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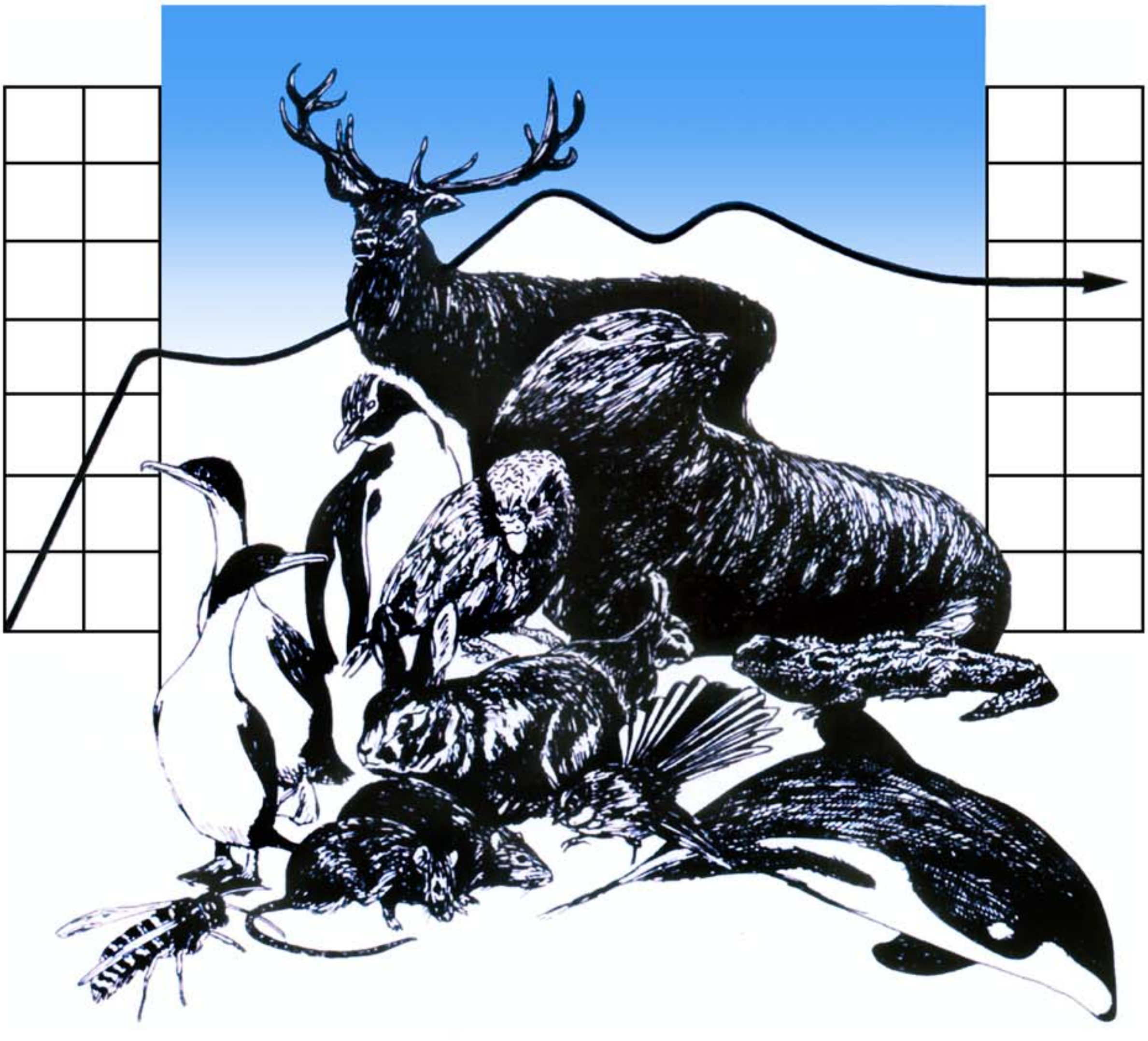

WILDLIFE MANAGEMENT

The effectiveness of sampling lizard populations with artificial cover objects at Macraes Flat

Ryan Clark

A report submitted in partial fulfilment of the
Post-graduate Diploma in Wildlife Management

University of Otago

Year 2006

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WLM Report Number: 243

THE EFFECTIVENESS OF SAMPLING LIZARD POPULATIONS WITH ARTIFICIAL COVER OBJECTS AT MACRAES FLAT

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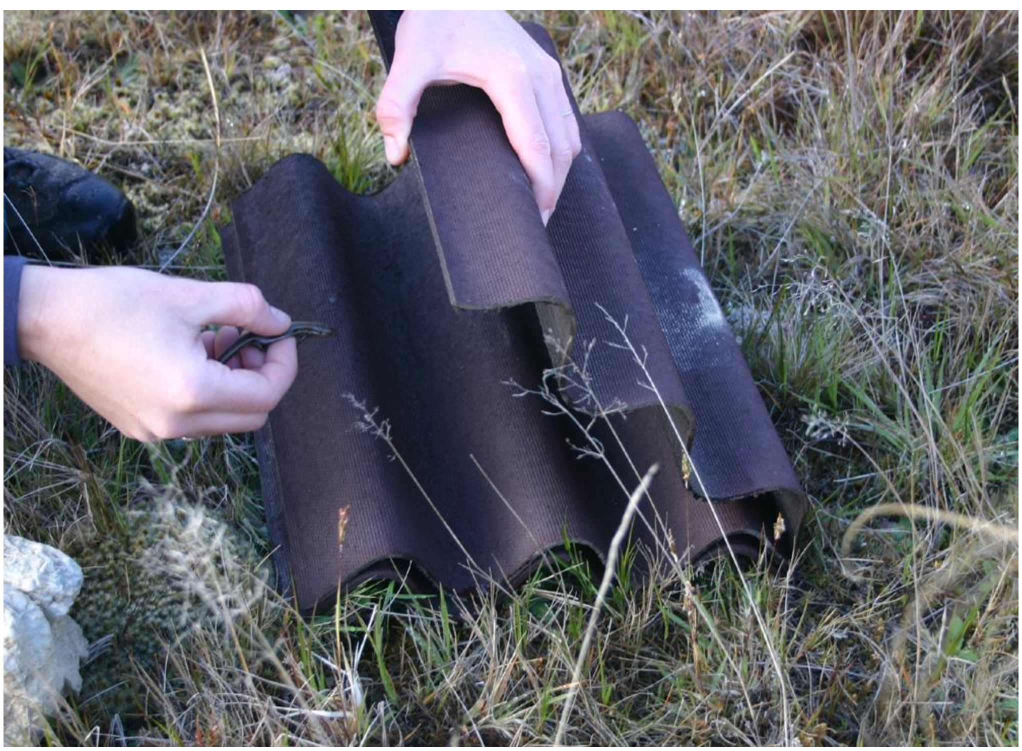

