SCIENCE & RESEARCH INTERNAL REPORT NO.133

DEVELOPMENT OF OTAGO SKINK AND GRAND SKINK POPULATION CENSUS AND MONITORING TECHNIQUES

by

G. B. Patterson

Published by
Head Office,
Department of Conservation,
P O Box 10-420,
Wellington
New

ISSN 0114-2798
ISBN 0-478-01431-7

Keywords: *Leiolopismagranda, Leiolopisma otagense,* census techniques, population monitoring

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G. B. Patterson

Science & Research Division, Department of Conservation
P.O. Box 10-420, Wellington

ABSTRACT

Capture and census techniques for giant skinks, *Lewlopisma grande* and *L. otagense,* were investigated at two sites in Central Otago. General recommendations for similar surveys are given, and specific comments are made for preserving the two species in the study area. Conditions for efficient use of the Lincoln-Petersen method are discussed. Selected references on population monitoring of lizards are included.

1. INTRODUCTION

The aim of this study was to investigate trapping and census-taking techniques for the so-called "giant" skinks, *Leiolopisma grande* (Gray) and *L. otagense* form *otagense* McCann. Both species are large skinks by New Zealand standards. *Leiolopisma grande* is the smaller of the two, reaching a snout-vent length of 109 mm and 25 g weight. *Lewlopisma otagense* ranges up to 126 mm snout-vent and 44 g for a large gravid female, but with most animals weighing less than 35 g. These are two of New Zealand's rarest lizards and are in category "A", the highest in the Department of Conservation's species priority ranking.

They are presently known from only two areas in Central Otago: near Macraes Flat, Hyde, Sutton and Pukerangi in the east, and in the Lindis area in the west. There are grave fears for their survival, since their populations appear to be declining rapidly due to habitat loss, predation and other factors. The draft species recovery plan for these species (Whitaker and Loh, not published) lists several major research topics which are crucial to its success. Foremost amongst these and given the highest priority are the development of appropriate techniques for the safest and least disruptive methods of capture, handling, marking and monitoring these animals.

Capture techniques for lizards range in sophistication from simple hand capture to the use of specially designed traps. Methods of capture, handling and marking should affect the study animals as little as possible. Obviously this rules out methods that kill them or prevent reproduction, but techniques that alter the habitat significantly may also have similar effects, and these should be avoided where possible. Because of giant skinks'

wariness and the amount of cover in their habitat, capture methods used for other lizard species may not be appropriate for them.

In monitoring studies, lizards are usually either caught by hand (see Tinkle 1967, Turner *et al*. 1970, Van Devender 1982, Ruby and Dunham 1984, Heulin 1985), with a noose (Dunham 1980, 1981, 1982, Smith 1981, Tinkle and Dunham 1986) or by a mixture of the two methods (Ballinger 1973, Ruibal and Philibosian 1974).

Pitfall traps are occasionally used in population studies (Spoecker 1967); these may be used in connection with drift fences (e.g. James 1991), although drift fences are generally effective only with widely foraging, mobile species such as *Cnemidophorus* (Milstead 1959). Pitfall traps may sometimes contain bait to attract lizards; in New Zealand Whitaker (1967) found that traps baited with canned pear attracted more lizards than did empty traps. Funnel traps have been used to catch wide-ranging species (*Varanus komodoensis,* Auffenberg 1981). Modified insect nets have been used to capture particularly wary lizards (Stebbins 1967).

In long-term monitoring studies, lizards are almost always assigned unique identifying marks. This is done by clipping off the distal phalanx of one or more toes. Toe clips are permanent and apparently cause little trauma. The system has worked well in a number of studies (Barwick 1959, Blair 1960, Brooks 1967, Ballinger 1973, 1979, Ruibal and Philibosian 1974, 1981, Smith 1981, Schoener and Schoener 1982, Ruby and Dunham 1984, Heulin 1985, and Tinkle and Dunham 1986). Branding has occasionally been used to mark lizards (Burrage 1974). Tattooing has been used to mark snakes (Woodbury 1948) and could be applied to lizards.

As well as marking lizards permanently, investigators frequently apply unique paint marks to individuals. Examples of the use of this technique include Blair (1960), Dunham (1981), Schoener and Schoener (1980, 1982).

Since it is usually impossible to mark all animals within a given area, some sort of population estimate will need to be made. There are two major categories of technique – mark-recapture and capture/resight (Minta and Mangel 1989). I examined both types to determine which was most appropriate for counting giant skinks.

Noosing has been the most commonly used method for catching giant skinks. These lizards have apparently never been caught in any form of trap (Towns *et al.* 1984). I investigated passive trapping techniques to see if these were more efficient than noosing or catching by hand.

Finally, I constructed a database written in dBase4.1 to record captures of marked Otago and grand skinks. This database can be used to construct profiles of the populations of both species, for use in calculating mortality, natality and other ecological variables.

2. MATERIALS AND METHODS

2.1 Study Sites

All work for this study was carried out in Emerald Stream, Macraes Flat, on freehold land owned by Keith Philip. Scattered schist outcrops occur along the ridges and in the stream valleys. These are often fractured horizontally, and range in form from single slabs to large tors. The vegetation throughout the area has been extensively modified by farming, although in the sites where this study was carried out the vegetation was still dominated by snow tussock, *Chionochloa rigida,* silver tussock *Poa laevis,* and hard tussock *Festuca novaezelandiae.* Line transects and population census-taking were out in a fenced plot called "Canyon", while pitfall trapping was carried out in another fenced plot called "Falcon".

The "Canyon" site is about one hectare, at grid reference NZMS262/I43, 23077 55243, at 500 m altitude, and includes both banks of the stream. The banks of the stream have an east-west aspect, with schist outcrops primarily on the west-facing bank. The site is defined by a rabbit fence.

The "Falcon" site is defined by a stock fence and is on both banks of the stream, also with an aspect similar to that of "Canyon" (grid ref NZMS262/I43, 23082 55247 - 23084 55250, altitude 520 m; approximately 2.5 ha).

Otago skinks and grand skinks were first toe-clipped by Ian Southey in December 1987. The sites are recognised by the landowner and the Department of Conservation in a management agreement.

2.2 Pit Traps

The two "passive" trapping techniques investigated in this study were pit trapping and artificial retreats. Funnel traps and drift fences were not investigated because they would be difficult to set up and maintain in the skinks' habitat, and they have been used successfully in general only with active free-ranging lizards. Going by the available data, the giant skinks are more like sit-and-wait predators.

