Assessment of methods to monitor Otago skink and grand skink populations, New Zealand

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Catherine M. Roughton

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CONTENTS

Appendix 1

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Catherine M. Roughton

32B Huria Lane, Woodend, North Canterbury, New Zealand

ABSTRACT

There is a need to improve monitoring methods for populations of the vulnerable Otago skink (*Oligosoma otagense*) and grand skink (*Oligosoma grande*) at Macraes Flat, Central Otago, New Zealand. Detection probabilities for Otago skinks are < 1; imperfect detectability leads to biased estimates of population size using traditional monitoring programmes. A method using presence–absence of Otago skinks to estimate site occupancy was trialed at Macraes Flat in February 2004. Data derived from surveys in consistently sunny weather, with a standardised scanning and searching technique, will provide a good basis for robust estimates of the percentage of area occupied by skinks; this technique should be applied for future larger-scale monitoring programmes. Although a long-term survey technique has been developed for the grand skink, there remains a need to quantify trends in site occupancy. Ten years of grand skink count data were analysed to assess the applicability of the monitoring method to model rates of site extinction and colonisation. It was found that site occupancy may undergo periods of being both year-specific and constant, whereas extinction is year-specific.

Key words: Otago skink, grand skink, *Oligosoma otagense, Oligosoma grande,* detection, occupancy, monitoring, population, Macraes Flat, Otago, New Zealand.

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1. Introduction

The Otago skink (*Oligosoma otagense*) and grand skink (*Oligosoma grande*) are two of New Zealand's rarest reptiles, with population estimates currently thought to be around 2000 for each species. The two broadly sympatric species inhabit rock outcrops amongst tussock grasslands alongside streams (Whitaker & Loh 1995). Both species were previously found over much of Central Otago, South Island, ranging from Queenstown in the west to Macraes Flat in the east (Whitaker & Loh 1995). They have since suffered a dramatic reduction in both population numbers and distribution, and are presently known in only two areas, Macraes Flat and the Lindis Pass area; these are close to the extreme east and west regions, respectively, of the previous range (Patterson 1992; Whitaker & Loh 1995).

The decline in population numbers and distribution of Otago skink and grand skink is thought to be due to several factors, the most significant of which are habitat loss and mammalian predation. After the arrival of European settlers in the area around 150 years ago, much skink habitat in tussock grassland was converted to pasture for farming (Whitaker & Loh 1995; Whitaker 1996). This resulted in massive losses of the original vegetation and associated constriction of the distribution of Otago skink and grand skink. With the settlers came predatory mammals, such as rats, cats, and ferrets (Whitaker & Loh 1995). Two additional possible factors contributing to declines of skinks are unintended poisoning from pest control operations and habitat degradation from grazing and mining operations (Whitaker 1996).

Due to the restricted numbers and habitat of these two species, the development of monitoring techniques and the improvement of their status are high priorities (e.g. Whitaker & Loh 1995). There is a need to be able to assess trends in population numbers and habitat occupancy in order to assess the effects of conservation actions. In the past, various methods have been attempted to count numbers of the two species. Each year the New Zealand Department of Conservation (DOC) carries out mark-recapture surveys of the two species at various sites in the Macraes Flat area (Whitaker & Houston 2002). They have also carried out rock tor counts of total grand skink numbers at various sites at Macraes Flat over the past decade. Population size estimates of Otago skink and grand skink were carried out at three study sites near Macraes Flat, Otago, using a mark-resight technique (Coddington & Cree 1997). It was found that numbers at the sites surveyed were low, with only 11-56 individuals of each species being found. It was also found that grand skink was more likely to emerge during less optimal weather conditions than Otago skink. Patterson (1992) investigated various survey techniques for Otago skink and grand skink, using pitfall traps, hand capture, line transects, and application of the Lincoln-Petersen estimator. He concluded that line transects were the easiest to use, being fast with minimal habitat disruption. Patterson did note that on some days no skinks were observed, highlighting one of the main problems faced by those attempting to count these two species—variability in detectability. Detectability may vary also between the two species, with grand skink appearing to be relatively straightforward to observe and count, whereas Otago skink seems a considerably more elusive species (e.g. Coddington & Cree

1997). Houghton & Linkhorn (2002) looked at population survey data for both species from 1986 until 2001 at Macraes Flat, Otago. It appears that there were once large populations present, but that numbers have declined. In the Emerald Creek catchment between 1996 and 2000, there was a decrease of 124 grand skinks. Factors causing this population change are largely unidentified, and despite intensive survey work, relative abundance and population trends of both species are still relatively unknown.

In situations where it is unrealistic to carry out a census (i.e. a complete count) of all individuals in a population, population size must be estimated using count data (MacKenzie et al. 2004). There are two possible sources of error that must be considered when undertaking counting techniques. The first relates to the area sampled. The inability to completely survey large areas (because of restraints of time, money, and personnel) means that most commonly the area sampled is only a fraction of the total area occupied by the target species (Yoccoz et al. 2001; MacKenzie et al. 2002; MacKenzie 2003). Of concern is the selection of the appropriate areas to be surveyed so that the entire area of interest is accurately reflected (MacKenzie et al. 2002). The second source of error arises from the incomplete detectability of individual animals. Few species are so obvious that all individuals can always be detected in the area of interest. When the detection probability of a species is less than one, it is considerably more difficult to estimate population size (Kery 2002; Gu & Swihart 2003; MacKenzie et al. 2004).

For large-scale monitoring programmes, efficient, practical and cost-effective methods must be used (MacKenzie et al. 2002). A method that is relatively simple and efficient is presence/absence data. This method involves surveying a sample area and noting the presence or absence of a particular species (Usher 1991; Peres-Neto et al. 2001). The majority of studies that have used presence/absence in the past have not considered detectability to be an important variable (Gu & Swihart 2004). More recent studies that have utilised presence/absence methods have acknowledged the need to include detection probabilities into the study design (e.g. Bayley & Peterson 2001; Kery 2002; MacKenzie 2003; Royle & Nichols 2003).

A model has recently been developed to estimate the proportion of sites occupied by a species when the detection probability is less than one (MacKenzie et al. 2002, 2003). This model can be carried out over a short time interval (MacKenzie et al. 2002) or a longer period (MacKenzie et al. 2003). Both sample specific environmental variables, and site-specific habitat variables can be incorporated into the model to improve the estimation of site occupancy. The model consists of N sites being visited on T sampling occasions. The presence or absence of the species is recorded at each visit as well as any environmental or habitat co-variates. The detection histories for each site are then constructed and site occupancy rates are estimated (MacKenzie et al. 2002, 2003).

