

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

**Geospatial and temporal patterns of stoat  
(*Mustela erminea*) activity in Tongariro Forest,  
central North Island, New Zealand.**

**A thesis presented in partial fulfilment of the requirements of the degree of**

**Master of Science  
in  
Ecology**

**at Massey University, Palmerston North, New Zealand.**

**Ross David Martin**

**2012**



**Abstract**

Spatial and temporal characteristics of stoat (*Mustela erminea*) activity in Tongariro Forest were quantified using two well documented monitoring methodologies : i) radio telemetry using motion sensitive radio collars provided high detail measurement of individual activity of a number of stoats, and ii) footprint tracking tunnels provided measurement of population-level tendencies in activity, abundance and habitat use. The specific objectives were to identify predictable times of high and low stoat activity, and identify habitat types and specific locations within Tongariro Forest where stoat visitation to a control station is likely to be especially high and low. Prior to field data collection the radio transmitters were assessed and calibrated using captive stoats and video equipment to compare telemetry signals with actual behaviour. Two motion sensitivities were tested (fine and coarse), and the fine sensitivity transmitter was identified as most suitable for a field study. Estimates of locomotor activity derived from telemetry data correlated with directly observed behaviours at hourly and greater time scale, and verified suitability of activity transmitters for field study of stoat activity. Eleven stoats were tagged with motion-sensitive radio transmitters and monitored in the field in Tongariro Forest to quantify temporal patterns in wild stoat activity. Four monitoring 'seasons' representing early and late summer, autumn and spring seasons of the year, provided a total of 896 hours of stoat activity. On average, stoats were active 28% of the 24-hour day (seasonal range 16-41%). Both the total time spent active per day and the partitioning of this activity through the day varied between seasons. Tracking tunnel visitation indices obtained in subsequent years showed similar seasonal patterns to the data obtained using telemetry, except during early summer when tracking rates were lower than the equivalent locomotor activity estimate. Most radio-tagged stoats were predominantly diurnal in all seasons. Winter and spring had the largest proportions of daytime activity even though daytime was on average about 4 hours shorter during these seasons than in summer. Crepuscular peaks in activity were apparent in all seasons but particularly so during late summer. Activity was least structured in early summer, when it was spread more or less evenly throughout the 24 hours of the day. Active periods usually lasted at least 40 min, and up to 43% of activity was maintained continuously for >3 hours. Variability in activity between and within stoats was high, but variability in spring was marginally lower than in the other seasons. Temperature had some influence on activity at an hourly timescale, and the correlation between activity and temperature strengthened with increasing timescale. Autumn

activity comprised more extended bouts of movement so might represent a time of year when stoats are ranging further, or exploring or searching within their ranges more intensively. This suggests that stoat control and monitoring devices might be most effective in autumn. Habitat use by stoats was quantified using a Geographical Information System (GIS) approach and statistical modelling with multi-year tracking tunnel records to data-mine for terrain variables that predict stoat visitation to stations in a New Zealand indigenous forest. Spatial analysis scale was found to be important for modelling outcomes, and an optimal model equation was derived using model selection techniques assessing at a range of relevant scales. The sensitivity of the model to different terrain parameters was tested by systematically substituting each variable and calculating the difference this made to the model derived estimates of stoat visitation. The most dominant terrain predictors influencing stoat visitation were proximity to tracks, altitude, northerly and easterly aspect, mean curvature, topographical position and slope. Proximity to tracks and mean curvature were the most sensitive variables to analysis scale. Indices of mouse and rat activity, which are known prey of stoats, and autocorrelation factors for previous and nearby stoat visitation, significantly improved the model and reduced the effects of terrain. Visitation to tracking tunnels was negatively correlated with rat visitation suggesting possible prey aversion of predators. Mouse visitation had no detectable effect on stoat tracking rates. Relevance for management and fit with known stoat ecology are discussed.

