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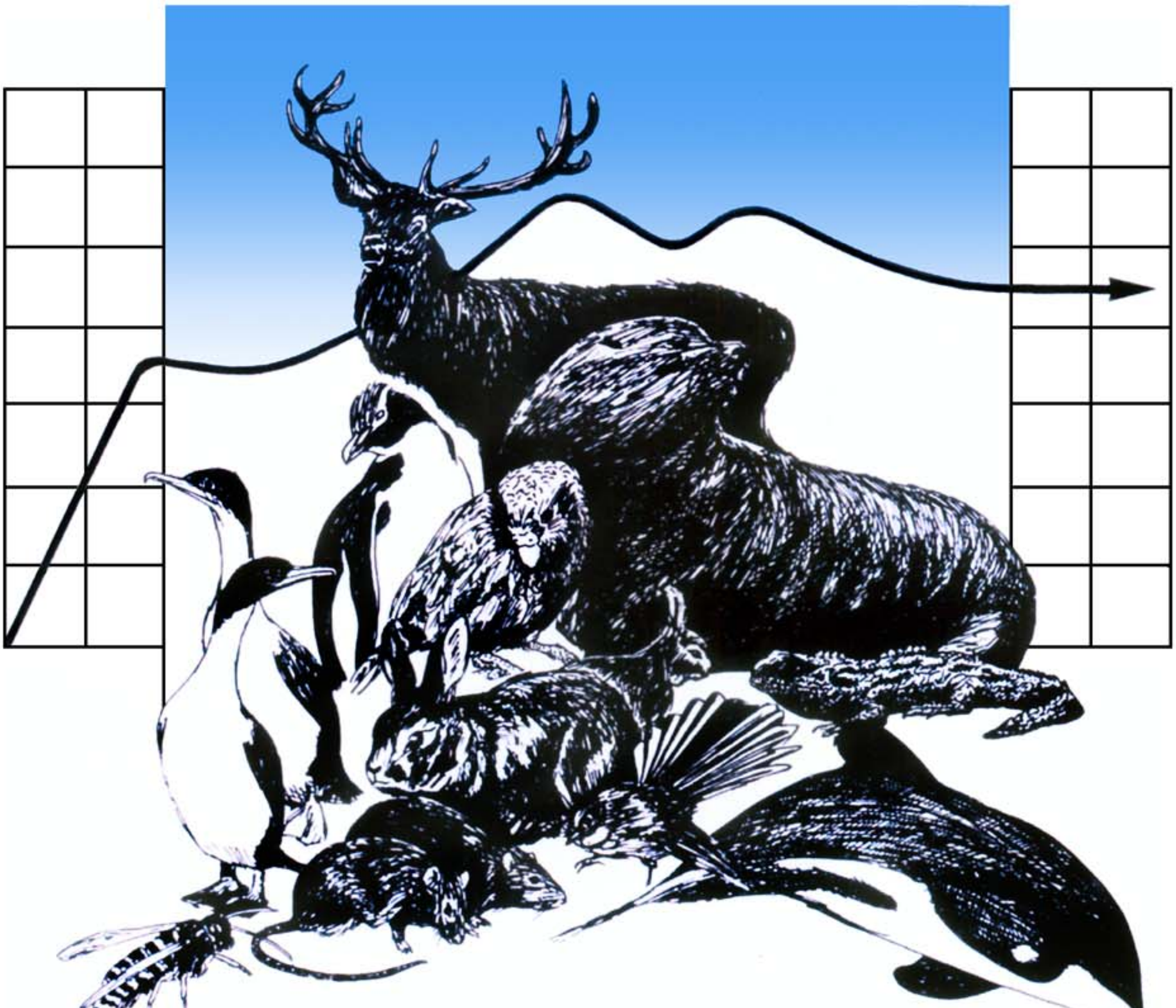

WILDLIFE MANAGEMENT

Occupancy and detectability of *Oligosoma grande* in relation to rock characteristics at Macraes Flat, Otago

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Abstract

The endangered grand skink (*Oligosoma grande*) inhabits tussock grassland in Central Otago, New Zealand. Habitat (rock) specific characteristics were gathered in an attempt to relate these to grand skink site occupancy and detection probabilities. The overall estimated occupancy rate for grand skinks in tussock and pasture habitat was 0.42 (0.05) while the overall estimated detection probability was 0.65 (0.001). When tussock and pasture survey data were compared it was found that the overall occupancy probability in tussock habitat was 0.53 (0.02); while in pasture habitat the overall occupancy probability was 0.27 (0.02). Reasons for this difference possibly relate to the extreme disturbance that pasture habitat has experienced. Agricultural development has reduced the between-rock vegetation cover that would normally provide shelter and safety for the skinks and habitat for insects - a staple in the diet of the grand skink. This could mean that in pasture habitat fruiting plants growing on rocks may provide a very important food source for the grand skink. Another result of this study was the finding that the location of the study sites (north or south) is a major influence on occupancy and detectability. In northern sites the occupancy probability was 0.28 (0.04), while in southern sites occupancy probability was 0.57 (0.02). However reasons for this difference are unknown as there are no obvious differences between northern and southern areas. Further investigation into this difference would be valuable. It is hoped that the rock characteristics gathered in this study will be of use in long-term metapopulation studies of this species.

Introduction

The grand skink (*Oligosoma grande*) and Otago skink (*O. otagense*) are two of New Zealand's largest and most endangered endemic reptiles. They currently occupy only 8% of their former Central Otago range, being found only at Macraes Flat and the Lindis Pass (Houghton and Linkhorn 2002; Whitaker and Loh 1995). The decline in skink numbers is believed to be a result of several factors including: tussock burning and dispersal of exotic grasses for pasture development; predation by introduced mammalian species such as feral cats (*Felis catus*) and stoats (*Mustela erminea*); and poisoning by baits spread for pest control (Whitaker and Loh 1995). Continued localised extinctions in the last 30-40 years highlight that these are on going concerns (Whitaker 1999). In order to assess the effects of current conservation efforts - including predator control and the establishment of predator exclosures - population and habitat occupancy trends need to be efficiently monitored (Roughton 2005).