The development of appropriate monitoring techniques to enable assessment of population status and trends of Otago skink and O. *grande* is considered a current priority. This report has two main objectives:

1. To report on trials of a method to detect presence/absence of Otago skinks on rock tors at Macraes Flat, Otago. To advise on the suitability and limits of

the monitoring method and make any recommendations of variations that would improve the accuracy or affordability of the method.

2. To apply the presence/absence modelling of detectability in the analysis of 10 years of count data for grand skinks to determine the efficacy of the rock tor count method as a basis for quantifying trends in site occupancy.

2. Site occupancy by Otago skinks

2.1 INTRODUCTION

The development of successful monitoring methods seems to have been achieved for the grand skink, although similar methods for Otago skinks are still lacking. The Otago skink is considered vulnerable by IUCN standards and is estimated to number around 2000 individuals in the wild (Whitaker & Loh 1995). To ensure there is a future for the Otago skink it is vital to develop an accurate and successful method to assess its status.

Several factors create difficulty when attempting to monitor Otago skink. Firstly, the skinks' emergence behaviour is extremely weather-dependent (Coddington & Cree 1997). In marginal conditions (low temperatures, windy, damp) Otago skink is unlikely to emerge. This may be due to its large body, which takes a long time to reach optimal temperature, and may therefore require precise basking conditions (Coddington & Cree 1997). It has been found that Otago skink showed a seasonal peak in emergence in autumn and a daily unimodal emergence pattern (Marshall 2001). These findings all place restrictions on a programme to monitor Otago skink. The weather must be optimal, and the time of day must be correct, as must be the time of year.

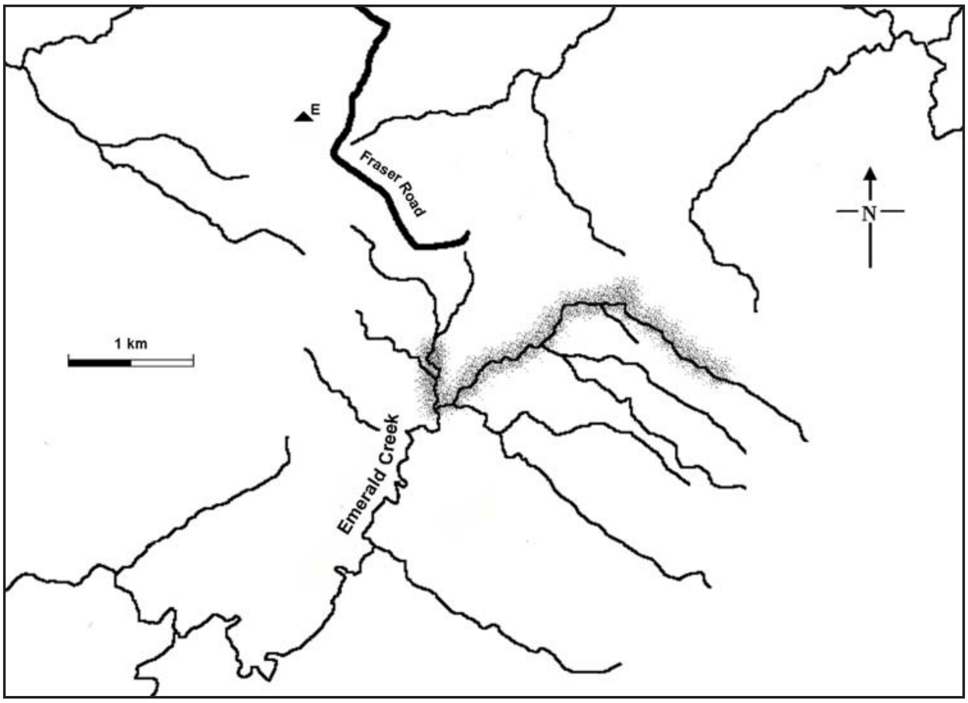
Otago skinks are found in schist rock outcrops surrounded by tussock grassland (Towns et al. 1984; Whitaker & Loh 1995), commonly along valleys and streams, on rocks with extensive deep crevices for shelter (Whitaker & Loh 1995). This type of habitat makes monitoring quite difficult. If the skink is not out of the crevice, basking, it is usually well hidden and may seem to be absent from a site. Also, a skink is sensitive to objects moving into the sun (Graeme Loh pers. comm.). An observer must move toward the skink or rock with the sun behind them. Therefore, a method must be developed to observe a rock from afar, before thoroughly searching the crevices.

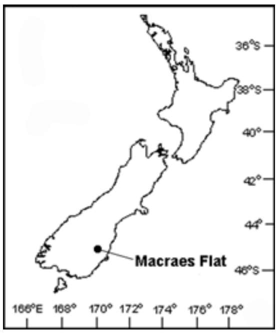
Obviously, this type of method requires trained people to carry out surveys. Labour is an issue in monitoring programmes, and the method must be straightforward so that a small amount of training is enough for successful surveys to be done quickly and efficiently.

2.2 STUDY SITE AND STUDY ANIMAL

The study site was located in the Macraes Ecological District, about 8 km from Macraes Flat, Central Otago. It consisted of a roughly 3 km length of Emerald Creek (Fig. 1).

Figure 1. Location of Macraes Flat, Central Otago, New Zealand. Otago skink study site along Emerald Creek (shading). Grand skink study site around trig E point. Creeks in Otago skink study area are shown in greater detail.





The area occurs within the Rolling Hills land system (altitude: 440–540 m) and consists of extensive Haast Schist rock outcrops and rock tors (Bibby 1997). Mixed shrubland occurs in many areas of the hill-slopes, with manuka (*Leptospermum scoparium*) being the dominant species. Narrow-leaved snow tussock (*Chinochloa rigida*) grassland, golden spaniard (*Aciphylla aurea*), and mountain flax (*Phormium cookianum*) are also present on the steeper slopes (Bibby 1997). In lower areas, snow tussock dominates along with hard tussock (*Festuca novae-zelandiae*) and matagouri (*Discaria toumatou*) (Bibby 1997). On the gully floors there is a range of plant species inhabiting wetland conditions. The exotic soft rush (*Juncus effusus*) and the native bog rush (*Schoenus pauciflorus*) dominate wet areas (Bibby 1997).