Abstract

At the Macraes Flat conservation reserve, Otago, there is a need for a simple, efficient, inexpensive, low impact and reliable method of assessing the effect of the current mammal control strategy on the common lizard species in the community. The use of artificial cover objects (ACO) to sample lizard populations is a relatively new technique that is simpler and less weather dependent than the commonly used pitfall trapping method. We tested the effectiveness of using grids of Onduline ACOs to capture and estimate the abundance of common geckos (*Hoplodactylus maculatus*), common skinks (*Oligosoma nigriplantare polychroma*), cryptic skinks (*O. inconspicuum*), and McCann's skinks (*O. maccanni*) at Macraes Flat. Two five-day capture-mark-recapture (CMR) sessions were conducted at four sampling sites (three treatments and one experimental control) with different levels of mammal control and agricultural use. ACOs appeared to be more effective for capturing skinks, which accounted for over 70% of all lizards captured in both CMR sessions. The few geckos we captured were caught primarily in ACOs near rock outcrops. In contrast to geckos, skinks were recaptured much less often, which indicated that skinks were much more trap-shy than geckos. Zippin (M_b) skink abundance estimates, while significantly different between sites in the second CMR session, were unreliable due to the presence of individual and temporal variability in skink capture probabilities. Chao (M_{th}) estimates, while not significantly different between sites, appeared to be the most accurate and reliable where adequate data was collected. At Macraes Flat, ACOs may provide a fast, simple and low impact method for obtaining periodic one-day counts of skinks. More research on the movements and habitat use of lizards and different ACO sampling designs could improve the effectiveness and reliability of the method for a broader range of sampling and monitoring objectives.

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1 INTRODUCTION

With an escalating number of species, habitats, and ecosystems becoming threatened or endangered, there is a growing need for fast and efficient development and implementation of conservation plans. In order for these plans to be effective, adequate information about the population(s) or habitat(s) of concern must first be obtained. It can often take many years of study of the ecology and dynamics of a population or ecosystem before appropriate and effective conservation plans can be implemented. Similarly, many years may pass before the effects of a particular management plan can be seen (Towns et al. 2001). Limited funding can also delay the implementation and reduce the effectiveness of conservation projects. Furthermore, some sampling and monitoring techniques may be detrimental to the taxa or habitat of concern, which would nullify the value of the information that would be obtained. The development therefore of fast, efficient, inexpensive, low impact, adaptable and reliable sampling and monitoring techniques is imperative.

Conservation managers in New Zealand are particularly familiar with the urgency, risk, and uncertainty in the management of endangered species and ecosystems (Saunders 2000, Towns et al. 2001, Walker et al. 2005). The rate of extinction and decline of the indigenous plants and animals of New Zealand has been considered second only to the extinction of the dinosaurs (Anon. 2000). Currently over one-thousand species of the country's native plants and animals are threatened with extinction, and many more are in decline due to the combined impacts of habitat loss, human land alteration, and a multitude of introduced mammals (Anon. 2000, Tisdall 1994, Clout 2002, Towns et al. 2001, Walker et al. 2005). With a large number of conservation and management plans in operation, and some of the most aggressive and intensive mammal eradication programmes in the world, New Zealand is considered a leading pioneer in many aspects of endangered species and ecosystem conservation and management (Diamond 1990).

A recent conservation strategy adopted in New Zealand is the intense management of patches of mainland habitat, and entire offshore islands, where populations of introduced mammals are heavily controlled and in some cases completely eradicated (Saunders 2000, Towns et al. 2001). Some of these intensely managed patches have been enclosed within specialised fences designed to keep out all introduced mammal species. One of these fences was recently installed at Macraes Flat in north-east Otago. Macraes Flat is part of the dryland region that dominates much of the land east of the Southern Alps. Due to the suitability of the area for stock grazing, the dryland region has become one of the most altered and threatened of all of New Zealand's terrestrial ecosystems (Walker et al. 2005). The region now contains a high proportion of threatened and endangered endemic species (Walker et al. 2005). Two of the most acutely endangered species, the grand skink (*Oligosoma grande*) and Otago skink (*O. otagense*), are predicted to become extinct in the wild within a decade (J. Reardon pers. comm.). Macraes Flat is the largest known stronghold of these two skink species. Therefore, a 2400 ha conservation reserve has been established in the area, within which comprehensive mammalian predator control and monitoring programmes have been implemented.

The fenced, mammal-proof exclosure (about 18 ha) in the reserve has been in place for about one year and all mammals except for a few rabbits and mice have been removed (J. Reardon pers. comm.) Intensive mammal trapping also occurs within a 1200 ha area surrounding the exclosure, centred on a core area of 25 ha that contains grand and Otago skink populations and has habitat characteristics that are similar to the exclosure area (J. Reardon, pers. comm.). While there has been ongoing assessment of the effectiveness of this management strategy on the grand and Otago skinks, monitoring plans for other species in the habitat have not been implemented. In order to thoroughly assess the effectiveness of the current management regime, its impact on other community components needs to be evaluated. There are populations of several other lizard species in the Macraes Flat area that are also expected to benefit (e.g. *Hoplodactylus maculatus*, *O. inconspicuum*, *O. maccanni*, and *O. n. polychroma*), and may exhibit a faster response to the predator control than the grand and Otago skink populations. Therefore, a monitoring technique to assess the effect of the predator control management on these other lizard species needs to be implemented.

Capture-mark-recapture (CMR) studies are a common and effective method of sampling and estimating animal abundance (Lancia et al. 1996, Lettink and Armstrong 2003). In studies of ground dwelling lizards, a common technique for capturing individuals is with pitfall traps (e.g. Patterson 1985, Towns and Elliott 1996, Freeman 1997, Dixon 2004). Installation of these traps requires some minor, long-term disturbance and alteration of the habitat by digging small holes in the ground, within which a plastic container is usually placed (Patterson 1985, Freeman 1997). While pitfall traps are generally quite effective, the method is weather dependent, relying on warm, sunny days when lizards are active and likely to encounter a trap (Monti et al. 2000, J. Reardon and C. Jones pers. comm.).

Another, more recently developed technique that is less weather dependent involves the capture of lizards from under artificial cover objects (ACOs). Cover objects, or shelters, are an important habitat feature for many terrestrial reptiles, particularly because they provide protection from predators and assist with thermoregulation (Beck and Jennings 2003, Souter et al. 2004, Webb and Shine 2000). ACOs take advantage of this habitat requirement, which can make them attractive to reptiles as a temporary shelter in either warm and dry, or cold and wet conditions. The ACO method requires little training and observer bias is minimal (Fellers and Drost 1994, Lettink and Patrick in press). In addition, the method involves less habitat disturbance, and is generally easier to implement than pitfall trapping (DeGraaf and Yamasaki 1992, Fellers and Drost 1994).

The ACO method has been effective and efficient for sampling populations of amphibians and reptiles such as frogs (Wakelin et al. 2003), salamanders (DeGraaf and Yamasaki 1992, Fellers and Drost 1994, Monti et al. 2000), geckos (Webb and Shine 2000), and snakes (Reading 1997). A recent study on the Banks Peninsula in New Zealand has also demonstrated the usefulness of the ACO method for sampling gecko and skink populations (Lettink and Cree unpubl.). While pitfall trapping has been used in previous studies on skinks at Macraes Flat (Dixon 2004, C. Jones pers. comm.), the method is not suitable for the type of monitoring needed because of its dependency on warm and sunny weather, and its time and labour requirements (J. Reardon and C. Jones pers. comm., M. Lettink pers. comm.). In addition, geckos are capable of escaping from pitfall traps (Towns and Elliott 1996, Lettink unpubl.). The ACO method, therefore, may be a more viable option. In this report, I analyse the results of two trial CMR sessions using ACOs in sites with different levels of predator control at the Macraes Flat area. I also evaluate the effectiveness of the method and its potential for use as a long-term lizard population monitoring tool.