**Contents**

Abstract .....	1
Contents .....	3
List of Figures .....	6
List of Tables.....	7
Acknowledgements .....	8
Chapter 1. Introduction - background, study plan and objectives.....	9
1. Introduction .....	9
2. Stoats .....	9
2.1. Brief history of stoats in Tongariro Forest. ....	9
2.2. Stoat biology and ecology .....	10
2.3. Impacts on species and ecosystem .....	12
2.4. Stoat control and monitoring .....	13
3. Study Area.....	16
3.1. Site description .....	16
3.2. Kiwi recovery .....	17
3.3. Other flora and fauna.....	19
3.4. Tracking tunnel network .....	19
4. Habitat use modelling and GIS .....	20
5. Objectives.....	23
6. Thesis plan: .....	24
7. References .....	25
Chapter 2 Calibration of activity transmitters using captive stoats. ....	35
1. Abstract. ....	35
2. Introduction.....	36
3. Methods.....	39
3.1. Overview .....	39
3.2. Stoat capture and radio tagging. ....	40
3.3. Captive enclosures and video set-up. ....	41
3.4. Activity data collection .....	43
3.5. Data analysis.....	45
3.5.1. Stoats in captivity.....	45
3.5.2. Comparison of transmitter types .....	45
3.5.3. Assessment of timeout removal .....	46
3.5.4. Refinement of the data set for estimating locomotor activity. ....	46
4. Results .....	46
4.1. Stoat behaviour in captivity.....	46
4.2. Comparison of transmitters. ....	51
4.2.1. Equivalence of behaviours experienced by the transmitters.....	51
4.2.2. Transmitter performance.....	51
4.3. Factors influencing interpretation of data.....	54
4.3.1. Variability in activity between stoats.....	54
4.3.2. Timeout period.....	54
4.3.3. Overestimation of activity by transmitters.....	55
5. Discussion .....	56
6. Conclusion .....	59
7. References.....	60

Chapter 3. Seasonal patterns in stoat ( <i>Mustela erminea</i> ) activity in Tongariro Forest...	63
Abstract .....	63
1. Introduction .....	64
2. Methods.....	65
2.1. Research overview .....	65
2.2. Study Area.....	66
2.3. Capture and tagging.....	68
2.4. Activity transmitter function and settings .....	69
2.5. Data collection and processing.....	69
2.6. Statistical analyses.....	70
3. Results .....	72
3.1. Locomotor activity component .....	72
3.2. Duration of active bouts .....	72
3.3. Seasonal changes in daily activity.....	74
3.4. Seasonal changes in day and night activity .....	75
3.5. Seasonal changes in dawn, midday, dusk and midnight partitioned activity ...	78
3.6. Seasonal changes in 24-hour activity patterns .....	78
3.7. ANOVA model effects.....	80
4. Discussion .....	81
5. Acknowledgements.....	86
6. References .....	87
Chapter 4. Sensitivity of GIS derived terrain variables at multiple scales for modelling stoat ( <i>Mustela erminea</i> ) activity. ....	95
Abstract .....	95
1. Introduction.....	96
2. Methods.....	98
2.1. Study area and monitoring data.....	98
2.2. Terrain data, GIS and data processing.....	99
2.3. Statistical analysis .....	105
2.3.1. Term reduction.....	105
2.3.2. Model selection.....	106
2.3.3. Sensitivity analysis.....	106
3. Results.....	107
3.1. Term reduction .....	107
3.2. Model selection .....	108
3.3. Sensitivity.....	111
4. Discussion .....	112
5. Conclusion .....	113
6. Acknowledgements.....	114
7. References .....	114
Appendices.....	118
Chapter 5 The influence of mice and rats on stoat ( <i>Mustela erminea</i> ) activity. ....	121
Abstract .....	121
1. Introduction.....	121
2. Methods.....	124
2.1. Study Area.....	124
2.2. Source Data .....	125
2.3. Statistical Analysis .....	127
3. Results.....	128

4. Discussion .....	130
5. References .....	133
Chapter 6. Synthesis, conclusion and discussion .....	139
1. Introduction .....	139
2. Main findings .....	139
2.1. Objective 1. Identify predictable times of high and low stoat activity where they exist. ....	139
2.2. Objective 2. Identify habitat types and specific locations within Tongariro Forest where stoat visitation to a control station is likely to be especially high and low. ....	140
2.3. Objective 3. Understand relevance and limitations of results. ....	142
3. Fit with ecological theory.....	145
4. Recommendations and Future Direction.....	147
5. References.....	149