The region experiences coastal climatic conditions. Westerly-moving depressions result in higher rainfalls and more moderate temperatures than the rest of Central Otago (Bibby 1997). In summer, cool moist northeasterly winds dominate, with periods of dry northwesterly winds. Dry seasons generally occur during years dominated by an El Niño weather pattern (Graeme Loh pers. comm.).

The Otago skink is one of New Zealand's largest skinks, with snout–vent lengths reaching up to 130 mm, and weights of up to 46.5 g (Cree 1994; Coddington & Cree 1997). The species is robust and coloured dark green or brown with large yellow blotches (Marshall 2001). There is no obvious sexual dimorphism. The Otago skink is a diurnal species, being active during daylight hours (Coddington & Cree 1997). This is a positive factor when considering monitoring programmes. The species is most active from November until late May, although some have been observed basking during good weather in winter (Marshall 2001). Otago skink also appears to be a social species; while often observed alone, groupings of two or three are not uncommon (Coddington & Cree 1997).

The home ranges in which Otago skinks move (Marshall 2001) are mostly smaller than 300 m^2, while some are as large as 1200 m^2. Despite the size of the home range area, only a small part of it is used by Otago skink for most of their activity (Marshall 2001). The possible area in which an Otago skink is moving each day could affect monitoring success, and may add to the possibility of false absences recorded by observers. Therefore the number and size of areas sampled is an important factor when considering monitoring programmes for this species.

It has been found that movement and dispersal of Otago skinks is primarily due to foraging and the availability of food (Houghton 2001). Otago skink is omnivorous and feeds primarily on the fruit from *Coprosma taylorae* and *Leucopogon fraseri* and on invertebrates such as small-bodied coleopterans and large-bodied dipterans (Tocher 2003). Feeding may take place on the rock outcrops or in the tussock surrounding the fringes of the rock tors (Houghton 2001). Around the fringes of rock tors where the skinks forage for fruit and insects, vegetation can obscure them from view and may result in missed sightings.

2.3 METHODS

2.3.1 Sampling and scanning

A total of 50 sample survey plots were chosen. This number was a compromise between too few plots, which would reveal only coarse scale trends, and a larger number of plots that could not be repeatedly surveyed in the time available (Mackenzie et al. 2002). In order to define all possible sample units, the 3 km section of Emerald Creek (Fig. 1) that was surveyed was divided into roughly 100 sections, with lengths of 30 m, each being given a number (1–100). Fifty of these sample units were randomly chosen using a random numbers table. The survey plots or sample units were 30 m × 40 m (Anderson & Burgin 2002; McKenzie et al. 2002). The area surveyed includes sites of high, medium, and low abundance of Otago skinks (Graeme Loh pers. comm.). A hand-held Garmin® GPS 12 Personal Navigator® 12-channel Global Positioning System (GPS) provided the coordinates of each survey plot (with average estimated position error of ± 8 m). For every sample unit, the percentage of rock cover was visually estimated as a possible correlation factor. This site-specific factor provided information about the habitat quality of a site that is important for detection and presence probabilities because skinks inhabit rock outcrops and rock tors (Coddington & Cree 1997). This also enabled the sampling of units with very little rock cover to be carried out with the same effort as those units with more rock cover.

A standardised rock-scanning method was used to search for skinks in each of the sample units. This comprised three search phases: the first entailed an observer standing stationary 10 m away from the rock surface being surveyed using binoculars (Patterson 1992) and scanning left to right from the top of the rock. If no skink was seen, the observer then moved 5 m forward and scanned once more with binoculars. If still no skink was seen, the observer then moved right up to the rock and thoroughly checked each crevice and surface. The time and distance from the rock when a skink was seen was recorded. Skinks are particularly active and visible on sunny days (Coddington & Cree 1997), so to ensure consistent results, visits were only carried out on days when some sun was visible. Because of both time restrictions and emergence behaviour of the skinks (Marshall 2001), visits were only carried out between 9 am and 12 pm, and 1 pm and 5 pm.

The scanning method described above was carried out on each rock in each sample unit using a combined line transect/point count method (Patterson 1992; Greenwood 1996). A line was placed through the middle of each sample unit in such a way that it maximised visibility for the observer, but minimised disturbance for the skinks, while ensuring that the sun remained behind the observer (Marshall 2001). The line was quite flexible, in that it moved away from areas without rocks. The observer walked along the line stopping at intervals of 5 m. Every rock visible within the 40 m width of the sample unit was scanned using the scanning method above. A maximum scanning time limit of 10 minutes was observed for each sample unit. If no skink was seen within this time the search was abandoned. Each sample unit was surveyed five times.

If any sighting of a skink was made within a sample unit, this was recorded on a sheet in the field. Presence was recorded as 1, whereas absence was recorded as 0. Detectability of skinks was modelled to provide an estimate of the proportion of the study site occupied. The analytical technique developed by Mackenzie et al. (2002) was applied. It uses repeated surveys of sites to model presence, allowing for the possibility that the species of interest may be present but undetected during a given survey. The model consists of: N units being surveyed over time where the aim is to determine the presence or absence of a species. The surveyed units may be a naturally occurring sampling unit, or some artificial construction such as a quadrat. The study therefore comprises T primary sampling periods, between which changes in the occupancy state of sites may occur. Within each year, investigators use an appropriate technique to detect the species at k_t surveys of each site, where k_t is the number of surveys per primary period. The resulting detection history for each site may be expressed as T vectors of 1s and 0s, indicating detection and non-detection of the species, respectively. Potential models can then be tested to select which best describes the data (Mackenzie et al. 2003). Detectability of skinks was modelled using the computer programme PRESENCE (Mackenzie et al. 2003).

2.3.2 Akaike's information criterion

Information-theoretic approaches are becoming increasingly widely used in ecological studies. They provide a simple, effective strategy for objective data analysis by ranking, scaling and selecting models (Burnham & Anderson 2001). Akaike's information criterion (AIC, Akaike 1992) was used to select the most parsimonious model for the data in the present study. AIC is an efficiency measure that provides a method to rank hypotheses or models in order to avoid the dangers of null hypothesis testing. If a set of *a priori* models has been defined, the AIC is calculated for each of the approximating models in the set. The model which has the lowest AIC is selected as the most parsimonious for the data at hand (Burnham & Anderson 2001). The more parameters that are added to a model, the more accurate the description, although the parameters will be less precisely known. The AIC attempts to find the best-fitting model with as few parameters as possible (Burnham & Anderson 1998). AIC is not a test; instead, there are concepts of evidence and a 'best' inference. AIC allows the best model in the set to be identified, but also allows the rest of the models to be ranked using the relative difference in AIC or ΔAIC (Δ_i = AIC_i – lowest AIC). A goodness-of-fit test or other measure must be used to determine whether any of the models are good in some absolute sense. It cannot be assumed that the 'true model' is contained in the set of models identified (Burnham & Anderson 2001).

