Rat activity between regular and irregular spaced bait-lines at Ark in the Park Waitakere Ranges, Auckland

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1.0 TITLE

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2.0 ABSTRACT

New Zealand (NZ) has three introduced rat species (kiore, norway rat and the ship rat). All species were established in New Zealand by 1860's through human colonisation, causing a large detrimental effect on NZ biodiversity. Rat control is deemed necessary in the future success of many pest control programmes in NZ. However a balance between effectiveness and efficiency is sort after in order to gain the ideal control method.

In this study tracking tunnels were used, monitoring potential elevated rat activity rates within divergent areas of the Ark in the Park pest control gridding system, Waitakere Ranges, Auckland NZ.

This is assessed by addressing the following questions, (1) is there higher rat activity on divergent lines compared with control lines (2) is there a relationship between rat activity levels and distance between tracking tunnels to bait-stations(3) do rat activity levels show seasonality effects (4) do rat activity levels vary with edge effects and pre/post baiting procedures.

Results conclude, there is no significant relationship between rat activity rates and divergent vs. control lines. However there is a strong linear (R=0.889) and non-linear/quadratic correlation (R=0.986) between rat activity and the distance (metres) between tracking tunnels to bait-stations.

This study reflects the complexity of rat activity and the many confounding variables involved. Therefore the importance of accurate and systematic gridding

systems in conservation is vital, for effective and efficient pest control. Further more for the control of indigenous biodiversity.

This study signifies the importance of greater research into rat activity and behaviour, in order to gain more efficient and effective pest control methodologies permitting cost effective and successful restoration programmes.

3.0 INTRODUCTION

3.1 New Zealand's mammal predator problem/ control issues

There are three introduced rat species in NZ, the kiore, the norway rat and the ship rat. All species were established in NZ by 1880, arriving as ship stowaways (Towns & Daugherty, 1994). Rats have had a large detrimental effect on NZ biodiversity since their introduction (Atkinson, 1996; Atkinson & Cameron, 1993; Fukami, et al., 2006). During post human settlement NZ had a bird, reptile and invertebrate biased tropic system (Towns & Daugherty, 1994), therefore rat introduction changed the natural predator/prey dynamics and thus causing native species declines e.g. North Island (NI) bell bird, NI robin, hihi and the saddleback (Wendy, et al 2010). Rats and other introduced mammalian predators, have an aggressive temperament. They forage on native species as well as compete for native species food resources e.g. fruit and seeds (Beverage, 1964). Furthermore, reducing forest regeneration, threatening the natural structure and function of forest ecosystems (Wendy et al., 2010), (Innes, et al., 1995). As a result, rat control is deemed an essential requirement in the success of ecosystem, biodiversity and conservation management within NZ, in order to rehabilitate NZ biodiversity (Atkinson, 1996).

3.1.1 New Zealand History of Pest Control

The importance for effective and efficient rodent control has led to the development of many control methods e.g. bait poisoning, fumigant poisoning and non-poisonous measures such as trapping (Meerburg, Brom & Kijilstra, 2008). Pre 1950s acute rodenticide bait poisoning was the conventional form of pest control, due to its positive high toxicity and quick acting properties. Negatively it was environmentally toxic and rodents began demonstrating bait shy behaviour (Meerburg., et al, 2008). Therefore the first generation anticoagulants were generated e.g. Pindone (1950s). However genetically resistant rodent populations soon developed (Meerburg., et al, 2008). In turn (1970s) second-generation anticoagulants were formulated (Brodifacoum), reducing the risk of genetic resistance. This new formulation changed people's negative opinions on pest control, resulting in larger scale NZ pest control programmes (Hasler, Klette, & Rosenhahan, 2004).

Fumigation poisons and traps are also used as secondary control measures throughout NZ, however they are less efficient in the use of large scale programmes (Meerburg., et al, 2008).

3.1.2 Logistical and animal welfare issues regarding pest control

Poisoning is the most effective and efficient, pest control method in large conservation projects. However poison baiting, raises animal welfare concerns, as it is not an instant kill method (Littin & Mellor, 2005).

Alternative, fumigation and trapping methods pose less welfare concern, due to reduced animal suffering (Littin & Mellor, 2005), however they are less efficient due to labour intensity and costs (Beverage, 1964).

A combination using both poison bait and trapping is an effective and efficient rodent control method, viewed as a sustainable long-term environmentally friendly method of rodent control (Beverage, 1964). Effective and efficient control is deemed necessary due to the rats fast ecological reproductive nature (Innes et al, 2001 & Rowett, 1965).Rats can recover from an 80% kill rate obtained during poisoning, to pre-poisoning numbers in 9 to 12 months (Innes, 2001).

3.1.3 Ecology of rat species

Kiore are now found only in Fiordland, Stewart Island and some off-shore islands. They were introduced to New Zealand by early polynesian settlers and have cultural and spiritual values to some Maori today (e.g., Ngatiwai on Hauturu). They are less abundant than the norway and ship rat, and are largely herbivorous, therefore pose less threat to NZ biodiversity and conservation programmes (Innes, 1990),

The ship rat and the norway rat can be distinguished by their anatomy. The ship rat's torso length is ~20 centimetres (cms), with a tail exceeding this (23 cm). In comparison the norway rat has a longer torso ~22 cms, and a shorter (~18 cm) thicker tail (Innes, 1990). The norway rat has small ears of around ~1 cm in length whereas the the ship rat has ears ~3 cm in length (Innes, 1990).

Both rat species have strong, sharp teeth (Corbet & Museum, 1978), and are nocturnal (Innes, 1990), omnivorous and opportunistic feeders. They commonly forage on seeds and berries (e.g nikau palm *Rhopalostylis sapida*, insects, such as the weta *Hemideina sp.*, skinks, such as the striped skink *Oligosoma striatum* and also birds and their eggs) (Innes, 1990; Wendy et al., 2010; Beverage & Daniel, 1964).

Both species are associated with human activity, found in houses, tips, waterways and cropland. Both species can swim up to 2 kilometres (Russell, Beaven, et al., 2008) and are exceptional climbers. Ship rats spending most of their time in trees (Ewer, 1971), whereas the norway rat prefers lower spatial areas.

Ship rats and norway rats often use the same den site for three days (Dowding & Murphy, 1994; Russell 2007), however den site use does vary (Russell 2007). Hooker & Innes, (1995), found that male rats often have larger (1.1 hectare) home ranges than females (0.3 hectare), being as low as 50 metres when pregnant (Land Care Research, 2010).

Rats have extremely high reproduction rates. Ship rats reach sexual maturity at 3-4 months (Eatt & Aslin, 1981) and norway rats at 1-2 months, (Meany & Stewart, 1981). The gestation period for both species is 22 days (Innes et al, 2001 & Rowett, 1965). The average time between each litter is ~32 days, with 3-6 pups commonly being born (Cowan, 1981).

These rapid reproduction rates signify the need for more significant control than other predators (e.g bush-tail Possums, which generally breed around April- July, take longer to reach sexual maturity (~18 months) and produce ~1-2 joeys per litter) (Clout & Gaze, 1984).

3.2 Ark in the Park

The Ark in the Park organisation is a conservation project partnership between Forest and Bird and the Super City. The project began in 2003, focussing on controlling pests in a 1200 hectare area in the Waitakere Ranges, 22 km west of Auckland city.

The forest area is made up of regenerating broadleaf and podocarp species, which was partially burnt in the 1950s, and further undergoing damage from introduced pest species. All aspects of a native forest are demonstrated, containing lowlands, ranging hills and dense forests (Staniland, 2007).

Many of NZ’s rare and endemic species live in this area as remnant populations (e.g. long tail bat *Chalinolobus tuberculatus,* forest gecko *Hoplodactylus granulates*, and hochstetter's frog *Leiopelma hochstetteri)* (Daniel & Williams, 1984).

Ark in the Park aims at keeping rodent levels to a minimum of 10 percent (%). In order to improve local ecology, maintain biodiversity and re-construct a future matrix close to the historic one. In turn, allowing for future re-introductions of indigenous species (Bellingham, Jack, Makan, Sumich, De Poorter, 2009). This has produced the predator control grid system and monitoring techniques, allowing for effective analysis of pest control results.