A study of the emergence behaviour of grand and Otago skinks by Coddington and Cree (1997) showed that both species were observed in greater numbers in sunny, warm, dry conditions. Thus variable detectability will be a major challenge faced by researchers attempting to provide accurate estimates of population size, variable detectability (Roughton 2005). The non-detection of a species does not necessarily mean it is absent from a site; instead it may be that the species concerned has incomplete detectability (i.e. a detectability rate that is different from one) (MacKenzie *et al.* 2002). Two frequently used survey methods that can provide estimates of detection probabilities are distance sampling and mark recapture. However such methods can be costly, time consuming, and impractical for large scale monitoring programs (Yoccoz *et al.* 2001; MacKenzie *et al.* 2002). As a result, a

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popular alternative is the collection of site occupancy data. Such presence/absence data for specific habitat patches within a study area can be used as a substitute for estimates of population size, as well as providing a basis for estimation of meta-population parameters such as colonisation and extinction probabilities (MacKenzie and Bailey 2004). The stability of ~~the~~ grand skink numbers relies heavily on recolonisation following the extinction of other local populations, however, the rate of this population turnover is unknown (Whitaker 1996). Ongoing estimates of rock occupancy and the introduction of "incidence functions" (such as habitat patch characteristics) into the analysis of occupancy data will therefore be extremely valuable in tracking trends in metapopulation parameters, such as colonisation and extinction.

The aims of this study were to derive robust estimates of rock occupancy by grand skinks in the Redbank Ridge area, Macraes Flat, Otago, and to collect subsidiary data on patch (rock) specific characteristics to facilitate long term monitoring and assessment of metapopulation dynamics and distribution in relation to habitat characteristics.

Methods

Site Description

The Macraes Flat Redbank Ridge study site consists of approximately 250 ha of land oriented NE/SW along a ridge top. A fence line divides the area into two distinct habitat types. The Redbank Conservation Area, SE of the fence, is dominated by tussock (*Chionochloa rigida, C. rubra, Poa cita* and *P. novae-zealandiae*) with scattered shrubs, herbs and some mosses. The NW side of the fence was cultivated in the early 1980s, replacing the native tussock with permanent pasture that is heavily grazed by sheep and cattle (Whitaker 1996; Houghton and Linkhorn 2002).

Rock Characterisation

The study site was divided into four areas, two of which were tussock dominated (one north site, one south site) and two pasture dominated (one north site, one south site). This was done to reduce the number of rocks in each area for logistical reasons, and also because past surveys have found greater differences between north and south sites rather than pasture and tussock sites (Dave Houston, pers. comm. January 2006). Within each of the four sites each rock patch (‘rock’) has been historically defined as a schist outcrop (or group of outcrops) that is separated by a minimum of 10m from any other surrounding outcrops. This broad definition means the rock patches vary significantly in shape, size and complexity (Whitaker 1996). Each rock was characterised according to its relative size (small, medium, large), the presence of vegetation on the rock (none, moderate, lots), maximum height (0-<2m, 2-<4m, >4m), structure (discrete, spread), and the type of surrounding matrix (tussock or pasture), and the location/direction of the rock (north or south) (Appendix A). The same observers carried out all rock characterisation in order to maintain consistency.

Survey Design

A survey team of between six and eight observers was used to survey each rock four times over a two-week study period between January 16th and 27th 2006. Each observer avoided surveying the same rocks multiple times in order to avoid possible observer bias (prior knowledge of skink presence). Each rock was surveyed by approaching with the sun behind the observer. From a distance of 10-20m the rock was scanned using binoculars. If no skinks were sighted the observer would walk slowly toward the rock and search the rock surface, in cracks or under slabs. The survey was concluded once a grand skink had been observed, or after a maximum of five minutes had elapsed in order to standardise search effort and thereby ensure consistency and repeatability.

Analysis

If a skink was observed its presence was recorded as a 1, while absence (or no sighting) was recorded as a 0 (Appendix B). The detectability of grand skinks was modelled and estimates of the proportion of rocks occupied were calculated using modelling techniques developed by MacKenzie *et al.* (2002) using the computer programme PRESENCE (MacKenzie *et al.* 2003). It was assumed that no grand skinks were falsely observed when they were absent from a rock, and that the population was closed during the two week survey period. Rock characterisation data was entered into the programme as both site and sampling covariates to determine what effect these had on occupancy and detectability probabilities. The models consisted of N sampling units (rocks). These sampling units can be observed over T primary sampling periods (years), between which changes in the occupancy of sampling units may occur. Within each primary sampling period k_t surveys are conducted (MacKenzie *et al.* 2002). Because past surveys had noted differences between northern and southern sites but were unsure why, two analyses were carried out in this study; the first did not include the direction covariate (north/south), while the second did. For both analyses N= 292, T= 1 and k_t = 4.

Akaike's Information Criterion (AIC) and Goodness-of-Fit Testing

Traditional methods of testing ecological data (such as null hypotheses) are widely thought to be relatively uninformative and to have relatively little utility (Burnham and Anderson, 2001). An alternative method for analysing ecological data is the information-theoretic approach such as Akaike's Information Criteria (AIC). This method allows one to develop a set of *a priori* models and find the most parsimonious model, using ranking and scaling. The most parsimonious model will be one that best fits the data using as few parameters as possible (Burnham and Anderson, 2001).

For results of an analysis such as this to be valid and useful a goodness-of-fit test must be carried out to determine how well the models truly represent the data (Mackenzie and Bailey, 2004). A Pearson chi-square statistic was used to measure model fit, carried out on the most global model within which all others are nested. The method uses the observed and expected numbers of observations and through parametric bootstrapping calculates a test statistic. From this test statistic an estimate of the overdispersion parameter c-hat may be calculated. If the model is an adequate description of the data then c-hat should be around 1. Values greater than 1 show overdispersion, this means there is more variation in the observed data than predicted by a Poisson distribution. If the data is overdispersed then c-hat may be used as a variance inflation factor to adjust model selection procedures and standard errors using quasi-likelihood theory (QAIC) (MacKenzie and Bailey, 2004).