Three kinds of pit trap were used: 41 metal paint tins (19 cm deep x 17 cm diameter), cylindrical black plastic calf feeders (22 cm deep x 24 cm diameter), and square white plastic ice cream containers (19 cm deep x 17 cm diameter). A total of 90 traps was set in the "Falcon" site from 11 February 1992 - 6 March 1992, in groups of three (one of each design) at 30 trap sites. Traps were adjacent to each other, and they were in or next to giant skink habitat. The metal tins were covered with metal lids weighted with a rock. The two kinds of plastic trap were covered with old terracotta roofing tiles with a gap large enough to admit a giant skink but too small for a cat or possum. Traps were stabilised with concrete tiles. Sites were identified by small brick tiles with numbers painted on.

I had planned to test bait selection by using tinned pear slices, tinned pineapple pieces, and no bait, but it became apparent that, owing to the small number of animals being caught, there would be too many null values in the sample. Also, it became clear that

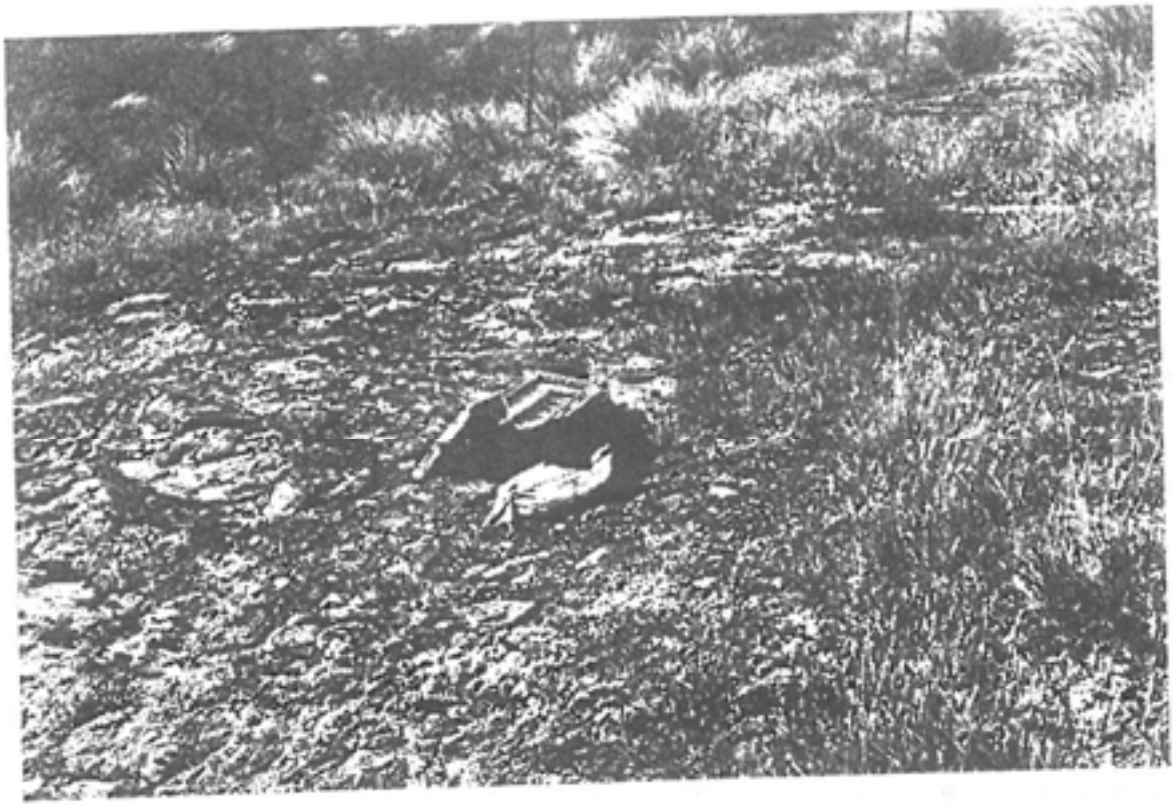

Figure 1. Pitfall trap on rock. This trap caught one *L. grande* and two *L. otagense* individuals.

some animals, probably *L. otagense,* were eating the bait and climbing out of the tines and white plastc pails during the daytime. Two thirds of the sites were on rock outcrops (including rock flush with the ground (Fig.1)), while the rest were on soil immediately adjacent to rock outcrops (Fig. 2).

The skinks were toe clipped where this had not already been done, weighed, measured (snout-vent), marked with a silver marker pen, and released next to the trap.

2.3 Nooses

Catching the skinks by hand is very difficult owing to their wariness and the ab7undant cover in their habitat. Once the animals have rushed into a crevice it is usually impossible to extract them by hand. Sometimes they can be winkled out with a piece of wire, but this is not n easy option, especially for people unfamiliar with the skinks. Noosing appears to be the most effective method of actively catching them.

The noose consists of nylon fishing line either looped through a metal tube or looped on the end of a fishing rod. After the loop is slipped over the head of the animal (which may be either in the open or in a crevice) it is convulsively tightened and the animal caught by hand as it dangles from the end of the rod. It is sometimes helpful to shine a torch into a crevice to more clearly distinguish an individual that is being noosed.