2.3.3 Correlates of emergence

Correlating detectability of Otago skink with environmental conditions was undertaken simultaneously with the sample unit surveys. It is important to understand the environmental conditions that are optimal for detecting skink presence (Coddington & Cree 1997) and it was practical to do this while carrying out surveys. In every sample unit, even those where no skinks were detected, environmental measurements were recorded. At sites in which skinks were present the measurements were taken at the rock on which the skink was seen. At sites without a skink, the measurements were taken at a rock in the middle of the sample unit. Rock and air temperatures were measured using a digital thermometer, wind speed was measured using a wind meter, and wind direction was found using a compass. To limit effects of disturbance on skink detectability, these measurements were taken after the scan had occurred. The length of time that each sample unit was scanned was also recorded, and the length of time before a skink was seen. These correlates were entered into PRESENCE to add information to the model.

2.3.4 Distance measure

The distance at which the observer first saw each skink was also recorded, as well as the distance from the observer at which each skink ran away. These measurements were estimated using a stick 1 m long. As soon as a skink was seen, the stick was placed lengthwise on the ground between the observer and the skink. The distance at which the skink was seen could then be estimated from that 1 m length. The observer then moved slowly towards the skink, and the distance from the observer at which the skink ran was estimated by sight.

2.4 RESULTS

2.4.1 Detectability and site occupancy

Between 13 and 27 February 2004, an observer carried out five surveys of 50 sample units at Emerald Creek in the Macraes Flat district of Otago, South Island (Fig. 1, Appendix 1).

Otago skinks were detected at least once in 33 of the 50 sample units yielding a naïve estimate of occupancy of 0.66 (66% of area occupied). The proportion of sample units in which skinks were observed was quite similar during each of the five surveys (Fig. 2). Eight models with co-variates and one without were fitted to the data (Table 1) and ranked according to AIC (Burnham & Anderson 2001). The first eight models considered have similar AIC values, and values

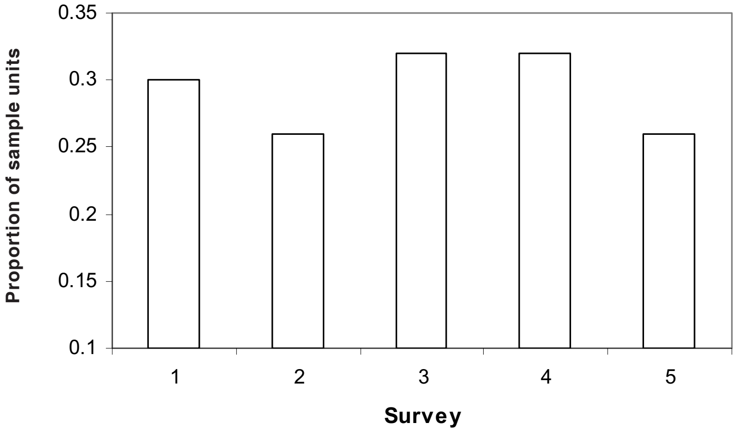


Figure 2. Proportion of sample units in which Otago skinks were observed in each of the five surveys.

TABLE 1. RELATIVE DIFFERENCE IN AIC (ΔAIC) OF EACH MODEL TESTED. Ψ = probability that a species is present at a site. P = probability that a species will be detected at a site. (.) = probability is constant. ΔAIC ≤ 2 have substantial support (Burnham & Anderson 2001).

MODEL	ΔAIC
Ψ(Habitat) *P*(Air temp)	0.00
Ψ(Habitat) *P*(.)	0.07
Ψ(Habitat) *P*(Rock temp, air temp, wind speed, wind direction)	0.13
Ψ(Habitat) *P*(Wind speed)	0.28
Ψ(.) *P*(Air temp)	0.37
Ψ(.) *P*(.)	0.41
Ψ(.) *P*(Wind speed)	0.41
Ψ(Habitat) *P*(Rock temp)	1.73
Ψ(.) *P*(Rock temp)	2.10

< 2, which suggest that these all provide a comparable and good description of the data. Therefore, it is not possible to come to any definite conclusions regarding the importance of the co-variates in relation to detection probability. However, it does appear that the habitat co-variate (percentage rock cover) plays a relatively important role in detectability. All models provide very similar estimates of the overall occupancy rate (c. 0.72) which is larger than the naïve estimate of occupancy. The estimated detection probability for Otago skink over the five surveys is 0.40. Figure 3 shows the difference in presence or absence results between the two different search methods used: scan and

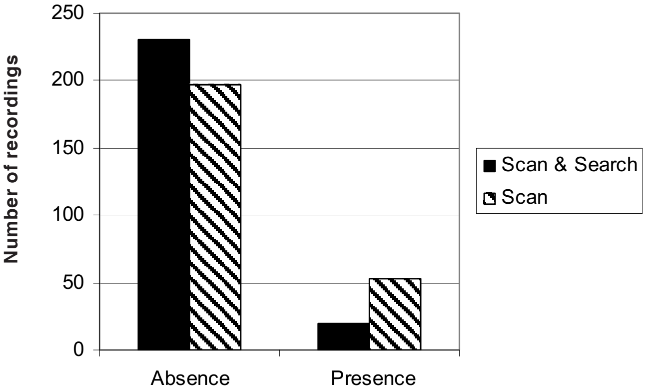


Figure 3. Number of recordings of presence or absence during the two search techniques used: scan & search, or scan.

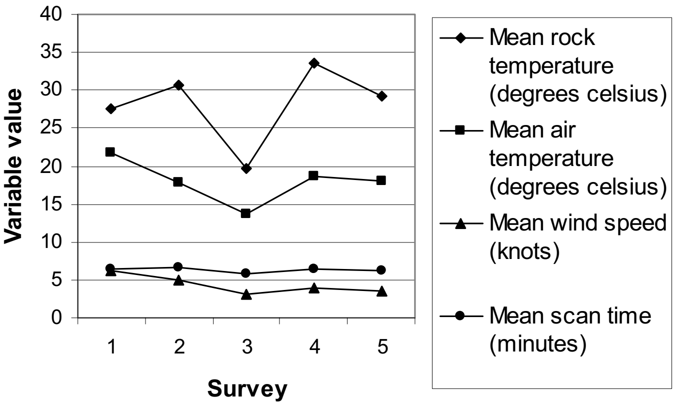


Figure 4. Mean values of four variables over each of the five surveys.

search or scan. When skinks were recorded as present, they were detected using the scan method more than using the scan and search method.

