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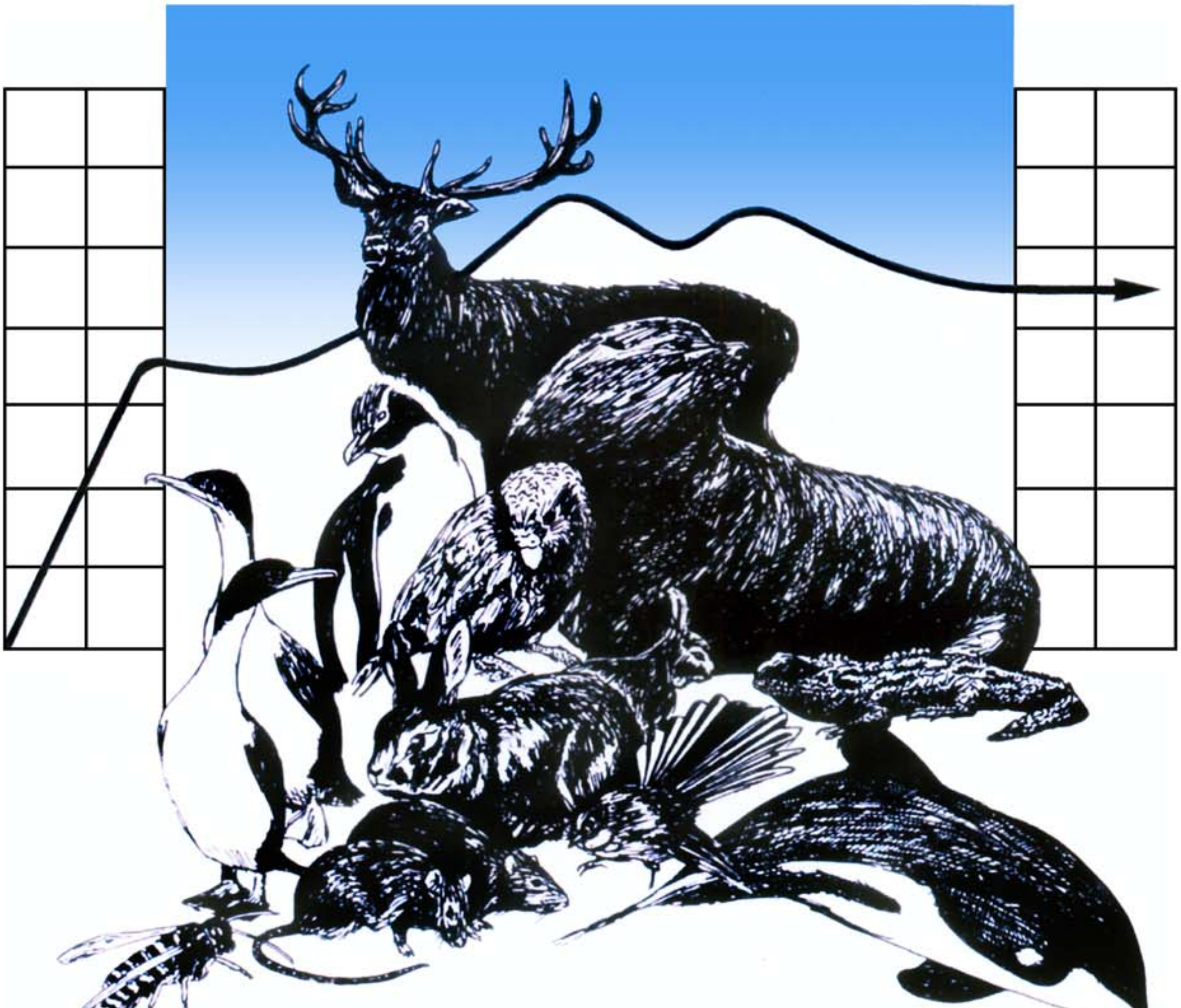
DEPARTMENT OF ZOOLOGY



WILDLIFE MANAGEMENT

Analysis of trap catch data in relation to environmental variables in the Dart, Routeburn and Caples valleys, Mt Aspiring National park

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Report for WILM403 – Practice in Wildlife Management

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Executive Summary

With native species at risk of predation from introduced predators and limited resources available to combat them, any information that can improve the effectiveness of control programmes will be beneficial. In New Zealand, information on ship rat behaviour and habitat use or preference is limited, yet ship rats have been implicated in the decline of many native bird species. In an attempt to gain more insight, environmental and vegetation surveys of Fenn trap sites were conducted along four trap lines in beech forest in the Wakatipu area, South Island, New Zealand. Logistic regression analysis of the survey data with trap kill records aimed to identify any environmental characteristics associated with successful traps. Results were very site-specific, with trap capture probabilities differing across the four trap lines. Each result was related to the Caples trap line as the reference category. Overall trap capture probability was highest at Sylvan and where trap sites featured more litter and loose rock. Moss was important at Sylvan where higher trap capture probability existed with increased moss ground cover. However drier sites at Sylvan were also more likely to catch ship rats. Where red beech (*Nothofagus fusca*) dominated the canopy at Sylvan, capture probability was again higher. Sylvan was also more likely to have successful traps when mountain beech (*N. solandri*) and small-leaved coprosma (*Coprosma* spp.) were fairly abundant in the ground cover vegetation. Sites with more leaf litter at the Daleys trap line reported higher probability of capture. Trap capture probability was lower for gently sloping sites when compared to flat sites overall, and for steep sites at the Routeburn. The best model for predicting trap capture success was indicated by the Akaike Information Criterion (AIC). The model contained red beech, mountain beech and small-leaved coprosma as predictors. The results suggested it is very difficult to identify and generalise about the environmental factors relevant to trap placement, on a broad scale. Interpretation was largely limited to results at each trap line. Other forms of measurement (i.e. non-categorical) and scale of the predictor variables may enable easier interpretation and prediction.

Introduction

Mammalian predators introduced into New Zealand are assumed to be responsible for many native bird species declines (King, 1984). Introduced via human settlement, terrestrial predators have inflicted devastating losses on native birds over the last thousand years or so (King, 1983) and include stoats (*Mustela erminea*), weasels (*M. nivalis*), ferrets (*M. furo*), cats (*Felis catus*) and three species of rodents (O'Donnell, 1996). The Kiore (*Rattus exulans*) is a rodent thought to have arrived with Polynesian settlers (Atkinson and Moller, 1990) and the Norway rat (*R. norvegicus*) with the first European settlers to New Zealand (Moors, 1990). Ship rats (*R. rattus*) became the most widespread of the three rat species in New Zealand after approximately 1900 (King and Moller, 1997) and are a pest in many indigenous forest ecosystems (Innes *et al.*, 1995).

Ship rats have been implicated in the decline of several bird species, including the bellbird (*Anthornis melanura*), robin (*Petroica australis*), stitchbird (*Notiomystis cincta*), saddleback (*Philesturnus carunculatus*), thrush (*Turnagra capensis*), mohua (*Mohoua ochrocephala*), South Island Kokako (*Callaeas cinerea cinerea*) and red and yellow-crowned parakeets (*Cyanoramphus novaezelandiae* and *C. auriceps*) (Atkinson, 1973). Ship rats are a particular threat to New Zealand's forest passerines which display few predator-avoidance behaviours (O'Donnell, 1996). Mostly arboreal, ship rats are omnivorous generalists that feed on native plant seeds, animals and invertebrates (Clark, 1981). Ship rats are skilful climbers (Ewer, 1971 as cited in King, 1990) using both trees and the forest floor (Innes and Skipworth, 1983) and are seldom seen and little known (Innes, 1990). Nests are built in epiphyte clumps or tree hollows, while also constructing multiple feeding platforms within the tree structure (Innes, 1990). Peak numbers usually occur in autumn with low numbers in spring and early summer (Innes, 1990). Ship rats have a 6-7 month breeding season and will feed on almost any animal or plant product, making them a very flexible species (King, 1990).

Studies on mohua suggest predation by stoats and rats has had a major impact on mainland populations and that mohua population declines are continuing (O'Donnell, 1996). Mohua are especially at risk from predation as they nest when stoat numbers are typically high and a biased sex ratio results because only females incubate (O'Donnell, 1996). Mohua are endemic to the South Island of New Zealand and are absent from 75% of their former range (O'Donnell, 1996). In order to protect mohua, methods to control introduced predators have occurred over the last two decades (Lawrence and O'Donnell, 1999) including trapping and poisoning. According to O'Donnell and Phillipson (1996), predator control will be required to prevent extinction of many mohua populations. While stoats and rats are known predators of mohua, the impact on mohua populations is intensified in beech (*Nothofagus* spp.) forests, where mass synchronous seeding (masting) occurs every four to five years (Fitzgerald *et al*., 1996). Masting may also be defined as "pulsed resources" or the temporary availability of dramatically higher than normal levels of resources which then become depleted with time (Ostfeld and Keesing, 2000). King (1983) found a relationship between a beech mast and the predator irruptions that result after such a dramatic rise in food resources. The author found that a beech mast can lead to increased mouse, ship rat and stoat populations and suggested a flow-on effect of intensified predation of birds. For mohua, the effects of a beech mast are most intense during the summer following mass seed production but this lessens in the summers following poor mast production (O'Donnell and Phillipson, 1996). Nonetheless a beech seed mast is probably only one of the dynamics that influence ship rat populations (Studholme, 2000).