In this study two sets of candidate models were produced in order to describe the survey data. The first set did not include the direction (north/south) covariate while the second did. A goodness-of-fit test was carried out on the most global model for each set; c-hat was calculated as 5.6 for the first and 3.3 for the second; as a result QAIC was applied to the models in both sets to identify the one that best described the data (MacKenzie and Bailey, 2004). As with AIC the model with the lowest QAIC value is considered the most parsimonious. In order to rank the models ΔQAIC was calculated (each QAIC value minus the lowest QAIC value); models with ΔQAIC values less than two are considered to have substantial support (Burnham and Anderson 2001). Akaike model weights (w_i) were calculated to illustrate the weight of evidence in favour of each model (Burnham and Anderson 2001). Standard errors were inflated by the square root of c-hat (MacKenzie and Bailey 2004). Occupancy and detection probabilities for different habitat types were derived using the covariate coefficients obtained in the PRESENCE output. The equations that were used to analyse the data are presented below, where: $\log_e(L(\theta \mid data))$ = value of the maximised log-likelihood over the unknown parameters (Θ); K = number of estimable parameters; Δ = delta function; O_h = number of sites observed to have detection history h; E_h = the expected number of sites with history h; 2^T = the number of possible detection histories that may be observed; X^2_B = average of the test statistics obtained from the parametric bootstrap:

1. Akaike's information criterion (AIC):

$$\text{AIC} = -2\log_e(L(\Theta \mid data)) + 2K$$

2. Quasi-likelihood modified Akaike's information criterion (QAIC):

$$\text{QAIC} = \frac{-2\log(L(\Theta))}{\text{c-hat}} + 2K$$

3. Relative difference in AIC:

$$\Delta_i = \text{AIC}_i - \text{minAIC}$$

4. Akaike model weights:

$$w_i = \frac{\exp(-\Delta_i / 2)}{\Sigma\exp(-\Delta_r / 2)}$$

5. Test statistic for assessing model fit:

$$X^2 = \sum_{h=1}^{2T} \frac{(O_h - E_h)^2}{E_h}$$

6. Overdispersion parameter:

$$\text{c-hat} = X^2_{\text{Obs}} / X^2_B$$

7. Deriving occupancy and detection probabilities from covariate coefficients:

Covariate code 0 = 1/(1+exp(-(intercept)))

Covariate code 1 = 1/(1+exp(-(covariate coefficient + 1 x intercept)))

Results

During the survey period a grand skink was observed at least once on 122 of the entire 292 study rocks surveyed. Several models (excluding direction covariate) were fitted to the overall survey data and ranked according to QAIC values (Table 1). The top four models had ΔQAIC values less than 2, indicating they all provide good descriptions of the data. Three of the top four models contained the site covariate 'matrix', indicating that the vegetation surrounding the rocks (tussock or pasture) plays a major role in determining occupancy. The second ranked model contains 'matrix' as a sampling covariate. This indicates that matrix may also play a role in determining detectability. The third ranked model is the simplest possible model, and suggests that detectability and occupancy are constant and are unrelated to any of the covariates recorded. The fourth ranked model contains 'structure' as a sampling covariate, indicating that rock structure may also play a role in determining detectability. The estimated overall occupancy probability for grand skinks on

Redbank Ridge was 0.42 (SE 0.05), and the estimated overall detection probability was 0.65 (SE 0.001). The proportion of rocks on which grand skinks were observed during each of the four surveys is shown in figure 1.

Table 1: Relative difference in ΔQAIC for each model. ψ = probability that a species is present at a site; p = probability that a species will be detected when it is present; (.) = constant probability; w = weight of evidence in favour of model; K = number of parameters included in model; ψ = overall estimate of the fraction of sites occupied by the species; SE (ψ) = standard error of psi. The last model in the table is the global one.

Models	**k**	**ΔQAIC**	**w_i**	**$\overline{\Psi}$**	**SE ($\overline{\psi}$)**
Ψ(Matrix)p(.)	4	0	0.32	0.42	0.07
Ψ(Matrix)p(Matrix)	5	1.18	0.18	0.42	0.07
Ψ(.)p(.)	3	1.63	0.14	0.42	0.07
Ψ(Matrix)p(Structure)	5	1.76	0.13	0.42	0.07
Ψ(Structure)p(.)	4	3.09	0.07	0.42	0.07
Ψ(Size, Matrix)p(.)	6	3.60	0.05	0.42	0.07
Ψ(Matrix)p(survey)	7	5.20	0.02	0.42	0.07
Ψ(Height)p(.)	5	5.26	0.02	0.42	0.07
Ψ(Veg)p(.)	5	5.30	0.02	0.42	0.07
Ψ(Size)p(.)	5	5.37	0.02	0.42	0.07
Ψ(Size, Veg, Structure, Height, Matrix)p(Matrix, structure, survey)	16	20.29	<0.0001	0.42	0.07

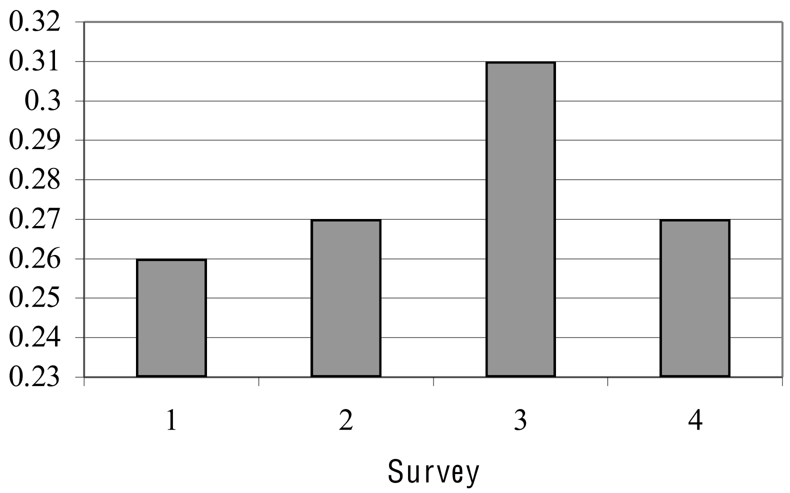

Figure 1. The proportion of rocks where skinks were detected at least once in each survey.

Estimates of occupancy and detection probabilities were derived for each of the two habitat types. In tussock habitat the estimated occupancy probability was 0.53 (SE 0.02) while in pasture habitat the estimated occupancy probability was 0.27 (SE 0.02). The estimated detection probability in tussock habitat was 0.68 (SE 0.03) while in pasture habitat the estimated detection probability was 0.57 (SE 0.02).