**List of Figures****Chapter 1.**

Figure 1. Stoat in fenn trap. ....	14
Figure 2. Footprint tracking tunnel .....	16
Figure 3. Study area topography .....	18
Figure 4. Broad land cover classification .....	18
Figure 5. Northern brown kiwi with northern white male. ....	19
Figure 6. Cave weta. ....	19

**Chapter 2.**

Figure 1. <i>a.)</i> Transmitter tilt switch orientations. <i>b.)</i> Stoat in nest box .....	41
Figure 2. Captive enclosure setup. ....	42
Figure 3. Characteristics of stoat activity outside of the nest box (behaviours). ....	48
Figure 4. Characteristics of stoat activity outside of the nest box (locomotor). ....	51
Figure 5. Mean hourly activity patterns across the 24 h of the day. <i>a)</i> video-derived activity budget; <i>b)</i> telemetry-derived data for fine transmitter; and <i>c)</i> telemetry-derived data for coarse transmitter. ....	53
Figure 6 Day and night activity levels outside of the nest box .....	55
Figure 7 Day and night activity levels as proportion of daily activity .....	55

**Chapter 3.**

Figure 1. Location of study area. ....	68
Figure 2. Activity time-lines. ....	76
Figure 3. Seasonal change in visitation to footprint tracking tunnels .....	77
Figure 4. Seasonal changes in day and night activity budget of stoats .....	78
Figure 5. Seasonal changes in quarter-day activity of stoats. ....	79
Figure 6. Seasonal changes in 24 h activity patterns.. ....	80

**Chapter 4.**

Figure 1. Study area, and location of tracking tunnels.....	99
Figure 2. Example illustrations of GIS-generated terrain variable layers. ....	102
Figure 3. Predicted probability surface for likelihood of stoat visitation based on optimal linear regression equation.. ....	109
Figure 4. Predicted probability surface (from Figure 3) classified into categories of <i>very good</i> , <i>good</i> , <i>moderate</i> or <i>poor</i> likelihood of stoat visitation.....	110

**Chapter 5.**

Figure 1. Study area, and location of tracking tunnels on lines. ....	126
---	-----

**List of Tables****Chapter 2.**

Table 1. Details of stoats held in captivity for filming. ....	40
Table 2. Behaviour categories and groups. ....	44
Table 3. Summary of video footage collected for behaviour analysis. ....	47
Table 4. Characteristics of excursions outside of the nest box. ....	47
Table 5. Proportion (%) of total time stoats spent outside of their nest box engaged in each behaviour category. ....	49
Table 6. Proportion of total observable time outside of the nest box that was spent engaged in each behaviour class. ....	50
Table 7 Correlation coefficients for comparison of transmitter activity indices (unadjusted and time-out adjusted data sets) with video-derived records ....	52
Table 8. Percentile values for duration of transmitter activity bouts ....	54
Table 9. Total timeout error component and degree of overestimation ....	55
Table 10. Timeout overestimation in activity data for individual stoats. ....	55
Table 11. Comparison of transmitter performance. ....	56
Table 12. Correlation between telemetry-based measures of hourly activity and video-based measures of times spent outside of the nest box. ....	56

**Chapter 3.**

Table 1. Identity of stoats and monitoring achieved in each season. ....	73
Table 2. Timeout error and den activity components ....	73
Table 3. Transmitter-active bout size distribution ....	74
Table 4. Mean day and night activity. ....	75
Table 5. Correlation between day and night mean activity estimates and mean temperature for the corresponding hourly activity data ....	80
Appendix 2. Daily and day-night activity for stoat individuals in each season. ....	93
Appendix 3 a. Model outputs from analysis of variance. ....	93
Appendix 3 b. Model fit statistics ....	94

**Chapter 4.**

Table 1. Source and description of response and predictor variables. ....	103
Table 2. Performance of different spatial variants of terrain predictors. ....	107
Table 3. Parameter estimates and test statistics output from model. ....	108
Table 4. Proportion (%) of randomly sampled test-locations for which predicted stoat activity changed. ....	111
Appendix A. Performance of different spatial variants of terrain predictors	
Appendix B. Reduction of collinearity ....	118

**Chapter 5.**

Table 1. Individual parameter estimates from each model output. ....	128
Table 2. Alternative models tested, rat, mouse, and autocorrelation factors. ....	129