with a dissertation focusing on the impacts of introduced mammalian predators on behavior and ecology of New Zealand lizards. Jo's main research interests concern testing the effectiveness of conservation management actions for threatened herpetofauna, bats, and birds and developing monitoring techniques for cryptic taxa. (Photographed by Gerry Keating)