A beech mast in two consecutive years is extremely rare (Dilks *et al.,* 2003). A project aimed at combating such processes was developed by the Department of Conservation (DoC) in 2003, after the double beech mast years of 1999-2001 that had devastating effects through predation on forest bird populations (Bain, 2006). Operation Ark manages 10 sites in the South Island to protect whio (*Hymenolaimus malacorhynchos*), mohua, orange-fronted parakeets (*Cyanoramphus malherbi*) and short and long-tailed bats (*Mystacina robusta* and *Chalinolobus tuberculatus*) (Department of Conservation, 2006). Rat control carried out by bait stations and aerial drops of 1080 (sodium monofluoroacetate) was instigated to protect native species in several areas after a mast year in 2005/2006 (Bain, 2006). In the past, Innes *et al*. (1995) achieved reductions of at least 90% in ship rat abundance indices after ground and aerial-based 1080 poisoning. The Dart/Caples valleys bordering Lake Wakatipu all started rat control, using rat poison in bait stations in the middle of 2006 while trapping for stoats continues year-round (Department of Conservation, 2006). Mohua are a critical species at risk in this area, managed by the Department of Conservation's mohua recovery plan (O'Donnell, 1993).

Ship rats are known predators of mohua (Studholme, 2000). Data on rat kills in individual traps along trap lines in the Dart, Routeburn and Caples valleys have been recorded by the Department of Conservation (B. Lawrence, pers. comm.). Rats are a common by-catch in the types of traps used in this area (Fenn traps) (Studholme, 2000) although their target animal is the stoat. Since another South Island beech mast occurred in 2005/2006, rat numbers are likely to have surged, increasing the risk to mohua and other native birds in the area. Unfortunately, there have been few published studies of ship rat population biology in high altitude beech forest (Studholme, 2000) and little systematic surveys on their distribution (King and Moller, 1997). Information is patchy at best, and conflicting opinions exist. While Innes (1990) suggested ship rat individuals or family groups were evenly distributed throughout available habitat, Dowding and Murphy (1994) stated that ship rats were not evenly distributed in large areas of New Zealand forest. There is a lack of data on the mechanisms that control ship rat abundance (Studholme, 2000) yet ship rats react much more quickly to beech masts and can increase in population size before stoats (King and Moller, 1997; Blackwell *et al.*, 2003). This response means information on ship rat population dynamics, habitat use, movements and preferences would be valuable for control operations, population modelling and assessment of the impact of ship rats on native species in mast conditions.

King and Moller (1997) found that concentrated Fenn trapping can reduce local numbers of rats, at least in the short term. There has been little investigation to date of trap catch data and the factors that maximise capture success, for both rats and stoats (Christie *et al.*, 2006). Cameron *et al.* (2005) stated that little data exists on fine-scale habitat use by invasive species in New Zealand and that such information could help with trap placement. Known characteristics of successful traps may enable managers to develop strategies for effective, efficient trap placement and achieve higher capture rates as a result. While ship rats are habitat generalists in some areas (e.g. Stewart Island; Harper *et al.*, 2005), the current study investigated trap capture success with respect to environmental characteristics of trap sites in beech forest. While the environmental data were largely subjective, exploratory analysis of trap kill data aimed to identify characteristics associated with successful traps. With finite resources and environmental variation, more strategic targeting of control operations should improve their efficacy and value-for-money, if analysis of trap site data demonstrates some predictability in ship rat habitat use. Pryde *et al.* (2005) stated that behavioural studies of rats are important to provide information on optimum spacing for trap sites. Detailed studies of habitat or resource use by animals often provides vital information for conservation and management strategies (Cox *et al.*, 2000). If such information enables conservationists and managers to make predictions that reduce the risk of predation to native species, the impacts of events such as beech masts could hopefully be mitigated.

Methods

Study Areas

The environmental survey data was collected from four trap lines within Mount Aspiring National Park (44°42-3’S, 168°20’E). The Dart, Routeburn and Caples valleys are located near the head of the Lake Wakatipu catchment within the Department of Conservation’s Wakatipu area conservancy (Appendix 1). The trap lines were set up to help control stoats and rats using Mark IV Fenn kill traps and were baited with hen's eggs. The Routeburn trap line begins at the Routeburn road end and winds uphill along the track edge to Emily Creek, entailing 38 traps. The Sylvan trap line starts at the Lake Sylvan car park near Weka Flat and runs up to the Rockburn hut and 43 traps were surveyed. The Daleys trap line begins at Chinaman's car park and extends to Daley's Flat Hut with 40 traps surveyed. The Caples trap line begins at the Greenstone/Caples Track car park and extends to the Upper Caples Hut for a total of 80 traps. Traps were located 200m apart and to one side of public walking tracks. The traps were double-set within a wooden tunnel housing with one entrance to each trap.

The study areas consisted of indigenous forest dominated by beech (*Nothofagus* spp.) species. Red beech (*Nothofagus fusca*) is the most prominent canopy species at a height between 20m and 30m (Lawrence and O'Donnell, 1999). Considerable stands of silver beech (*N. menziesii*) and mountain beech (*N. solandri*) also exist. The climate is wet, temperatures moderate and the understory fairly open with little variation in vegetation (Lawrence and O'Donnell, 1999).

The Surveys: Vegetation and Environmental Variables

Surveys (Appendix 2) were conducted on foot in December 2006 and January 2007 by two individuals. One form was filled in for each trap with the recorder completing the survey as close as possible to the physical trap site. Categories included assessment of ground cover, aspect, slope, topography, drainage, ground cavities and vegetation at three levels. Ground cover categories were divided into vascular plant cover, moss, boulders, loose rock or leaf litter, under 30cm high. Ground cover was estimated as per cent cover for each category totalling 100%. This was assessed by estimating the per cent cover of each category less than 30cm high around each trap site. For Tier 1 vegetation, one dominant canopy species was identified out of the three possible beech species. This was often estimated by the dominant leaf litter species detected on the ground. For Tier 2 vegetation (understory; 30cm-5m), plant species were ranked in terms of abundance between one and four, where that species was present. A value of "1" represented "just one individual"; "2" represented "a few"; "3" represented "several" and "4" represented "many or dominant species". The same ranking system applied for Tier 3 (ground cover; under 30cm).

Data Analysis

Data on the number of kills each trap had achieved was provided by DoC staff members who were checking, baiting and setting traps and recording the number of individuals (rats) caught in each trap. The kill data spanned three years, from January 2003 to February 2006. Trapping time periods were not identical for all trap lines. Although several traps achieved multiple kills, the outcome measure for this study was binary: whether or not the trap had attained one or more rat kills over the entire time period.

The period where trap catch was recorded was over two phases of the mast cycle. There were non-mast conditions from 2003 to autumn of 2004. There was a partial mast in autumn 2004 which led to an increase in rat numbers during August 2004 to Summer 2005-06, but this was not a rat eruptive period (Lawrence, pers. comm.).

A binary generalised linear model (Logistic regression: Hosmer and Lemeshow, 2000) was used to determine which variables (predictors) best explained trap capture success for each trap. Logistic regression is suitable for analysis of dichotomous outcomes and categorical data forming one or more predictor variables (Peng and So, 2002) which were the dominant form of data in this research. Logistic regression can be used for modelling binary response data by the method of maximum likelihood (SPSS 13.0 Software Products, Chicago, USA, 2005). Where β_0 is the intercept parameter and $\beta_{1\text{-}p}$ are the parameter intercepts:

$$\log\left(\frac{p}{1-p}\right) \rightarrow \beta_0 + \beta_1 X_1 + \cdots + \beta_p X_p$$

When data are categorical, one level of the predictor is classed as the reference category, so that the results for that predictor must always be interpreted with respect to its reference category (Table 1). The binary outcome was defined as “1” for one or more rat captures and “0” for none. Models were constructed for each group within the survey: aspect, slope, topography, drainage, ground cover (continuous data), ground cavities and vegetation cover at three levels. Trap line was also modelled using the complete dataset with regards to trapping outcome.

