Response of Western Skinks to Ecosystem Restoration at Fox Tree Hill

2008 Progress Report

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1.0 Introduction

The Western Skink (*Eumeces skiltonianus*) is a small lizard species that inhabits open warm habitats in the southwest Kootenay region (Dulisse 2004, 2005). The species is federally listed as a species of concern (COSEWIC 2007) and are blue-listed in British Columbia (CDC 2008). Western skinks are commonly found in the hottest and driest micro-habitats of the region. This habitat usually consists of rocky, sparsely treed sites with under storey shrubs. The suppression of forest fires has likely resulted in a loss of skink habitat due to forest in growth and encroachment on these open sites (Dulisse 2005). Forest in-growth decreases the quality of existing skink habitat and may isolate skink populations due to their poor dispersal abilities (Rutherford and Gregory 2001). The goal of this project is to measure the response of a local western skink population to ecosystem restoration (ER) treatments (forest thinning) designed to improve habitat quality and connectivity for this species. The results of the project will be used to restore habitat for skinks and help maintain and recover their populations in the Kootenay region. ER efforts will also benefit other species dependent on fire-maintained ecosystems (e.g. Common Nighthawks).

The goal of this project is to determine if western skink abundance and distribution change following habitat restoration. Population parameters and habitat conditions will be measured before and after treatment at treated and control sites to determine if populations respond to ER treatment. This will be done using occupancy models (MacKenzie et al. 2002, MacKenzie et al. 2006) in program MARK (White et al. 1999) in a robust design analysis that combines yearly survey data to estimate trends between years. This analysis will allow the estimate of occupancy, extinction and colonization rates of skinks in response to treatment of the areas using pre and post treatment data.

2.0 Methods

2.1 Study Area

Skink sampling and habitat restoration treatments are being conducted at the Fox Tree Hill study area south of Creston (Figure 1). The objective of ER at Fox Tree Hill is to reduce encroaching conifers and maintain the open structure of the site. The 8.0 ha treatment occurs in the ICHxw (Interior Cedar Hemlock very dry, warm variant) on Crown Land (Part of Block A, Section 13, Township 7) immediately west of the Creston Airport. The site is an excellent representation of this ecosystem and is relatively free of invasive plants.

2.2 Data Collection

Sample Stations

Twenty-four skink sampling stations were established within the treatment area and 24 sample stations were established in an adjacent control (untreated) area (Figure 1). In the spring of 2007, two plywood and two concrete patio stone artificial cover objects (ACOs) were placed at each sample point (Photos 1 & 2). ACO's measured 30cm square and were placed within 5.5 m of the station centre points. Placement depended on micro-topography (i.e. the ACO's need to be quite tight to the ground so suitable skink habitat develops underneath) and presence of proximal natural cover objects (generally, ACO's were placed near natural cover objects).

Timing and Frequency of Sampling

Surveys occurred from 5-8 June 2007 (3 sessions), 4-6 September 2007 (3 sessions), 12-16 May 2008 (5 sessions) and 6-13 June 2008 (5 sessions) (Table 1).

Table 1. Summary of sampling sessions.

Primary session	Year	Dates	Secondary Sessions	Interval[1] (days)
1	2007	June 5-8,	3	
2	2007	Sept 4-6	3	88
3	2008	May 12-16	5	249
4	2008	June 6-13	5	21

[1]Days between current and previous primary session

Effort-constrained searches of 20 natural cover objects (NCOs) were also conducted at each point within a 20 m radius of each plot.

Because of low capture rates in September 2007, we sampled earlier in the 2008 season. In 2008, each station was sampled five times during each primary sampling session (Table 1).

Data Collected

Appendix 1 summarises the type data collected at each station and skink capture. Ground and air temperature was measured during sampling to use as a temporal covariate in occupancy analyses. Temperature measurements from data loggers (see below) will be analysed in the future. In addition, vegetation plots were conducted at sites to obtain covariates for each site. Slope, proportion bedrock and loose rock were measured. In addition A layer (tree layer including all woody plants greater than 10m tall), B (shrub layer including all woody plants from 15cm-10m tall), and C layer (herb layer including all herbaceous species and woody plants less than 15cm tall) vegetation characteristics were measured.

Temperature Data Loggers

In addition to measuring gound and air temperatures at each plot during sampling, we have deployed data loggers throughout the site for more detailed future analysis. In 2007, two I-button temperature loggers were placed at each plot (one under a plywood ACO and one under a concrete ACO) to record temperature fluctuations for the duration of the 2007 season. The I-button temperature loggers were not available for the 2008 season so HOBO Pro high-resolution temperature and relative humidity dataloggers (Onset Computer Corporation, Bourne, MA) were deployed on site. (How many and where?)