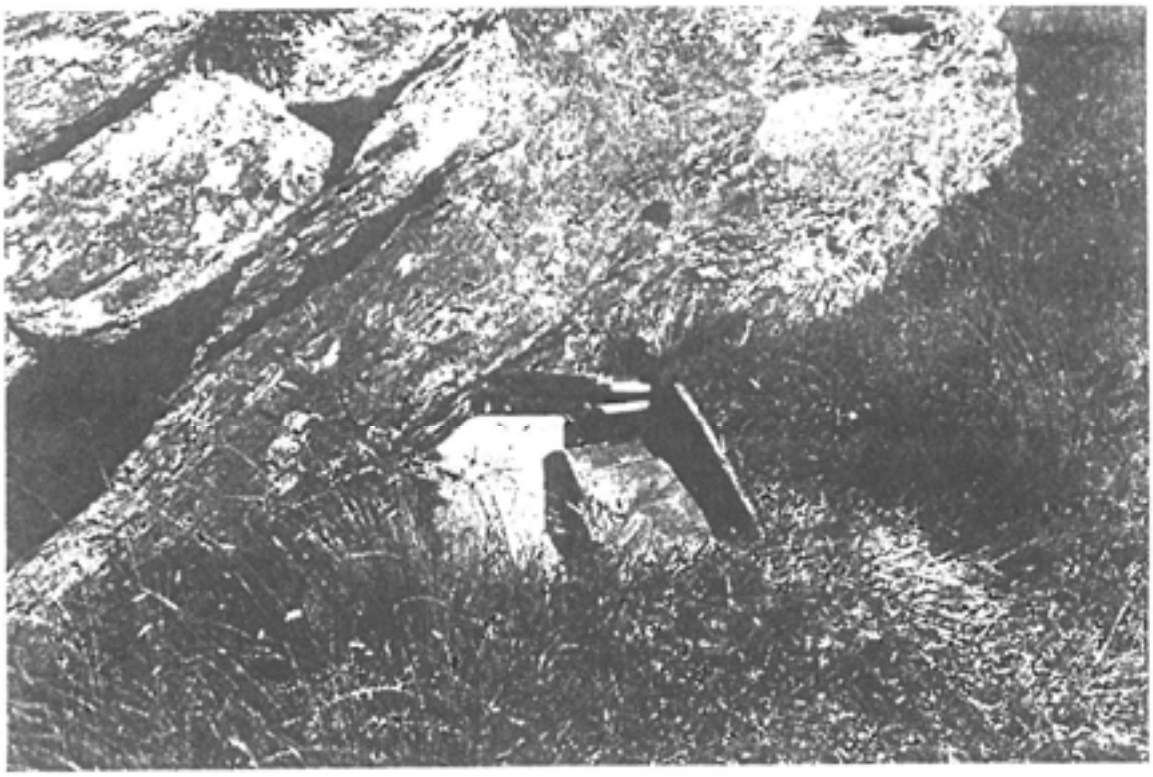

Figure 2. Pitfall trap adjacent to rock outcrop. This trap caught one *L. grande* individual.

Some workers have found that animals became noose-shy, and will not permit the noose to touch them after being caught once in this manner (Stebbins *et al.* 1967). They have had to resort to other techniques to recapture the lizards, such as insect nets with padded rims that conform to the rock surface. There is no evidence, however, that giant skinks become noose-shy to such an extent.

2.4 Line Transects

Between 12 February and 5 March 1992 I conducted line transect at various times of the day through the "Canyon" site. The transect line was 110 m long and followed the fence line from north to south. The habitat extended about 20 m from the transect line on my right. It took 15 minutes each time I walked the transect.

I focused on distant rocks with binoculars while remaining stationary for one or two minutes; I dod not use the binoculars on the closer rocks but did move along the transect line. The same procedure was followed during each transect. No animal was counted more than once.

Shade air temperature and temperature on exposed rock faces was measured before each transect with an electronic temperature gauge with a metal probe, accurate to 0.1^{o}C. Wind speed was measured with a hand-held anemometer before the transects, and cloud cover was estimated by eye during the transects. If clouds moved over the sun during a transect the results were included in both the 'overcast' and 'sunny' categories. This occurred in fewer than 10% of the transects.

2.5 Population Census

I decided to use the Lincoln-Petersen method as the census technique, for reasons outlined in the Discussion. A census was made at the "Canyon" site on 4 March 1992 between 10.45am and 12.00 noon. I carried out the census in only that area of habitat where I had carried out the line transects, 75% of the habitat. Four people with paint brushes (some tied to 1 m sticks) moved through the census area from north to south. We tried to mark at least half of the maximum number of lizards seen under the best conditions during the transects (10 *L. grande* and six *L. otagense*), as the Lincoln-Peterson method is more accurate if this condition is met.

We used acrylic paint on all animals, in case different markers had different visibilities, which could have affected the census results. Acrylic paint seemed to have the best visibility on *L. maccanni*, a noticeably smaller species which also appeared in the trap.) Most animals were marked after they had been chased into crevices. The weather was fine and sunny during the census, with wind about 5 m/sec and air temperature 15°C.

2.6 Retreats

At five sites within the "Falcon" site, I placed two concrete tiles, one on top of the other, on rock surfaces, to see whether giant skinks would use these as shelters. By placing a container around the tiles with its rim flush to the rock and then lifting the tiles it should be relatively easy to catch any skinks that are there.

2.7 Marking Techniques

2.7.1 Temporary Marking

Between 10 February to 5 March I marked two *L. nigraplantare polychroma* and 12 *L. macanni* with various colour markers to determine which would he most suitable for temporary marking. I used

"Pilot" silver marker pens (two animals),
"Chromacryl" white acrylic paint (four animals),
nail varnish (two animals),
typists' correction fluid (“Twink”) - white pigment dissolved in 1,1,1-Trichloroethane (two animals), and
“Wraddle” sheep marker dye (two animals).

Each pigment was applied in a single patch (approx. 0.5 x 0.5 cm) to the back of the animals. The solution was allowed to dry (10 - 30 sec), and then the animals were released back into a cage, which contained three schist rocks approx. 10 x 10 x 5 cm. The marks were monitored daily; when they were no longer easily discernible the date was noted.

2.7.2 Permanent Marking -Toe Clipping

I marked previously unmarked giant skinks caught in pit traps by toe-clipping on two distal digits from different feet. The toe closest to the body was “1” while the toe most distant from the body was "5". I used ultra-sharp surgical scissors to avoid unnecessary mutilation. The scissors were sterilised with 100% ethanol. To avoid duplication, toe combinations were always different from those used previously in both the "Falcon" and "Canyon" sites.

As part of my contract I built a computer database which should allow easy storage and retrieval of toe-clip data from the sites in this study, and other sites where this type of marking is used.

2.8 Bait Tests

On 20 and 25 February I tested various baits on *L. otagense* and *L. grande* in the wild. Once the animals had retreated into crevices I placed different baits in a line on the rock outside and watched the animals' behaviour on re-emergence. I placed pieces of tinned pear, tinned pineapple, raw apple, and steak mince of about the same size outside crevices occupied by five grand skinks. I placed similar bait outside the crevices of three Otago skinks (but substituted banana for apple). Fish-based products such as cat-food were not used since these might have attracted the unwelcome attention of cats. Invertebrates which had fallen into the pit traps were kept there as live bait.

2.9 Handling Techniques

On removing giant skinks from the pitfall traps I was careful not to handle them by their tails, which can break off easily if pressure is applied to the vertebrae. If the tail breaks off the skinks, they may lose vital fat reserves that enable them to winter. I was also careful to store skinks away from the direct rays of the sun, since they could suffer heat stress and possibly die if unable to escape the sun's heat.