Prior to model fitting, correlations between predictor variables were assessed using the non-parametric Spearman Rank Correlation statistic (*rho*) (Niven, pers. comm.). Where predictor variables (within each group) had a correlation of 0.7 or more, each variable in question was modelled using a single parameter logistic regression and evaluated. The variable with the largest effect size on the trap outcome was included in comprehensive modelling. Backward stepwise selection was used to identify the best model. This method sequentially removes the least significant predictor variables from the global model by starting with all variables and deleting them one at a time, in the order they are worst by certain criteria. The likelihood ratio test was used as the step function and is based on the difference in deviances. It tests the significance of the difference between the deviance for the specified model and the deviance ratio for a reduced model (Peng and So, 2002). The likelihood ratio test was used instead of the Wald statistic as the former test is more powerful. The Wald statistic is too conservative and less suitable for testing the significance of dummy variables and is biased towards Type II errors (Tabachnick and Fidell, 2001; Hosmer and Lemeshow, 2000). The Wald statistic indicated significant variables in the final model but information about whether or not variables could be removed from the model, using the likelihood ratio test, was also included in the interpretation.

Table 1. Environmental and Vegetation Predictor Variables.

Name of Variable	Description	Type of Variable	Categories	Omitted Due to Lack of Data or Correlation	Measurement Scale
Trap line	Trap line where surveys conducted	Categorical	Routeburn	No	n.a
			Daleys	No	
			Sylvan	No	
			Caples	No	
Aspect	Direction a slope faced	Categorical	N	No	n.a.
			E	No	
			S	No	
			W	No	
			NE	No	
			NW	No	
			SE	No	
			SW	No	
			n.a.	n.a.	
Slope	Degree of slope	Categorical	Flat	No	n.a
			Gentle	No	
			Moderate	No	
			Steep	No	
			Vertical	No	
Topography	Type of landform	Categorical	Terrace	No	n.a.
			Slope	No	
			Ridge	**Yes**	
			Gully	**Yes**	
			Other	**Yes**	
Drainage	Drainage at ground level	Categorical	Poor	No	n.a.
			Medium	No	
			Good	No	
Ground Cover	Per cent cover at ground level	Continuous	Vascular	No	Per cent
			Mosses	No	
			Loose Rock	No	
			Boulders	No	
			Bedrock/Litter	No	
Cavities	Cavities below ground	Categorical	Under root systems	No	No / A few / Several / Many
			Under boulders	No	
			Many boulders	**Yes**	
Average boulder size	Estimate of boulder diameter	Categorical	<30cm	No	n.a.
			30cm-1m	No	
			1m-2m	No	
			>2m	No	

Continued over

Name of Variable	Description	Type of Variable	Categories	Omitted Due to Lack of Data or Correlation	Measurement Scale
Tier 1	Dominant canopy species	Categorical	Red beech	No	n.a.
			Mountain beech	No	
			Silver beech	No	
Tier 2	Understory vegetation (30cm-5m)	Categorical	Red beech	No	Abundance rank (0-4; 0 = absent; 4 = dominant)
			Mountain beech	No	
			Silver beech	No	
			Totara	**Yes**	
			Celery Pine	**Yes**	
			Lancewood	**Yes**	
			Wineberry	**Yes**	
			Broadleaf	**Yes**	
			Weeping Mapou	**Yes**	
			Small-leaved Coprosma	No	
			Three Finger	**Yes**	
			Hoheria	**Yes**	
			Large-leaved Coprosma	**Yes**	
			Horopito	**Yes**	
			Marbleleaf	**Yes**	
Tier 3	Ground level vegetation (<30cm)	Categorical	Red beech	No	Abundance rank (0-4; 0 = absent; 4 = dominant)
			Mountain beech	No	
			Silver beech	**Yes**	
			Totara	**Yes**	
			Celery Pine	**Yes**	
			Lancewood	**Yes**	
			Wineberry	**Yes**	
			Broadleaf	**Yes**	
			Weeping Mapou	**Yes**	
			Small-leaved Coprosma	No	
			Three Finger	**Yes**	
			Hoheria	**Yes**	
			Large-leaved Coprosma	**Yes**	
			Horopito	**Yes**	
			Shield Fern	**Yes**	
			Astelia	**Yes**	
			Other Fern	**Yes**	
			Marbleleaf	**Yes**	

Where presumed relevant, interactions between predictor variables were included (e.g. between aspect and trap line) that might speak for the multiplicative effect between two or more predictors (Peng and So, 2002). All satisfactory final models were compared using the Akaike Information Criterion (AIC) to identify the best model or models (Harraway, pers. comm.). The log-likelihood always decreases when adding predictors and the AIC balances this effect by adding a penalty that increases with the number of parameters to find the most parsimonious models.

Results

Initial Data

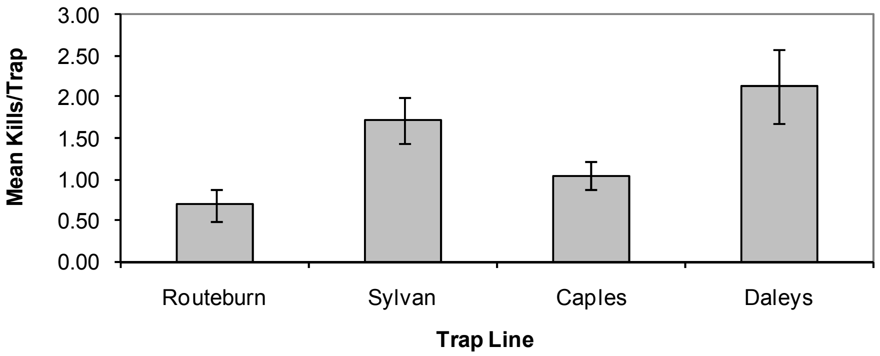
A total of 256 surveys were completed over the four trap lines. There were 38 surveys completed for the Routeburn trap line, 82 for Daleys, 54 for Sylvan and 80 for Caples. However several surveys were incomplete and the data were inspected prior to analysis for missing sections. A total of 91 surveys were incomplete in one way or another due to human surveying error. In the case where a form had an incomplete section or sections, this survey was removed from the relevant analysis. In addition, where there were less than 10 cases for a particular variable, the variable was deleted from the analysis. Table 1 shows such variables which were excluded due to low column totals.

Exploratory Analysis

Overall Trap line Data – Trap Captures

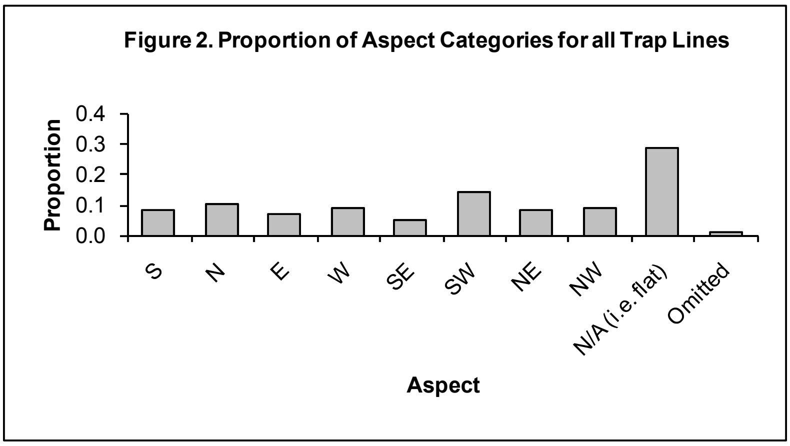
Mean kills per trap (Fig. 1) indicated that Daleys and Sylvan had the highest average kills over the entire time period, and Routeburn the lowest.

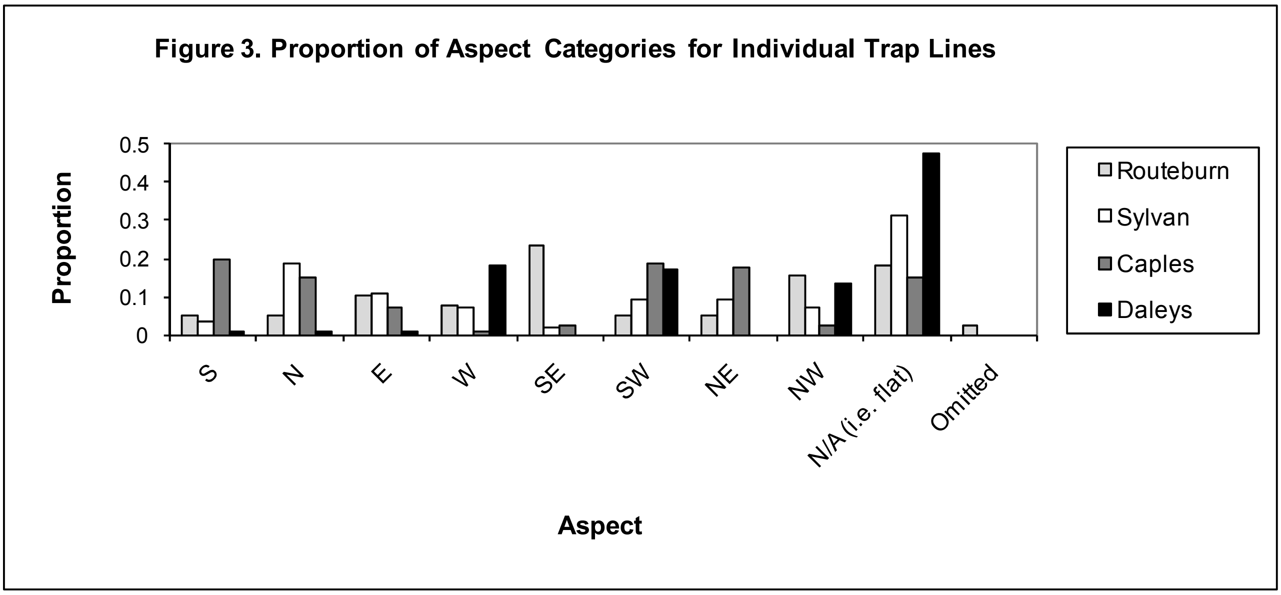
Figure 1. Mean kills per trap for each trap line



Aspect

Most of the trap sites were flat (Fig. 2) and south-west facing slopes appeared to the dominant aspect category. For each trap line, Daleys had the most flat and west-facing sites (Fig. 3). Caples featured more south and northeast-facing sites. Sylvan had more north-facing sites and the Routeburn contained more southeast-facing sites.