3.2.1Predator control – baiting grid system

Predators are controlled with brodifacoum bait poison and kill traps. Baiting control is done using a systematic grid of bait-lines. Each bait-line is 100 metres apart, and runs in a straight line, bait-stations are placed 50 metres along each line (100 X 50 m). Each bait station is baited with pre-bagged brodifacoum bait, every three months by Ark in the Park volunteers (Figure 1) (Colgan 2010). Kill traps are used on the edges and the tracks of each block, catching potential invaders. Traps are baited every two weeks all year round.

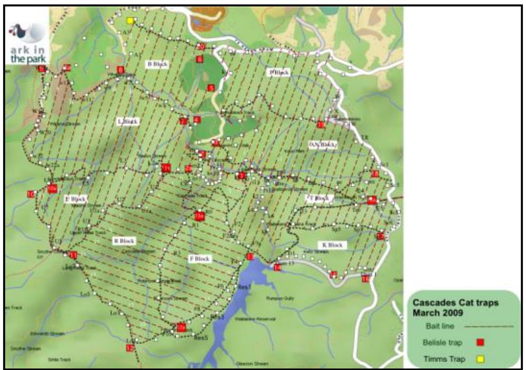

Figure 1: *Ark in the Parks predator control gridding system. Colgan, 2010*

In addition the success of these predator control measures can only be assessed with the use of monitoring techniques.

3.2.2 Predator Control- monitoring

Monitoring techniques have been used in scientific studies since 1980, now they are used as a standard for general monitoring and predator control. The most common predator monitoring technique is black tracking tunnels (Handford, 2000).

Ark in the Park has 110 stationary, randomly placed black tracking tunnels throughout the Ark reserve, allowing a variety of habitats to be sampled. The Ark also has 30 stationary and randomly placed monitoring tunnels outside of the Ark. This allows a comparison between pest controlled areas and non-pest controlled areas. All monitoring tunnels are used over a two day period every two months, monitoring the effectiveness of pest control throughout the Ark.

Results show there is currently around 5% rats in the Ark and currently around 70% outside of the Ark. Since 2003, the reduction in rat numbers has been significant. However a study by Martineau (2010) found, that there are areas of large bait uptake and areas of low bait uptake within the Arks gridding system, potentially indicating areas of high and low rat activity within the grid system.

3.2.3 Reason for study/importance and relevance

Adrien Martineau (2010), studied “Management and predator control in a ‘Mainland Island’ ecosystem: Assessment of rodent control efficiency”. Findings indicated the presence of high and low bait uptake in the Ark., indicating varying levels of rat activity within the grid. Significantly these areas of high bait uptake (Figure 2), present an un-systematic divergent grid.

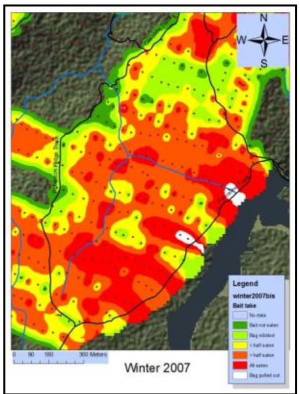

Figure 2: *High and low bait uptake areas.* Martineau, 2010

Forest navigation and bait-line instillation is difficult as many factors need to be considered (e.g. technology, typography and experience). This leads to Andy Warneford (2011) study, comparing the ‘original’ Ark in the park gridding system (100 X 50m) to a ‘Trial’ version (100 X 100m grid). Warneford (2011), applied a mathematical principle (Figure 3) calculating the maximum distance of any single rat to approaching a bait-station (A-B) within the gridding system. The maximum distance of a rat to a bait station within a 100 X 50 m grid as opposed to a 100 X 100 m grid is only 15 m difference. However, should the accuracy of a bait-line within the grid increase and become divergent, the distance quickly increases to to 93 + metres (Warneford, 2011).

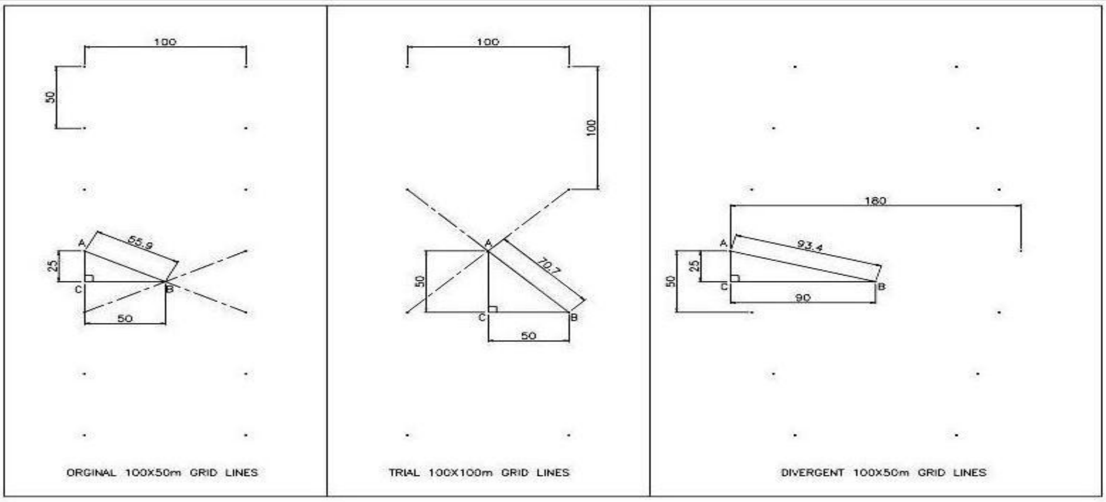

Figure 3: *Mathematical indication of distances, given the three scenarios original grid, trial grid and a divergent grid.*
Warneford, 2011

Given that pregnant female ship rats are known to have a home range of 50 metres radius (Land Care Research, 2010), efficient breeding systems (Asdell, 1946; Rowett, 1965) and large home ranges (Dowding & Murphy, 1994). This suggests rats could potentially live within a divergent gridding system without coming in contact with a bait-station. In turn causing embedded residual rat populations within the grid.

4.0 AIMS/OBJECTIVES

In this study we address the following questions (1) is there a relationship between rat activity levels and distance between tracking tunnels to bait-stations(2) do rat activity levels show seasonality effects, (3) do rat activity levels vary with edge effects and pre/post baiting procedures.

This information is important to the Ark in the Park and other rodent control programs. We know from prior studies that rat activity levels vary significantly on a seasonal basis. In addition, rat activity levels vary in relation to distance between bait-stations and this has important implications regarding the design, funding and maintenance of pest control operations.

5. 0 METHODS

5.1 Study area and previous study analysis

Martineau (2010), graphical data was analysed (Figure 4) in order to identify large divergent bait-line areas with high bait up-take, within the Ark in the Park project of the Waitakere Ranges. Six areas were selected, three in the 'F' block of the Ark (36^{0}54'12.37"S, 174^{0}31 '11.00"E) and three in the 'L' block of the Ark (36^{0}52'55.69"S, 174^{0}30'33.17"E). In each block an area between two bait-lines which represented an accurate spaced (100x50 m) grid was selected, and an area between two bait-lines which represented a divergent (100x50+ m) grid was selected.

Figure 4: *Location of the Waitakere Rangers Google Maps, 2011*

5.2 GPS mapping

Once these sites were selected, the location of each bait-station on the bait-line to the left and to the right was identified by walking each of the 12 bait-lines, saving each bait-station GPS location (Figure 5). This

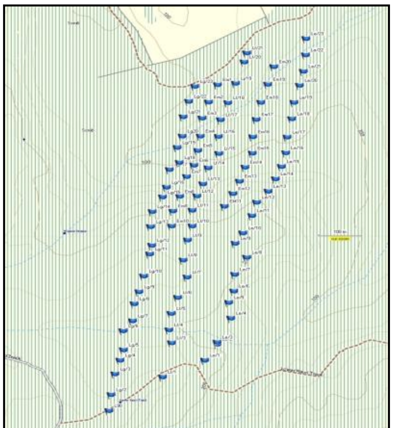

Figure 5: *GPS map of 'L' block control (left) and 'L' block divergent line 1.* McGregor, 2011

was essential in order to identify the mid-point, in which each monitoring tunnel would be situated.