2 METHODS

2.1 Study Area and Sampling Sites

Two lizard capture-mark-recapture (CMR) sessions were conducted at four sampling sites (three treatment sites and one experimental control site) in the Macraes Flat region (Fig. 1). Located in north-east Otago, Macraes Flat consists primarily of rolling hills of tussock grassland interspersed with schist rock outcrops and gullies, some of which are steep and narrow. Elevation ranges from 100 m – 800 m, and the vegetation consists primarily of native snow tussock (*Chionochloa rigida*), manuka (*Leptospermum scoparium*), and *Coprosma* spp., and the exotic grasses *Agrostis capillaris* and *Holcus lanatus* and herbs *Hieracium lepidulum* and *Rumex acetosella*. There are also patches of native spaniard (*Aciphylla* spp.), matagouri (*Discaria toumatou*), and flax (*Phormium cookianum*) (Bibby 1997). While much of the area is used for livestock grazing, it is also the location of a 2400 ha reserve managed by the Department of Conservation primarily for the conservation of the endangered grand skink (*O. grande*) and Otago skink (*O. otagense*). Other lizards present in the area include the common gecko (*Hoplodactylus maculatus*), common skink (*O. nigriplantare polychroma*), cryptic skink (*O. inconspicuum*), green skink (*O. chloronoton*), and McCann's skink (*O. maccanni*) (Bibby 1997).

We selected sampling sites based on the similarity of habitat features (i.e. rock outcrops and gullies) and the difference in the level of mammal control and agricultural use. The level of mammal control was determined by the amount of trapping and removal of introduced mammals such as feral cats (*Felis catus*), hedgehogs (*Erinaceus europaeus*), rats (e.g. *Rattus rattus*), rabbits (*Oryctolagus cuniculus*), and stoats (*Mustela erminea*). Agricultural use was any amount of grazing by livestock in a site. The treatment site with the highest level of mammal control (i.e. virtually all mammals removed) and no agricultural use was located inside the mammal proof exclosure (Inside). The experimental control site, Alistair's Gully (Alistair), had no mammal control and no restrictions on agricultural use. The other two treatment sites were located in the area just outside the fence (Outside) and at Falcon, and both had the same

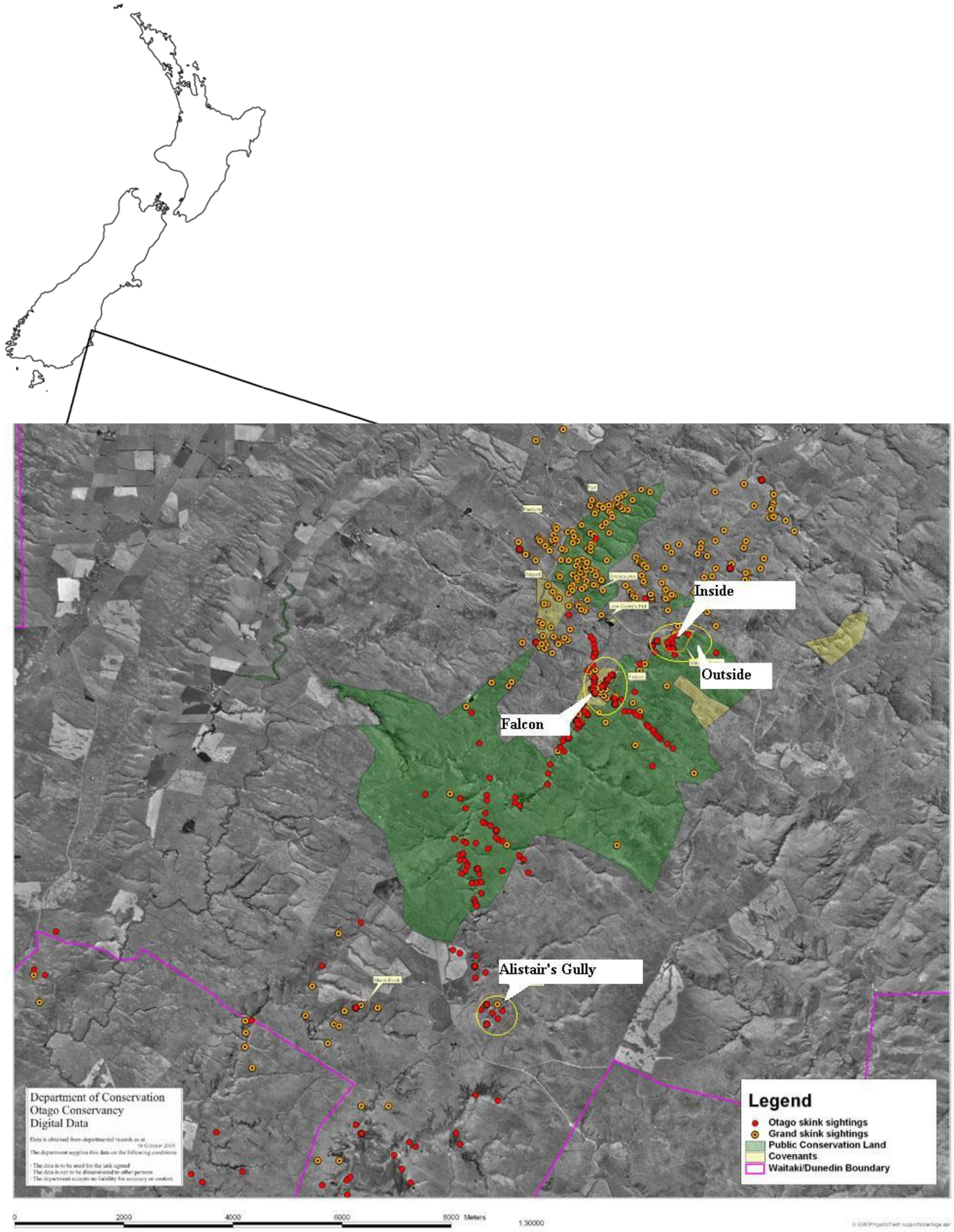


Figure 1. Digital image of the Macraes Flat region and surrounding area. The location of the three treatment sites (Inside, Outside, Falcon) and the experimental control site (Alistair's Gully) are shown. The approximate location of the Macraes Flat region on the South Island of New Zealand is indicated above. Digital image provided courtesy of J. Reardon from the Grand and Otago Skink Recovery Programme.

intermediate level of mammal control and no agricultural use. The area of the sampling sites ranged from 18 ha (Inside) to 25 ha (Falcon).

2.2 Sampling Design

Each sampling site was stratified into gully and ridge habitats. All gully habitats surrounded a stream and most had a greater density of shrubby vegetation than the higher elevation and more gently sloping ridge habitats, most of which contained schist rock outcrops. We captured lizards under artificial cover objects (ACOs, described below) spaced 5 m apart in 5 × 5 or 4 × 4 grids. When an ACO could not be placed 5 m from its neighbours, it was put in the closest suitable position. ACOs were installed 4 weeks prior to each CMR session to allow time for lizards to become accustomed to their presence (R. Wiedemer, pers. comm., Lettink and Cree unpub.).