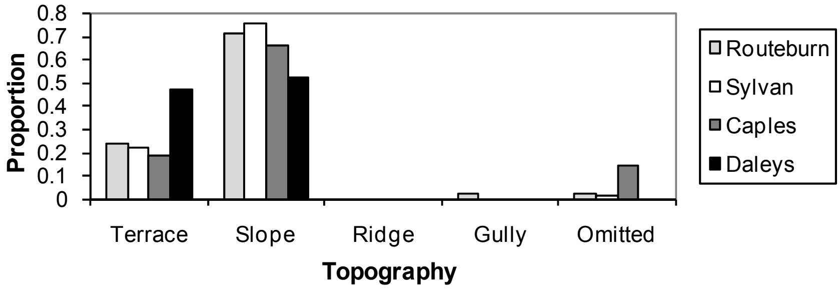




Topography

Slope was the most common topographical category across all trap lines (Fig. 4). Ridge and gully classifications were rarely identified leaving terrace as the other dominant category. Routeburn had the only gully classifications, Sylvan had the most slope classifications and Daleys had the majority of the terrace classifications.

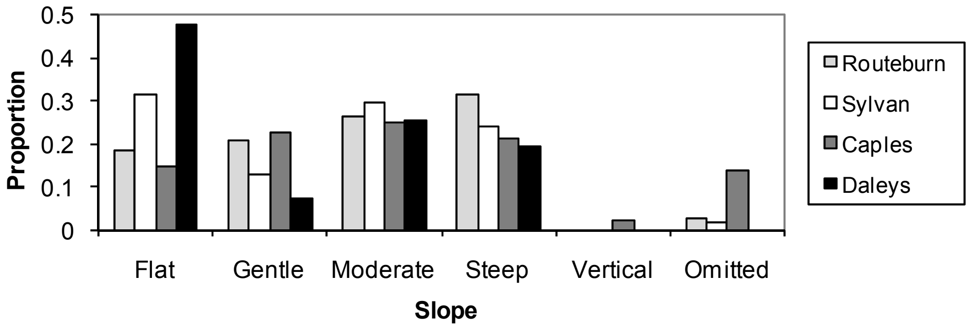
Figure 4. Proportion of Topography Categories for Individual Trap Lines



Slope

Overall, the majority of sites were deemed flat, followed by moderate and steep slopes. For individual trap lines (Fig. 5), Daleys had more flat trap sites. Caples featured more gently sloping sites but also had the most data omitted for slope classification. Sylvan contained the highest number of moderate slopes while Routeburn had the steepest slopes.

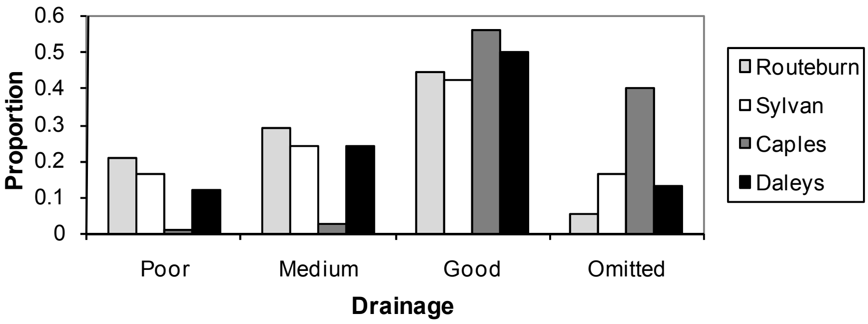
Figure 5. Proportion of Slope Categories for Individual Trap Lines



Drainage

Good drainage was the dominant classification for all trap lines, with medium and poor categories similar in frequency of occurrence. However nearly 20% of surveys omitted the drainage classification altogether. The trap line with the best drainage (i.e. classed as “good”) was Caples (Fig. 6). Routeburn was the leading category for poor and medium drainage.

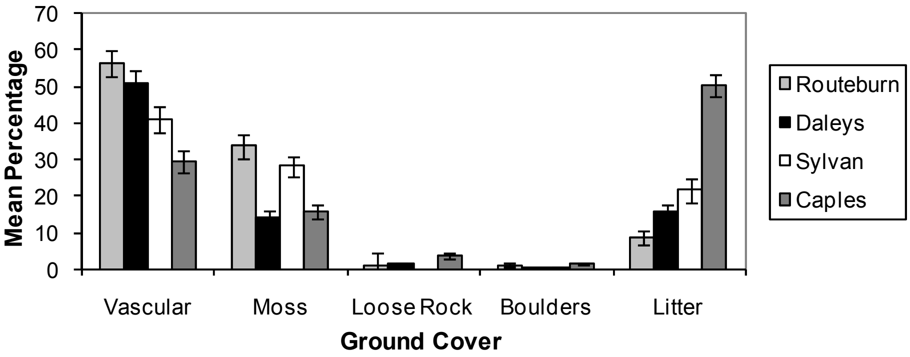
Figure 6. Proportion of Drainage Categories for Individual Trap Lines



Ground Cover

Vascular cover dominated the ground cover category with litter and moss being the next most frequent categories. Loose rock and boulders hardly featured in the surveys. Routeburn and Daleys had the most vascular ground cover while Routeburn and Sylvan had the most moss ground cover (Fig. 7). Caples had the largest proportion of litter as ground cover.

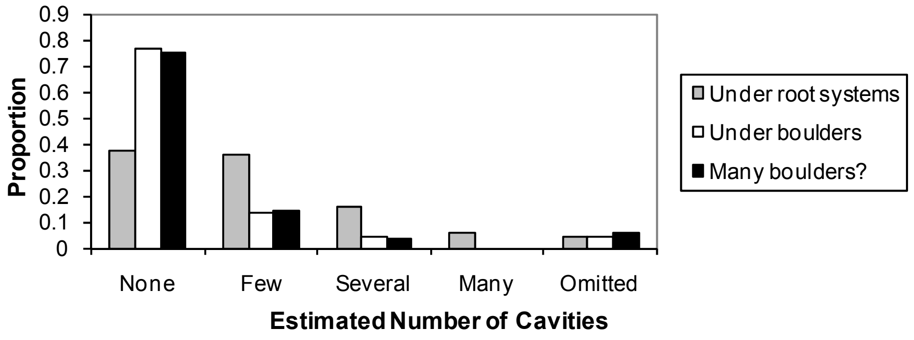
Figure 7. Average Ground Cover for Individual Trap Lines



Cavities

For all trap lines, cavities under root systems and boulders were quite rare (Fig. 8). Boulders themselves were uncommon and correspondingly, so were cavities under boulders. Routeburn and Daleys both featured few boulders and cavities under roots or boulders. Sylvan and Caples lacked many boulders or cavities.

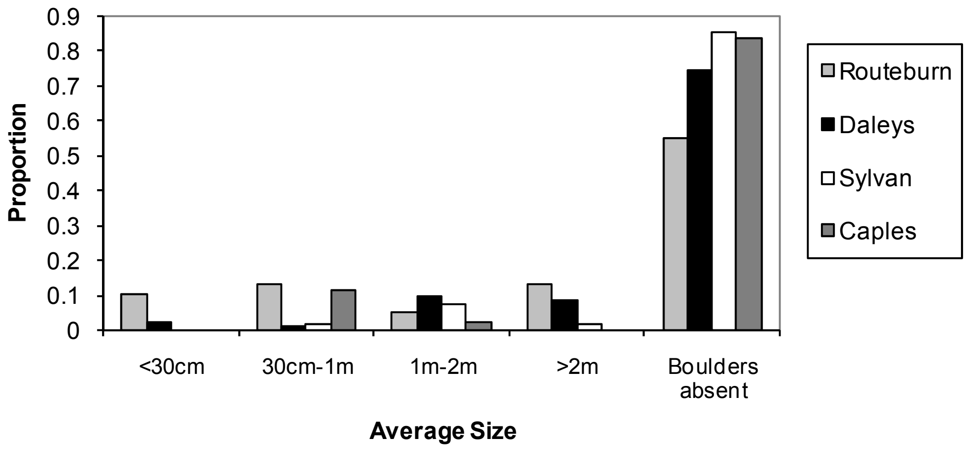
Figure 8. Proportion of Cavities Below Ground for all Trap Lines



Average Size of Boulders

Boulders were largely absent across all trap lines with all size categories at negligible levels. Routeburn featured the majority of boulders of all sizes.