5.3 GPS mid-point calculation

A mathematical strategy using the GPS co-ordinates of each bait-station directly to the right and left of each area was used to locate the middle point (e.g. first bait-station on the bait line to the right, compared to the first bait station on the left). The difference between the two co-ordinates was found, divided by two and added to the smallest co-ordinate, thus giving the mid-point co-ordinate. This method was used to calculate all 60 mid-points for all 60 of the tunnels over the six monitoring lines.

E.g.

Left Bait station co-ordinates-E1734083-N5917181
Right Bait station co-ordinates- E1734184-N591717188

Left bait-stations Easting- E1734083
Right bait-stations Easting- E1734184

Difference between the Easting's=101/2=50.5

Add to the smallest Easting to the calculated difference- E1734083+ 50.5= ***E1734133.5*** *(Mid-point)*

Left bait-stations Northing: N5917181
Right bait-stations Northing: N5917188

Difference between the Northing's=7/2=3.5

Add to the smallest Northing to the calculated difference: N5917181+ 3.5= ***N5917184.5*** *(Mid-point)*

Note: all GPS were rounded to the nearest d.p
Calculated Easting Mid-point= E1734134

5.4 Physical set up of monitoring lines

Once all the GPS mid-points were calculated, the 'go to' function on the GPS was used. Starting at the first closest mid-point the second mid-point was selected and so on. Blue tape was attached to trees on the most direct route, identifying the path for future monitoring. Orange tape was used by each tracking tunnel, clearly identifying the location so they were not missed (Figure 6). I ensured that the GPS stayed at +5 or -5 when locating each mid-point, in order to gain the best accuracy possible. Once a 1 km line was in place, ten black tracking tunnels were placed every 50 metres along the monitoring line, in a randomly systematic manner, placed within 5 metres of the 50 metre point. Each tunnel was, folded, pinned into the ground and labelled. Lines were labelled North to South ('L' block) or West to East ('F' block) (Figure 7).

Figure 6: *Label example*
McGregor, 2011

All tracking tunnels were left for three weeks before monitoring started and left in the same location during all monitoring, ensuring

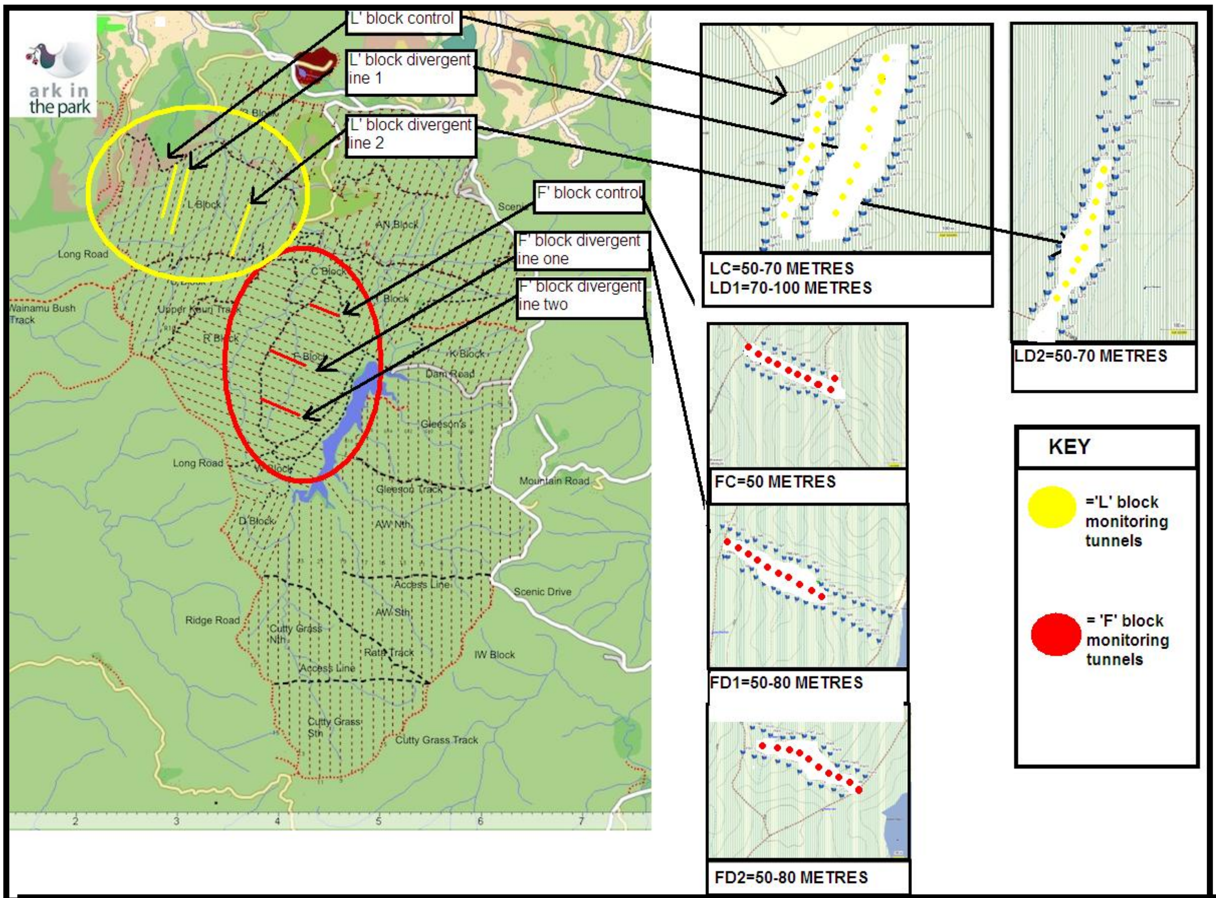

Figure 7: *Grid system with monitoring lines identified in 'F'block area and 'L' block area*
McGregor, 2011

animals are familiar with the tunnels therefore less likely to avoid them.

5.5 Monitoring card placement

Monitoring was only conducted on dry days. An ink card was placed in all ten tracking tunnels along the six monitoring lines (60 tunnels). Each card was baited with a blob of peanut butter on either side of the ink and named and dated. All monitoring cards were left for the remaining day and night, and collected at around the same time the following day.

Figure 8: *Tracking tunnel example*
McGregor, 2011

Each monitoring session was conducted every three weeks starting in February 2011 and finishing in October 2011. Over the duration of the study eight monitorings were conducted.

5.6 Monitoring card observations

The cards were observed, using rat foot print examples (Figure 9), in order to identify the presence or absence of rats. All results were recorded on an excel graph spreadsheet, under each monitoring station number. The data was labelled 1 for rat activity and 0 for no rat activity. Cards which showed no activity were reused to reduce costs and the cards which showed activity were kept as evidence. Photographic records were taken in order to compare different levels of activity.

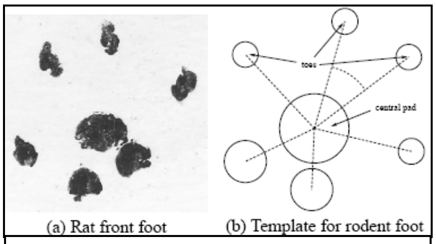

Figure 9: *Rat foot print identification*
Hasler.,et al, 2005

5.7 Statistical analysis

5.7.1 Differences in rat activity due to location

Differences in rat activity in control vs. divergent, lines were investigated in a descriptive manner using means, standard deviations and standard errors. They were also presented side by side in histograms presenting each variables activity and no-activity rates along with a monitoring comparison. These comparisons were made to observe potential differences in rat activity between control and divergent areas.

A Chi-square test in SPSS in order to observe "goodness of fit" between activity and location, with a level of significance of 0.05%.

5.7.2 Seasonality / months of the year, categorisation

All data was sectioned into categorical months on which it was collected. An average monthly activity rate was calculated for all six of the monitoring months. Data was presented on a line graph, showing rat activity trends. The SPSS programme was used and a Chi-square test was calculated, observing the "goodness of fit" between rat activity and months of the year (0.05% level of significance).