I weighed the skinks on a 50 g spring balance. The skink was placed inside a plastic bag which was clipped to the scales and weighed. The weight of the bag was then subtracted to give the skinks weight, accurate to 0.5 g.

For longer term storage skinks should be placed in a ventilated bag or box and kept cool and supplied with food and water if necessary.

3. RESULTS

3.1 Line Transects

Figures 3-5 show the number of skinks of each species that I saw at different times of the day and under varying climatic conditions. The graphs show similar patterns of behaviour for both species, although there appears to be some differences that may relate to species-specific behavioural characteristics. On sunny days most animals were seen in the morning; the best time of day for viewing grand skinks was between ca. 8.30 am and 11.30 am, and for Otago skinks between ca. 9.00am and 11.00 am (Daylight Saving Time).

In sunny weather on average 10 grand skinks were seen in the morning (up to and including noon), but only five were seen in the afternoon; whereas on average five Otago skinks were seen in the morning and two in the afternoon. This contrasts with overcast weather, when on average seven grand skinks were seen both in the morning and in the afternoon, and four Otago skinks in the afternoon but only two in the morning.

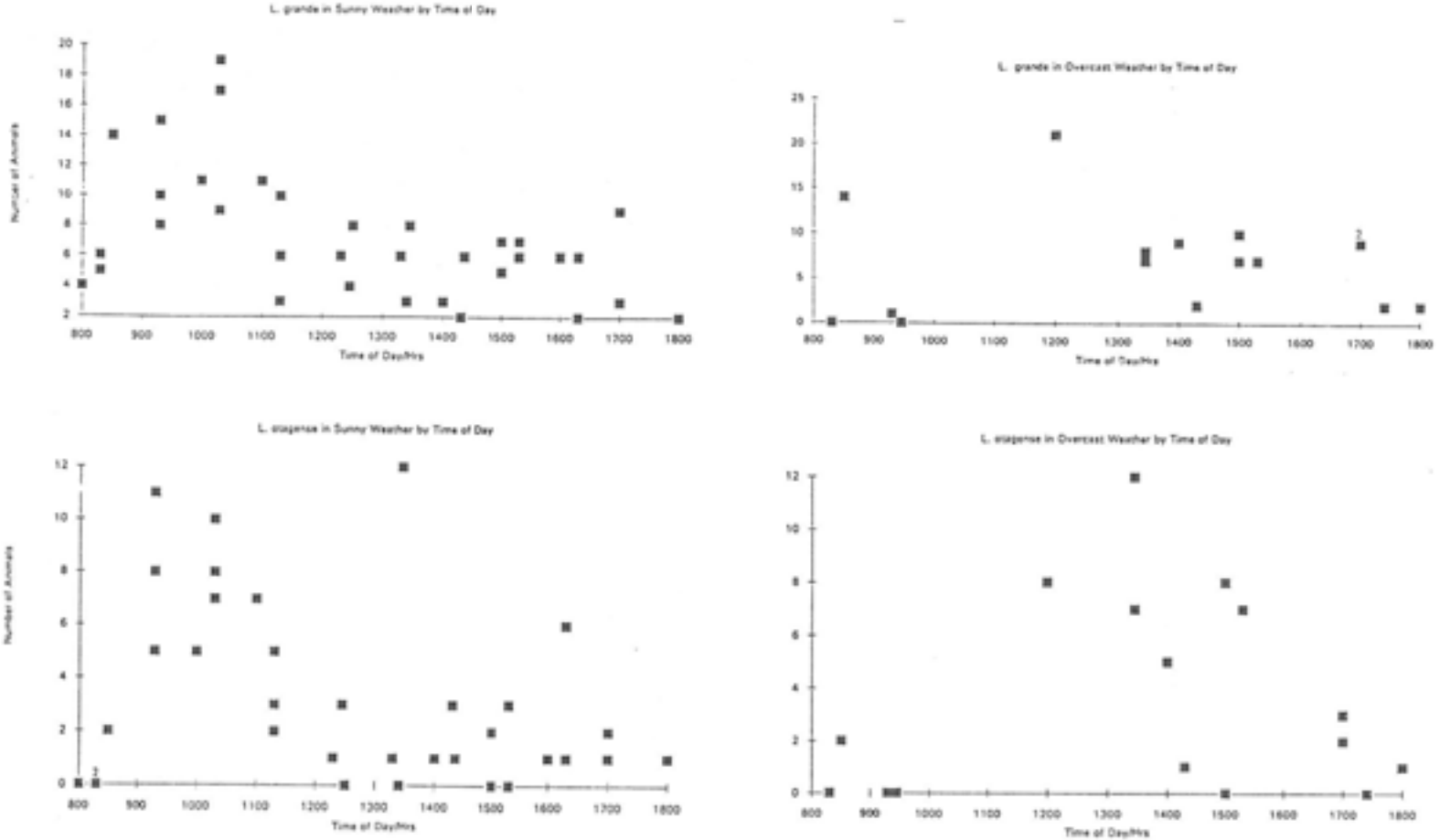

Figure 3. Time of day related to sightings.