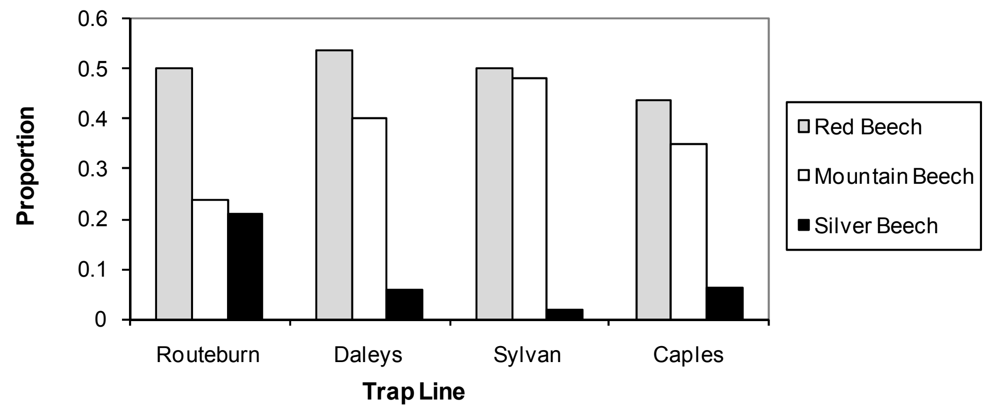
Figure 9. Proportion of Average Boulder Size for Individual Trap Lines



Canopy Beech Species – Tier 1

Red beech dominated the canopy along Routeburn, Daleys and Caples trap lines, with red and mountain beech approximately equal in dominance for Sylvan (Fig. 10). Routeburn had the most silver beech in the canopy compared to other trap lines and also featured the least mountain beech.

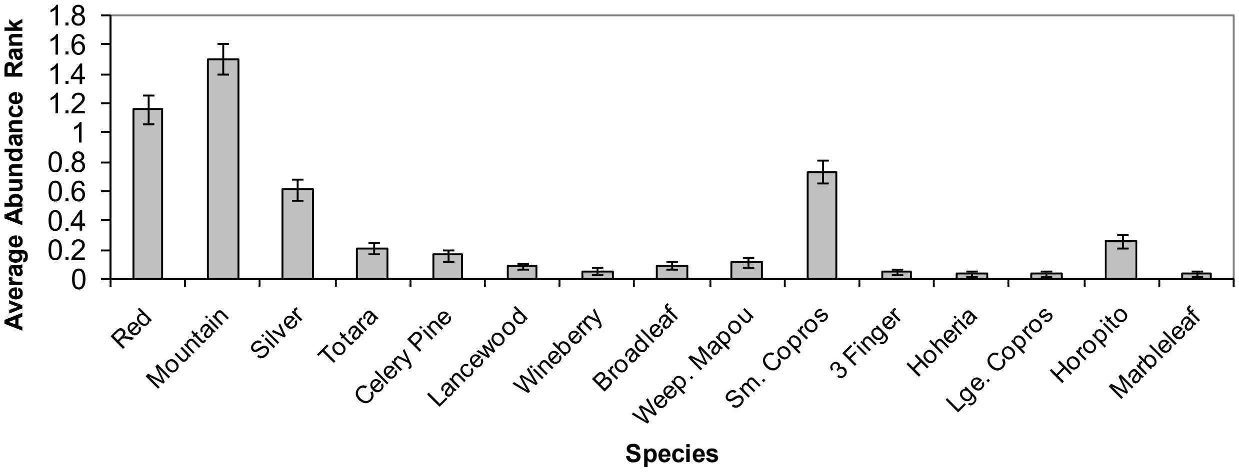
Figure 10. Dominant Canopy Species for Individual Trap Lines



Understory Vegetation Cover (30cm – 5m) – Tier 2

The average abundance rank for each species was calculated for all trap lines and demonstrated that mountain beech was the most abundant at Tier 2 (Fig. 11). Red beech, silver beech and small-leaved coprosma (*Coprosma* spp.) were the next most abundant species. Sylvan had the least red beech in the understory, while Daleys had more mountain beech than either Sylvan or Caples. Routeburn had more silver beech than any other trap line and Sylvan had more totara (*Podocarpus totara*). Sylvan and Caples were the only trap lines to feature considerable amounts of celery pine (*Phyllocladus trichomanoides*). All trap lines featured negligible amounts of weeping mapou (*Myrsine divaricata*). Daleys and Sylvan featured the most horopito (*Pseudowintera colorata*) but lancewood (*Pseudopanax crassifolius*), totara, broadleaf (*Griselinia littoralis*), wineberry (*Aristotelia serrata*), three finger (*Pseudopanax colensoi*), hoheria (*Hoheria* spp.), large-leaved coprosma and marbleleaf (*Carpodetus serratus*) were rare species in the understory.

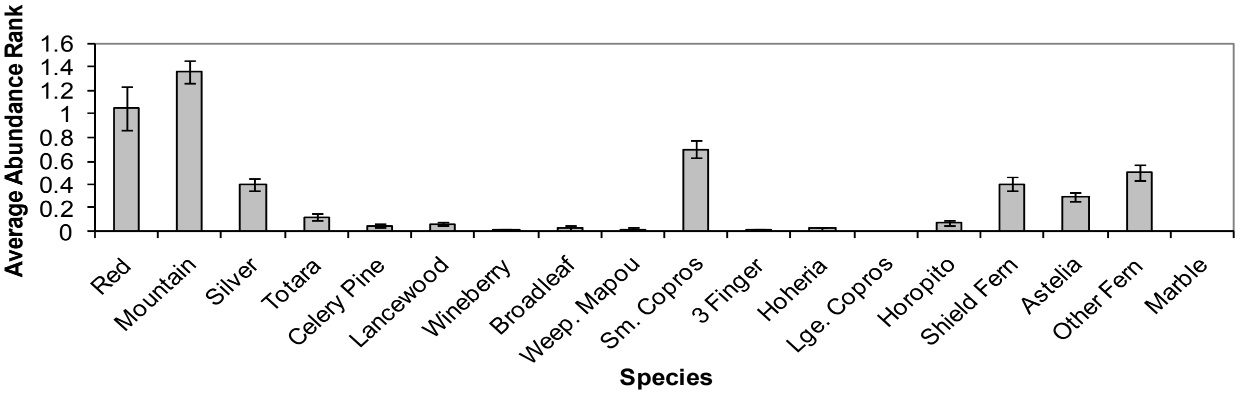
Figure 11. Average Abundance Rank for Understory Vegetation for All Trap Lines (0=absent - 4=dominant)



Ground Cover Vegetation (< 30cm) – Tier 3

Mountain beech dominated the ground cover classification for all trap lines (Fig. 12). Red beech and small-leaved coprosma were the next most common species, with silver beech, shield fern (*Polystichum vestitum*), astelia (*Astelia* spp.) and other ferns featuring appreciably. Caples recorded more red beech than Daleys or Sylvan and Sylvan had the most mountain beech at ground cover level. Routeburn and Daleys had more silver beech than the other trap lines and Daleys had more small-leaved coprosma species. Routeburn had the most horopito and other ferns. No other plant species achieved a considerable abundance rank.

Figure 12. Average Abundance Rank for Ground Cover Vegetation for All Trap Lines (0=absent - 4=dominant)



Model Fitting

A total of 26 models were constructed for the survey data (Table 2), with each model testing a group of predictor variables. All satisfactory models showed an acceptable fit of model's estimates with the data (> 0.05; Table 2) which was assessed by the Hosmer-Lemeshow goodness of fit statistic.

All Trap Capture Data

The first set of fitted models contained all trap kill data with trap line as a predictor. Caples was classified as the first reference category so that interpretation was with respect to trap capture at the Caples line. The model was significant (p = 0.009) suggesting that the information about trap lines allowed better prediction of trap capture. There was a fairly low success rate of correct predictions for the fitted model (59.7%) which was only a small improvement on the null model (51.2%) and implied the outcome cannot be reliably differentiated on the basis of trap line. The Sylvan trap line was the only significant parameter in the model (p = 0.010) which suggested there was a higher probability of trap capture at Sylvan compared to Caples.

When the Daleys trap line was the reference category, the model was also significant (p = 0.009) and Sylvan showed a higher probability of trap capture compared to the Daleys trap line. Sylvan also showed a higher probability compared to Routeburn. When Sylvan was the designated reference category, the significant coefficients suggested the Routeburn, Caples and Daleys trap lines all had a lower probability of trap capture compared to Sylvan.