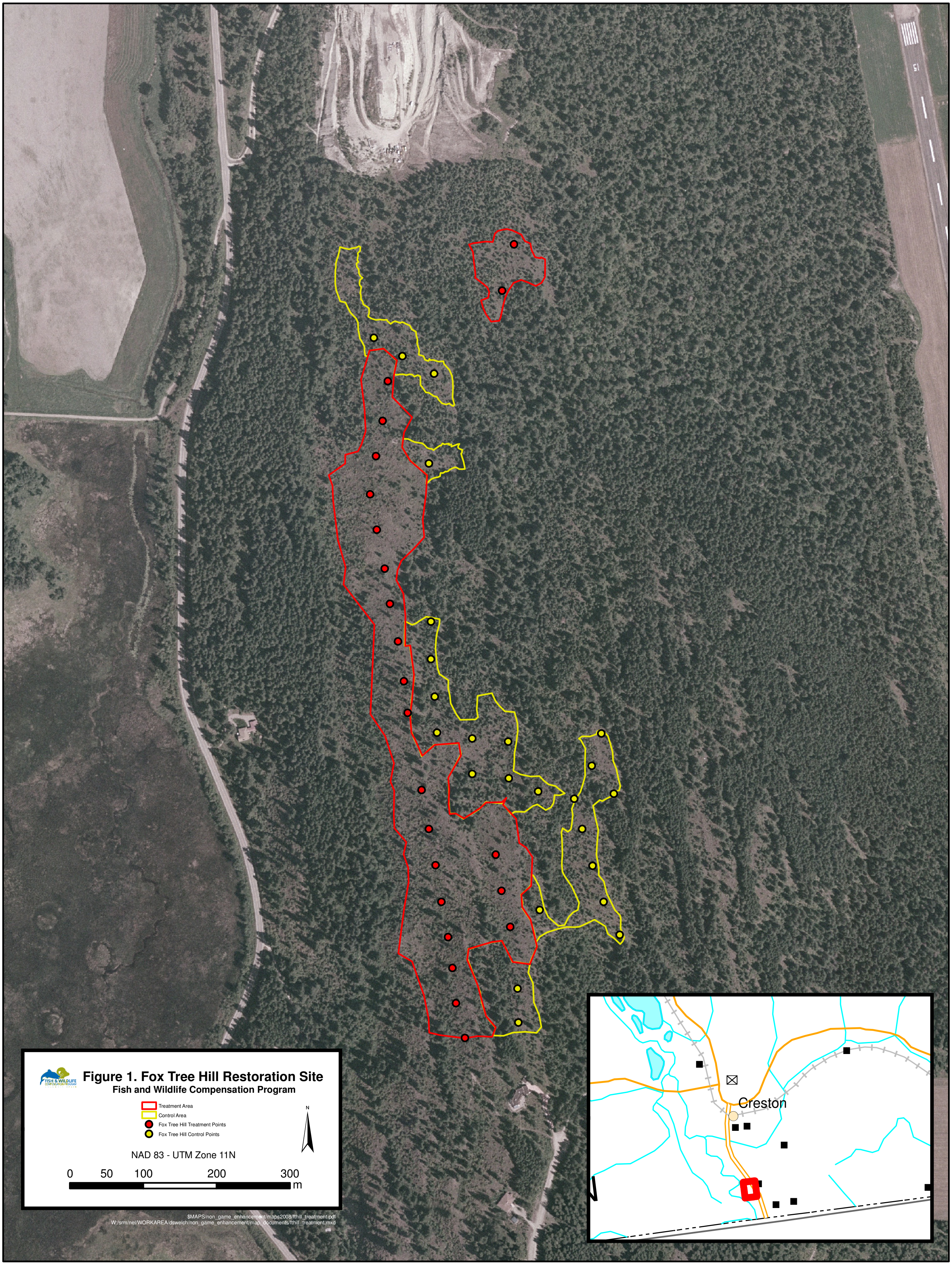

Figure 1. Fox Tree Hill Restoration Site

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Skink Capture and Marking

Cover object searches were completed as described in Dulisse (2004, 2005). We attempted to capture all western skinks found under ACOs and NCOs. All procedures followed guidelines recommended for the capture and handling of reptiles (MELP 1998, CCAC 2006). The location of all skink captures were recorded (Station and ACO #). All skink sign (guano and or exuvia) was recorded and cleared from under cover objects. Exuvia were kept for potential future genetic analysis.

Captured skinks were handled briefly at the capture site to collect basic information on size weight, and age class. Ziploc bags were used to contain lizards for the measurements. In 2007, permanent marking was attempted to allow us to measure detailed population parameters such as survival, and immigration and determine the cause of any changes in the population. We tested the Visible Implant Elastomer (VIE) technique on several individuals. In this method, a colored silicone material is injected under the skin using a sterile 28 gauge needle (NWT 2006), where it is intended to be visible externally. VIE tags are recognized as the least invasive method to permanently mark individual lizards (Penney et al. 2001). The study warrants the use of permanent marks because the information gained from their use will benefit skink populations throughout their range.

Photo recognition marking techniques will also tested during this study. Hopefully, this non-invasive marking method can be developed and used on western skinks in the future. Detailed macro photos of the top of the head and bottom of a rear foot were taken and will be compared with future capture photos to determine if the method is successful.

2.3 Data Analysis

Estimation of Occupancy

A robust design occupancy model (MacKenzie et al. 2003) as implemented in program MARK (White and Burnham 1999) was used to analyze the data. This model estimates the probability of occupancy (ψ) and the probability of detection (p) based on the repeated sampling of plots at close time intervals using methods that are very similar to the estimation of population size from mark-recapture surveys (Boulanger et al. 2008). In addition, the probability that sites would be colonized (symbolized as γ) or would become extinct (symbolized as ε) is estimated by considering changes in occupancy that occur between seasonal surveys. Using this information, the annual rate of change in occupancy (λ) is also estimated as a derived parameter. Probability of colonization and annual rate of change was expressed on a yearly scale rather than on the uneven time intervals between surveys.

In robust design terminology, the closely spaced sessions that occur each season (i.e. June 5-8, 2007) are termed *secondary sessions* and the seasonal surveys (i.e; June 2007, September 2007, May 2008, and June 2008) are termed *primary sessions* (MacKenzie et al. 2002, MacKenzie et al. 2006).

In addition to estimates of occupancy and trends in occupancy we were interested if there were any associations between occupancy, detection probability, and habitat and temporal covariates. For example, a prime assumption of the experiment is that vegetation layers may inhibit occupancy of some sites by shading rock areas and therefore limiting the thermal suitability of the area for skinks. In addition, it was potentially likely that the amount of bedrock or loose rock may influence both the probability of occupancy but also the likelihood of detecting skinks. For example, an area with a lot of loose rock may have higher occupancy but may also have lower detection probabilities if the skinks have more areas to inhabit making it less likely that all habitats are searched during effort-constrained searches.

We therefore introduced models that considered biological-based associations and compared their relative fit to models without covariates or models that assumed general differences between treatment and control areas. Models were evaluated using the sample-size-corrected Akaike Information Criterion (AICc) index of model fit. The model with the lowest AICc score was considered the most parsimonious, thus optimizing the trade-off between bias and precision (Burnham and Anderson 1998). The difference between any given model and the most supported (ΔAICc) was used to evaluate the relative fit of models when their AICc scores were close. In general, any model with an ΔAICc score of ≤ 2 was most supported by the data. Relative importance of models was evaluated using Akaike weights (w_i) which is the proportional support of a model when compared to other candidate models. When applicable, estimates from models were model-averaged with a models contribution to an estimate based on its Akaike weight.