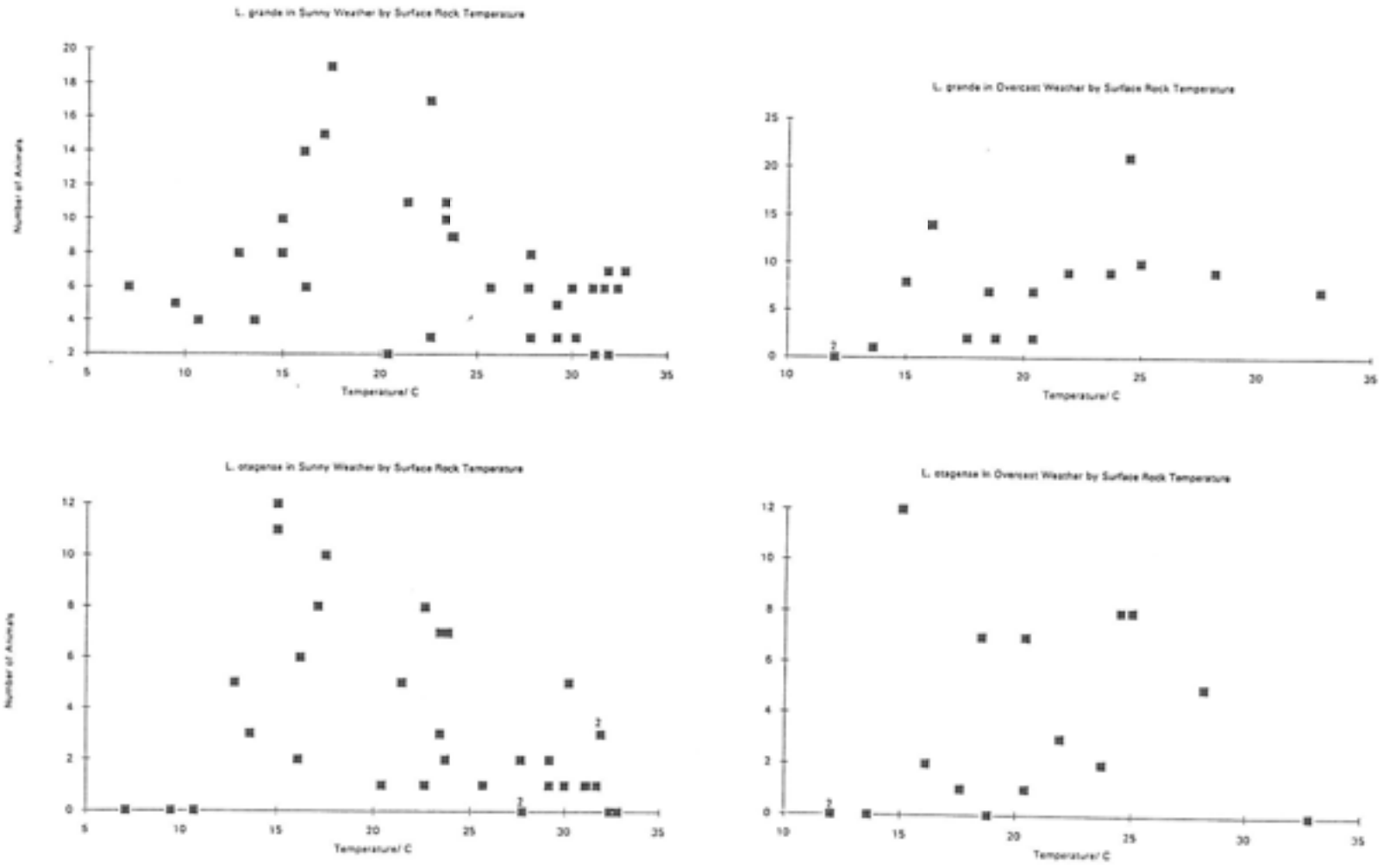

Figure 4. Surface rock temperature related to sightings.

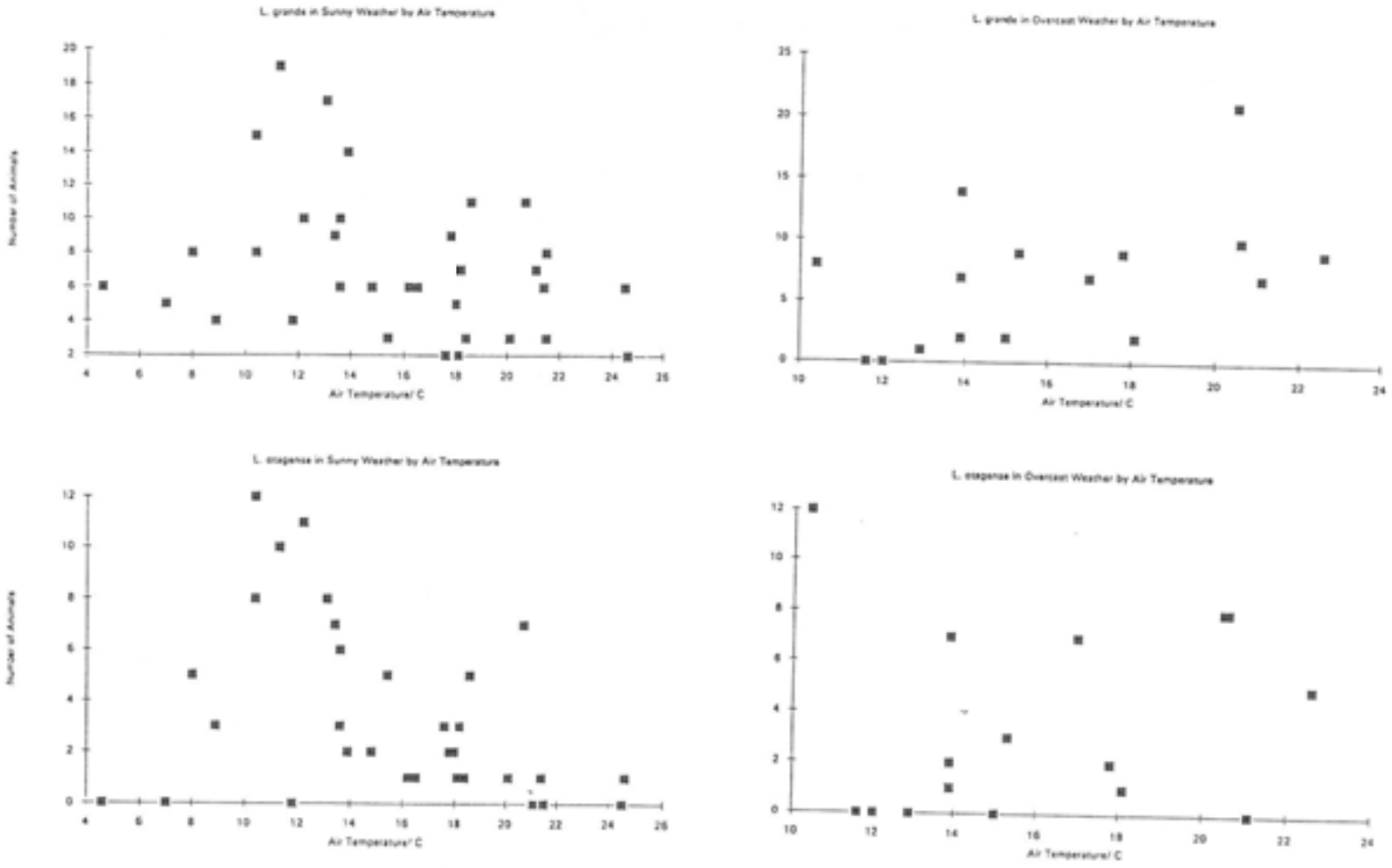

Figure 5. Air temperature related to sightings.