A second analysis was carried out on the data to include the covariate 'direction' (Table 2). The top two models had ΔQAIC values less than 2, indicating they provide good descriptions of the data. The top ranked model indicates that both matrix and direction affect occupancy and detectability. The second ranked model suggests that direction affects occupancy while both direction and matrix affect detectability. Estimates of occupancy and detection probabilities were derived for both northern and southern sites. In northern sites the estimated occupancy probability was 0.28 (SE 0.04) while in southern sites the estimated occupancy probability was 0.57 (SE 0.02). The estimated detection probability in northern sites was 0.51 (SE 0.05), while in southern sites the estimated detection probability was 0.72 (SE 0.04).

Table 2: Relative difference in ΔQAIC for each model. ψ = probability that a species is present at a site; p = probability that a species will be detected when it is present; (.) = constant probability; w = weight of evidence in favour of model; K = number of parameters included in model; ψ = overall estimate of the fraction of sites occupied by the species; SE (ψ) = standard error of psi. The last model in the table is the global one.

Model	***k***	**ΔQAIC**	**w_i**	**ψ**	**SE (ψ)**
Ψ(Matrix, Direction)p(Matrix, Direction)	7	0	0.54	0.43	0.052
Ψ(Direction)p(Matrix, Direction)	6	2.05	0.19	0.45	0.059
Ψ(Matrix, Direction)p(.)	5	4.10	0.07	0.42	0.049
Ψ(Direction)p(Direction)	5	4.19	0.07	0.43	0.052
Ψ(Matrix)p(Direction)	5	4.47	0.06	0.44	0.054
Ψ(Matrix, Direction)p(Matrix)	6	4.73	0.05	0.42	0.050
Ψ(Direction)p(.)	4	7.63	0.01	0.42	0.051
Ψ(Matrix)p(.)	4	9.07	0.006	0.42	0.051
Ψ(Direction)p(Matrix, Structure)	6	9.09	0.006	0.43	0.052
Ψ(Matrix)p(Matrix)	5	9.67	0.004	0.42	0.051
Ψ(Size, Veg, Structure, Height, Matrix, Direction)p(Matrix, structure, Direction)	15	13.83	0.0005	0.43	0.051

Discussion

The suggestion that matrix plays a major role in determining grand skink occupancy on the rocks of Redbank Ridge supports the findings of ~~A. H.~~ Whitaker (1996) and Houghton and Linkhorn (2002). ~~A.H~~ Whitaker found (during 3 surveys of 120 randomly selected rocks) that twice as many grand skinks inhabited tussock rocks than pasture rocks, while Houghton and Linkhorn found the percentage of rocks occupied by grand skinks in pasture habitat was significantly less than in tussock habitat. The negative impacts of agricultural development on grand skink populations are thought to include reductions in food availability due to poor growing conditions for flowering and fruiting plants (Tocher, 2003); fouling of crevices by sheep and cattle (Whitaker, 1996); reduction of cover due to the lack of tall vegetation between rocks (Whitaker, 1996); and changes in predation levels due to increased numbers of mammalian prey species (e.g. rabbits) in pasture areas and therefore higher numbers of predators (e.g. cats) (Whitaker, 1996).

The lack of tall vegetation in pasture habitat as stated above may be a large factor when considering the lower occupancy rates in pasture compared to tussock. Thick vegetation cover is readily found in tussock sites and is the type of habitat in which insects – a staple of the grand skink diet - are found (Eifler and Eifler 1999). It has also been found that fruiting plants, such as those found on rocks, are very important to grand skink diets, especially among females, and in pastures sites where there may be less insects to feed on, skinks may be forced to rely more heavily on fruiting plants (Eifler and Eifler 1999; Houghton and Linkhorn, 2001). It may be worthwhile to protect the vegetation found on rocks in pasture habitat – although this may be difficult due to the use of the land for stock - and even commence replanting. These actions may ensure a consistent supply of food for those skinks inhabiting pasture areas.

Matrix may also impact site occupancy through the provision of habitat corridors for dispersal. It has recently been shown that grand skink populations in pasture habitat display less dispersal than populations in tussock habitat (Berry *et al*.

2005). This has major implications on the genetic health of pasture populations because isolation can result in stochastic extinctions due to demographics and genetics (Berry *et al.* 2005). Therefore it seems important to manage tussock habitat to ensure dispersal corridors remain intact, and to monitor the genetic health of pasture populations.

Rock structure seemed to be a marginally important factor in determining skink occupancy and detectability. In both pasture and tussock habitat many of the rocks are well separated from each other; so inhabiting a discrete rock may bring different advantages to inhabiting a spread out rock. A spread out rock may provide more potential hiding crevices and more varied plant life than discrete rocks, both of which are important factors when considering the ability of a rock to suitably house skinks (Whitaker 1996; Eifler and Eifler 1999; Tocher 2003). Both types of rock structure have disadvantages when considering detectability. Considering the reasonably short length of time spent searching each rock an observer may only cover a fraction of a spread out rock and may miss a skink sighting. Discrete rocks are often very large and it is difficult to search the top of them, this may also result in missed sightings.

The impact of matrix on detectability may be the result of observer fatigue. For example in pasture, where fewer skinks are present, observers may become less attentive after a long period of time spent without seeing a skink, since if a skink is not expected to be seen the observer may not search as thoroughly. Skink density may also play a role in affecting skink detectability on tussock and pasture rocks. Because there may be more skinks inhabiting each rock in tussock areas than in pasture areas (~~A.H.~~ Whitaker 1996), the probability of observing at least one skink on a tussock rock could be greater than the probability of observing one of only a few skinks present on a pasture rock.

Introducing direction as a covariate had a huge effect on the structure of the top-ranked models. It was an extremely dominant factor for impacting both occupancy and detectability. The reasons for this are unclear because there appear to be no obvious differences in habitat or land management between the northern and southern areas (Graeme Loh, pers. comm. February 2006) and tussock and pasture sites are represented in both areas. Determining the cause of this difference would be an interesting avenue to explore in the future.

Naïve estimates of occupancy for each individual survey are very low compared to the overall occupancy rate. This illustrates the importance of carrying out multiple surveys to gain a more accurate picture of true occupancy rates.

In order for such data to be used to monitor the changing state of the grand skink populations on Redbank Ridge these surveys need to be repeated every year. Data collected over multiple years can be used to provide valuable estimates of meta-population parameters such as colonisation and extinction probabilities (MacKenzie and Bailey 2004). This is especially important since the stability of the grand skink numbers relies heavily on recolonisation (Whitaker 1996). Thus ongoing surveys will provide important data with which to assess the effectiveness of current management practice, and to identify new methods to improve the management of this threatened species.