2.4.2 Environmental correlates of emergence

Figure 4 shows the average time spent scanning, rock temperature, air temperature, and wind speed for each of the five surveys. The values are generally constant, although Survey 3 showed a decrease in each of the environmental variables (Fig. 4). The most common wind directions were northeast and west. The average time in which a skink was seen during a survey was 3 minutes. Figures 5–7 show the values of three environmental variables when skinks were recorded as present or absent; averages and standard errors are given in Table 2.

2.4.3 Distance measure

The average distance from which a skink was seen over all five survey days was 6.47 m, while the average distance from the observer at which the skink ran was 1.96 m.

2.5 DISCUSSION

All models that were applied to the data resulted in very similar estimates of total occupancy. This seems to suggest that this figure is relatively constant. However, it would be important to determine whether increasing the number of visits or the number of sites would increase this occupancy estimate (MacKenzie et al. 2002). If not, then the amount of effort required to successfully survey sites is relatively low.

Previous studies have found that emergence of Otago skink is weather-dependent, needing dry, sunny, warm conditions for successful observations (Coddington & Cree 1997). During this study, surveys were only carried out on days when the weather was of a certain standard (sunny), so there were no weather extremes that might have affected the results. The study included environmental co-variates in its design and these did vary during the study, although sun was always present. The models that were applied to the detection data did not show that the environmental co-variates were

Figure 5.
Rock temperatures at which Otago skinks were recorded as present or absent.

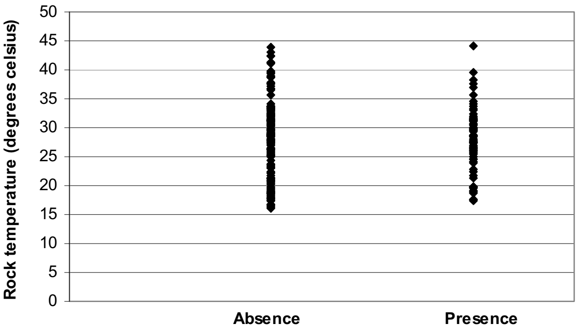


Figure 6.
Air temperatures at which Otago skinks were recorded as present or absent.

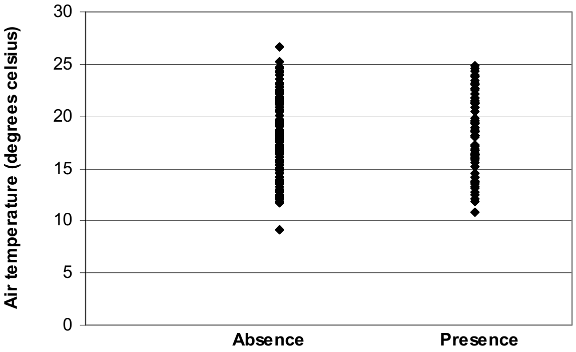


Figure 7.
Wind speeds at which Otago skinks were recorded as present or absent.

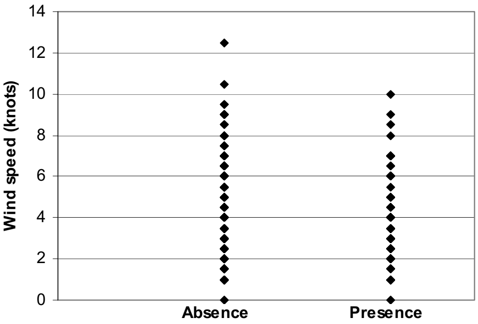


TABLE 2. AVERAGE VALUES AND STANDARD ERRORS OF THREE ENVIRONMENTAL VARIABLES.

VARIABLE	MEAN, ALL SURVEYS	MEAN, ALL RECORDS OF PRESENCE	MEAN, ALL RECORDS OF ABSENCE
Rock temperature, °C (S.E.)	28.16 (0.4)	27.84 (0.7)	28.26 (0.5)
Air temperature, °C (S.E.)	17.96 (0.2)	18.42 (0.4)	17.77 (0.2)
Wind speed, knots (S.E.)	4.3 (0.1)	3.98 (0.3)	4.48 (0.2)

particularly important in describing the data. However, the weather conditions under which surveys were carried out were optimum: the greatest wind speed recorded was 12.5 knots, which is a relatively low speed for the Macraes Flat area (Graeme Loh pers. comm.); also, the highest rock temperature was 44.1°C, which is very warm. This study has shown that, as long as surveys are carried out during sunny weather conditions, the probability of detection of Otago skink will not be influenced by weather.

The models that were applied to the data suggested that the amount of rock cover at a site has some impact on the probability that a skink is present. Otago skink primarily inhabit rocks (Houghton 2001), so this result is not unexpected. The more rock cover that a site contains, the higher the proportion of habitat for the skink. Therefore, if a site has a high rock cover percentage there is a greater chance of a skink being present than if the rock cover percentage is low.

The present study only had the use of a single observer. While this should have meant that survey conditions were kept constant, it may also have included some bias. The use of multiple observers would improve efficiency. If each site was re-checked at least twice—each time by a different observer—all skinks that are able to be observed in an area should be seen. With the use of a standardised method, randomisation of sites allotted to each observer, and effective training, the amount of between-observer bias should be minimised.

The average time in which skinks were seen was three minutes. The maximum amount of time spent searching in any sample unit was ten minutes. This seems to suggest that if a skink is present and visible, it will be seen sooner during the survey rather than later. Different observers may produce different results, and the amount of time needed in each sample unit may vary according to the amount of rock cover it contains. Standardising the maximum length of time allowed for searching each sample unit should ensure that a similar amount of effort is put into searching each unit.

The average distance at which a skink was seen was c. 6 m. Sightings from this distance were generally achieved using binoculars. The majority of observed skinks were found by scanning rather than by crevice search, possibly because of the observer's skill. The average distance from the observer at which the skink ran was 1.96 m. This means that if a skink is unseen and the observer walks towards it, the minimum distance before the skink will be startled is c. 2 m. Therefore, great care should be taken to carefully search a rock as the observer moves towards it. It was found that skinks in different parts of the study area reacted differently to the observer. Two regularly visited DOC study sites ('Wildlife' and 'Falcon') formed part of the present study area. Skinks in these two sites were observed to be more easily startled, and the distance from the observer at which they ran was greater than in other parts of the study area. This should be taken into account when carrying out these surveys. Great care must be taken to walk slowly and quietly with the sun behind the observer, to create as little disturbance as possible, while ensuring maximum skink visibility.