5.7.3 Distance to the nearest bait station categorization

All 60 tracking tunnels were categorised in to six different groups (0-50, 50-60, 60-70, 70-80, 80-90, 90-100 m) based on their distance to the nearest bait-station. This was done analysing GPS maps with all bait-station and monitoring tunnel waypoints. This was done in SPSS using the calculated mean percentage of activity for each categorisation, creating a scatter plot graph with significant r-value.

This data was also put under a Pearson's correlations test (set at 0.05%), testing for positive or negative correlation between Rat Activity and Bait-station distance.

5.7.4 Edge effect analysis

The level of rat activity for each tracking tunnel over the 8 monitorings was calculated and averaged using Excel. Each monitoring tunnel was categorised into groups (0, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500 m), regarding its distance, to the nearest walking track. The data was presented showing means and standard deviations and presented on a scatter plot graph. The r-value and level of Pearson's correlation between activity and distance was presented (0.01% significance level), signifying positive or negative relationship between rat activity and the distance to the nearest walking track, thus providing insight on the edge effect.

GPS maps of each monitoring line were used alongside each monitoring tunnel mean rat activity rate. Rat activity rates were categorised (extremely high, high, medium and low), and colour coded based on rat activity. This was done as a visual comparison to the other edge effect findings.

5.7.5 Pre and Post-baiting dates

All monitoring data was sectioned into two groups (1) Pre-baiting and (2) Post-baiting. Each months activity rate was averaged and the standard deviation was calculated and presented on a line graph, comparing pre-baiting activity rates with post-baiting activity rates. The pre and post-baiting data was also presented in a histogram, showing cards present of rat activity and cards absent of rat activity.

The data underwent a Chi-square test suing SPSS, testing the "goodness to fit" between rat activity and Pre and Post-baiting (0.05% level of significance).

6.0 RESULTS

6.1 Overall monitoring card results

In reference to Table 1 and 2, the 60 monitoring tunnels located in ‘L’ and ‘F’ block of the Waitakere Ranges collected 480 monitoring card results over eight monitoring sessions in a six month period. Over all 115/480 monitoring cards were tracked by rats. 42 /160 monitoring cards placed on both control lines were tracked by rats. On the ‘F’ block control 2/80 monitoring cards were tracked by rats. 40/80 monitoring cards were tracked by rats on the ‘L’ block control line. Over all four divergent lines 73 / 320 cards were tracked by rats. 9/80 on ‘F’ block divergent line 1, 13/80 on ‘F’ block divergent line 2, 40/80 on ‘L’ block divergent line 1 and 49/80 on ‘L’ block divergent line 2 (Table 1&2). These results were further analysed in regards to, location, seasonality, distance, edge effects and pre and post-baiting see Table ten for summary.

Table 1: *All tracking results over the six month monitoring*

Monitoring dates		10/02/2011	4/03/2011	2/04/2011	22/04/2011	13/05/2011	20/05/2011	4/06/2011	3/06/2011
L-block control monitoring line	1	0	0	0	1	0	0	0	0
	2	0	0	0	0	0	0	0	0
	3	0	0	0	0	1	1	0	0
	4	0	0	0	1	1	1	0	1
	5	0	1	1	1	1	1	0	1
	6	0	0	0	1	1	1	0	1
	7	0	0	1	1	1	1	0	1
	8	0	0	1	1	1	1	0	1
	9	0	0	1	1	1	1	0	1
	10	1	1	1	1	1	1	1	1
L-block divergent monitoring line 1	1	0	0	0	0	0	0	0	0
	2	1	1	0	0	0	0	0	0
	3	0	1	0	1	1	1	0	0
	4	1	0	1	1	1	1	0	1
	5	1	1	1	1	1	1	1	1
	6	0	1	1	1	1	1	1	0
	7	1	1	1	1	1	1	1	1
	8	0	0	1	1	1	1	1	1
	9	0	0	1	1	0	0	1	0
	10	0	1	1	1	1	1	1	0
L-block divergent monitoring line 2	1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	1
	10	0	0	1	0	0	0	0	0

Monitoring dates		10/02/2011	4/03/2011	2/04/2011	22/04/2011	13/05/2011	20/05/2011	4/06/2011	3/06/2011
F-block control monitoring line	1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	1	0
	5	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	1	0
	8	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0
F-block divergent monitoring line 1	1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0
	5	0	0	1	0	0	0	0	0
	6	0	1	0	1	1	1	1	0
	7	0	0	0	0	0	0	1	0
	8	0	0	0	0	0	0	1	0
	9	0	0	0	0	0	0	0	0
	10	0	0	1	0	0	0	0	0
F-block divergent monitoring line 2	1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0
	3	0	0	1	1	0	0	1	0
	4	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0
	6	1	0	0	0	1	1	1	1
	7	0	0	0	0	0	0	1	0
	8	0	0	0	0	1	1	1	0
	9	0	0	0	0	0	0	1	0
	10	0	0	0	0	0	0	1	0

- Activity
- No-Activity
- Control lines
- Divergent lines

Table 2: *Over all monitoring card results (N=presence of rats, mean tracking result, standard deviation and standard error).*

F-block Control Line	F-block Divergent Line 1	F-block Divergent Line 2	L-block Control Line	L-block Divergent line 1	L-block Divergent Line 2
N= 2/80	N=9/80	N=13/80	N=40/80	N= 49/80	N= 2/80
Mean=2.5	Mean=11.2	Mean=16.3	Mean= 50	Mean= 61.3	Mean= 2.5
SD=15.7	SD=31.8	SD=38.2	SD= 50.3	SD= 49	SD= 15.7

F-block	L-block
N=24/320	N=91/320
Mean=10	Mean=39
SD=34	SD=33
Control	**Divergent**
N=42/160	N=73/320
Mean=26	Mean=23
SD=44	SD=30

Table 3: *Rat activity variation between different measures and their significance levels*

Variation in rat activity	Significance
Between the six monitoring lines	x^2=137.419, d.f.=5, p=0.00
L' block vs. 'F' block	x^2=48.314, d.f.=1, p=0.00
Control vs. divergent lines	x^2=48.314, d.f.=1, p=0.545

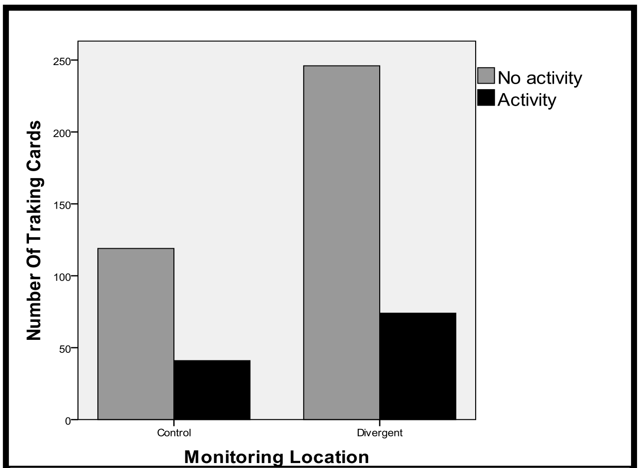

Figure 10: *Rat activity rates on control monitoring lines vs. divergent lines.*

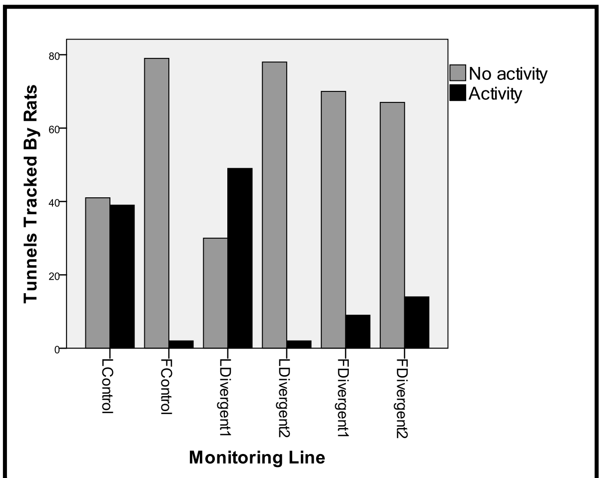

Figure 11: *Rat activity rates on all control and divergent monitoring lines.*

Figure 11, demonstrates the significant difference between rat activity over the individual monitoring lines (x^2=137.419, d.f.=5, p=0.00), with mean activity levels ranging from 2.5% to 60% (Table 2).