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Appendix A: Rock Characteristics

Area 1						
Rock #	**Size**	**Vegetation**	**Structure**	**Height**	**Area**	**Matrix**
P117	medium	moderate	spread	3.5	South	Pasture
P118	small	none	discrete	2	South	Pasture
P119	medium	none	spread	2	South	Pasture
P120	small	none	discrete	2	South	Pasture
P122	large	moderate	spread	5	South	Pasture
P123	medium	moderate	spread	1	South	Pasture
P125	small	none	discrete	2.5	South	Pasture
P126	medium	moderate	discrete	3	South	Pasture
P127	large	none	spread	4.5	South	Pasture
P128	large	moderate	spread	2	South	Pasture
P131	large	moderate	spread	3	South	Pasture
P132	medium	moderate	discrete	3.5	South	Pasture
P133	medium	none	spread	3	South	Pasture
P134	medium	moderate	spread	3.5	South	Pasture
P136	small	moderate	discrete	1.5	South	Pasture
P137	medium	moderate	discrete	3	South	Pasture
P139	small	none	discrete	2.5	South	Pasture
P140	small	none	spread	1.2	South	Pasture
P141	small	none	spread	1	South	Pasture
P142	small	none	spread	0.7	South	Pasture
P143	medium	moderate	spread	2	South	Pasture
P144/163	medium	none	discrete	2	South	Pasture
P145	medium	moderate	spread	1.5	South	Pasture
P146	medium	moderate	spread	3	South	Pasture
P147	small	moderate	discrete	2.5	South	Pasture
P148	medium	moderate	spread	2	South	Pasture
P151	large	moderate	spread	3	South	Pasture
P154	large	moderate	spread	4	South	Pasture
P1540	small	moderate	spread	1.2	South	Pasture
P156	small	moderate	spread	1	South	Pasture
P159	medium	moderate	discrete	4	South	Pasture
P174	large	moderate	spread	4	South	Pasture
P1280	medium	moderate	spread	2	South	Pasture
P1370	small	none	discrete	1	South	Pasture
P1500	small	moderate	discrete	1	South	Pasture
P149	small	none	discrete	2	South	Pasture
P150	medium	moderate	discrete	2	South	Pasture

P153	medium	moderate	spread	3	South	Pasture
P157	medium	none	spread	2.5	South	Pasture
P160	small	moderate	spread	1	South	Pasture
P161	medium	none	spread	2	South	Pasture
P162	medium	moderate	spread	1.5	South	Pasture
P164	medium	none	discrete	2	South	Pasture
P165	medium	none	discrete	2.5	South	Pasture
P166	small	moderate	spread	2	South	Pasture
P167	small	none	discrete	0.5	South	Pasture
P168	small	none	discrete	1	South	Pasture
P169	large	moderate	spread	3.5	South	Pasture
P170	large	moderate	spread	3.5	South	Pasture
P171	medium	moderate	discrete	3	South	Pasture
P172	medium	d	m	3	South	Pasture
P173	medium	moderate	discrete	3	South	Pasture
Area 2						
Rock #	**Size**	**Vegetation**	**Structure**	**Height**	**Area**	**Matrix**
P40	medium	lots	spread	2	North	Pasture
P41	small	moderate	spread	1.5	North	Pasture
P42	medium	moderate	spread	1.5	North	Pasture
P43	small	lots	spread	1	North	Pasture
P49	medium	moderate	discrete	3	North	Pasture
P51	medium	lots	discrete	2	North	Pasture
P52	medium	none	spread	3	North	Pasture
P53	small	moderate	spread	2	North	Pasture
P54	medium	moderate	spread	2.5	North	Pasture
P55	large	moderate	spread	3.5	North	Pasture
P56	medium	none	discrete	3	North	Pasture
P57	medium	moderate	spread	3.5	North	Pasture
P58	large	moderate	spread	3.5	North	Pasture
P59	large	moderate	spread	3	North	Pasture
P60	large	moderate	spread	8	North	Pasture
P61	small	none	spread	1.5	North	Pasture
P62	medium	none	discrete	3	North	Pasture
P63	large	moderate	discrete	5	North	Pasture
P64	small	moderate	discrete	2	North	Pasture
P65	medium	none	discrete	3	North	Pasture
P66	large	none	discrete	5	North	Pasture
P67	medium	moderate	spread	2.5	North	Pasture
P68	medium	none	spread	2	North	Pasture
P69	medium	moderate	discrete	2	North	Pasture
P70	large	moderate	discrete	5	North	Pasture

P71	small	none	discrete	0.5	North	Pasture
P72	large	moderate	spread	3	North	Pasture
P73	large	moderate	spread	3.5	North	Pasture
P74	medium	moderate	discrete	3	North	Pasture
P75	large	moderate	spread	5	North	Pasture
P76	large	lots	spread	3.5	North	Pasture
P81	medium	moderate	discrete	3	North	Pasture
P82	small	none	discrete	1	North	Pasture
P77	large	lots	discrete	2	North	Pasture
P78	large	lots	spread	5	North	Pasture
P79	medium	lots	discrete	2	North	Pasture
P80	large	lots	discrete	2	North	Pasture
P83	large	lots	spread	2.5	North	Pasture
P85	medium	moderate	spread	2.5	North	Pasture
P86	small	none	spread	0.3	North	Pasture
P87	medium	moderate	spread	1.2	North	Pasture
P88	small	moderate	spread	1.5	North	Pasture
P90	small	none	discrete	2	North	Pasture
P91	medium	none	spread	3	North	Pasture
P92	large	moderate	spread	1.5	North	Pasture
P93	large	lots	spread	2	North	Pasture
P94	large	moderate	spread	3	North	Pasture
P95	medium	moderate	discrete	2.5	North	Pasture
P96	small	moderate	spread	1	North	Pasture
P97	small	none	discrete	1.5	North	Pasture
P98	medium	lots	spread	1.5	North	Pasture
P99	medium	none	discrete	2.5	North	Pasture
P100	small	none	spread	1	North	Pasture
P101	medium	none	discrete	2.5	North	Pasture
P102	medium	moderate	spread	2	North	Pasture
P103	large	moderate	spread	3	North	Pasture
P104	small	moderate	discrete	0.5	North	Pasture
P106	large	moderate	spread	3	North	Pasture
P109	small	moderate	discrete	3.5	North	Pasture
P110	medium	moderate	discrete	3	North	Pasture
P111	small	moderate	spread	2	North	Pasture
P112	medium	lots	spread	3	North	Pasture
P113	medium	lots	discrete	2.5	North	Pasture
P114	large	moderate	discrete	2.5	North	Pasture
P152	medium	moderate	spread	2.5	North	Pasture
P800	large	lots	spread	2	North	Pasture
Area 3						