For a preliminary trial CMR session in December 2005, six grids initially consisting of nine ACOs in a 3 x 3 square were established in the Inside and Outside sites, with 3 grids each in gully and ridge habitats. In order to maximize the probability of capture, we later increased grid size to 5 x 5 (25 ACOs). For this session, placement of the grids was subjective and partly designed to maximize the probability of capturing geckos. Therefore, we intentionally placed two of the ridge habitat grids in each site (four in total) near schist rock outcrops, the preferred habitat of geckos (Spencer 1991, Whitaker et al. 2002).

For a second CMR session in March 2006, we placed twelve 4 x 4 grids in each of the four sampling sites (6 grids each in gully and ridge habitats within each site). We used generalised random-tessellated stratified sampling (GRTS; Stevens and Olsen 2004) to generate random sampling points that were evenly distributed within the gully and ridge habitats at each site. These points corresponded to GPS coordinates and were plotted on aerial photomaps of each sampling site using ArcView (J. Overton pers. comm.; Fig. 2). Grids in gully habitats were aligned parallel to streams, while grids in ridge habitats were aligned north to south. Due to the narrow width and steepness of some gullies, we adjusted the placement and shape of some grids into 3 rows, two with 5 ACOs and one with six.

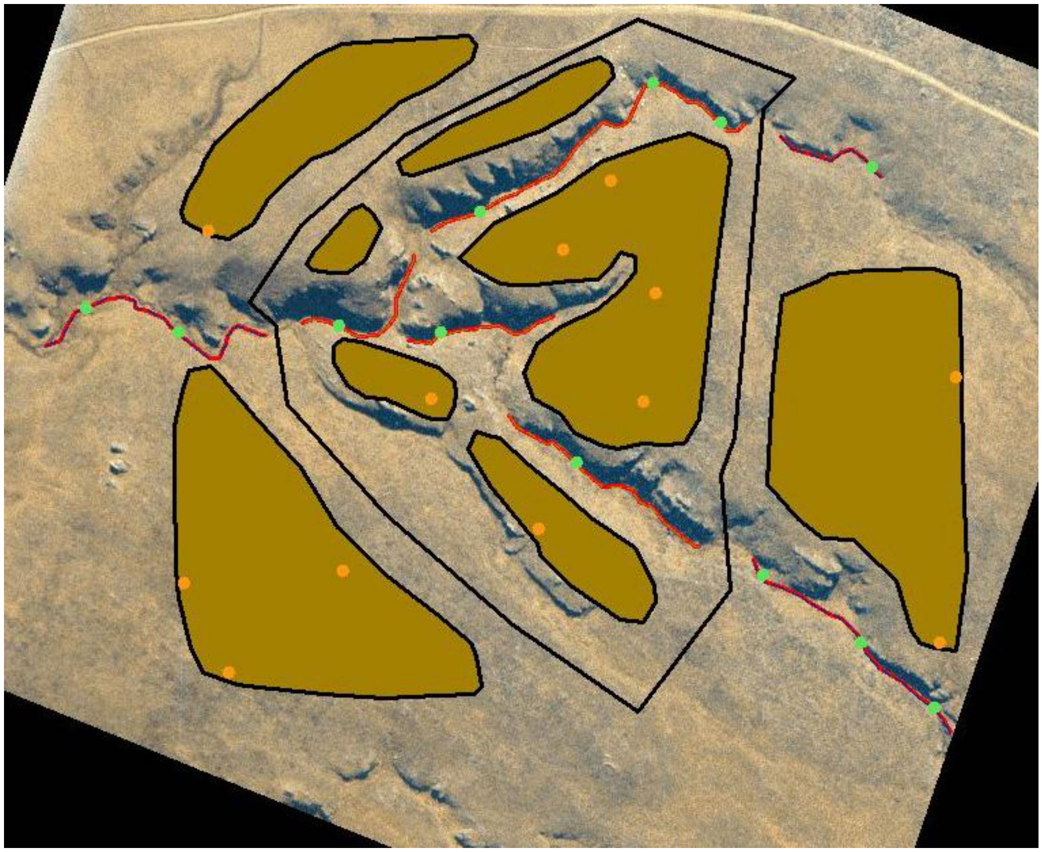


Figure 2. Digital image showing the sampling points where grids of artificial cover objects were placed in the Inside and Outside sampling sites at Macraes Flat conservation reserve. The Inside site is contained within the area outlined by the solid black line, which represents a mammal proof fence. Gully sampling points are indicated in green and ridge sampling points are indicated in orange. Image provided courtesy of J. Overton.

2.3 Artificial Cover Objects (ACOs)

Each ACO consisted of a 3-layer stack of Onduline roofing material (http://www.onduline.co.nz) cut into 40 cm x 28 cm tiles. Onduline tiles were first used by Lettink and Cree (unpubl.) in a study that compared the capture results of different types of ACOs to those obtained from pitfall traps. Onduline is a lightweight yet durable, corrugated, fibre-bitumen composite material that is easy to handle and has thermoregulation properties that make it suitable for use as an ACO (Lettink and Patrick in press, Lettink and Cree unpubl.). In order to provide spacing between the layers, we glued five 10 mm diameter by 20 mm long pine dowels onto the underside of the top two layers (one piece in each corner and one in the centre) (Lettink and Patrick in press). In exposed locations, small rocks were placed on top of ACOs to prevent displacement by wind. We labelled each ACO alpha-numerically (starting with A1 in each grid) using a white marker. All ACOs were placed on as flat a surface as possible with a minimal amount of vegetation underneath.

2.4 CMR Procedures

During both CMR sessions, we standardised the timing and conditions of each session as much as possible. Capture sessions began approximately thirty minutes before sunrise and usually under overcast skies. These were considered optimal conditions for capturing and handling lizards as they were more likely to be present under ACOs and less likely to escape (Lettink and Cree unpubl.). The December session took place over 6 consecutive days, with no marking of lizards on the first day. In this preliminary session, we baited ACOs with canned pear to increase the probability of capture. We chose canned pear as it has often been used to bait pitfall traps (e.g. Towns and Elliott 1996, Freeman 1997). Initially, we placed a $1cm^3$ piece of canned pear underneath each layer of each ACO. For the remainder of the session, pear was placed underneath only the top two layers of each ACO in order to attract lizards to these layers where they were more easily detected and captured. Since we often found partially eaten bait with no lizards present, it appeared that baiting did not increase the number of lizards caught and it was therefore not used in later sessions. For the March 2006 session, the number of capture days was reduced to 5, and marking began on the first day.

At each sampling site, two workers examined one grid at a time, checking alternate rows of ACOs. As each layer was lifted, any lizards were removed by hand, and when more than one lizard was caught in the same ACO, the additional lizard(s) were held in cotton bags until they could be processed. We numbered lizards on the abdomen with a silver or white xylene-free marker pen. Numbers were applied as soon as possible upon capturing and allowed to dry while the following data were recorded: the grid and ACO number, lizard number and species, and whether the lizard was a recapture. In the March CMR session we also recorded the snout-to-vent length and snout-to-tail length. When processing of a lizard was complete, it was released into the same layer of the ACO where it had been found.