Limits of the method, including time and logistical constraints, were largely due to the difficulty of one person carrying out all surveys, and should not apply if the method is carried out on a larger scale, i.e. more people and resources. In conclusion, the method described here seems to be an appropriate tool for determining presence/absence of the Otago skink on rock tors.

Because Otago skink is so elusive and difficult to monitor it would be unrealistic to expect any method to successfully observe all individuals. The method described above provided a good base for future monitoring programmes. Below are recommendations for the future implementation of this method:

1. Environmental variables need not be measured in the field as long as surveys are consistently carried out on sunny days appropriate for basking. This should decrease both cost and time.

2. A group of about five observers experienced in identifying and working with Otago skink should be used. Each sample unit should be searched by a different observer at least twice.
3. The method should be applied to other areas to investigate site occupancy and presence/absence of Otago skink.
4. Different numbers of visits and sample units should be investigated to determine which provide optimum results. Fifty sites is a minimum number of sample units, but increasing the number of visits and sites might not improve results further.
5. The method should be carried out during the time of year when Otago skink are most visible, i.e. from November to April (Patterson 1992).
6. Both scanning and crevice search methods should be used to increase the chances of finding all observable skinks. However, the success of either method may depend on the observer.
7. The sample unit sizes that were used in the present study were of an appropriate size for one observer. If more observers are available, larger sample units could be used, although this may not be necessary.

3. Site occupancy by grand skinks

3.1 INTRODUCTION

The grand skink has been the subject of several studies. Whitaker (1996) looked at the impact of agricultural development on grand skink in both a modified and unmodified area of Macraes Flat, Otago. He found that within the unmodified area local grand skink populations were distributed at random over rock outcrops. In the modified area, in contrast, over a 14-year period following conversion of the tussock to pasture, the number of local skink populations and their population density decreased dramatically. It was concluded that the decrease in numbers may be due to limitations on movements of grand skink between sites (Whitaker 1996). Grand skink display frequent and extensive interpopulation movements (Whitaker 1996; Berry et al. 2004). The patchy distribution of the species indicates that local extinctions and recolonisations are common (Whitaker 1996; Houghton 2001), but rates of these trends are still to be determined. The recolonisation of sites where grand skink become locally extinct is important for the survival of the species (Whitaker 1996).

Houghton & Linkhorn (2002) conducted surveys of grand skink at Macraes Flat between 1986 and 2001 to identify population trends over time. They observed the disappearance of several rock tor populations, and concluded that local population extinctions and local population recolonisations may be useful indicators when looking at local population decline of grand skink (Houghton & Linkhorn 2002). The population decline appears to have been quite slow, which is not entirely consistent with a habitat effect. Due to the absence of pre-pasture grand skink population data for the same area, it is difficult to come to any reliable conclusions about the cause of the decline.

As has previously been mentioned, a monitoring method has been developed that is considered to be successful. For the past decade total counts of grand skink have been carried out by DOC at selected sites in the Macraes Flat area (Whitaker & Houston 2002).

The aim of this study is to apply the presence/absence modelling of detectability in the analysis of 10 years of count data for grand skink to determine the efficacy of the rock tor count method as a basis for quantifying trends in site occupancy. It was also hoped to determine the sensitivity of the method when detecting changes in status.

3.2 STUDY SITE AND STUDY ANIMAL

The study site consisted of rock outcrops in the vicinity of Trig E Ridge, Macraes Flat, Otago (Fig. 1).

The grand skink is one of New Zealand's largest skinks, with snout-vent lengths up to 106 mm, and weights up to 27 g (Cree 1994; Coddington & Cree 1997). It is slender-bodied and coloured black with yellow flecks (Marshall 2001). The species is diurnal and most active from November until late May, rarely being seen during winter (Marshall 2001). Emergence behaviour has a bimodal pattern, peaking both early and late in the day (Marshall 2001). Basking behaviour is very weather-dependent, grand skinks being more commonly seen in sunny, warm, dry conditions (Coddington & Cree 1997), although they are more likely to emerge in less optimal conditions and more quickly after bad weather than Otago skink (Coddington & Cree 1997).). It has been found that grand skink detectability is quite high; at 87% of sites investigated by Whitaker (1994), grand skink occurrence was determined on the first visit to a rock. This information could help to develop a reliable and efficient sampling method.

Grand skink home ranges are between 200 m^2 and 800 m^2, larger than for Otago skink (Marshall 2001). Home ranges for males were generally larger than for females and this may be related to food availability (Eiffler & Eiffler 1999). Grand skinks are omnivorous, feeding primarily on small-bodied dipterans and the fruit *Leucopogon fraseri* and *Melicytus alpinus* (Tocher 2003). They modify their foraging behaviour and diet in response to changes in prey distribution (Eiffler & Eiffler 1999). Feeding may take place on rock outcrops or nearby in surrounding tussock (Houghton 2001).

Dispersal of grand skinks from their home range is still not fully understood. Initially it was assumed that juveniles would be the primary dispersers from their natal range, but Houghton (2001) found that all classes of animals moved. Dispersal may be a result of foraging or mating behaviour (Houghton 2001). Dispersal may also be due to intraspecific aggression; adult grand skinks display aggression towards juveniles (Houghton 2001).

3.3 METHODS

Rock count surveys carried out between 1994 and 2003 by DOC at Trig E Ridge, Macraes Flat, between 255 and 275 rocks being searched each year. Random samples of 120 rocks were visited up to three times to assess grand skink presence and attempt to obtain total counts on each of the sample rocks.

This rock count monitoring method was developed by A.H. Whitaker in 1994 as part of a grand skink study (Whitaker 1996). The aim of the counts is to establish which rocks have grand skinks, to detect changes in distribution, and to search not only rocks proven to house skinks but all rocks within the study areas.

Rock counts were carried out in January due to the good weather conditions and long day length. They were done by a team of searchers to enable them to be completed in a short period and to allow several different observers to search the rocks to increase the chance of finding a skink. Searchers experienced in identifying and finding skinks were used. Counts were primarily undertaken during the morning to take advantage of optimum basking conditions and the best chance of finding skinks.

The usual search procedure was to scan the rock for basking skinks from nearby using binoculars, then to approach the rock to examine all aspects, finally peering into crevices that might be refuges. All grand skinks found on each rock were noted. Counts were said to be complete either when grand skink had been recorded at a site, or when three counts had been made, one of them in good weather. Good weather refers to good basking conditions between 9 am and midday.