Rock #	Size	Vegetation	Structure	Height	Area	Matrix
T119	medium	none	discrete	2	South	Tussock
T120	large	moderate	spread	3.5	South	Tussock
T122	large	moderate	spread	4	South	Tussock
T123	medium	moderate	discrete	3	South	Tussock
T124	medium	moderate	spread	2	South	Tussock
T125	medium	moderate	spread	1.5	South	Tussock
T1250	medium	none	discrete	2	South	Tussock
T126	small	lots	discrete	1.5	South	Tussock
T127	large	moderate	spread	5	South	Tussock
T128	large	lots	spread	1.5	South	Tussock
T129	large	moderate	spread	4	South	Tussock
T130	medium	moderate	spread	3	South	Tussock
T132	medium	moderate	discrete	4	South	Tussock
T133	medium	moderate	spread	3	South	Tussock
T135	small	moderate	discrete	1.5	South	Tussock
T136	small	moderate	discrete	1.5	South	Tussock
T137	medium	moderate	spread	2	South	Tussock
T171	medium	moderate	discrete	3	South	Tussock
T172	large	moderate	discrete	6	South	Tussock
T173	large	moderate	discrete	5	South	Tussock
T174	large	moderate	discrete	6	South	Tussock
T175	large	lots	discrete	6	South	Tussock
T176	large	moderate	discrete	5	South	Tussock
T178	medium	moderate	discrete	3	South	Tussock
T179	large	moderate	spread	2.5	South	Tussock
T1790	small	none	discrete	1.5	South	Tussock
T180	large	lots	discrete	4	South	Tussock
T181	large	lots	discrete	4	South	Tussock
T182	small	lots	discrete	1	South	Tussock
T183	small	lots	discrete	2	South	Tussock
T184	large	none	discrete	4	South	Tussock
T185	large	moderate	discrete	5	South	Tussock
T186	large	none	spread	3	South	Tussock
T187	medium	none	spread	2.5	South	Tussock
T188	large	moderate	spread	2.5	South	Tussock
T189/190	large	moderate	spread	3	South	Tussock
T102/103	large	moderate	spread	4	South	Tussock
T104	medium	moderate	discrete	3	South	Tussock
T105	small	lots	discrete	2	South	Tussock
T106	medium	moderate	discrete	2	South	Tussock
T107	small	none	spread	1.5	South	Tussock

T108	large	lots	discrete	4	South	Tussock
T109	small	none	spread	2	South	Tussock
T110	medium	none	discrete	3	South	Tussock
T111	small	moderate	discrete	1.5	South	Tussock
T112	small	none	discrete	2	South	Tussock
T113	medium	moderate	spread	3	South	Tussock
T114	medium	moderate	spread	2	South	Tussock
T115	medium	lots	spread	3	South	Tussock
T116	medium	moderate	spread	2	South	Tussock
T117	medium	moderate	spread	0.3	South	Tussock
T118	large	moderate	spread	3	South	Tussock
T134	large	none	spread	4	South	Tussock
T138	medium	moderate	spread	5	South	Tussock
T139	large	moderate	discrete	4.5	South	Tussock
T140	medium	moderate	discrete	3.5	South	Tussock
T141	medium	none	discrete	3.5	South	Tussock
T142	medium	lots	spread	1	South	Tussock
T144	medium	moderate	spread	1	South	Tussock
T1440	medium	moderate	discrete	3	South	Tussock
T145	medium	none	spread	1.5	South	Tussock
T146	medium	none	discrete	2.5	South	Tussock
T147	medium	none	discrete	2	South	Tussock
T148	large	moderate	discrete	3	South	Tussock
T149	small	moderate	spread	0.3	South	Tussock
T150	medium	moderate	spread	2	South	Tussock
T151	small	moderate	spread	1.2	South	Tussock
T152	small	none	discrete	2.5	South	Tussock
T153	small	moderate	spread	1.8	South	Tussock
T154	small	none	spread	0.4	South	Tussock
T155/160	small	moderate	spread	1.5	South	Tussock
T156	small	none	discrete	1.2	South	Tussock
T157	small	lots	spread	2	South	Tussock
T158	medium	moderate	spread	3	South	Tussock
T161	medium	moderate	discrete	3.5	South	Tussock
T162	small	moderate	spread	1.5	South	Tussock
T163	medium	lots	spread	1.5	South	Tussock
T164	medium	moderate	discrete	3.5	South	Tussock
T165	medium	moderate	spread	2	South	Tussock
T166	small	none	spread	0.5	South	Tussock
T167	large	moderate	spread	2.5	South	Tussock
T168	medium	moderate	discrete	4	South	Tussock
T169	small	moderate	spread	1	South	Tussock