2.5 Data Analysis

We derived abundance estimates (known as $\hat{N}$) with closed population capture models in the software program DENSITY (v. 3.3) (Efford et al. 2004). Population density (D) could not be estimated because we did not have enough data on the movement of lizards. Since we expected skinks and geckos to exhibit different behaviour related to trapping, we analysed the data sets of each group separately. In the March CMR session, however, too few geckos were captured for a separate estimate and these data were ultimately left out. To compare estimates between sampling sites, the data from all grids within a site were pooled. Since no lizards were marked on the first day of the December session, lizard captures from this day were not included in the CMR data.

We used the program CAPTURE (Otis et al. 1978) to select the most suitable closed population model and estimator for each data set. CAPTURE uses seven different Chi-square tests to compare the fit of the data to four basic closed population models, each of which considers a different source of variation affecting capture probability: null (M_0), behaviour (M_b), time (M_t), and heterogeneity (M_h). The p-values obtained from these tests are then evaluated using a multivariate discriminant function that assigns a selection criterion value (between 0.00 and 1.00) to each of eight possible models: the four above and M_{bh}, M_{th}, M_{tb}, M_{tbh} (Otis et al. 1978, White et al. 1982). The model that receives a value of 1.00 is considered to be the most appropriate for the data set. There were some models for which an estimator was not available (i.e. M_{bh}, M_{tb}, and M_{tbh}). When any of these models were recommended by CAPTURE, we used the estimator of the model that either had the second highest criterion value or was the most robust to the variation in capture probabilities. Based on the final recommendations of CAPTURE for each data set, we compared abundance estimates between sampling sites using a combination of the following estimators: maximum likelihood for the null model (M_0), Zippin for the behavioural model (M_b), Jackknife for the heterogeneity model (M_h), and Chao's second coverage estimator (Chao) for the time and heterogeneity model (M_{th}) (Otis et al. 1978, Lee and Chao 1994). Abundance estimates based on the same model were considered significantly different between sites when 95% confidence intervals did not overlap.

3 RESULTS

3.1 Capture Totals and Trends

We caught over 45% of the total number of captured lizards on the first day in both CMR sessions. Daily captures then declined by at least half by day three (Figs. 3a & b). Skinks were found under ACOs much more often than geckos, with *O. maccanni* and *O. n. polychroma* accounting for more than 70% of all lizards captured in both sessions. We also captured a small number of cryptic skinks (*O. inconspicuum*), which were caught only in gully grids and primarily at the Inside site in both sessions. In the December session, we captured at least 2 individual skinks in every grid, with a maximum of 11 and an average of 6.5 per grid. We captured an average of 3 skinks per grid and at least one skink in all but 6 grids in the March session. We captured many more geckos in the December session than in the March session. In the December session, 13 of the 18 individual geckos captured were found in the ridge grids placed near rock outcrops, while in the March session, three of the four individuals caught were found at the Inside site. A few skinks but no geckos escaped from ACOs before they could be marked in both sessions.

Recapture rates varied considerably between genera and sampling sites. Compared with skinks, a higher percentage of geckos were recaptured relative to the total number caught (Figs. 4a & b). We recaptured geckos more often than skinks in the December session, and at least one individual gecko was recaptured every day in both sessions. Compared with the other treatments, recaptures were most frequent at the Inside site, which accounted for more than 68% of the total number of recaptures in both CMR sessions.

3.2 Model Selection and Population Estimates

The variation in closed population models and estimators recommended by CAPTURE indicated that multiple sources of variation influenced the capture probabilities of skinks and geckos. For skinks, CAPTURE recommended either M_b or M_{tb} as the most suitable population models, with M_{th} the second most likely option. These models indicated that a behavioural response strongly influenced skink capture

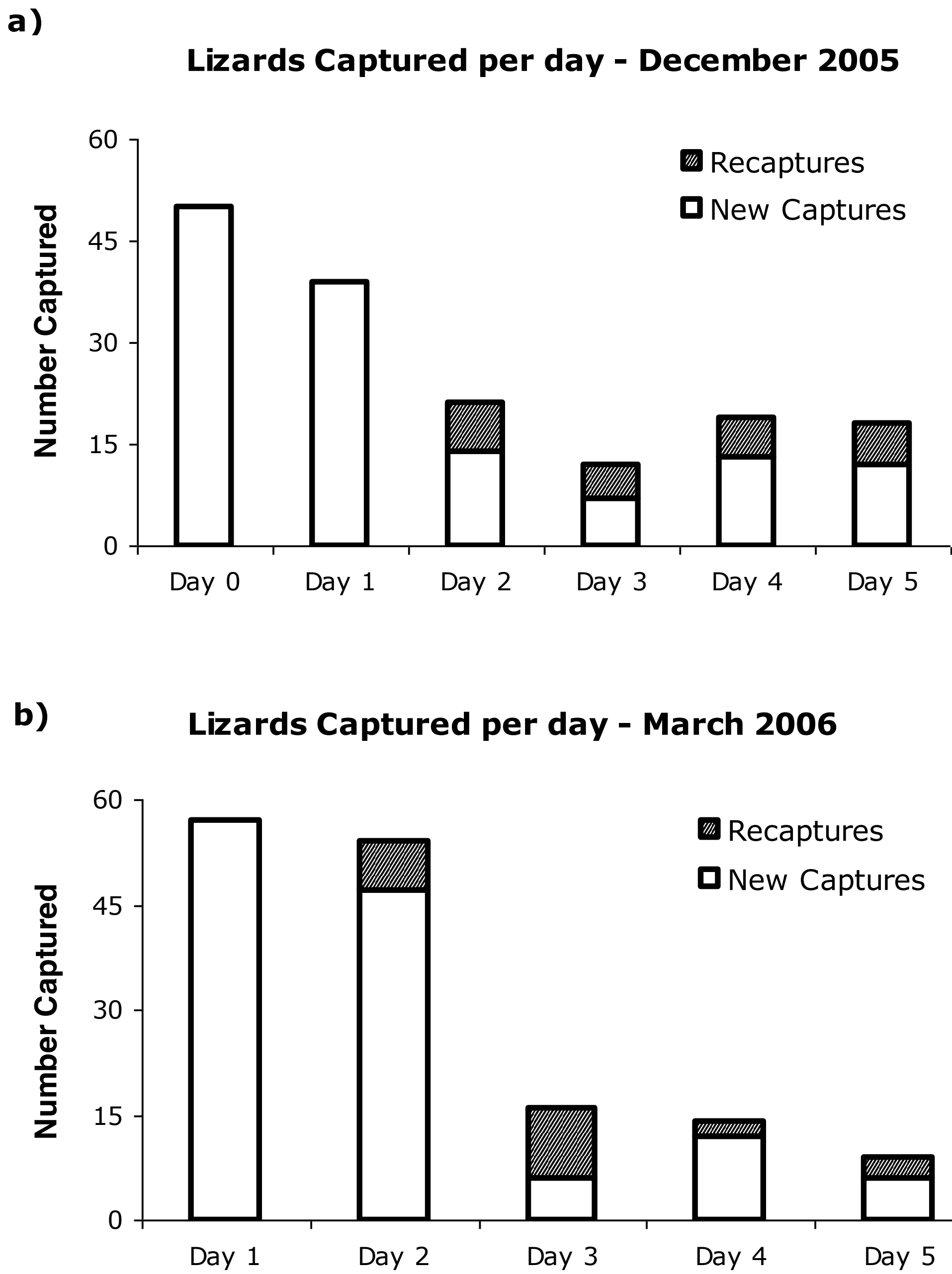
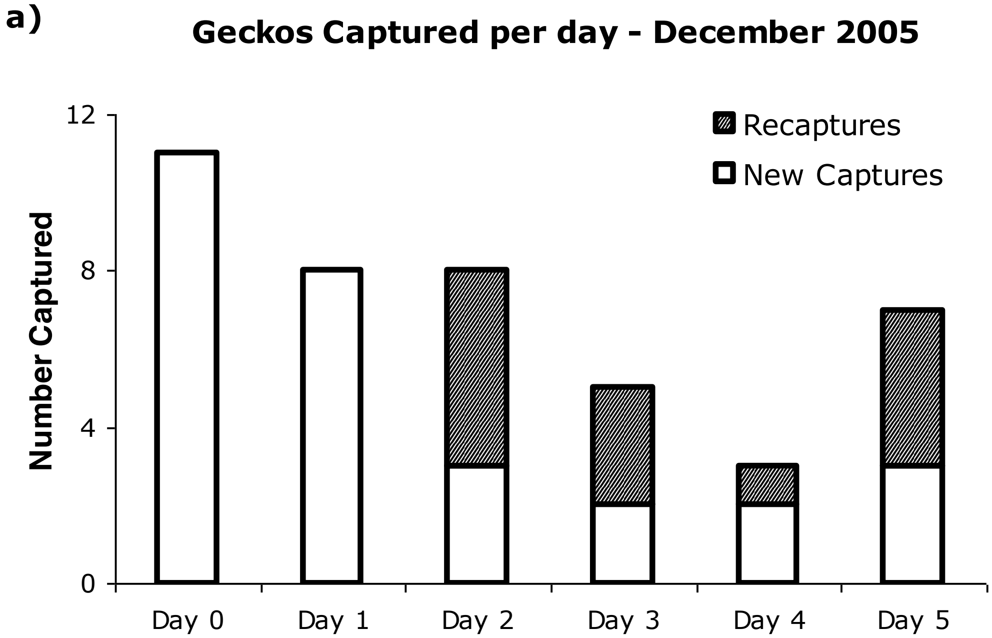