> **Key Findings:** Overall, trap capture probability was higher at Sylvan compared to all other trap lines.

Table 2. Model Summary Statistics

Model	Reference Category	No. of variables in global model	No. of variables in final model	Deviance of Final Model	Hosmer-Lemeshow		
					χ2	*P*	*d.f.*
Trap line	Routeburn	4	4	266.981	0.000	1.000	2
Trap line	Caples	4	4	266.981	0.000	1.000	2
Trap line	Daleys	4	4	266.981	0.000	1.000	2
Trap line	Sylvan	4	4	266.981	0.000	1.000	2
Aspect	West	8	8	142.403	0.000	1.000	5
Aspect x trap line	West Caples	25	25	119.930	0.000	1.000	7
Ground cover	Caples	6	3	249.349	13.374	0.100	8
Ground cover x trap line	Caples	17	9	226.941	8.306	0.404	8
Ground cover interactions	Caples	11	5	236.357	4.920	0.766	8
Cavities	“None”	5	4	241.449	0.000	1.000	2
Cavities interactions	“None”	4	1	248.096	-	-	-
Cavities x trap line	“None”	13	10	226.953	-	-	-
Average size (boulders)	<30cm	4	4	45.352	0.000	1.000	2
Average size x trap line	<30cm Caples	9	9	38.496	0.000	1.000	4
Topography	Flat slope Poor drainage Terraced topography	7	5	198.588	0.010	0.995	2
Topography x trap line	Flat slope Poor drainage Terraced topography Caples	22	20	169.826	0.000	1.000	6
Topography interactions	Flat slope Poor drainage Terraced topography	12	9	188.657	0.083	1.000	5
Tier 1	Not dominant	4	3	251.224	0.000	1.000	1
Tier 1 x trap line	Not dominant Caples	9	7	238.735	0.000	1.000	4
Tier 1 interactions	Not dominant	4	1	-	-	-	-
Tier 2	Zero abundance rank	15	5	243.897	0.000	1.000	3
Tier 2 interactions	Zero abundance rank	56	23	190.315	0.000	1.000	2
Tier 2 x trap line	Zero abundance rank Caples	42	22	198.362	0.043	1.000	4
Tier 3	Zero abundance rank	12	9	216.726	2.943	0.938	8
Tier 3 interactions	Zero abundance rank	34	23	193.872	0.476	0.788	2
Tier 3 x trap line	Zero abundance rank Caples	32	32	169.829	69.948	0.000	31

Aspect

The fitted model including aspect was not significant (p = 0.281) indicating aspect data does not predict trap capture at an acceptable level. When trap line was included as an interaction with aspect, the model was again not significant (p = 0.151). There were no significant interactions.

> **Key Findings:** Aspect was not a useful predictor of trap capture success, either overall or in relation to trap line.

Ground Cover

Ground cover variables were continuous so a reference category was unnecessary for the analysis. The model including ground cover variables was significant after four steps (p = 0.04) indicating the model predicted the outcome well. The step to remove variables was non-significant (p = 0.167) which is desirable as a non-significant p-value suggests keeping the particular variable would not have improved the model fit. The final model maintained a 56.4% success rate which was an improvement on a 52.1% success rate for the null model. Only vascular and moss per cent cover were retained in the final model. Vascular cover was the only significant variable (p = 0.003) and the coefficient suggested capture probability was lower with increased vascular ground cover. The likelihood ratio tests suggested both moss and vascular cover should be retained in the final model.

Interactions between ground cover and trap line were included and the final model was significant (p = 0.000) after four steps. The success rate was 68.6% which was an improvement on 52.1%. Significant interactions were litter x Daleys (p = 0.012) and moss x Sylvan (p = 0.049). Capture probability was higher for greater-litter sites at Daleys, compared to similar sites at Caples. The coefficient for the second interaction suggested capture probability was higher for mossy sites at Sylvan compared to similar sites at Caples. The likelihood ratio tests suggested both interactions should be retained in the final model.

When ground cover interactions only were fitted, the model was also significant (p = 0.000) after seven steps and the success rate was 62.2%. Litter x loose rock was the only significant interaction (p = 0.039) and the coefficient implied capture probability was only just higher at sites with more litter and loose rock. However the likelihood ratio tests suggested loose rock x moss, litter x loose rock and litter x boulders should all be retained in the final model.

> **Key Findings:** Lower capture probability for sites with more vascular cover. Higher capture probability at mossy sites at Sylvan, and greater-litter sites at Daleys, compared to Caples. Slightly higher capture probability when sites have more litter and loose rock.

Cavities

The variables "cavities under boulders" and "many boulders" were found to be strongly positively correlated (Spearman's rho correlation coefficient = 0.949; p = 0.000), therefore both variables were independently modelled as single parameter logistic regression models. The variable with the biggest effect size after this process was "cavities under boulders" which was kept in the global model along with "cavities under roots" for analysis. The final model was not significant (p = 0.084) after two steps and there were no significant variables. When interactions between the two variables were modelled, there was also a non-significant final model (p = 0.373) with no significant predictor variables. The interaction between trap line and cavities under boulders yielded a significant final model (p = 0.012) after two steps but provided no significant variables for interpretation.

> **Key Findings:** Cavities data is not useful for prediction of trap capture success.

Average Size of Boulders

The model of average size data was not significant after four steps (p = 0.250) and the initial step to include variables was not significant either (p = 0.250). There were only 36 cases for analysis which may be the reason for a non-significant outcome. Interactions with trap line were also modelled but there were no significant variables, nor was the model significant. The two results suggest average size data was not useful for predicting trap capture probability.

> **Key Findings:** Average size of boulders does not help to predict trap capture success, however analysis limited by low number of cases.

Slope, Topography and Drainage

Initially, slope, topography and drainage variables were modelled together. The model was significant (p = 0.017) after two steps. The success rate was 61.2% compared with 50.7% for the null model. The final model included slope and topography only with gentle slope being the only significant variable (p = 0.048). The result suggested a decreased probability of capture when slopes are gentle compared with flat ground. The likelihood ratio tests suggested both slope and topography be retained in the final model.

Including interactions between slope, topography and drainage with trap line in model fitting yielded a significant final model (p = 0.000) and a 72.4% success rate. Significant interactions entailed steep slopes at Routeburn (p = 0.026) where capture probability was lower compared to flat sites at Caples.

Good and medium drainage sites at Sylvan (p = 0.03) had a higher capture probability compared to poorly drained sites at Caples.

When slope, topography and drainage interactions were modelled alone, a final solution could not be found. There were no significant interactions between the predictors.

> **Key Findings:** Trap capture probability is lower for gentle sites compared to flat sites overall and for steep sites at Routeburn compared to flat sites at Caples. Dryer sites at Sylvan had a higher probability of capture compared to wetter sites at Caples.

Canopy Beech Species – Tier 1

When red, silver and mountain beech were added the model was not significant (p = 0.078). This suggested the dominant beech species in the canopy was not a good predictor of trap capture probability. When trap line was included as an interaction with canopy species, the final model was significant (p = 0.007). The success rate was 60.5% which is an improvement on 51.4% for the null model. The only significant interaction occurred when red beech was the dominant species at Sylvan (p = 0.020). Capture probability was higher when red beech was dominant in the canopy at Sylvan compared to Caples when red beech was not dominant. When interactions between the three species were tested, a final solution could not be found. The interactions were not useful predictors of trap capture probability.

> **Key Findings:** Higher capture probability existed where red beech was dominant at Sylvan relative to Caples sites where other species dominate the canopy.

Understory Vegetation Cover (30cm – 5m) – Tier 2

When Tier 2 species alone were modelled, the final model was not significant (p = 0.115) suggesting the independent variables did not predict the outcome well. Interactions between Tier 2 species were also not of value. When trap line was included as an interaction with Tier 2 species, the same conclusion was reached where a final solution could not be found.

> **Key Findings:** Information about understory vegetation cover was not a useful contributor to predicting the probability of trap capture.

Ground Cover Vegetation (< 30cm) – Tier 3

The majority of Tier 3 species were removed from the analysis as the number of cases was too low. Only the inclusion of red beech, mountain beech, trap line and small-leaved coprosma produced valid results. Modelling of Tier 3 species alone lead to a significant final model (p = 0.003) after two steps. The success rate for prediction was 63% compared with 50.9% for the null model. One significant variable was mountain beech (p = 0.008) at level three (i.e. three out of a possible four for abundance rank). The coefficient suggested greater capture probability when mountain beech was abundant at ground cover level compared to its absence. Small-leaved coprosma at level one (i.e. a low presence) was also a significant variable (p = 0.031). The coefficient suggested increased capture probability when small-leaved coprosma was present at a low level compared to its absence.

Interactions between the Tier 3 species did not yield a reliable solution and neither did interactions between Tier 3 species and trap line.

> **Key Findings:** Trap capture probability is higher for fairly abundant mountain beech and a few small-leaved coprosma individuals compared to an absence of both species.