T170	small	moderate	discrete	2.5	South	Tussock
T177	small	none	spread	0.5	South	Tussock
T195	large	moderate	spread	5	South	Tussock
T196	medium	moderate	spread	1.2	South	Tussock
T197	medium	moderate	spread	2	South	Tussock
T198	small	lots	spread	1	South	Tussock
T1410	large	moderate	discrete	4	South	Tussock
T1540	small	moderate	spread	2	South	Tussock
T1670	small	none	spread	1.7	South	Tussock
Area 4						
Rock #	**Size**	**Vegetation**	**Structure**	**Height**	**Area**	**Matrix**
T41	medium	moderate	spread	2	North	Tussock
T42	medium	lots	spread	4	North	Tussock
T43	large	lots	spread	4	North	Tussock
T430	medium	moderate	spread	1.5	North	Tussock
T431	small	moderate	discrete	2.5	North	Tussock
T44	medium	moderate	spread	3	North	Tussock
T45	large	moderate	spread	4	North	Tussock
T46	large	moderate	spread	4	North	Tussock
T47	medium	lots	discrete	2	North	Tussock
T48	medium	moderate	discrete	3.5	North	Tussock
T50	medium	moderate	discrete	2	North	Tussock
T51	small	none	spread	1	North	Tussock
T52	medium	moderate	discrete	3	North	Tussock
T53	medium	moderate	spread	3.5	North	Tussock
T54	small	moderate	discrete	1.5	North	Tussock
T55	small	moderate	discrete	6	North	Tussock
T56	large	moderate	spread	3	North	Tussock
T57	small	none	discrete	2	North	Tussock
T58	small	lots	spread	0.5	North	Tussock
T59	small	moderate	spread	3	North	Tussock
T67	small	lots	spread	1	North	Tussock
T69	large	none	spread	2	North	Tussock
T70	medium	none	spread	6	North	Tussock
T73	large	moderate	spread	4	North	Tussock
T77/78	large	moderate	spread	2	North	Tussock
T80	medium	moderate	spread	2.5	North	Tussock
T205	medium	moderate	spread	3	North	Tussock
T206	small	moderate	spread	1.5	North	Tussock
T207	medium	lots	discrete	2	North	Tussock
T440	large	lots	discrete	5	North	Tussock
T204	large	none	spread	4	North	Tussock

T2070	small	lots	discrete	1.5	North	Tussock
T9	medium	moderate	spread	2.5	North	Tussock
T10	large	moderate	spread	2.5	North	Tussock
T11	large	moderate	spread	2.5	North	Tussock
T12	medium	lots	spread	2	North	Tussock
T85	large	moderate	spread	5	North	Tussock
T86	small	none	discrete	5	North	Tussock
T87	small	lots	discrete	3	North	Tussock
T88	small	none	discrete	1.5	North	Tussock
T89	large	lots	spread	6	North	Tussock
T890	small	moderate	spread	1.5	North	Tussock
T95	medium	moderate	discrete	3	North	Tussock
T96	small	moderate	spread	2	North	Tussock
T97	large	moderate	spread	6	North	Tussock
T98	small	moderate	spread	4	North	Tussock
T99	medium	none	discrete	4	North	Tussock
T100	medium	moderate	spread	2.5	North	Tussock
T101	large	moderate	spread	3	North	Tussock
T192	small	none	discrete	2	North	Tussock
T193	small	moderate	spread	1	North	Tussock
T194	small	moderate	spread	2	North	Tussock
T16	medium	lots	spread	2	North	Tussock
T17	large	moderate	spread	2.5	North	Tussock
T18	medium	lots	spread	1.5	North	Tussock
T19	medium	none	discrete	5	North	Tussock
T20	medium	moderate	discrete	3	North	Tussock
T21	small	moderate	spread	0.5	North	Tussock
T24	small	moderate	discrete	2	North	Tussock
T240	medium	lots	discrete	2	North	Tussock
T25	medium	moderate	spread	1.5	North	Tussock
T26	small	moderate	spread	1	North	Tussock
T27	small	moderate	spread	1	North	Tussock
T270	small	moderate	discrete	1.5	North	Tussock
T28	medium	moderate	spread	2	North	Tussock
T29	small	moderate	discrete	1.5	North	Tussock
T30	medium	moderate	spread	2	North	Tussock
T31	medium	moderate	spread	3	North	Tussock
T71	small	moderate	spread	3	North	Tussock
T72	medium	lots	spread	3	North	Tussock
T74	small	none	discrete	1	North	Tussock
T75	medium	moderate	spread	1.5	North	Tussock
T76	small	none	spread	2	North	Tussock

T79	small	moderate	spread	1	North	Tussock
T81	small	moderate	spread	0.5	North	Tussock
T82	medium	none	spread	3	North	Tussock
T83	small	moderate	spread	0.5	North	Tussock
T84	large	moderate	spread	3	North	Tussock
T1701	small	lots	spread	1	North	Tussock
T1700	medium	lots	discrete	1.5	North	Tussock
T1702	large	lots	discrete	2.5	North	Tussock
T90	medium	lots	discrete	2.5	North	Tussock

Appendix B: Presence/Absence Data

Area 1				
Rock #	**Survey 1**	**Survey 2**	**Survey 3**	**Survey 4**
P117	0	0	0	1
P118	0	0	0	0
P119	0	0	0	1
P120	0	0	0	1
P122	1	0	0	0
P123	0	0	0	0
P125	0	0	0	0
P126	0	0	1	0
P127	0	1	1	0
P128	1	0	1	1
P131	0	0	1	0
P132	0	1	1	1
P133	0	0	0	0
P134	0	1	1	1
P136	1	1	1	1
P137	1	1	1	0
P139	0	0	0	0
P140	0	0	0	0
P141	0	0	0	0
P142	0	0	0	0
P143	0	0	0	0
P144/163	0	0	0	0
P145	1	1	1	0
P146	0	1	1	0
P147	1	1	1	1
P148	0	0	0	0
P151	0	1	1	0
P154	1	1	1	1
P1540	0	0	0	0
P156	0	0	0	0
P159	1	1	0	1
P174	0	0	0	0
P1280	0	0	0	0
P1370	0	0	0	0
P1500	0	0	0	0
P149	1	1	1	1
P150	1	1	1	1

P153	0	1	1	0
P157	0	0	0	0
P160	0	0	0	0
P161	0	0	0	0
P162	0	0	0	0
P164	0	0	0	0
P165	0	0	0	0
P166	0	0	0	0
P167	0	0	0	0
P168	0	0	0	0
P169	0	0	0	0
P170	0	0	0	0
P171	1	1	0	1
P172	1	1	0	0
P173	1	0	1	1
Area 2				
Rock #	**Survey 1**	**Survey 2**	**Survey 3**	**Survey 4**
P40	0	0	0	0
P41	0	0	0	0
P42	0	0	0	0
P43	0	0	0	0
P49	0	0	0	0
P51	0	0	0	0
P52	0	0	0	0
P53	0	0	0	0
P54	0	0	0	0
P55	0	0	0	0
P56	0	0	0	0
P57	0	0	0	0
P58	0	0	0	0
P59	0	0	0	0
P60	0	0	0	0
P61	0	0	0	0
P62	1	0	1	0
P63	0	0	0	0
P64	0	0	0	0
P65	0	0	0	0
P66	0	0	0	0
P67	0	0	0	0
P68	0	0	0	0
P69	0	0	0	0
P70	0	0	0	0