Count-based Abundance

Occupancy models potentially lose valuable information by only considering presence or absence of skinks at plots while ignoring information for sites that detected more than 1 skink. We therefore also conducted an analysis that considered counts of skinks at a site each session rather than just presence (as used for occupancy models). These models estimate the number of skinks at a plot and the probability of detecting at least one skink at a given plot (r). Detection probability (similar to occupancy models) relates to r as $p=1-(1-r)^N$ where N is the population size of skinks at the plot. N is assumed to follow a Poisson distribution with a mean of λ. So the parameters that are estimated by this model are λ (the Poisson mean) and r (Royle 2004). These parameters cannot vary temporally (like p in occupancy models) and this model is not available as a robust design. In addition, it is more difficult to accommodate data sets of varying sessions. Therefore only data from 2008 was considered for this analysis and each of the primary sessions was entered as a group rather than in a robust design framework. The same general tests were conducted as the occupancy models.

3.0 Results

3.1 Data Collection

Skink Sampling

A total of 282 western skink (204 captures and 78 escapes) observations were recorded over the 2007 and 2008 sampling session (Tables 2 & 3). Only 52 skink detections (36 captures and 16 escapes) were recorded in 2007 compared to 230 detections (168 captures and 62 escapes) in 2008. The higher numbers of observations this season are likely attributed to greater sampling effort (6 secondary sessions for 2007 vs. 10 secondary sessions for 2008) and earlier seasonal sampling periods. Skinks were found in the open (active) 16 times (5.7%), under artificial cover objects 58 times (20.6%) and under natural cover objects rocks) 208 times (73.8%).

Table 2. Western skink observations by activity, 2007-2008: Active (in the open), ACO (under artificial cover object), NCO (under natural cover object).

Primary Session	Secondary Session	Active	ACO	NCO	Totals
June 2007	1	0	1	10	11
	2	0	0	13	13
	3	1	2	12	15
Sept 2007	1	1	1	4	6
	2	0	1	2	3
	3	1	0	3	4
2007 Totals		**3**	**5**	**44**	**52**
May 2008	1	0	5	22	27
	2	0	4	18	22
	3	7	7	11	25
	4	3	6	23	32
	5	1	0	14	15
June 2008	1	0	8	9	17
	2	0	9	16	25
	3	1	6	19	26
	4	1	4	18	23
	5	0	4	14	18
2008 Totals		**13**	**53**	**164**	**230**
Grand Totals		**16**	**58**	**208**	**282**

Table 3. Western skink observations: captures versus escapes.

Primary Session	Secondary Session	Captures	Escapes	Totals
June 2007	1	9	2	11
	2	13	0	13
	3	7	8	15
Sept 2007	1	3	3	6
	2	3	0	3
	3	1	3	4
2007 Totals		**36**	**16**	**52**
May 2008	1	24	3	27
	2	17	5	22
	3	14	11	25
	4	18	14	32
	5	10	5	15
June 2008	1	17	0	17
	2	21	4	25
	3	21	5	26
	4	15	8	23
	5	11	7	18
2008 Totals		**168**	**62**	**230**
Grand Totals		**204**	**78**	**282**

VIE marking was attempted at the start of the 2007 sampling period (Photos 3 & 4) but was discontinued for the following reasons:

- •Many animals were too small to safely inject.
- •Western skink scales are opaque so it was often difficult or impossible to see the implant after injection (Photo 3). Some marked individuals were recaptured and it was often not possible to see the VIE.
- •In many cases, the implant appeared to migrate considerable distances under the skin after injection.

Detailed macro photos were taken of all captured individuals (Photo 5) for future individual recognition. The body locations of distinctive scars, marks, missing toes etc. (Photo 6) were noted for potential use in future individual recognition. Through 2008, photographs have been collected from 175 skink captures. These photos have not yet been analysed to determine if we have had any recaptures.

Sixty-one western skink exuvia have been collected for potential genetic analysis. 2007 I-button data were downloaded for future analysis and the two Hobo Pro dataloggers have not been downloaded yet.

3.2 Data Analysis

Data Summary

The number of detections varied by cover type and by primary session. There were relatively few detections in the first and second primary sessions that occurred in 2007 compared to the third and fourth primary sessions that occurred in 2008. In addition, the majority of detections were associated natural cover objects (NCO) surveyed during effort-constrained searches (Figure 2). Relatively few detections occurred under artificial cover objects (ACO). As a result data from artificial and natural cover objects as well as active sightings was pooled for the analysis.

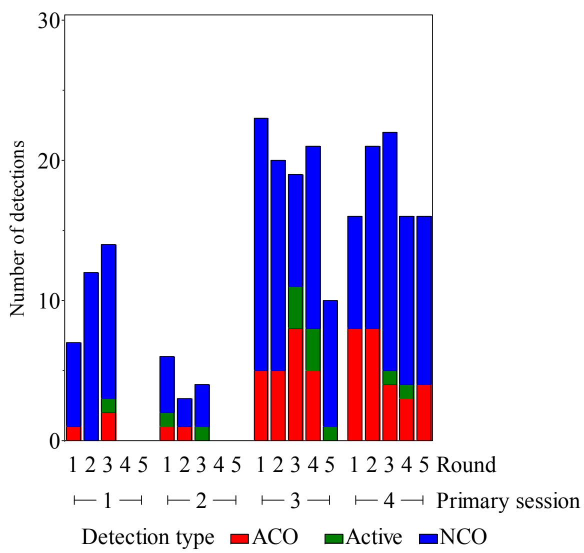

Figure 2. Number of detections per session by detection type. Only one detection per type was counted for each plot and session.

The artificial cover objects detected a higher proportion of juveniles than natural cover objects (Figure 3). To statistically test this we pooled the data for the sessions and used a contingency test to test whether age class capture frequencies were independent of capture type (ACO or NCO). The resulting test suggested that cover object type and age were not independent (χ^2=9.2, df=2, p=0.01). Examination of frequencies suggested that relative percentage of juvenile skinks was higher (41.8%, n=23 skinks) in ACO's when compared with NCO's (22%, n=45 skinks) (Figure 3). A similar test was done that tested whether age class and treatment (control or treatment) were independent. This test was not significant suggesting that control and treatment plots had similar proportions of age classes ((χ^2=1.57, df=2, p=0.45).