There was large variation between rat activity and blocks. With ‘L’ block showing 39% mean rat activity and ‘F’ block a 10% mean rat activity (Table 2). There was a significant difference in rat activity between the two (x^2=48.314, d.f.=1, p=0.00).

On average ‘F’ block control line had less rat activity (2.5 % mean), than L-block control (50% mean) (Table 2), however in reference to Figure 10, Table 2 and Table 3 there is no significant difference between control lines vs. divergent lines (x^2=48.314, d.f.=1, p=0.545). On average Control lines had 3% less rat activity than divergent lines (Table 2).

6.2 Differences in rat activity due to seasonality

Table 4: *Chi-squared tests for differences in rat activity rates per month*

Month * Activity Crosstabulation

Count

		Activity		Total
		No activity	Activity	
Month	February	55	5	60
	March	51	9	60
	April	86	34	120
	May	84	36	120
	June	42	18	60
	July	47	13	60
Total		365	115	480

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	15.724[a]	5	.008
Likelihood Ratio	17.742	5	.003
Linear-by-Linear Association	6.037	1	.014
N of Valid Cases	480		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 14.38.

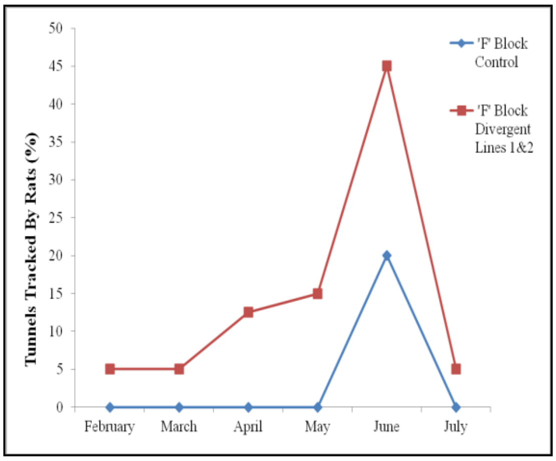

Figure 12: *Tunnels tracked by rats (%) on 'f' block control line and 'f' block combined divergent lines 1&2, from February to July.*

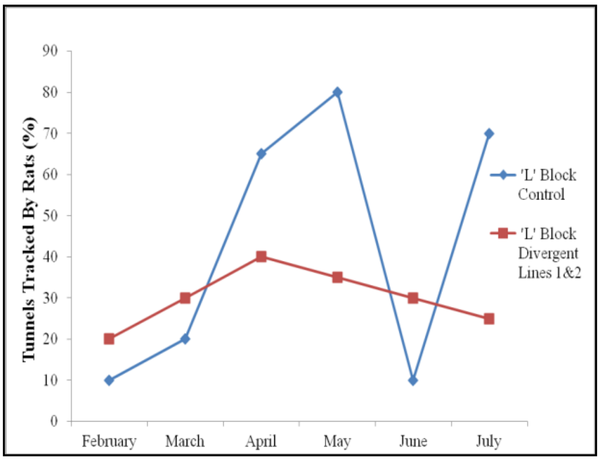

Figure 13: *Tunnels tracked by rats (%) on 'l' block control line and 'l' block combined divergent lines 1&2 from February to July.*

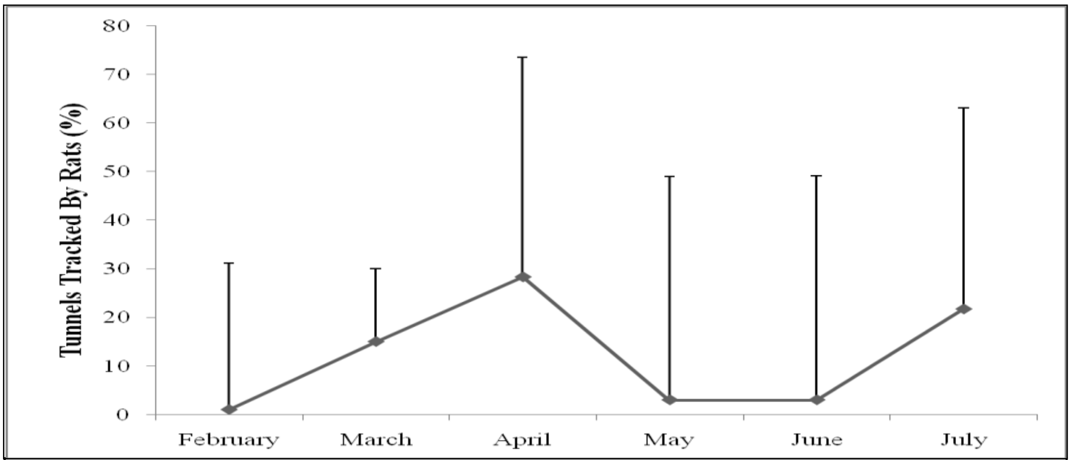

Figure 14: *Tunnels tracked by rats (%) over all combined monitoring lines from February to July.*

There is a significance in variation (Table 4) between rat activity levels among months in which monitoring took place (x^2=15.724, d.f.=5, p=0.01).

Overall rat activity over all monitored areas indicates a peak rat activity level in April (25% mean) and a low 3-4% activity level in February, May and June (Figure 14). 'L' block activity rates peak in early April to May, reaching an 80% maximum activity level (Figure 13). Activity levels decrease late May-June reaching a 30% maximum activity level, activity levels increase 60% in July (Figure 13).

'F' block peaks in June (45% maximum) with activity levels being lowest (4 % maximum) after June (Figure 12).

6.3 Differences in rat activity based on distances from each tracking tunnel to the nearest bait-station

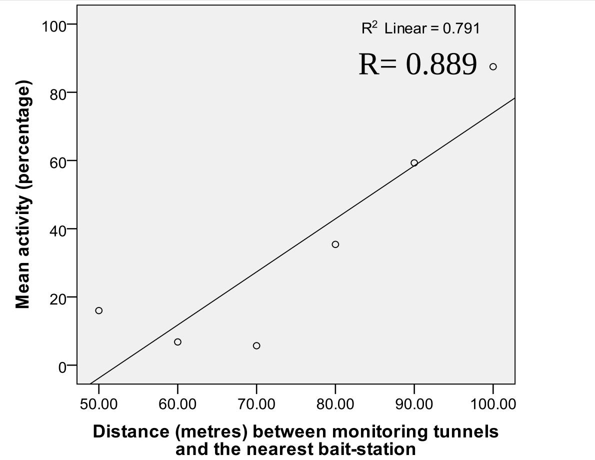

Figure 15: *Mean rat activity rates and distance to the nearest bait-station (linear relationship).*

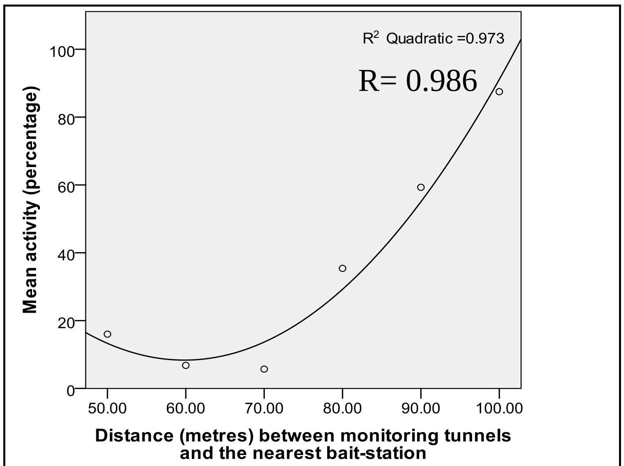

Figure 16: *Mean rat activity rates and distance to the nearest bait-station (quadratic relationship).*

Figure 15 indicates there is a significant linear (Pearson's correlation=0.89, p=0.02, R=0.89) (Table 5) and a more significant non linear, quadratic (R=0. 986) correlation between rat activity and the distance from each tracking tunnel to the nearest bait-station (Figure 16). Rat activity is highest at 100 metres and lowest at 670 metres (Figure 15&16). Rat activity rates remain relatively similar between the distances of 50-70 metres (9.2% maximum rat activity increase) however rat activity rates escalate over the distance of 70 metres with a 29.3% maximum activity increase (Figure 15&16).