The average number of grand skinks seen on any day in sunny and overcast conditions was the same: seven animals, or 18% of the estimated population. Slightly more Otago skinks were seen in overcast than sunny conditions, although the sample size is so small that this difference is probably not significant. Four animals on average (25% of the estimated population) were seen under cloudy skies, whereas three animals on average (19% of the estimated population) were seen under sunny skies.

The highest number of grand skinks were seen between approx. 15-25°C surface rock temperature and approx. air temperature in sunny weather. In cloudy weather there is no easily discernible behavioural pattern for grand skinks. Very few animals were seen when the rock temperature was below approx. 15°C. For Otago skinks in sunny weather, most animals were observed between approx. 10-21°C air temperature and surface rock temperature. In cloudy weather there was again no clear behavioural trend, although no animals were found when the surface rock temperature fell below 15°C or rose above 30°C. Generally, then, conditions that favoured one species seemed to favour the other as well.

3.2 Pit Trapping

The first lizard, a *L. maccanni,* was caught two days after the traps were opened. This indicated that lizards were becoming used to the traps. In my work on common skinks (Patterson 1985) I noticed that no lizards were caught in pitfall traps for at least a couple of days after I had put in the traps. However, other researchers have found that lizards are attracted to newly set traps, new objects in their home ranges and/or newly disturbed earth (A.H. Whitaker, pers. comm.).

The first giant skink, one *L. grande,* was caught on 20 February in a trap next to a rock outcrop on soil (Fig. 2). The trap was black plastic baited with pear (which was eaten); the white trap had pineapple pieces, and the paint tin was unbaited. On 26 February another *L. grande* was caught in a black plastic trap on open rocky ground (Fig. 1). This trap was baited with pineapple pieces, which the skink ate. At this time I removed most of the paint tins from the pitfall sites, since they were proving difficult to maintain (the lids kept falling off). Further, they would have been too small to trap most *L. otagense;* bait disappeared from the tins and white plastic traps during the day several times, but circumstantial evidence indicated that the most likely culprits were *L. otagense.* Therefore from this time on, no firm conclusions can be drawn as to trap preference, but there seems no good reason to use a trap from which a high proportion of target animals can escape. Possibly larger metal containers would prove more effective. However, compared to plastic containers of comparable size, these would be expensive, heavy to carry around and less portable since tins could not be stacked inside each other.

Five *L. otagense* were caught between 29 February and 5 March. All but one small were caught in the black plastic traps, and all were caught using either pineapple pieces or pear, the fruit being eaten in all cases. One individual was caught twice - on 1 March and on 5 March. It had been toe-clipped prior to the first capture, and so was paint marked, weighed and measured only before being released. The largest number of animals caught in one 24 hour period was three *L. otagense* (29 February -1 March).

There was no indication that giant skinks were eating invertebrates in the traps, or were being attracted to traos containing invertebrates but no fruit.

Throughout the duration of this experiment bait was removed from several traps on most nights, and the trap sites disrupted. We trapped one possum, but at least one other animal, probably another possum, interfered with the traps until the experiment was shut down. Tying the lids on with string or other similar measures should prevent this type of interference in future.

3.3 Population Census

The first day, 15 grand skinks and seven Otago skinks were marked with white acrylic paint on the tips of sticks. On the second day I counted the number of marked and unmarked individuals of both species as I moved slowly through the census area from north to south. The numbers were

Otago skinks	5 marked	8 unmarked
grand skinks	8 marked	14 unmarked

This gave population estimates of

Otago skinks 16 ± 9
grand skinks 38 ± 19

However, the minimum number of grand skinks must have been 29, since 15 were marked, and I saw 14 unmarked individuals the next day. Likewise the minimum number of Otago skinks must have been 15.

3.4 Marking Experiment Results

The average time white acrylic paint remained easily visible on the skinks was 9 days, silver marker 12 days, nail varnish 8 days, "Twink" 16 days, "Wraddle" 9 days. No animals seemed to suffer any ill effects from any of the markers. However, at least one of the markers, the silver marker pen, is labelled as "toxic to humans" and might adversely affect skinks. To minimise possible long-term damage to the skinks I recommend marking with paints or dyes, using the minimum necessary for identification, and using markers with proven low toxicity to vertebrates.

In most cases the marks appeared to have been lost through abrasion with the rock surfaces, but in one instance the animal shed its skin during the experiment and the mark was lost completely. Since giant skinks probably shed at least once during the summer (although there is no data on sloughing frequency in these species) this, as well as natural abrasion, will place another limit on the time surface marks can be expected to be visible in the wild. Note: try not to mark the head since the paint could get into the animal's eyes or nostrils.

3.5 Bait Test Results

Two grand skinks ignored the baits completely. One ate part of the pear immediately after coming out of the crevice. One licked the pineapple piece, then ate part of the

pear, returned to the pineapple piece and tried to bite a piece out of it unsuccessfully, and ate more of the pear. The fifth animal licked the apple but did not try to eat it, and then ate part of the pear. Two Otago skinks ignored the baits completely on re-emergence, while the third went straight to the pear and ate part of it.

The fact that several animals ignored the baits completely, even though in all cases they were only a few centimetres away from them, seems to indicate that olfaction does not play a large role in prey detection for these species.

3.6 Artificial Retreats

After a week, one grand skink and one Otago skink were observed under the tiles which had been placed horizontally on rocks.

3.7 Incidental Observation

On 11 February I saw a *L. grande* eating a live cicada. On 14 February I saw one *L. grande* chase another one away from its basking site. On a couple of occasions a grand skink ran onto a rock from neighbouring grassland. However, on no occasion did I observe Otago skinks off rocks.

4. DISCUSSION

4.1 Census Techniques

There are probably dozens of different census methods that could be used with giant skinks, with varying degrees of success. These include Bailey's triple catch method (Bailey 1951, 1952), the Jolly-Seber technique (Jolly 1965), the Zippin removal method (Patterson 1984) and the method of Minta and Mangel (1989). Realistically, however, there are very few that are both easy to implement and also give estimates that are simple to calculate while being statistically robust.

Line transects are probably the easiest to implement, and are the main methods used to date to estimate population numbers of both species. They are fast, require minimum equipment, and cause minimum disruption to the environment. However, they have several drawbacks. Trained workers are needed to identify skinks which may be quite distant from the observer in many instances. More crucially, my results show that the number of animals visible is dependent on time of day and weather conditions to a considerable degree. Even under optimal conditions no more than 75% of the estimated population was visible, and on some days no animals were seen at all. There is no way of calculating statistical error with this method, and therefore I do not recommend it as a census technique.