Identifying the Best Model – Akaike Information Criterion

Table 3 shows the Akaike Information Criterion (AIC) method for selecting the best model using the log-likelihood of all of the fitted models. A lower AIC value indicates a more parsimonious model. The best model as identified by the AIC criterion was for Tier 3 data which included red and mountain beech and small-leaved coprosma. Hence this model should be considered primarily in attempting to predict trap capture probability. The Tier 3 species interactions model was the second-most parsimonious model but the final model did not contain significant predictor variables, therefore interpretation is limited. Topography and ground cover models were the next best models but featured a considerable increase in AIC value from the Tier 3 models. The worst model with regards to the AIC model selection was developed when trap line was the only predictor.

Table 3. Akaike Information Criterion (AIC) Results for Satisfactory Models.

Survey Category	Model	Log-Likelihood of final model (Deviance)	Number of Parameters	AIC	Significant Variables in Final Model
Tier 3	Red + Mountain + Small-coprosma	23.051	8	39.051	Yes
Tier 3	All Tier 3 interactions	45.905	23	91.905	No
Topography	Slope + drainage + topography	198.588	5	208.588	Yes
Topography	Topography x trap line interactions	169.826	20	209.826	Yes
Ground Cover	Ground cover x trap line interactions	226.941	9	244.941	Yes
Ground Cover	All ground cover interactions	236.357	5	246.357	Yes
Tier 2	Red + Mountain + Silver + Small-coprosma	236.475	5	246.475	No
Tier 1	Tier 1 x trap line interactions	238.735	7	252.735	No
Ground Cover	Vascular + Moss	249.349	3	255.349	Yes
Trap line	All combinations	266.981	4	274.981	Yes

Discussion of Results

The beneficial effects of the beech mast years of 2000/2001 for rodents should have diminished by January 2003 which was the start of the rat capture data for the current analysis. King and Moller (1997) found that ship rat abundance was usually low during one to two years after significant beech seedfall. Therefore, the implications of beech masting could probably be disregarded for the present interpretation.

Despite the significant volume of data in multiple categories in this analysis, there were only a few results that qualified for further interpretation. Initial exploratory investigation suggested the most successful trap lines were Sylvan and Daleys in terms of the highest mean capture rate over the entire time period. Model fitting suggested that the Sylvan trap line had the highest probability of capture overall, compared to the other trap lines. The Routeburn trap line had the lowest mean capture rate. Studholme (2000) suggested that rats were cryptic when present in low numbers and the trap lines with lower capture probabilities could simply be a reflection of low population size. Studholme (2000) stated that ship rat numbers fluctuated most in beech forests and that their abundance could be linked to seedfall. However the author also implied that it was not clear whether rats actually ate beech seed or if beech masts are in fact an indication of other environmental conditions favourable to rats. Ideally, a few of the 'other' favourable conditions have been identified in the following analyses.

Aspect was not a useful predictor of trap capture in the logistic regression analysis. Sylvan featured more north-facing sites but the majority of surveys were flat sites. Christie *et al.* (unpublished) found a greater probability of rat capture with an increasing easterly aspect for one podocarp-broadleaf site in New Zealand. However despite unsatisfactory model fitting for the aspect category, the trap lines with the highest mean capture rate (Daleys and Sylvan) had differing dominant aspect categories. Sylvan had more north-facing sites while Daleys had more flat and west-facing sites. These differences would also suggest aspect is unrelated to trap capture probability.

Overall, most sites were classified as "slope" for the topography section, compared to terrace, ridge or gully. The majority of Sylvan sites were slopes whereas Daleys had more terrace sites. Model fitting suggested that slope and topography were important in trap capture prediction. Christie *et al.* (2006) found no effect of slope in their analysis of micro-habitat factors and ship rat and stoat capture success. However other studies (Christie *et al.*, unpublished; King *et al.*, 1996) observed that rat capture probability escalated with increasing slope though that was not indicated by this study's findings. The present study only had two key results in terms of slope which indicated a lower probability of rat capture on gentle slopes compared to flat sites. Analysis involving interactions with trap line suggested steep slopes along the Routeburn had a lower capture probability compared to flat sites along the Caples line. The Routeburn line featured the steepest sites along with lowest overall capture success. Since capture probability was not significant for steep slopes on the other trap lines, there may be other factors at the Routeburn that are affecting trap success such as higher vascular ground cover (Fig. 7) and poor drainage (Fig. 6). Cox *et al.* (2000) emphasised that it is important to consider both large and fine-scale factors in order to interpret local patterns of black (ship) rat distribution. Christie *et al.* (2006) suggested that micro-habitat data can provide useful predictors of trap capture success. The current analysis implies that important predictors are probably site and scale-specific and it may only be possible to relate such findings to trap placement in the individual area of analysis.

Of all the trap lines, the Caples line had the most well-drained trap sites (Fig. 6) but one of the lower mean capture rates (Fig. 1). Christie *et al.* (2006) found a decreased capture probability with poorly-drained sites which was inconsistent with the Caples line. Poor drainage at higher altitude locations may be an indication of less fertile soils and therefore, only specially-adapted plant species

(Leathwick, 2003) and substandard food resources for rats (Christie *et al*., 2006). This may lead to a lower rat abundance and consequently, trap capture success in higher altitude locations such as the Upper Caples or the Routeburn. There was a higher capture probability for good/medium drainage sites at Sylvan compared to poorly-drained Caples sites. Better-drained sites could have provided more resources according to Leathwick's (2003) statement above but the relevance of drainage and trap placement to a largely arboreal animal may not be significant. Christie *et al.*'s (unpublished) conclusion that increased capture probability occurred at more waterlogged sites may support the Caples finding but disagrees with the Sylvan finding. Therefore, perhaps comparison of trap lines is irrelevant and only examination of a single area at a time should be carried out with respect to significant predictors of trap success and ensuing trap placement.

Vascular ground cover was greater at the Routeburn and Daleys trap lines, while Sylvan had the most moss ground cover. Vascular and moss cover were both retained in final model although only vascular cover was significant. Capture probability was lower with increased vascular cover. Therefore, it is a possibility that increased moss cover at Sylvan (where capture probability was higher generally), means a higher capture probability. The results seem to be very site-specific, as demonstrated by the finding that sites with more litter at Daleys had a higher capture probability when compared to Caples. In Dowding and Murphy's (1994) kauri forest study, active rats were found on the ground more often than in trees. The authors speculated that reasons for this behaviour could have been due to the open, sparse understory, or because the main food source was on the ground. Therefore, perhaps increased food resources associated with mossy ground is one reason for greater capture probability at Sylvan. It is possible that the invertebrates associated with moss provide a good food source for ship rats.

Cox *et al*. (2000) suggested that dense microhabitat provided abundant and/or accessible resources, and an increased ability to avoid predators and competition. There may be characteristics of Sylvan that enable ship rats to find food and avoid predation and competitive interactions more easily than the other trap lines. Plant matter contributes to around 80% of ship rat diet around the world (King, 1990) which implies that a dominance of vascular ground cover would yield greater capture success. However the results at Daleys (more exposed sites had greater capture probability) and Sylvan (mossy sites achieved more success) suggest the features at each site vary with respect to ship rat habitat preference and trappability.

Cox *et al*. (2000) found rats preferred areas with deep leaf litter at North Head, New South Wales whereas Harper *et al.* (2005) discovered that ship rat abundance did not vary with the amount of forest litter on Stewart Island. Capture probability was slightly higher when there was more leaf litter overall. Although leaf litter may mean more insects (and food for ship rats) it does not appear to be a dominant factor contributing to trap capture success.

Cavities under root systems were rare and analysis did not suggest such data were useful predictors of trap capture probability. However burrowing is more characteristic of Norway rats rather than ship rats (King, 1990) so cavity availability or frequency may not be as crucial for ship rats in their habitat use or movement choice. Red beech provides many cavities as its root systems push aboveground (Lawrence, pers. comm.). Therefore one would expect that a dominance of red beech would provide more under-root cavities and consequently, higher capture probability. Red beech dominated the canopy (i.e. mature specimens) for these trap lines but not understory or ground cover vegetation. However, analysis of the three beech species alone indicated the canopy species data was not a useful predictor of trap capture probability. Where overall capture probability was highest (Sylvan), red and mountain beech were in similar proportions in the canopy. When interactions with trap lines were introduced into the analysis, a higher probability of capture existed when red beech dominated at Sylvan, compared with Caples. Innes (1990) found a positive correlation between ship rat density and the proportion of red beech in a forest which may have been the case at Sylvan but also could occurred at the other trap lines, where red beech dominated the canopy (Fig. 10). In trees, rats feed on any available flat surface, as well as in limb crotches (King, 1998). It is possible that the structure of mature red beech (and/or mountain beech) provides ample feeding platforms for ship rats.