Table 5: *Correlation between rat activity and distance from each tracking tunnel to the nearest bait-station.*

Correlations

		Distance	Activity
Distance	Pearson Correlation	1	.889*
	Sig. (2-tailed)		.018
	N	6	6
Activity	Pearson Correlation	.889*	1
	Sig. (2-tailed)	.018	
	N	6	6

*. Correlation is significant at the 0.05 level (2-tailed).

6.4 Edge effect- distance to the nearest track and rat activity

Table 6: *Correlation between distance to the nearest track and rat activity.*

		Distance	Activity
Distance	Pearson Correlation	1	.866**
	Sig. (2-tailed)		.001
	N	11	11
Activity	Pearson Correlation	.866**	1
	Sig. (2-tailed)	.001	
	N	11	11

**. Correlation is significant at the 0.01 level (2-tailed).

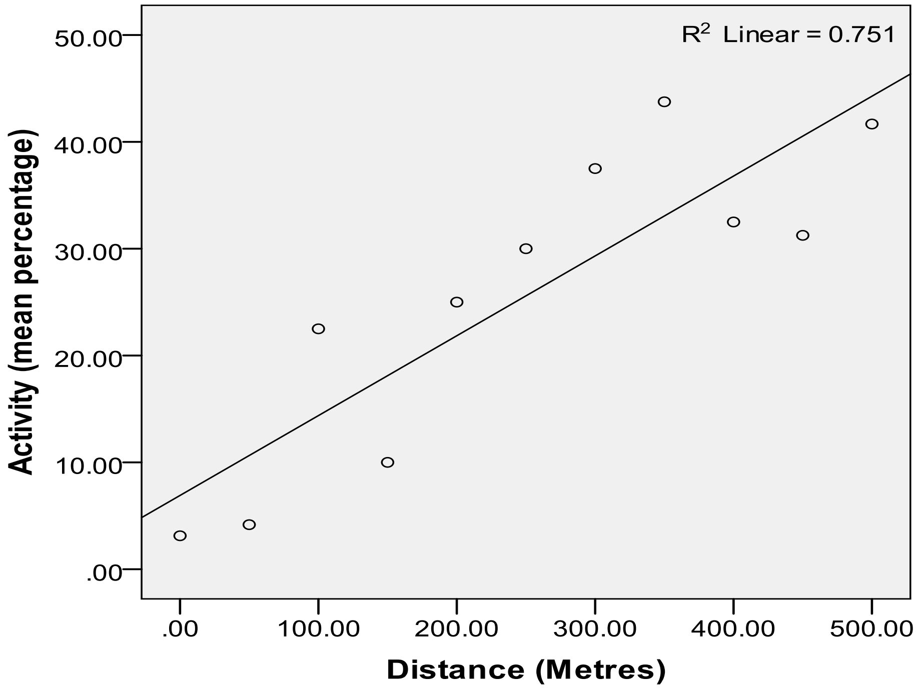

Figure 17: *Correlation between rat activity and the distance from each tracking tunnel to the nearest walking track.*

There is a strong and positive linear relationship (Table 6 and Figure 17) between rat activity and the distance from each tracking tunnel to the nearest walking track (Pearson's correlation=0.87, p=0.001). Rat activity is lowest at 0-50 metres and highest at 350 metres from the nearest walking track (Figure 17). There was more rat activity present in areas in the middle of monitoring lines than at the track ends (Figure 18 and 19).

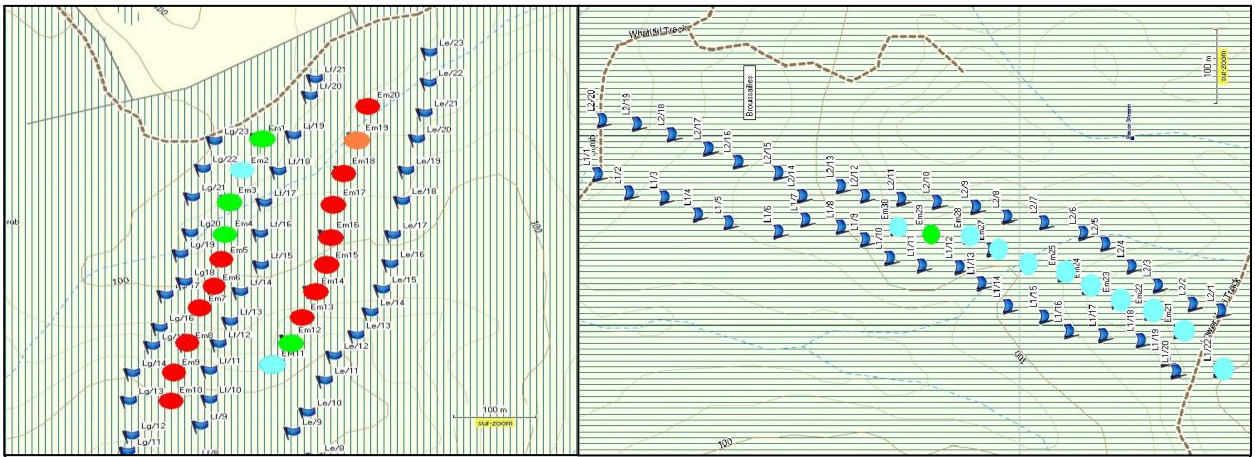

Figure 18: *'L' block monitoring lines (control, divergent line 1& divergent line 2)*
Blue= low-activity
Green= moderate-activity
Orange=high-activity
Red=extremely high-activity

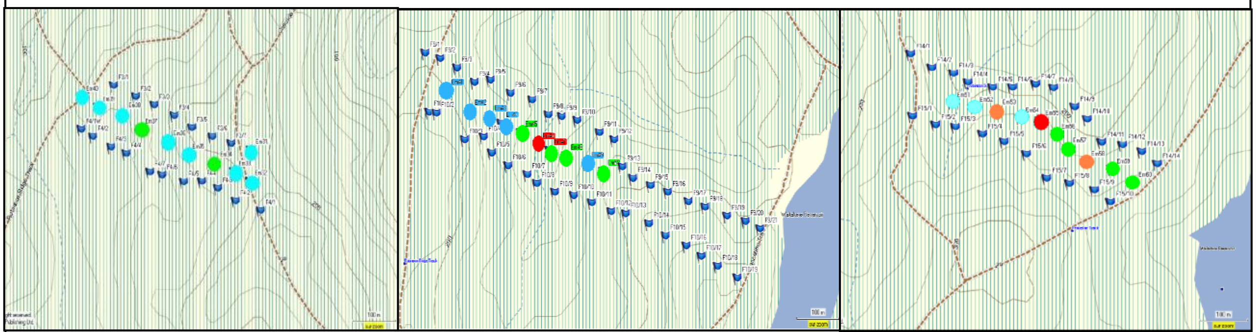

Figure 19: *'F' block monitoring lines (control, divergent line 1& divergent line 2)*
Blue= low-activity
Green= moderate-activity
Orange=high-activity
Red=extremely high-activity

6.5 Differences in rat activity due to pre and post-baiting

Table 7: *Chi-Squared and correlation tests regarding rat activity pre-baiting and post-baiting.*

		Activity		Total
		No activity	Activity	
Baiting	Prebaiting	254	66	320
	Postbaiting	111	49	160
Total		365	115	480

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	5.855[a]	1	.016		
Continuity Correction[b]	5.319	1	.021		
Likelihood Ratio	5.708	1	.017		
Fisher's Exact Test				.017	.011
Linear-by-Linear Association	5.843	1	.016		
N of Valid Cases	480				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 38.33.