Figure 3. Combined total number of new and recaptured common geckos (*Hoplodactylus maculatus*) and skinks (*Oligosoma inconspicuum, O. maccanni,* and *O. nigriplantare polychroma*) caught per day during two capture-mark-recapture sessions at the Macraes Flat conservation reserve, Otago. a) In December 2005, lizards were captured using 12 grids of 25 Onduline artificial cover objects (ACO) distributed evenly between two sampling sites. No lizards were marked on Day 0 and all ACOs were baited with 1cm^3 of pear. b) In March 2006, lizards were captured using 48 grids of 16 Onduline ACOs evenly distributed between four sampling sites, one of which was a control site outside of the reserve.



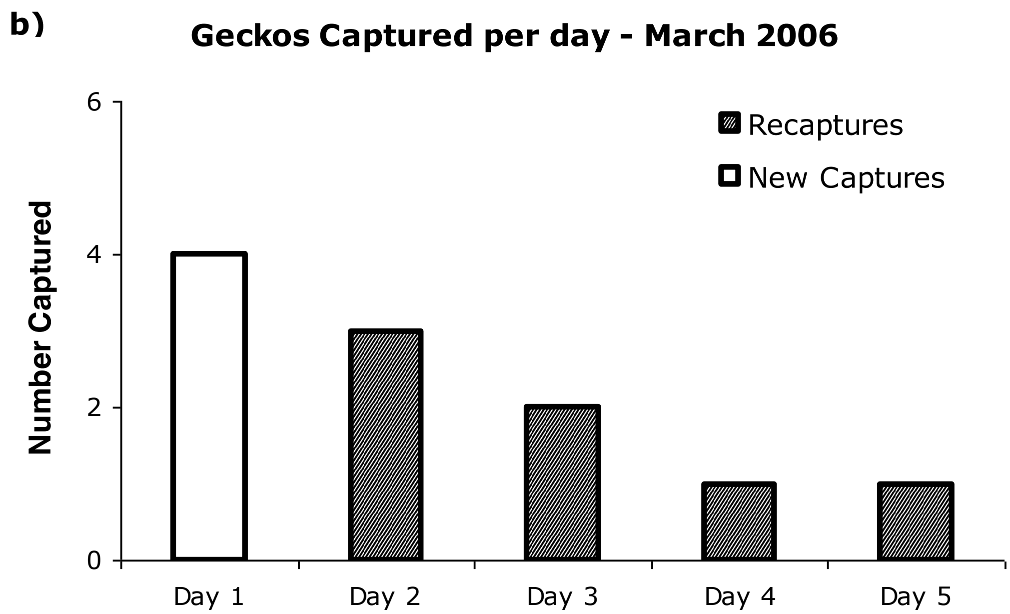
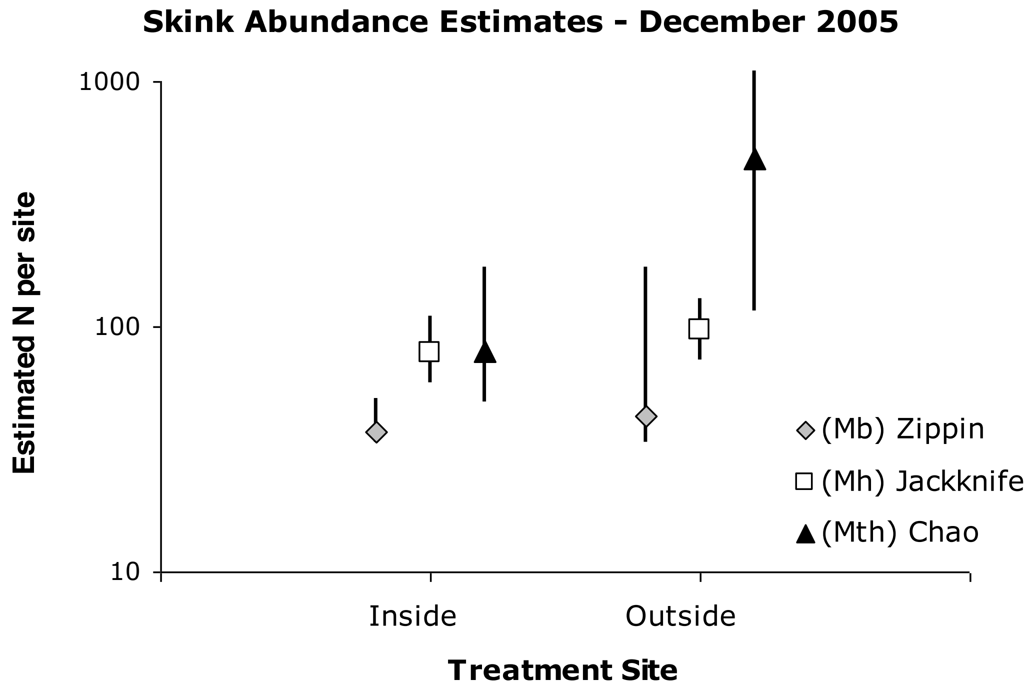