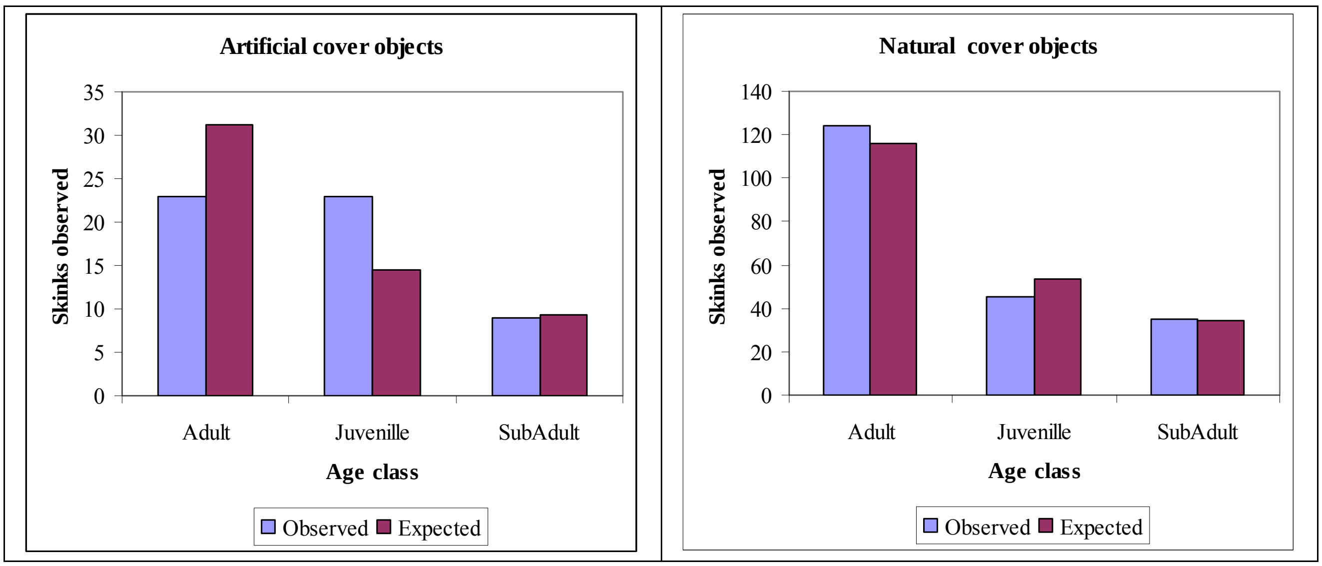

Figure 3: The pooled frequencies of skink age classes observed as a function of cover object type. The observed and expected frequencies (under the assumption of independence of age class and cover object) are shown.

The proportion of sites detecting skinks varied by primary session as well as secondary sessions (Figure 4). In general the proportion of detections were much higher in 2008 (primary sessions 3 and 4), however, there were still low detections in some secondary sessions in 2008. Ground temperature displayed the same general distribution of values across all sessions. Air temperature was correlated with ground temperature so ground temperature (Pearson ρ=0.72, df=586, p<0.0001) was considered mainly in the analysis since this more directly related to skink habitat.

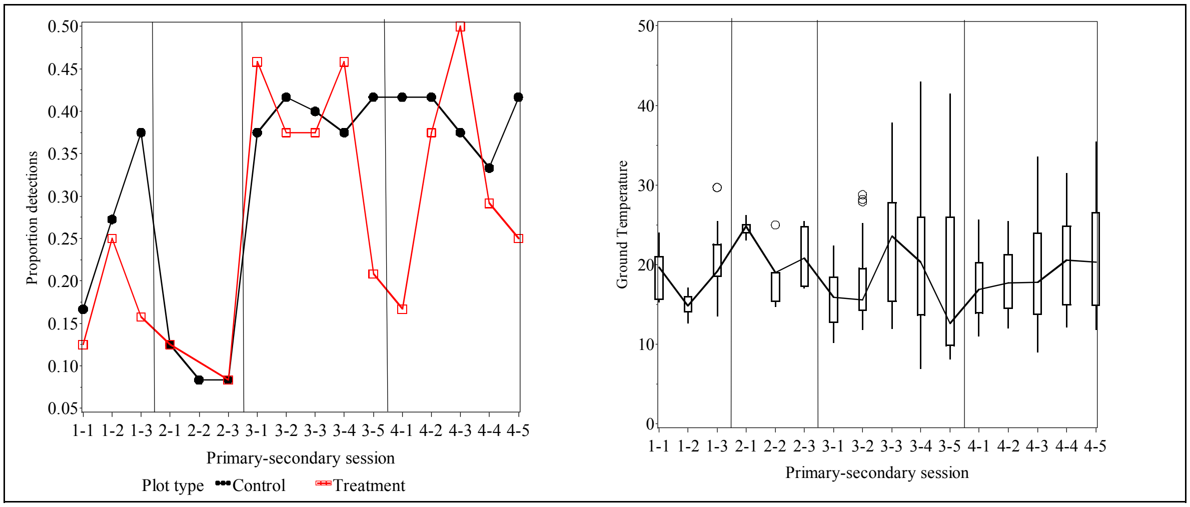

Figure 4. Proportion of sites detecting skinks by primary and secondary sessions (left) and the distribution of ground temperatures by primary and nested secondary sessions (right). The vertical lines denote breaks between primary sessions.

Habitat variables were compared between treatment and control sites. In general, treatment sites were on steeper areas with more loose rock. In addition, control sites had a higher level of B-layer vegetation and a lower amount of C-layer vegetation (Figure 5).