b. Computed only for a 2x2 table

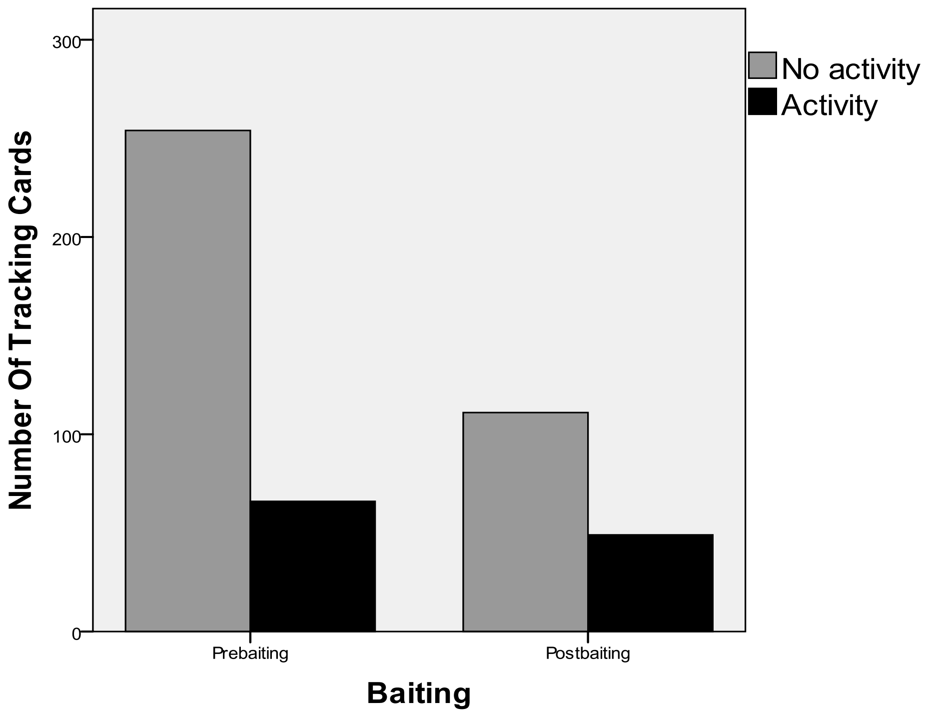

Figure 20: *Rat activity rates pre-baiting vs. post-baiting*

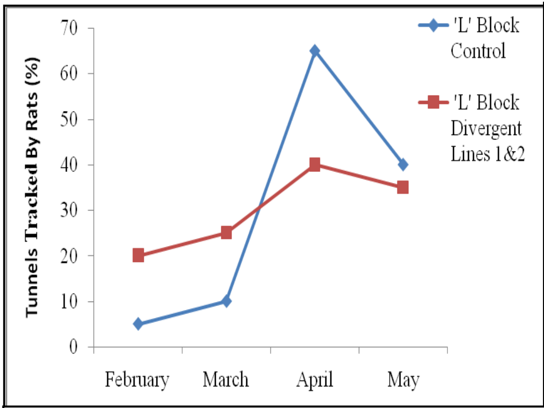

Figure 21: *Average rat tracking rates in 'L' block control and 'L' block divergent lines 1&2 pre-baiting.*

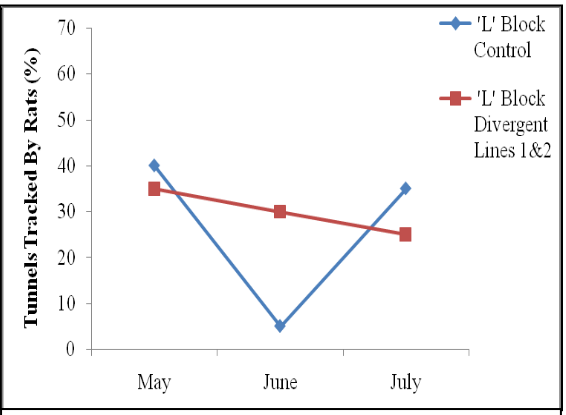

Figure 22: *Average rat tracking rates in 'L' block control and 'L' block divergent lines 1&2 post-baiting.*

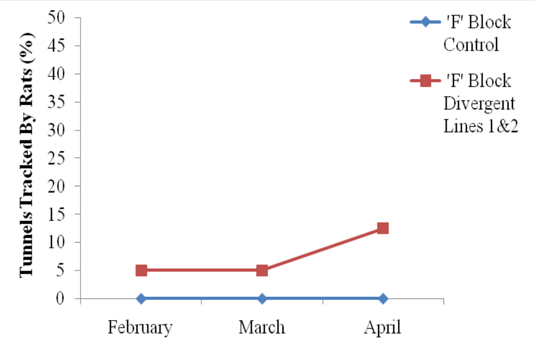

Figure 23: *Average rat tracking rates in 'F' block control and 'F' block divergent lines 1&2 pre-baiting.*

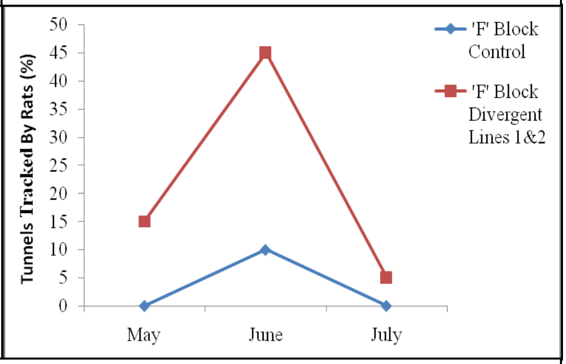

Figure 24: *Average rat tracking rates in 'F' block control and 'F' block divergent lines 1&2 pre-baiting.*

There was a significant difference (Table 7) between rat activity and pre and post-baiting (x^2=5.855, d.f.=1, p=0.02).

Pre-baiting rat activity levels were 18% higher than post-baiting rat activity levels (Figure 20). Pre- baiting had an overall 26% rat activity level (66/254 cards tracked by rats), were as dates after baiting had a 44% (49/111 cards tracked by rats) activity level (Table 7).

'L' block rat activity rates before baiting increased (65% maximum) and dropped after baiting (40% maximum) to a minimum of 5% rat activity in June (Figure 21 and 22). However 'F' block activity levels were low before baiting (12.5% maximum) and increased (45% maximum) after baiting (Figure 23 and 24)

6.6 Summary of results

Table 8: *Summary of results*		
Comparison	**Test statistic**	**Significance**
Distance	Pearsons= 0.89	P=0.02 R=0.986 N=6
Seasonality	x^2 = 15.724	P=0.01 N=480
Edge effect	Pearsons=0.87	P=0.001 R^2=0.751 N=11
Pre and post-baiting	x^2 =5.855	P=0.02 N=480

This summary of results table identifies the different levels of significance measures. Such as the distance between each tracking tunnel to the nearest bait-station and also other confounding variables of distance such as seasonality, edge effect and pre and post-baiting.

7 DISCUSSION

7.1 Principle findings

There was large variation in rat activity found over all monitoring lines (Figure 11), however there was no significant difference identified (Table 3) between rat activity on divergent lines and rat activity on control lines (x^2=48.314, d.f.=1, p=0.545). This was due to the high rat activity on 'L' block control line (50%), hindering the low activity in 'F' block control line (2.5%) causing a high combined rat activity (Table1).

However results largely support the idea that irregular spaced bait-lines within a pest control gridding system can harbour rat populations. The strong non-linear quadratic correlation (R=0.986), demonstrates that rat activity remains low prior to 70 metres (9.2%) increase 35.4% at 80 metres, 59.3% at 90 metres and 87.5% at 100+ metres from each tracking tunnel to the nearest bait-station (Figure 16). This idea is also supported as there is a positive linear correlation between rat activity and the distance from each tracking tunnel to the nearest walking track (Figure 17) (Pearsons correlation=0.87, p=0.001, n=), with rat activity levels increasing (from 3 to 45%) in areas further away from tracks and activity levels being highest (45%) in the middle of monitoring lines (Figure 18 and 19).