Count data recorded for each rock were: rock number, search start time, search finish time, time of first grand skink sighting, tally by size class of grand skink, *Oligosoma maccanni* sightings, and weather conditions.

Rock count data were converted into presence/absence data for each rock over all survey periods; presence was recorded as a 1, while absence was recorded as a 0. This resulted in 10 primary sampling periods (years) with a total of 21 surveys for 352 different rocks. Some rocks for which there was just one survey were deleted from the dataset as they would not contribute to the results. Data were then entered into the computer programme PRESENCE (Mackenzie et al. 2003). The multiple summers analysis was used to provide estimates of site occupancy, colonisation, and local extinction probabilities when a species had imperfect detectability (MacKenzie et al. 2003). It used repeated surveys of sites over several years to model presence, allowing for the possibility that the species of interest might be present but undetected during a given survey. The model consisted of N units being surveyed over time, where the aim was to determine the presence or absence of a species. The surveyed units could be a naturally occurring sampling unit, or some artificial construction such as a quadrat. The occupancy status of the different states may not be constant over time. The study therefore comprised T primary sampling periods, between which changes in the occupancy state of sites may occur. Within each year, investigators used an appropriate technique to detect the species at k_t surveys of each site, where k_t is the number of surveys per primary sampling period, t. The detection history for each site may be expressed as T vectors of 1s and 0s (detection and nondetection respectively). The detection history for the k_t surveys of site i at primary sampling period t is $X_{i,t}$, and the complete detection history for site i over all primary periods is X_i. Detection histories for the sites were then used to estimate site occupancy, colonisation, and local extinction probabilities. Three different models werre fitted to the data. In the first, the proportion of sites occupied in the first year was estimated, with the dynamic parameterisations of colonisation and extinction probabilities. The second and third models both allowed the proportion of sites occupied in each year to be estimated, with one of the two dynamic parameterisations (colonisation and extinction). Potential models were then tested to select which best described the data (MacKenzie et al. 2003).

3.4 RESULTS

Table 3 presents the different models and their respective AIC values. There is strong evidence that detection probabilities should be modelled as year-specific. The most parsimonious model (lowest AIC) suggests that occupancy is best modelled as being constant over years whereas extinction probabilities are year-specific. The model ranked second has some support, which may suggest

TABLE 3. RELATIVE DIFFERENCE IN AIC (ΔAIC) OF EACH MODEL TESTED. Ψ = probability that a species is present at a site. ε = local extinction probability. γ = colonisation probability. P = detection probability. (.) = probability is constant. (1994) = only the proportion of sites occupied in the first year of sampling is estimated. (year) = probability different in each year. (year, .) = detection probability different in each year, constant over surveys. (., year) = detection probability different in each survey, constant over years. ΔAIC ≤ 2 have substantial support (Burnham & Anderson 2001).

MODEL	ΔAIC
$\Psi(.)\varepsilon(\text{year})P(\text{year}, .)$	0.00
$\Psi(\text{year})\varepsilon(\text{year})P(\text{year}, .)$	4.45
$\Psi(1994)\gamma(\text{year})\varepsilon(\text{year})P(\text{year}, \text{year})$	5.81
$\Psi(\text{year})\gamma(\text{year})P(\text{year}, .)$	10.76
$\Psi(.)\varepsilon(\text{year})P(., .)$	183.82
$\Psi(.)\gamma(\text{year})P(., .)$	402.72
$\Psi(1994)\gamma(\text{year})\varepsilon(.)P(., .)$	729.1
$\Psi(\text{year})\varepsilon(.)P(., .)$	729.1
$\Psi(1994)\gamma(.)\varepsilon(\text{year})P(., .)$	787.89
$\Psi(\text{year})\gamma(.)P(., .)$	893.85
$\Psi(.)\gamma(.)P(\text{year}, .)$	907.06
$\Psi(.)\varepsilon(.)P(\text{year}, .)$	907.06
$\Psi(.)\gamma(.)P(\text{year}, \text{year})$	909.71
$\Psi(.)\varepsilon(.)P(., \text{year})$	990.48
$\Psi(1994)\gamma(.)\varepsilon(.)P(., \text{year})$	991.79
$\Psi(1994)\gamma(.)\varepsilon(.)P(\text{year}, .)$	991.79
$\Psi(.)\gamma(.)P(., \text{year})$	1000.44
$\Psi(.)\gamma(.)P(., .)$	1015.44
$\Psi(1994)\gamma(.)\varepsilon(.)P(., .)$	1016.95
$\Psi(.)\varepsilon(.)P(., .)$	1019.57

Model-averaged estimate of site occupancy rate between 1994 and 2003 = 0.39

Naive estimate of site occupnacy between 1994 and 2003 = 0.33

Model-averaged estimate of detection probability between 1994 and 2003 = 0.73

an annual change in the proportion of sites occupied. The model-averaged estimate of site occupancy over the ten-year period was 0.39, which is larger than the naïve estimate of site occupancy (or the proportion of sites where skinks were detected at least once) (Table 3). The rate of change in site occupancy over the ten-year period was calculated as approximately 1, which is constant. Figure 8 shows the proportion of sites occupied in each of the ten years. There appears to be a steady decrease in site occupancy since 2001. The other models that were tested have limited support in terms of AIC. Colonisation is included in the third-ranked model, which suggests that it is year-specific. The average detection probability for all models over all years was 0.73 (Table 3).

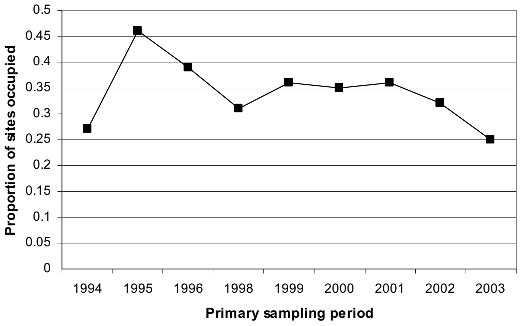


Figure 8. Proportion of sites occupied by grand skinks between 1994 and 2003 (1997 was removed because of poor data quality (Graeme Loh, pers. comm.)).