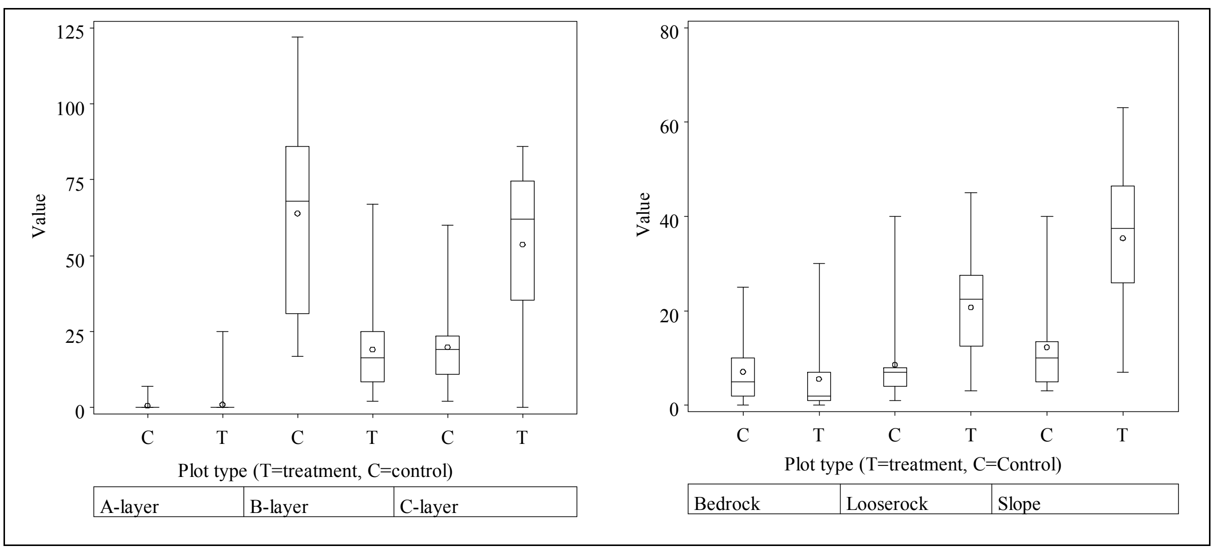

Figure 5. Distribution of habitat covariates for treatment and control plots. The whiskers show the range of interquartile range of the data. Means are denoted by circles and the median is denoted by a horizontal line.

The B1 and B2 layer measurements were highly correlated and therefore these were summarized as a general B-layer variable.

Occupancy Analysis

Occupancy analysis suggested that occupancy was influenced by whether a plot was a treatment or control plot (trt term), by the amount of B-layer vegetation (bl term), and temporally by primary session (as described by a quadratic trend (T^2) in occupancy). In addition, detection probabilities varied by primary session (*ps term) and treatment and control plots (trt term) (Table 4, Model 1). In addition, models that had occupancy varying only in terms of the B-layer only (model 4) or as a function of treatment and B-layer (model 3) were also supported. A model that had detection probabilities influenced by the amount of loose rock (loose term) (model 2) was also supported by the data as indicated by an ΔAICc value of less than 2.

Table 4. Occupancy Robust Design model selection results. Symbols are: trt=treament , T^2=quadratic temporal effect (primary sessions), bl=B-layer, loose=loose rock, ps=primary session, ps_2=model assumed unique value for interval between 2nd and 3rd primary session, gtemp=ground temperature for a given session.

No.	ψ	γ	p	AICc	ΔAICc	wi	K	Deviance
1	trt+T^2+bl	ps_2	*ps+trt	833.40	0.00	0.196	11	809.9
2	trt+ T^2+bl	ps_2	*ps+loose	834.11	0.71	0.137	11	810.6
3	trt+bl	ps_2	*ps+loose	834.39	0.99	0.119	10	813.2
4	bl	*ps	*ps+loose	834.89	1.49	0.093	9	815.9
5	trt+ T^2+bl+loose	ps_2	*ps	835.39	1.99	0.073	11	811.9
6	trt+ T^2+bl	ps_2	*ps	835.48	2.08	0.069	10	814.3
7	T^2+bl	ps_2	*ps+loose	835.52	2.12	0.068	10	814.3
8	trt+ T^2+bl+loose	ps_2	*ps+loose	835.70	2.30	0.062	12	810.0
9	trt+ T^2+bl	ps_2	*ps+loose+gtemp	836.05	2.65	0.052	12	810.3
10	bl	ps_2	*ps+loose+gtemp	836.83	3.43	0.035	10	815.6
11	bl	ps_2+cl	*ps+loose+gtemp	837.34	3.94	0.027	11	813.9
12	T^2+bl	ps_2	*ps+loose+gtemp	837.46	4.06	0.026	11	814.0
13	T^2	*ps	*ps	837.54	4.14	0.025	8	820.8
14	constant	*ps	*ps	838.52	5.12	0.015	8	821.7
15	*ps	*ps	*ps	841.89	8.49	0.003	10	820.7

Model averaged estimates of occupancy from the models in Table 4 revealed that occupancy was relatively constant or slightly increasing whereas detection probabilities varied especially between 2007 and 2008 (Figure 6). Occupancy probabilities were slightly lower for the treatment than the control plots. Detection probabilities were roughly equal for treatment and control plots. This may seem counter to the most supported model. However, the Akaike weight (w_i) of this model was only 0.196 and therefore estimates of other models (that did not assume different treatment and control detection probabilities) moderated the estimates of the most supported model when estimates were model-averaged.