P71	0	1	0	0
P72	1	1	0	1
P73	1	1	1	0
P74	0	0	0	0
P75	0	0	0	0
P76	0	0	0	0
P81	0	0	0	0
P82	0	0	0	0
P77	0	0	0	0
P78	0	0	0	0
P79	0	0	0	0
P80	0	0	0	0
P800	0	0	0	0
P83	0	0	0	0
P85	0	0	0	0
P86	0	0	0	0
P87	0	0	0	0
P88	0	0	0	0
P90	0	0	0	0
P91	0	0	0	0
P92	0	0	0	0
P93	0	0	0	0
P94	0	0	1	0
P95	0	0	0	0
P96	0	0	0	0
P97	0	0	0	0
P98	0	0	0	0
P99	0	1	0	0
P100	0	0	0	0
P101	0	0	0	0
P102	0	0	0	0
P103	0	1	0	1
P104	0	0	0	0
P106	0	0	0	0
P109	0	0	0	0
P110	0	0	0	0
P111	0	0	0	0
P112	0	0	0	0
P113	0	0	0	0
P114	0	0	0	0
P152	0	0	0	0
Area 3				

Rock #	Survey 1	Survey 2	Survey 3	Survey 4
T119	1	1	1	1
T120	1	1	1	1
T122	0	0	1	1
T123	1	1	1	1
T124	0	1	1	0
T125	1	1	1	1
T1250	1	1	1	1
T126	1	1	1	1
T127	1	1	1	1
T128	1	0	1	1
T129	0	0	1	0
T130	1	1	1	1
T132	1	1	1	1
T133	0	0	0	1
T135	0	0	0	0
T136	0	0	0	0
T137	0	1	1	1
T171	0	0	0	0
T172	1	1	1	1
T173	1	1	1	1
T174	1	1	1	1
T175	1	1	1	1
T176	1	1	1	1
T178	1	1	1	1
T179	1	1	1	1
T1790	0	0	0	0
T180	1	1	1	1
T181	0	1	0	1
T182	0	0	0	0
T183	0	0	0	0
T184	1	1	1	1
T185	1	1	1	0
T186	1	1	1	1
T187	1	1	1	1
T188	1	1	1	0
T189/190	1	1	1	1
T102/103	0	0	0	0
T104	1	1	1	1
T105	1	0	0	1
T106	1	1	1	1
T107	1	1	0	1

T108	0	1	1	1
T109	0	0	0	0
T110	0	0	0	0
T111	0	0	0	0
T112	0	0	0	0
T113	0	1	1	1
T114	0	0	0	1
T115	1	0	1	1
T116	0	0	0	0
T117	0	1	0	0
T118	0	0	0	0
T134	0	0	1	0
T138	1	0	1	0
T139	1	1	1	1
T140	1	0	1	1
T141	0	0	0	0
T142	0	0	0	0
T144	0	0	0	0
T1440	1	1	1	0
T145	0	0	0	0
T146	1	1	0	0
T147	0	0	0	0
T148	1	1	1	1
T149	0	0	0	0
T150	0	0	0	1
T151	0	0	0	0
T152	0	0	0	0
T153	0	0	0	0
T154	0	0	0	0
T155/160	0	0	0	0
T156	0	0	0	0
T157	0	0	0	0
T158	1	1	1	1
T161	0	0	0	0
T162	0	0	0	0
T163	0	0	1	1
T164	1	0	1	1
T165	0	0	0	0
T166	0	0	0	1
T167	1	1	1	1
T168	1	0	1	1
T169	0	0	0	0

T170	0	0	0	0
T177	0	0	0	0
T195	0	0	0	0
T196	1	0	0	1
T197	1	0	0	1
T198	0	1	1	1
T1410	0	1	1	1
T1540	0	0	0	0
T1670	0	0	0	0
Area 4				
Rock #	**Survey 1**	**Survey 2**	**Survey 3**	**Survey 4**
T41	0	0	0	0
T42	0	0	0	0
T43	1	0	0	0
T430	0	0	0	0
T431	0	0	0	0
T44	1	0	0	0
T45	0	0	0	0
T46	1	1	1	1
T47	1	1	1	1
T48	0	0	0	0
T50	0	0	0	0
T51	0	0	0	0
T52	0	0	0	0
T53	0	0	1	1
T54	0	0	0	0
T55	0	1	1	1
T56	1	1	1	0
T57	0	0	0	0
T58	0	0	0	0
T59	0	1	1	0
T67	0	0	1	0
T69	0	0	0	0
T70	0	0	0	0
T73	1	1	1	1
T77/78	0	0	0	0
T80	1	1	1	0
T205	1	1	0	0
T206	0	0	0	0
T207	1	1	1	0
T440	0	0	1	0
T204	1	0	1	1

T2070	0	0	0	1
T9	0	0	0	0
T10	0	1	1	0
T11	0	0	0	0
T12	0	0	0	0
T16	0	0	0	0
T17	0	1	1	0
T1700	0	0	0	0
T1701	0	0	0	0
T1702	0	0	0	0
T18	0	0	0	0
T19	1	1	1	0
T20	0	0	0	0
T21	0	0	0	0
T24	0	0	0	0
T240	0	0	0	0
T25	0	0	0	0
T26	0	0	0	0
T27	0	0	0	0
T270	0	0	0	0
T28	0	0	0	0
T29	0	0	0	0
T30	0	0	0	0
T31	0	0	1	0
T71	1	1	0	1
T72	0	0	0	1
T74	0	0	0	0
T75	0	1	1	0
T76	0	0	0	0
T79	0	0	0	0
T81	0	0	0	0
T82	0	0	0	0
T83	0	0	0	0
T84	0	0	1	0
T85	1	1	0	0
T86	0	0	0	0
T87	0	0	0	0
T88	0	0	0	0
T89	1	1	1	1
T890	0	0	0	0
T90	0	0	0	1
T95	0	0	0	0

T96	1	1	1	1
T97	1	1	1	1
T98	0	0	0	1
T99	0	0	1	0
T100	0	0	1	0
T101	1	1	1	1
T192	1	0	0	0
T193	0	0	0	0
T194	0	0	0	0