Years in which at least two surveys were undertaken were tested to determine whether two visits to a site offered the same detection and occupancy results as three visits (Table 4) (the programme used was unable to test just one visit). There was no significant difference in estimated site occupancy between two visits and three visits (two sample *t*-test, *t*-statistic = 0.43, *t*-critical = 2.3, *P* = 0.68, DF = 8). There was also no significant difference in detection probabilities between two visits and three visits (two sample *t*-test, *t*-statistic = –0.28, *t*-critical = 2.3, *P* = 0.79, DF = 8).

TABLE 4. DIFFERENCES IN SITE OCCUPANCY AND DETECTION PROBABILITIES YEARS WHEN TWO AND THREE VISITS WERE MADE.

YEAR	NO. OF VISITS	SITE OCCUPANCY	DETECTION PROBABILITY
1998	3	0.39	0.68
1998	2	0.42	0.63
1999	3	0.45	0.65
1999	2	0.48	0.61
2000	3	0.46	0.62
2000	2	0.38	0.75
2001	3	0.39	0.86
2001	2	0.39	0.86
2002	3	0.43	0.61
2002	2	0.40	0.66

3.5 DISCUSSION

The results suggest that between 1994 and 2003 the overall level of occupancy by grand skink has been constant, but there may be systematic changes in the occupancy state of individual sites. Figure 8 shows the changes in site occupancy over the last decade, with apparent periods of increasing and decreasing site occupancy. It is known that colonisation and extinction have some importance in the population dynamics of grand skink, and the fluctuations in site occupancy may reflect this (Whitaker 1996; Houghton & Linkhorn 2002).

The model-averaged estimate of site occupancy is c. 2% higher than the estimate of naïve site occupancy. This suggests that the true occupancy level is slightly higher than the proportion of sites where skinks were detected at least once. Therefore it is important to survey sites more than once to ensure an accurate estimate of site occupancy. The number of claims and apparent evidence (Whitaker 1996; Houghton & Linkhorn 2002) about the decline of grand skink over time appear to contradict the results of this study, which show an estimated rate of change in site occupancy of c. 1 (constant). This may be due to lowering of population sizes rather than restriction of distribution in the area studied. The number of rocks occupied by grand skink may not have declined, but the number of skinks on rocks may be lower. Dispersal of both juveniles and breeding adults, and movements of skinks within home ranges, may account for the apparently static levels of site occupancy. It is known that adult grand skink inhabit home ranges of c. 200–800 m^2 (Marshall 2001), which may allow enough movement over the period of the rock tor counts to ensure that there is little or no loss or gain of site occupancy (i.e. the same number of rocks occupied at all times).

There is strong support for the models that show local extinction as year-specific. The variability in average extinction probabilities suggests that if grand skink populations are indeed going through fluctuations in site occupancy, there may be some extinction events occurring at certain time intervals. The same may be said for colonisation, which, although it has less support from the AIC values, also seems to be year-specific. Average colonisation probabilities display an obvious decrease after 1994, although there is only a small amount of variability between years.

Although the average probability of occupancy is constant over time, the models that were applied to the data suggest that site occupancy goes through periods of being year-specific, but at other times may be constant between years. Year-specific extinction seems to be a major factor in the population dynamics of grand skink. Average extinction probabilities tended to be higher than average colonisation probabilities. Reasons for this are still unclear, although habitat degradation and habitat loss seem likely (Whitaker 1996; Houghton & Linkhorn 2002). Even though the overall level of occupancy appears to be constant, there may be individual sites that are experiencing higher levels of extinction than others. This could increase the risk of isolating small populations.

The overall model-averaged estimate of detection probability was c. 0.73; this is lower than the hypothesised level of c. 0.8 (Graeme Loh, pers. comm.). The model-averaged estimates produced for each year of the study showed that detection probabilities remain constant within each year, but may vary between years. This variation may be a result of observer error and skill level; it is unknown whether the same observers were used each year. A reliable training programme for potential observers should reduce potential errors.

There was no significant difference found in site occupancy and detection probabilities between sites visited twice and those visited three times in a year. This seems to suggest that most skinks that are going to be detected will be detected in earlier visits. Values for sites visited just once are unknown because the computer programme was unable to carry out that analysis. The current practice of not visiting rocks after skinks have been detected could be considered appropriate in the light of these results.

The large numbers of rocks surveyed and the consistency of surveying every year for a decade has produced large amounts of data concerning site occupancy of grand skinks. If used in the correct way, this can provide important information about the population status and trends in the population dynamics of grand skink. The rock tor count method seems to be a useful tool and is worth continuing; however, there is a need for some improvements:

1. All rocks should be surveyed at least twice each year to provide a standard and consistent range of data.
2. All observers should undergo a standardised training programme to ensure all rock tor counts are carried out the same way, and to limit observer error.
3. Rock tor counts should continue to be carried out in similar weather conditions (fine), and at a similar time of the day (morning) and year (January).
4. Analysis of the data should be performed after the completion of the three surveys each year to ensure that knowledge of site occupancy trends is current.

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Appendix 1

RAW SURVEY DATA FOR THE OTAGO SKINK STUDY

SAMPLE UNIT	SURVEY 1	SURVEY 2	SURVEY 3	SURVEY 4	SURVEY 5
1	0	0	0	1	0
2	0	1	0	0	1
3	1	0	0	0	0
4	0	0	0	0	0
5	0	1	1	0	1
6	1	1	1	0	1
7	0	0	0	0	0
8	0	0	0	0	0
9	0	0	1	1	0
10	0	0	0	0	0
11	1	1	1	1	1
12	0	0	0	0	0
13	0	0	0	0	0
14	0	0	0	0	0
15	0	0	0	0	0
16	0	1	1	1	1
17	0	0	0	0	0
18	1	0	0	1	0
19	1	1	1	1	1
20	0	0	0	1	0
21	0	1	0	1	1
22	1	0	0	0	0
23	0	1	1	0	1
24	1	0	0	1	0
25	0	0	1	1	0
26	0	0	1	1	0
27	0	0	1	0	0
28	0	1	0	0	1
29	0	0	0	0	0
30	0	0	0	0	0
31	0	0	1	0	0
32	0	0	0	0	0
33	0	0	0	0	0
34	0	0	0	0	0
35	0	0	1	0	0
36	0	0	1	1	0
37	1	1	0	0	1
38	0	1	0	0	1
39	1	0	0	1	0
40	0	0	0	1	0
41	1	1	0	0	1
42	1	0	0	0	0
43	0	0	1	1	0
44	1	0	1	0	0
45	1	1	0	0	1
46	0	0	0	0	0
47	0	0	0	0	0
48	1	0	1	1	0
49	0	0	0	0	0
50	1	0	0	0	0