Figure 4. Total number of new and recaptured common geckos (*Hoplodactylus maculatus*) caught per day during two capture-mark-recapture sessions at the Macraes Flat conservation reserve, Otago. The percentage of geckos recaptured was much higher than skinks in both sessions. a) In December 2005, geckos were captured using 12 grids of 25 Onduline artificial cover objects (ACO) distributed evenly between two sampling sites. No geckos were marked on Day 0 and all ACOs were baited with 1cm^3 of pear. b) In March 2006, geckos were captured using 48 grids of 16 Onduline ACOs evenly distributed between four sampling sites, one of which was a control site outside of the reserve.

probabilities, and there was additional variation with time and between individuals. The M_0 and M_{th} models were the most suitable models recommended for geckos. While these choices suggested that there were no strong sources of variation in gecko capture probabilities, there was again some variation with time and between individuals. We therefore computed abundance estimates for all skink data sets with the Zippin (M_b) estimator, and all gecko data sets with the maximum likelihood (M_0) estimator. Additional estimates for all data sets were computed with the Jackknife (M_h) and Chao (M_{th}) estimators. These were considered to be the most robust to the multiple sources of variation in capture probabilities (Otis et al. 1978, White et al. 1982, Efford et al. 2004).

In the December 2005 CMR session, skink abundance estimates were not significantly different between sampling sites (based on overlapping 95% confidence intervals) (Fig. 5a). All three estimators, however, indicated significantly larger abundance of geckos at our Outside site ACO grids than at our Inside site ACO grids (Fig. 5b). In the March 2006 CMR session, Zippin abundance estimates for skinks differed significantly between all sampling sites, with the largest estimate at the Inside site, followed by the Outside, Falcon, and then Alistair (experimental control) sites (Fig. 6). Neither the Jackknife nor the Chao estimates, however, differed significantly between sites (Fig. 6).

a)



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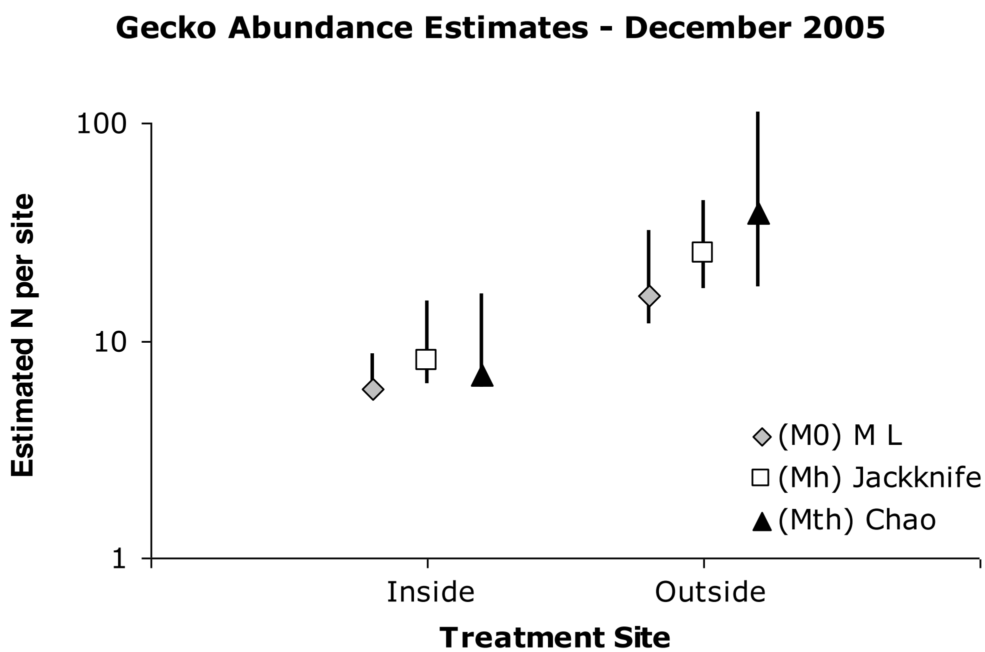

Figure 5. Abundance estimates ($\hat{N}$) of a) skinks (*Oligosoma inconspicuum*, *O. maccanni*, *O. n. polychroma*) and b) common geckos (*Hoplodactylus maculatus*) derived from capture-mark-recapture data obtained at the Inside and Outside treatment sites at Macraes Flat conservation reserve, Otago, December 2005. Error bars indicate 95% confidence intervals and the y-axis is plotted on the log scale.

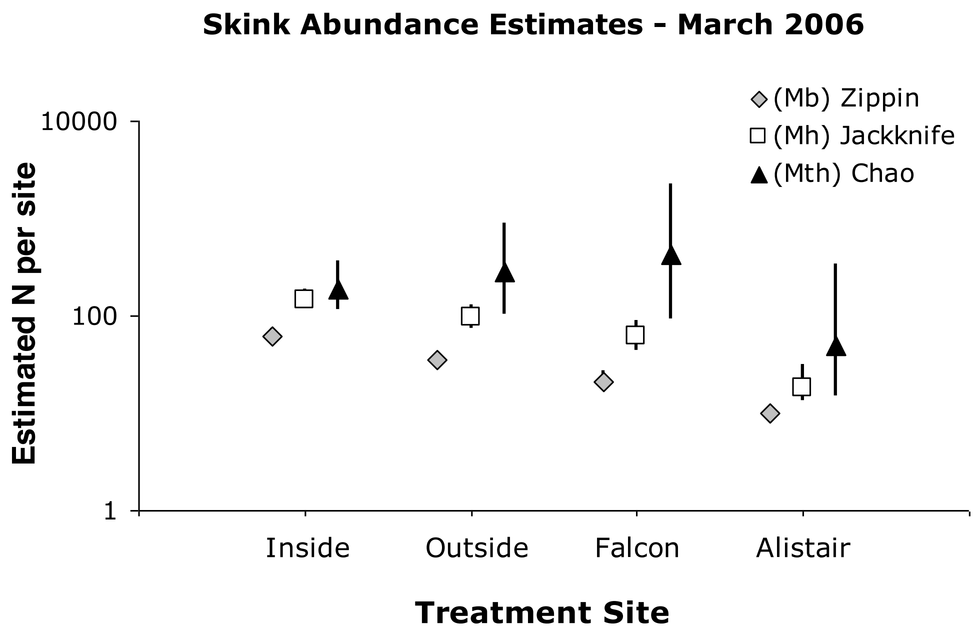

Figure 6. Abundance Estimates ($\hat{N}$) of skinks (*Oligosoma inconspicuum*, *O. maccanni*, *O. n. polychroma*) derived from capture-mark-recapture data obtained at three treatment sites (Inside, Outside, Falcon) and one experimental control site (Alistair) at Macraes Flat conservation reserve, Otago, March 2006. Error bars indicate 95% confidence intervals and the y-axis is plotted on the log scale.