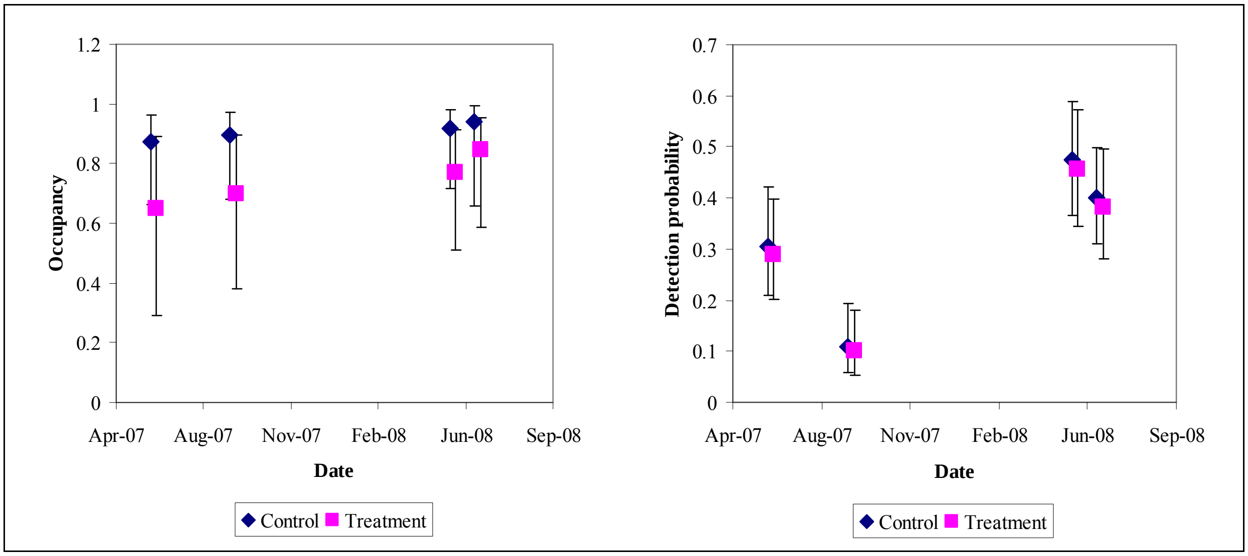

Figure 6. Model averaged estimates of occupancy and detection probability for each primary session. Dates are staggered for primary sessions to ease interpretation. Confidence intervals are also shown.

Model averaged estimates of γ (annual probability of colonization) for the interval between 2007 and 2008 was 0.73 (SE=0.28, CI=0.13-0.98). Model averaged estimates of λ (the rate of change in occupancy between surveys) was 1.03 (SE=0.037, CI=0.96-1.1) for control areas and 1.15 (SE=0.11, CI=0.94-1.37) for treatment plots between 2007 and 2008 suggesting an increase in occupancy especially for treatment areas. This is the only interval of biological interest since the other intervals were relatively short.

Estimates of occupancy as a function of the B-layer revealed a decrease in occupancy as B-layer increased with different intercept values for treatment and control areas (Figure 7). The estimates in Figure 7 are for primary session 2. Plots for other sessions would have similar slopes but the y-intercept values would be different (i.e. Figure 6).

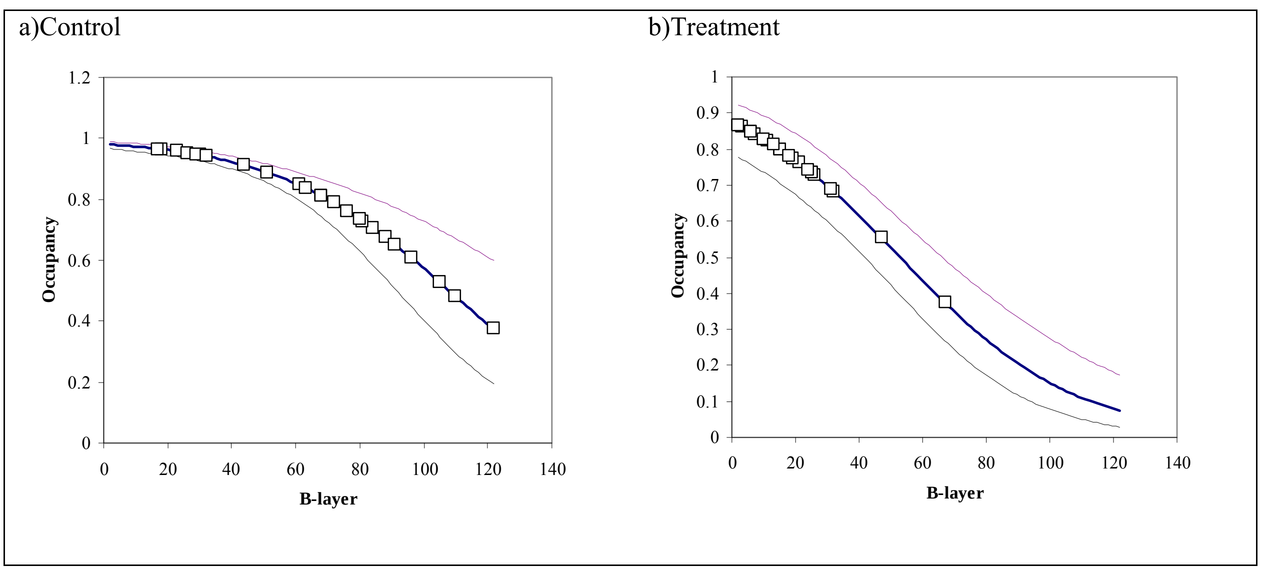

Figure 7. Estimates of occupancy in relation to B-layer for treatment and control plots for primary session 2 (September 2007). The squares are estimates for actual plots. Confidence intervals are also shown.

Estimates of detection probabilities as a function of loose rock were also plotted to explore factors affecting detection probabilities. It can be seen that there was a slight decrease in detection probabilities as a function of loose rock (Figure 8).

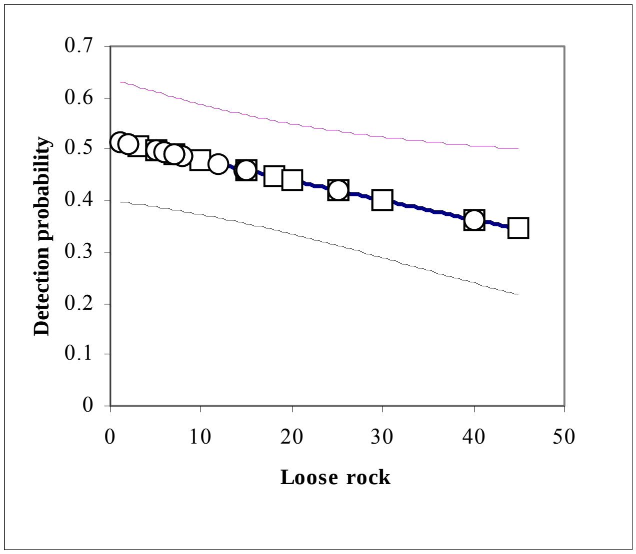

Figure 8. Estimates of detection probability relative to loose rock on plots from Model 2 (Table 2). Estimates are for primary session 2 (secondary session 2). Estimates for plots are shown as squares (treatment) or circles (control).

Count-based abundance analysis

Count based analyses revealed similar associations between vegetation layers and skink occupancy/abundance. Namely, mean abundance on plots (λ) was most associated with the B-layer and detection (*r*) was most associated with treatment or control plots (Table 4, model 1). Also supported was models that had detection associated with loose rock (model 2).