Better census estimates are given when the animals are captured, marked and released. For giant skinks, capture/resight techniques appear to have several advantages over techniques for population census-taking. The Lincoln-Petersen method, e.g. is susceptible to the behavioural biases caused by a response to capture. These can produce underestimates (trap-happiness) or overestimates (trap-shyness).

Visually "recapturing" animals by observation allows more catchability assumptions to be met, by removing the biases caused by retrapping. Initially "capturing" the animals by marking them with paint on a stick or paintbrush removes initial trapping biases, by obviating the need to handle the animals at all.

The advantages of capture/resighting have been long known, and the method has been applied to an array of organisms (Minta and Mangel 1989). Overall field effort is period, fewer people are needed to make More data can be accumulated in less time, and resightings can be made while conducting other research on the animals. Overall, the method is less disruptive to the animals and their environment. Most capture/resight estimates used have been the Lincoln-Petersen type. In this case, individual marks don't need to be identified, only whether the animal is marked or unmarked.

The conditions that should be satisfied for this index to be valid are:

The animals should not be affected in behaviour or lie expectancy by being marked, and the marks should last an appropriate time.

Two studies of paint-marking in lizards suggest that this marking method does not increase the mortality rate of marked individuals (Jones and Ferguson 1980; Simon and Bissinger 1983). There is no evidence that marking the skinks in this study affected their behaviour or health, but to ensure this does not occur marking should be kept to a minimum. Results from my marking experiment indicate that as long as the second sampling period is within about a fortnight of the first there is little likelihood of marks being lost. Paint marks on giant skinks have lasted as long as six months in the field (Graeme Loh, pers. comm.).

The marked animals should become completely mixed in the remainder of the population.

This should occur to some extent when the second sampling period is not less than 24 hours after the first, and when the first sampling is done in fine weather. However, since the animals appear to be territorial to some degree, completely random mixing is not likely to occur. Also some areas of the habitat may be inaccessible to the experimenter, and so the animals are not able to be marked in the first period. If this is the case, this area of habitat should not be included within the census area.

The probability of seeing a marked animal should be the same as that of seeing any member of the population.

Marked animals could possibly be more visible than unmarked ones. This could happen for direct reasons (the mark itself makes animal more visible) or indirect reasons (some behavioural or physical property of the animal makes it easier to catch for marking purposes than other animals and also made it more likely to be resighted than other animals). Unequal sightability that affects marked and unmarked animals equally will not bias the population estimate. There is no evidence to suggest that marked animals are

more easily visible than unmarked ones. However, it is possible that certain classes of animals (e.g. adult males) are more accessible than others. One advantage of the marking technique chosen is that even animals in crevices can be marked. Every effort should be made to mark each animal seen in the initial sample period, to guard against possible behavioural biases.

Sampling must be at distinct time intervals, and the actual time involved in taking the samples must be small in relation to the total time over which observations are spread.

The population should be closed.

By "closed" I mean that there are no births, deaths, net immigration or emigration during the sampling period. This can be ensured by sampling over a short time interval, and/or ensuring that the census population is isolated from other populations. To minimise the chance of births or deaths, the sampling should be carried out at a time when births are not occurring. A population is likely to be closed over a two week period, which is approximately the time paint marks could be expected to last. I observed many of the same animals over two weeks in the same locations in the "Canyon" site.

If these conditions are fulfilled, it is legitimate to estimate the total population from the index used by Lincoln (1930) (see Appendix 1). It is not essential that the first four assumptions above are met completely, but they should be satisfied as much as is practicable (Southwood 1978).

Before carrying out a census using this technique, it is important that as many line transects through the area as possible are carried out in good conditions for viewing giant skinks. These should be conducted immediately prior to the census period and should follow as closely as possible the same path each time. In this way the census - taker can obtain an initial population estimate which will indicate when at least half the animals in the area have been marked during the census. It will also allow the minimum number to be determined.

It is clear that the estimate in the present study erred on the low side, probably due to the small sample sizes. To improve the accuracy of the estimate, a worker could

1. increase the number of marked animals marked in the first sample by, e.g. increasing the number or skill level of the people carrying out the census. This should, all things being equal, have the effect of increasing the proportion of marked animals in the second sample.

2. increase the overall number of animals sampled in the first sample and the second sample. Two methods of obtaining this goal could be by increasing the number of people carrying out the census, or by increasing the length of the sample periods.

3. take several independent samples after the initial sample and use several subsamples when estimating the population.

Obviously the choice of which technique is used will depend on the amount of time and resources available to the researcher. If time and resources permitted, marking all the skinks in an area would give a completely accurate census, but this is impracticable at present.

4.2 Capture Methods

Although marking skinks with paint is useful for census-taking over a brief time, some method of permanent marking is needed for long-term population studies (see below for discussion).

Whichever method chosen will inevitably involve capturing and handling the animals. The best technique for catching large numbers of animals seems to be by noosing. As an indication of its effectiveness, in one afternoon during my study eight people caught 20 giant skinks in the "Canyon" site. The most skinks I caught in my pitfalls during 24 hours in exceptionally good weather was three Otago skinks. To have caught 20 skinks in the same period I would have needed about six times as many traps, which would have posed major logistical problems. Also, this 24-hour catch rate was exceptional. Only seven skinks were caught in the entire trapping period of 25 days. Noosing seems to provide consistently high catch rates as long as animals are visible and the noosers are reasonably experienced (or enthusiastic and agile even though inexperienced).

Pitfalls might be useful in trapping skinks where nooses have proved unsuccessful – e.g. where the animal is inaccessible or exceptionally wary. If large numbers of animals are needed over a brief period, pitfalls used in conjunction with noosing could increase the catch rate. In this study I was not using pitfalls simply as an attempt to catch as many animals as possible. The techniques I used could almost certainly be improved to increase catch rate – e.g. by siting pitfalls only in known basking sites.