4 DISCUSSION

4.1 Capture effectiveness of Artificial Cover Objects

We found that grids of Onduline ACOs were effective for capturing skinks, but less so for geckos. Skinks were found under ACOs much more often than geckos in both CMR sessions. This result was most likely a consequence of our sampling design and reflected the differences in habitat preference of the two genera. In central Otago, the habitat use of the common gecko is primarily restricted by their preference for rocky habitats, which are important for thermoregulation (Spencer 1991, Whitaker et al. 2002). The higher number of geckos caught in the December CMR session can therefore be attributed to the placement of some ACO grids near rock outcrops, which was where the majority of geckos were captured in that session. In contrast, the common skink and McCann's skink were generally widespread, especially throughout the Inside, Outside, and Falcon sites where at least one skink was caught in each grid. This reflected the broader habitat use and widespread distribution of these two species (Patterson 1985, Spencer 1991, Whitaker et al. 2002). Cryptic skinks, on the other hand, were found only in a few gully grids, which contained the moist, densely vegetated habitat that this species prefers (Whitaker et al. 2002).

In contrast to our study, Lettink and Cree (unpubl.) found many more geckos than skinks under Onduline ACOs. That study, however, was conducted in a grazed coastal shrubland with no rock outcrops, and ACOs were checked once a month for one year. Since the climate and other characteristics of this coastal shrubland were quite different from Macraes Flat, it is likely that the habitat use and distribution of geckos and skinks were also different. In fact, Freeman (1997) studied the habitat use of *O. maccanni* and *O. n. polychroma* in the same coastal shrubland and found that their habitat preferences were the opposite of what has been observed in central Otago. Lettink and Cree (unpubl.) speculated that the multi-layered structure and heat retaining ability of Onduline ACOs were attractive features for geckos. However, Lettink and Cree (unpubl.) also considered that daily and seasonal variation in ACO use indicated a greater preference for natural cover objects, and that geckos were more likely to use ACOs in areas where natural cover was lacking. Although we did tend to capture more geckos when ACOs were placed near rock outcrops, the number captured at each site was still considered inadequate for reliable abundance estimates (i.e. at least 20 - 30 individuals; Otis et al. 1978). Therefore, the ACO method may not be suitable for sampling and estimating the abundance of *H. maculatus* at Macraes Flat; unless, perhaps, grids of ACOs are concentrated near rock outcrops.

4.2 CMR abundance estimates

The multiple sources of variation in capture probabilities and the low recapture rates, particularly of skinks, complicated the selection of a single most appropriate and reliable estimator for all skink and gecko datasets respectively. Indeed, the number of recaptures was an important factor influencing model selection, and had a strong effect on the accuracy and precision of the abundance estimates. For the March session skink data, we did obtain significantly different abundance estimates between sampling sites with the Zippin (M_b) estimator, which is generally the most suitable when there is a strong behavioural response to capture and recaptures are low (Otis et al. 1978). However, underestimates often occur when the behavioural response varies across individuals and with time (Otis et al. 1978). This strong behavioural response, called trap-shyness or avoidance, has often been observed in common skinks and McCann's skinks caught in pitfall traps (e.g. Patterson 1985, Towns and Elliott 1996, Dixon 2004). However, this behaviour does vary across individuals, and possibly even populations. For example, Freeman (1997) recaptured 40% of *O. maccanni* compared to only 4% of *O. n. polychroma* that were caught in pitfall traps. Individual variability in trap shyness was present in our study as we did recapture some individual skinks, including two that were recaptured twice. We therefore assumed that our Zippin estimates were biased downward, especially since they were nearly the same as if not equal to the total number of individuals caught. In addition, the narrow confidence intervals of the estimates were questionable considering the relatively small sample sizes, especially those obtained at the Alistair's Gully and Falcon sites.

The Jackknife (M_h) estimates appeared to be more realistic than the Zippin estimates. However, the Jackknife estimator is subject to underestimation, particularly when capture probabilities are low (Otis et al. 1978, White et al. 1982), as they were in our study. Furthermore, CAPTURE outputs indicated that there was also a temporal source of variation in capture probability (see Appendix 2). Considering this variation, the application of the Chao (M_{th}) estimator appeared to be the most appropriate for the skink datasets. Compared with the Zippin and Jackknife estimates, the precision of the Chao estimates was very sensitive to low sample sizes (i.e. wider confidence intervals for data sets with low total captures or low recaptures). In addition, when there were very few recaptures, Chao estimates were erratically large (i.e. the Outside site in the December session, and the Falcon and Alistair sites in the March session). Nevertheless, we considered the Chao estimates to be the most accurate when there were enough data, i.e. for skink abundance at the Inside and Outside sites in the March CMR session. Wilson et al. (in prep.) provided additional support for the Chao estimates when they obtained similar results with narrower confidence intervals in a subsequent weekly CMR session on the same ACO grids.

In contrast to skinks, geckos did not appear to be trap-shy due to their relatively high recapture rate, which supported their apparent attraction to Onduline ACOs observed by Lettink and Cree (unpubl.). In fact, none of the apparent sources of variation in capture seemed to have much of an effect on the abundance estimates as all three were quite similar within each dataset in the December CMR session. Instead, it appeared that spatial variation (i.e. due to grid or ACO placement as mentioned above) may have been the most important factor in the capture probability of geckos. The significantly greater abundance of geckos observed at the ACO grids in the Outside site could therefore reflect a greater abundance or proximity of suitable rock outcrops than in the Inside site. However, larger sample sizes are needed before these estimates can be considered reliable.

4.3 Conclusion and Recommendations

Despite the relatively low capture rates and unreliable abundance estimates, we captured a reasonable number of common and McCann's skinks in two of our sampling sites. This result provides support for the use of ACOs in capturing skinks at Macraes Flat. Yet, observations at Macraes Flat (Dixon 2004) and nearby areas of central Otago (Patterson 1985) indicate that *O. maccanni* and *O. n. polychroma* are probably more abundant than our results indicate. If so, then captures in ACOs could potentially be increased by adjusting the sampling design according to the objectives of the study. For example: more ACOs could be placed closer together in a grid; grid placement could be concentrated on habitats where different species are most likely to be found (e.g. rock outcrops for geckos, moist and densely vegetated habitats for cryptic skinks); and, considering that the timing of daily and seasonal activity periods may vary between species (Lettink and Cree unpubl.), checking ACO grids at different times could indicate which time(s) provide the most optimal capture rates. Clearly, before improvements can be made, more information is needed on the movements and habitat use of skinks and geckos, and how these vary between sex and age groups. Increasing the number of skink recaptures, however, may be difficult.

Currently, it appears that the best use of ACOs at Macraes Flat may be for periodic one-day counts to provide a rough index of abundance in areas with different levels of management. These counts would need to be calibrated against CMR surveys, which, for skinks, may be best conducted with pitfall traps. Indeed, Fellers and Drost (1994) and Lettink and Patrick (in press) do not recommend the use of ACOs for detecting population trends. Nevertheless, ACOs do provide a fast, efficient, inexpensive, simple, and low impact method for obtaining counts of lizards. With more research and improvements in the sampling design and technique, the ACO method could potentially provide a more reliable means of estimating lizard abundance and density.

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Acknowledgements

First and foremost I thank my supervisor, Deb Wilson, for her invaluable advice, comments and encouragement. I thank Robin Wiedemer for her enthusiasm, leadership, and friendship. Along with Deb and Robin, I thank the Dunedin and Alexandra Landcare Research teams for providing a fun, friendly, and inspiring work environment. I would also like to thank the Dunedin Landcare Research office for providing facilities for the completion of this report. Finally, this report is not complete without thanking Kim Capone for her enthusiasm and support, and for being a great friend.