Table 5. Model selection for Royle (2004) count-based abundance analysis.

no	*r*	λ	AICc	ΔAICc	w_i	K	Deviance
1	trt	bl	763.06	0.00	0.348	4	754.6
2	trt+loose	bl	763.17	0.11	0.329	5	752.4
3	trt	Trt+ bl	764.68	1.63	0.154	5	753.9
4	loose	bl	767.20	4.14	0.044	4	758.7
5	constant	constant	769.14	6.08	0.017	2	765.0
6	constant	bl	769.47	6.41	0.014	3	763.2
7	ps	constant	769.82	6.77	0.012	3	763.5
8	al	bl	769.90	6.84	0.011	4	761.4
9	bed	bl	770.05	6.99	0.011	4	761.5
10	constant	cl	770.08	7.02	0.010	3	763.8
11	constant	ps	770.40	7.34	0.009	3	764.1
12	constant	trt	770.78	7.72	0.007	3	764.5
13	constant	slope	770.98	7.92	0.007	3	764.7
14	constant	bed	771.01	7.95	0.007	3	764.7
15	bl	bl	771.06	8.01	0.006	4	762.6
16	constant	al	771.20	8.14	0.006	3	764.9
17	cl	bl	771.67	8.61	0.005	4	763.2
18	ps	ps	771.91	8.86	0.004	4	763.4

A plot of mean abundance also suggests a decrease in abundance as a function of the B-layer (Figure 9). A weak trend is also shown when raw counts are overlaid on model predictions. The trend is strongest for the control plots that exhibit a greater range of mean counts compared to treatment plots. In general, model estimates are higher than mean counts. This makes sense given that estimates of λ are of actual abundance (accounting for detection probabilities) whereas mean counts are observed counts (and may be negatively biased).

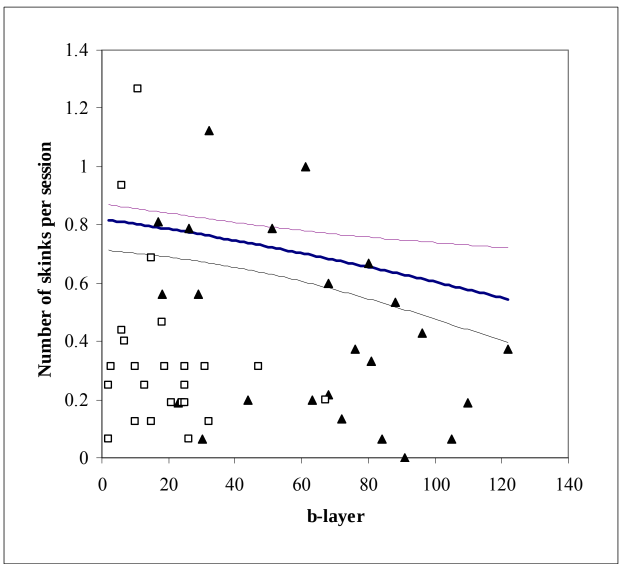

Figure 9: Estimates of relative abundance of skinks as a function of B-layer. Mean abundances for plots are shown as data points. Triangles are control plots and squares are treatment plots.

4.0 Discussion

This study illustrates the utility of occupancy modelling to estimate not just occupancy but trends in occupancy and associations of occupancy with habitat covariates. Plots of the raw data illustrate that the actual proportion of plots that detected skinks was quite variable throughout the study (Figure 3). Naïve interpretation of a single survey or even a set of surveys (i.e. primary session 2) might lead to the conclusion that occupancy is low. However, by replicating surveys and considering surveys over a long time interval it is evident that detection of skinks varies the most and not occupancy at sites. It is suspected that seasonal factors as well as site covariates influence both occupancy and detection probabilities of skinks.

Estimates of colonization 0.73 (SE=0.28, CI=0.13-0.98) suggest that there was some movement of skinks into plots in the interval between 2007 and 2008. In general, occupancy increased especially from 2007 and 2008 especially for treatment sites which was presumably due to emigration or birth of skinks. It may be possible to further determine the mechanisms for increase through the interpretation of individual skinks using individual markings.

The most supported occupancy model (Table 4) included a treatment term for both occupancy and detection probability. This suggests that factors beyond other covariates such as B-layer or loose rock are affecting these parameters. Other potential factors affecting occupancy may be distance of sites to other areas of suitable habitat or interspersion of sites. For example, a site that is surrounded by unsuitable habitat may show very different dynamics as a site in a mosaic of other habitat types. It should be possible to consider multiple scales when modelling factors influencing occupancy rates at sites. It may also be possible that some areas are source whereas other areas are sink areas. A few more years of data should help refine extinction and colonization estimates to further assess this trend.

The large degree of temporal variation in detection probabilities suggests a strong seasonality component to skink detection. It is likely that some skinks may have been less active during some of the surveys in 2007. It looks like this is not directly related to actual temperature during the survey but may be controlled by a broader seasonal component. It may be possible to consider weather/temperature preceding surveys to better describe this component of temporal variation in detection probabilities.

This analysis primarily considered trends in occupancy based upon presence or absence or counts of skinks at sites. The occupancy model allowed the most inference regarding temporal trends as well as estimation of colonization and extinction rates. In contrast, the count-based analysis considered site-specific abundance and therefore was potentially more sensitive to differences in plots due to actual population size. A mark-recapture demographic analysis of individually marked skinks could further extend inference by allowing measurements of apparent survival, rates of addition, and rate of population change at treatment and control sites This type of analysis should be considered further if it is possible to identify individual skinks reliably across yearly sample periods.

We need to list some hypotheses for why the control area has higher skink occupancy than the treatment area because this goes against our perceptions of good skink habitat. One possible explanation is that the control areas represent islands of skink habitat in a forested matrix whereas the treatment area is a more contiguous patch of skink habitat. So we might expect higher occupancy of small patches of habitat in a matrix of unsuitable habitat- even though the population size may be lower. If this is true then is occupancy the best parameter to evaluate pre& post restoration? Or do we need an estimate of population size.

<u>Recommendations for future work</u>

The following recommendations are made for future research efforts.