4.3 Permanent Marking

No permanent marking technique other than toe-clipping was investigated during this study. Inserting transponders into the skinks was rejected as being too traumatic for such comparatively small animals. Scale clipping, which has been used mainly on snakes, is impractical because of the small size of the skink scales, and the fact that most lie flush with the body surface. Freeze branding has been used on snakes (Lewke and Stroud 1974) and could theoretically be used on lizards. It is more humane than branding with hot irons, but could still traumatise the animals. Two other points against this method are that the mark may not be very obvious, and the technique involves the use of expensive equipment (compared with a pair of scissors for toe-clipping). Tattooing can sometimes injure or kill the subject, and the marks would probably not be very obvious on giant skinks, which have a black ground colour.

Toe-clipping, which does not appear to adversely affect the skinks, seems to be the most practical method of permanently marking the lizards at present. I am concerned that as the same two-toe codes are being used at more than one site within Emerald

Stream, there is no definite evidence at present as to how far giant skinks can move in their lifetimes. I measured movements of 100 m over two years for *L. n. polychroma* (Patterson 1985), which is a smaller animal than the two species in the present study. I think that the likelihood of duplicating codes outweighs any (unproven) risks to the animals, and that three-toe codes should be adopted immediately.

4.4 Monitoring Aims

In the draft giant skink recovery plan (Whitaker & Loh 1991: 12) it is stated that there are possibly 5000 individuals of both species in the wild. Altogether 275 Otago skinks and 349 grand skinks have been recorded during all of the surveys of the Macraes area (Towns *et al.* 1984; Whitaker 1985, 1987, 1988). Based on an estimate from the transect data, this would give a population in the wild of about 1400 and 1800 animals for Otago and grand skinks respectively. Given that most of populations are fragmented, this gives great cause for concern. On page 14 the recovery plan states: "If population monitoring shows a continued decline in either species such that the number of populations is halved or the lizard density at the sites where the largest populations occur is halved then that species should be immediately regarded as endangered." Therefore the minimum aims of any monitoring program can be considered as already having been defined.

The results from my line transect program should aid in determining when best to view a site to determine whether any giant skinks are present. If no lizards are seen over several consecutive hours under optimal conditions (sunny mornings or warm overcast days in late spring, summer or early autumn) then it is unlikely that any are present at the site. This assumption should be tested by searching for other signs of giant skink habitation, such as fresh scats. If it is thought that no lizards are present, a series of baited pitfall trips could be left out at likely basking sites and checked regularly once a week) over several weeks to test this idea.

The recovery plan states that as soon as a monitoring technique has been determined, population monitoring should occur on all populations with the highest priority for protection. The three key sites for both species are Emerald Stream (1500 ha), Trig E (225 ha) and Deighton Creek (400 ha). These areas are probably too large to be sampled in their entirety, so some form of subsampling will have to be carried out. There should be a census taken at least one area within each site. Each area should contain at least about fifty animals from each species, to ensure that sample sizes are not too small for the census technique to be accurate. The "Canyon" and "Falcon" sites should not be sampled as part of this census, since after being fenced off they are not truly representative of the entire catchment. (The "Falcon" site could be used if stock were removed from the rest of Emerald Stream.) It is also important to monitor the western populations of both species, but this could prove if population levels are already low. All of the Morven Hills sites may have to he treated as a single site to minimise this problem. The Smiths Creek and Breast Creek sites should be able to be treated independently.

If time permits, populations at the eight sites selected for preservation under cooperative agreements with landowners should also be counted. The sites are:

Pukerangi Ridge (two sites)
Trig D, Pukerangi Ridge
Trig C, Pukerangi Ridge
Hummock Runs Road
Deighton Creek
"Falcon" site, Emerald Stream
"Canyon" site, Emerald Stream.

The recovery plan also suggests that there be a sampling interval sensitive enough to detect population declines before they become critical. An appropriate interval is, however, difficult to determine without knowledge of recruitment and mortality. There is good evidence that populations of both species have declined drastically in a comparatively short time (Whitaker and Loh 1990), and so there should be census-taking (preferably at similar times of the year) as often as is feasible. Animal populations are generally counted yearly, and this should be regarded as the minimum period for giant skinks

5. RECOMMENDATIONS

1. To catch giant skinks, noosing by hand seems to be the most effective technique, so this should be used wherever possible. Pitfall trapping or artificial retreats could be used as an adjunct to live trapping to increase catch sizes.

2. Census-taking should be carried out using the Lincoln index in at least the three key sites as soon as possible, followed by the important western sites.

3. Census-taking should be undertaken at the time of year when most lizards are visible - from November to April.

4. Before the first census sample, multiple line transects should be taken when many lizards are likely to be visible to determine likely population levels in the census areas. The worker should aim to see at least 20 individuals of the census species/transect.

5. The accuracy of the census must be such that a population decline of one half is unambiguously detectable. This means that the 95% confidence limits from the first census must be less than half the estimated population number (preferably less than 25%). All effort must be made to ensure that the census is as rigorous as possible.

6. ACKNOWLEDGEMENTS

I would like to thank Graeme Loh and Otago Conservancy for logistical support during this work. Keith Philip, Alison Cree and Marcus Simons provided comfortable accommodation, Tony Whitaker and Graeme Loh provided helpful advice on the manuscript. Mike Ball graciously allowed me time off for this work, which was only slightly related to programming.

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APPENDIX 1

The Lincoln Index

Total population/original number marked = total second sample/total recaptured or:

(1) $N = an/r$

where N = the estimate of the number of individuals in the population (N), n = total number of individuals in the second sample, a = total number marked and r = total recaptures.

The variance is given by:

(2) $\text{var } N = a^2 * (n*(n-r))/r^3$

If the second sample (n) consists of a series of subsamples and a large proportion of the population have been marked then it is possible to utilize the recovery ratios (r/n) to estimate the total population:

(3) $N = a/R_T$

where R_T = the recovery ratio (r/n) based on the total animals in all of the samples; the variance is approximately

(4) $\text{var } N = (a/R_T^2)^2 * R_T*((1-R_T)/y)$

where y = total animals in subsamples.

The above methods are applicable to samples where the number of resightings of marked animals is greater than 20. With samples smaller than this the following formula should be used to estimate population number:

(5) $N = a * (n+1)/r+1$

The variance is given by:

(6) $\text{var } N = a^2*(n+1)*(n-r)/((r+1)^2*(r+2))$

Menu options in the giant skink database on PC can be used to calculate formulae 1 to 6, as long as n, r and a are known. Formulae 1 and 2 can be calculated using the "population estimate (large) (1)" option; 3 and 4 using the "population estimate (large) (2)" option; 5 and 6 using the "population estimate (small)" option. These programs also calculate the 95% confidence limits for the estimates.