Mountain beech was the most abundant understory species (Fig. 11). Red beech, silver beech and small-leaved coprosma were the next most abundant species of note. The understory species data were not useful predictors of trap capture probability, but the majority of species (15 in total for analysis) were eliminated due to low numbers. According to Salmon (1980) southern beech forest forms dense stands of trees with quite sparse undergrowth of smaller trees and shrubs. Hence an analysis of understory species may not be relevant or significant for analysis of trap capture characteristics in beech forest, although the behaviour of rats should also be taken into account. Analysis of plant species in sparse undergrowth may lead to an increased chance of making a Type I error where analysis finds significance where in fact there is none. However the same could be said for the other groups of data in the current analysis, where records of “zeroes” or “Absent” or “None” were frequent.

Boulders were also rare in the surveys and the low number of cases for analysis (36) was probably unsuitable for analysis. Identification of boulders was difficult when they were covered by vegetation and may have been more frequent but difficult to see with the naked eye.

Christie *et al*. (2006) found an increased capture probability with shorter sub-canopy forest. Perhaps the height of the Tier 2 species would have been useful and could have been related to refuge opportunities, ground cavity frequency or type, or soil condition. King *et al*. (1996) hypothesised that ship rats preferred more complexity in the structure of indigenous forests in New Zealand. Therefore, an index of diversity at various height levels could be of use in predicting ship rat abundance and potentially trap capture probability.

Overall, at ground level (Tier 3) mountain beech was the dominant species once more (Fig. 12). Sylvan had the most mountain beech at ground level which suggests a possible link between higher capture probability and abundance of mountain beech. This hypothesis was supported by the analysis that indicated a higher probability of capture when mountain beech was abundant, but not dominant. There was also a higher probability of trap capture success when there were a few small-leaved coprosma individuals at ground level. Lawrence and Hardy (unpublished) found coprosma to be associated with damp areas with light penetration and accordingly, broken/mature beech canopy at Lake Sylvan. Such factors may be important to ship rat habitat selection and could be additional predictor variables in future analysis. The current study indicated most trap sites had good drainage (Fig. 6) but perhaps dampness on another measurement scale would yield more accurate results.

General Discussion

A possible flaw present in the study was that the data collected were largely subjective. Data were mainly comprised of judgements of the physical appearance and makeup of the surroundings at each trap site. Collection of quantitative measurement data would have been too time-consuming for the scope of this report. Christie *et al.*'*s* (unpublished) proposed that data collected in a standardised manner and via an experimental design framework would have more significance. Christie *et al*. (2006) recommended the use of continuous variables and standardised micro-habitat variables to enable comparison between areas. Certainly the use of continuous variables would have enabled easier interpretation of logistic regression models as the coefficients produced reflect the magnitude or influence a particular variable has on the outcome. In addition, Dowding and Murphy (1994) suggested that other factors may cause variation in rat trap catch success, such as home range size, food availability and trappability. The current analysis has suggested only a few environmental characteristics that may be of use for trap placement only in specific areas.

The success rates for each analysis were generally quite low (50-70%). The classification table within the SPSS output shows the percentage of cases correctly allocated by the model (Harraway, 2006). Low success rates may indicate only casual interpretation of the developed models. Hosmer and Lemeshow (2000) suggested that "the classification table is only appropriate when classification is a stated goal of the analysis; otherwise it should only supplement more rigorous methods of assessments of fit" (p. 160).

Two people were involved in data collection over the four trap lines, and ideally, one person would have collected the entire dataset to ensure consistency. Another possible analysis could include the human element with the data collector as an additional factor. The energy levels, experience, time of day and understanding of the survey items are some factors that could have differed for the two people who carried out the surveys.

Christie *et al*. (2006) could not determine whether small-scale factors such as vegetation structure and habitat complexity were crucial to rat capture success. Cox *et* al. (2000) suggested both fine and large-scale spatial factors should be taken into account for interpretation of ship rat distribution patterns. Therefore, the current study may only contain a snapshot of the conditions relevant to ship rats and trap placement. There are likely to be factors at both scales that were excluded yet may be important to ship rat habitat selection and use. It also seems apparent from the analysis that habitat features that are significant at certain sites are specific to that site. It is possible that larger-scale factors would be more applicable for the wider area (covering all trap lines). Lawrence and O'Donnell (1999) found that lines of Fenn traps failed to protect mohua from stoats compared to a grid layout in the Routeburn, Hawdon and Dart valleys. Ideally, an experimental design where trap placement or structure varied in the four areas in the present study may indicate that trap layout is another factor affecting capture success.

The timing of trapping or trapping effort may mean capturing different ship rat sub-populations. It may also be true that ship rat habitat preferences and use are overall, quite unpredictable. When Blackwell *et al*. (2001) modelled rodent and predator population dynamics, variation in food availability was the primary process that influenced rodent population eruptions. Stoat numbers may be another factor influencing ship rat populations although Dilks *et al*. (2003) found that the presence of absence of stoat control had little effect on an increase in rat numbers. King (1983) found that ship rats were most abundant in more diverse forests. The dynamics of mice and stoats around masting periods is also likely to change the behaviour and distribution of ship rats as well as any control activity occurring. Dilks *et al*. (2003) suspected that high rat numbers in many South Island areas in

2000 and 2001 were influenced by good climatic conditions and food availability rather than any restrictive effect of predation by stoats. King (1983) stated that ship rat capture rates fluctuated widely in beech forest in relation to infrequent and irregular seedfalls. It may not be possible to predict trap capture success when beech masting events will complicate predator-prey dynamics in beech forest systems. Other factors may trigger a rise in rodent numbers, such as an increase in litter-feeding invertebrates that arise after seedfall, for example (Fitzgerald *et al.*, 1996).

Male ship rats have larger home ranges than females (Pryde *et al.*, 2005) and it would be interesting to know the sex ratio of ship rats caught in the capture data used for this analysis. Increased knowledge of ship rat behaviour may be crucial in trap placement strategies. Dowding and Murphy (1994) suggested that male ship rats ate poison faster than females (although the sample size was small) and have a larger home range while breeding. The heavier trigger mechanism of Fenn traps probably selects against lighter, younger animals (Innes *et al.*, 2001) and effects on the rat population would be valuable information where control using Fenn traps is intense. Innes *et al.* (2001) found ship rat numbers rebounded after control operations at any time of the year, but particularly in spring and summer months. Therefore, sex, weight and time of year could be other useful variables in analysis of trap capture success.

Ship rats are generally assumed to be uniformly spread in suitable habitat (Innes, 1990), which suggests analysis of possible factors predicting their habitat use to be futile. If rats are patchily distributed and the patches can be identified, then control operations can focus on these areas (Christie *et al.*, unpublished). Christie *et al.* (2006) agreed that the focus for this type of analysis should be on aspects for which definite predictions can be made about the mechanisms behind predator habitat use. If one ship rat disappears, a neighbour will soon take over the vacant range which suggests long-term control strategies are not useful in continuous habitat (Innes and Skipworth, 1983). However Studholme (2000) found significant annual variation in ship rat abundance in which indicates short-term control strategies would be ineffective. However the reality is that there has been limited investigation into ship rat trap catch data (Christie *et al.*, 2006) and ship rat population biology in beech forest (Studholme, 2000). Such information can only provide better understanding of invasion of predators into natural environments, highlighting potential overlaps with native (prey) species and help alleviate any negative consequences by developing control programmes (Cox *et al.*, 2000).

Conclusions

Although there were few significant results from the analyses, the most relevant conclusions from the study relate to trap placement in the wider Wakatipu area as well as within each trap line. Overall, traps should be placed in sites where there is/are:

- Less vascular ground cover
- More leaf litter at ground cover level
- Flatter sites
- Fairly abundant mountain beech at Tier 3 (≤ 30cm)
- A few small-leaved coprosma individuals at Tier 3 (≤ 30cm)

For the Routeburn trap line, traps should be placed on flat or gentle slopes if possible. For the Daleys trap line, traps should be placed where there is more leaf litter at ground cover level. For Sylvan, traps should ideally be placed at dryer and/or mossier sites (if such a combination can be found). The Caples trap line was treated as the reference category for the analysis, so unfortunately little interpretation is possible. Mohua predation is likely to be the most intense in the summer following a beech mast (O'Donnell and Phillipson, 1996) so trap placement strategy could be further concentrated during such periods within beech forest, when mouse, stoat and rat numbers surge.

Post Script

Since this analysis was conducted and findings reported, two additional factors have arisen which would have been interesting to include in the analysis. The two factors are altitude and period within mast cycle. Barry Lawrence at DoC Wakatipu may undertake further analysis of this data with the above factors included and a particular focus on where rats are found at the lowest phase of a mast cycle. Altitude will have affected rat numbers in some trap lines more than others, where fewer rats will be found in the upper Caples and Routeburn, for example. Rats are scarcer at high altitudes (King, 1990) and capture probability generally decreases with increasing altitude (Christie *et al.*, 2006). The Sylvan trap line is generally at a lower altitude (Lawrence, pers. comm.). Timing of mast cycles may also affected rat numbers and ideally, this timing will also be built into future analyses of environmental variables and trap success.

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