1. More in-depth description of vegetation, physical, and interspersion of skink habitat types. This should allow further exploration of factors influencing variation skink occupancy and abundance. An example of simple metrics to describe habitat interspersion is in (Otis 1998). If we are going to get more habitat data before treatment we need specific examples of what to collect in this report e.g. suggested habitat data form. Given that we may have yet another year of pre-treatment data (if FN issues don't resolve). Jakob and I can look at this reference and perhaps discuss with Thomas to identify additional habitat sampling requirements.

2. Further in-depth analysis of weather data may allow better description of factors influencing temporal variation in detection probabilities. Assessment of monthly temperatures of a moving window of temperatures preceding surveys may help delineate seasonal cues that decrease skink activity and subsequent detection probabilities. Information from on-site data loggers will be analysed and we will also attempt to incorporate local weather data (Environmnet Canada) into future models.

3. It is suggested that 5 sample sessions should be conducted to ensure adequate precision of occupancy estimates. Detection probabilities ranged from 0.1 to 0.5 whereas occupancy estimates ranged from 0.6 to 0.8 in this study. Precision of occupancy estimates depends on mean detection probability, mean occupancy probability, then number of sites sampled, and the number of sessions. We applied the formulas of (MacKenzie and Royle 2005) to explore precision of occupancy estimates given 48 sites, the range of detection and occupancy probabilities observed, with 3 or 5 sampling sessions (Figure 10). It can be seen that detection probabilities of at least 0.3 and occupancy levels of 0.8 are needed to obtain adequate precision (CV occupancy=0.2) if 3 sessions of sampling are conducted. If 5 sample sessions are conducted than detection probability can be 0.3 and occupancy can be approximately 0.7. Therefore, the 5 session design provided more "insurance" especially given the wide range of detection probabilities that were observed in the project.

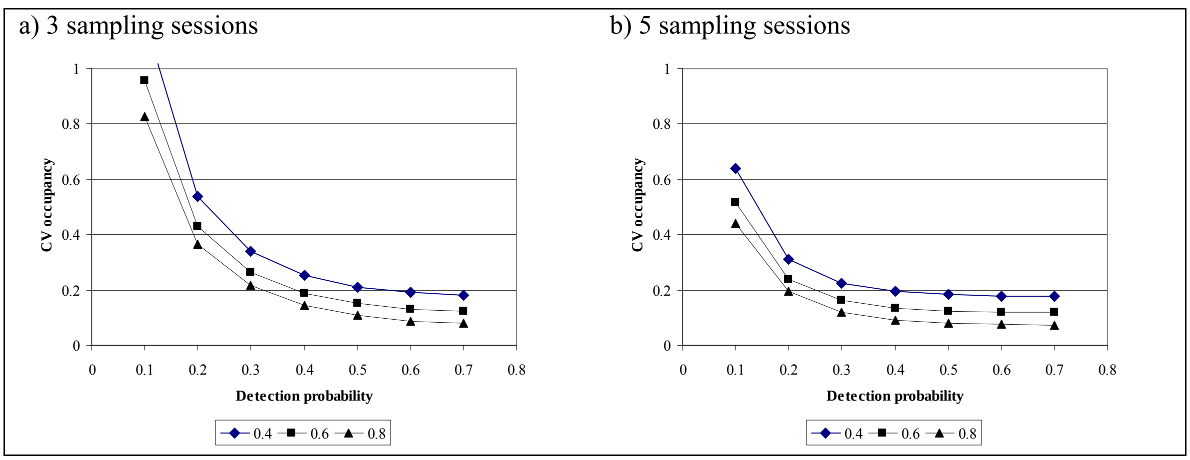

Figure 10. Precision of occupancy estimates as a function of detection probability (x-axis) and levels of occupancy (in legend box). Simulations with 3 and 5 sampling sessions are shown.

4. We will test photo identification techniques to determine if they can be used in mark recapture population estimates. This should be evaluated before post-treatment data collection and is in progress. An algorithm called I^3S has been developed to recognise individual sharks and rays (http://www.reijns.com/i3s/). This program has been applied to reptiles in B.C. and we will test the method with skink photos from this project.

This study is well situated to determine the effects of proposed thinning of treatment areas now that two years of data have established baseline levels of occupancy of treatment and control plots. It is entirely possible to model a BACI design (Underwood 1991) using occupancy models and this data should further help to asses the relationships of pre and post treatment covariate levels on skink occupancy and abundance.

5.0 Acknowledgements

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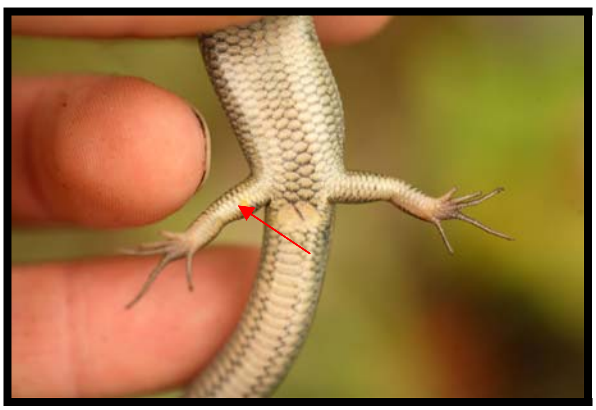
7.0 Appendix 1. Summary of data collected at each sample station and skink capture.

Occupancy	Sample point	Weather	skink sign (guano)
	Date	Temp (air)	Skink sign (shed skin)
	Time	Temp (ACO/ground)	
	Session#	Wind	
	Skink ID#	% cloud	
	ACO#		
Skink capture	Skink ID #	Sample point	
	Mark description	Date	
	SVL	Time	
	weight	Session#	
	sex	ACO#	
	Photo #		
Habitat Covariates	Slope %	B1layer %	# of stems per A B1 B2 layer
	Aspect	B2 layer%	% bare soil
	Fd A%	C layer%	% cover CWD
	Fd B1%	Bedrock %	% cover litter
	Fd B2 %	Looserock %	C layer total % and dominant species
	Alayer %		# of NCO's in plot

8.0 Appendix 2. Photographs.

1. Artificial Cover Objects (ACOs); concrete patio block and plywood.

2. An example of ACO placement in relation to a plot centre.



3. This freshly injected VIE implant is difficult to see.

4. An example of a successful VIE.

5. Macro photo of western skink head.

6. Macro photo of western skink foot.