Rat activity rates vary over seasons and months in which they were monitored, with rat activity highest (25%) in April and July and lowest it February (3%) (Figure 14). Over all rat activity was 18% higher post-baiting than rat activity levels pre-baiting (Figure 20). However 'L' block showed a decline (35% maximum) in rat activity after baiting (Figure 21 & 22). Seasonal and pre and post baiting results are important to analyse in order to investigate any changes in rat activity due to other outlying factors other than distance measures.

7.2Examination of the studies strengths and weakness

7.2.1 Choosing 'L' control line as a typical control

The 'L' block control line presented consistently high rat activity rates (Table 1)(50% mean). This line was situated 100 m north of 'L' block divergent line 1 the largest of the divergent lines (200 m+), which presented extremely high rat activity rates (61.3%). Therefore choosing an area next to this for a control may explain the high rat activity levels and may have hindered the results.

7.2.2 Comparison of rat activity in the two different blocks

Both blocks differ in ecology. They both demonstrate complex native forest habitats, however 'F' block is a complex forest habitat amongst a large area of complex forest. Whereas 'L' block is a complex forest ecosystem situated next to farmland. This habitat structure is less complex, consisting of open grass, tussock and exotic tree areas (e.g. gorse *Ulex europaeus*, and woolly nightshade *Solanum mauritianum*) (Figure 25). Therefore it is obvious that these two areas are not directly comparable. However contrary, this may be seen as a strength. The purpose of the study was to measure rat activity between bait-lines therefore monitoring a range of different habitats is beneficial in gaining a generalised result.

Figure 25: *Example of vegetation in 'L' block.*
McGregor, 2011

7.2.3 Monitoring duration

This study was limited by its duration. The six month duration ranging from February to July, did not allow for an accurate seasonality measure. Data was not received for late winter or spring season. Handford (2000) suggests that tunnels should be sampled four times a year in February, May, August and November. Having a data set consisting of all four season, would have allowed a complex comparative measure, thus strengthening the study.

7.2.4 Effectiveness and efficacy of tracking tunnel measure

The 50x50 m one night tracking method is a simple, rapid and cost-effective technique distinguishing rat activity. It provided the correct level of information in terms of this study and the nature of the tracking cards allowed them to be re-used if they were clean of prints, saving costs.

Large fluctuations in environmental factors can influence the effectiveness of tracking tunnels. Such as, weather conditions, and seasons. Bad weather on monitoring days may have caused rats to hide away, reducing rat activity and thus tracking effectiveness (Quy et al, 1993). Seasonality can make monitoring indicators difficult, due to food abundance and availability.

Therefore the usefulness of monitoring rodent populations and whether it will provide meaningful results needs to be carefully considered (Handford, 2000).

7.2.5 Limitation of samples in the distance category

This study was limited by the number of tunnels in which fell under each measurement category (n=6). There were more tunnels categorised in the smaller distance categories than the large distance categories. Potently presenting a lack of homogeneity in the sample from which a correlation was calculated. In order to avoid this many researchers follow a rule of thumb that if you keep your sample size to 50 or more then serious bias is unlikely (Thomas & Lewicki, 2005).

7.3 Study results compeered with other studies

7.3.1 Seasonality

Seasonally affected rat activity rates with activity highest in April and July. This is not consistent with Hooker & Innes (1995) and Brown et al. (1996), suggesting that rat activity is highest reaching densities of c. 6 rat's ha–1 in January. However it is partly consistent with Handford (2000), which suggests that rodent populations undergo large fluctuations both seasonally, peaking in Autumn and declining through Winter (Warburton, 1989). Innes, (1990) & Dowding, (1995), state that rat numbers are largely dependent on food availability which affects their breeding rates and survival.

7.3.2 Edge Effect

The negative edge effect result in this study was not consistent with other studies that suggest that rat composition is higher on the landscape edges (Adren & Angelstram, 1988). Laurence et al, (2007) states that generally the strength of edge effects diminishes as one moves deeper inside forests, in this case rat activity levels were greater as the distance from the edges increased.

Lahti (2000), states that edge effects, are stronger in forest landscapes of higher fragmentation (<50% prey habitat) than lower fragmentation (>75% prey habitat). This conforms to the study, as 'L' block has high rat activity levels (60%

mean) and large fragmented (farm environment). Whereas ‘F’ block has lower rat activity (11.6% mean) and is situated in a complex forest ecosystem.

7.3.3 Pre and post-baiting rat activity rates

Overall rat activity rates increased after baiting. This was a shocking result as many studies have shown rat numbers to drop after baiting procedures (Clout, et al, 1995;Buckle & Fenn, 1992;Brown et al, 2006), taking up to 3-4 months to recover (Innes, et al, 1995). Ark in the Park has demonstrated an initial increase in mice numbers after baiting has taken place, thought to be due to the reduced competition of rats (Colgan, 2010). This may also be due to baiting success reducing rat competition by killing possums, ferrets, weasels and stoats.

7.4 Other interpretations of results

7.4.1 ‘L’ block Scenario

There is a likely scenario to explain the unexpectedly high rat activity results (61.3% mean) on ‘L’ block control line. This control line was situated next to ‘L’ block divergent line 1. This line was in-between bait-lines which were 200 m+ apart, producing a large un-controlled area for rats to breed. It is possible these rats dispersed across to the neighbouring control (L-control line) given their large home ranges (males 1.1 h and females 0.3 h)(Hooker & Innes, (1995).

7.4.2 Season Interpretation

The increased rat activity rates in the month’s April through to July is potently due to the increased food sources available, from trees shedding leaves and fruit, such as karaka (Jan-April), mapou (Late summer), puiriri (Mid winter) and nikau (all year round flower and fruit) **(**Salmon, 1994**)**. The presence of high seed production can influence breeding and survival resulting in peaks in rat populations (Innes, 1990 & Dowding, 1995) and predator increase after years of high seed fall (Wendy et al., 2010). There is also an increase in litter biomass and invertebrate abundance around this time (Didham et al. 2009), thus further increasing rat food (Innes, 2001).

7.4.3 Edge effect interpretation

The increase in rat activity as the distance from the edge of the track increases could be due to divergent bait lines harbouring rat populations in the centres.

However this also could be due to the success of the kill-traps randomly located on tracks throughout the Ark area.

Other aspects that may have effected the results are: age of habitat edges, edge aspect and classification, the combined effects of multiple nearby edges, fragment size, the structure of the adjoining matrix vegetation, seasonality and extreme weather events (Laurence et al 2007).

7.4.4 Baiting interpretation

Over all rat activity rates increased after baiting. However ‘L’ block increases in rat activity after bait and ‘F’ block did not. This could be due to the increased food sources in the area (e.g. fruit and seeds), as it is a more complex forest structure than ‘L’ block. Another interpretation is, regardless of baiting time rat activity in divergent areas would not change, as there is a decreased possibility of coming into contact with bait-stations.

7.4.5 Location interpretation

The high level of rat activity in ‘L’ block opposed to ‘F’ block could be due to location. It could be possible that the lower tracking rates in the ‘F’ block compared with ‘L’ block, were due to behavioural differences rather than activity levels.

‘L’ block has a less dense forest structure than ‘F’ block. Therefore there is more food available in tree tops (e.g. fruit and seeds). It is likely that rats in these food rich areas spend more time in tree tops than on the forest floor, where the tracking tunnels are located.

8.0 CONCLUSION

This study investigated whether there is higher rat activity between irregular spaced bait-lines within a pest control grid system. No significant difference was found in rat activity between control and divergent lines.

The most important conclusion addresses the initial problem of irregular bait lines. If the distance from each tracking tunnel to the nearest bait station exceeds 70 metres, rat activity levels increase 29.7%, if the distance exceeds 80 metres, rat activity increases a further 23.9% and if the distance exceeds 90 metres rat activity increases another 28.2%. This relationship also co-insides with the edge effect data, which indicates there is higher rat activity in the centre of the grid and less activity the closer the distance to the tracts. Therefore this strongly indicates that divergent bait-lines (exceeding 70 metres) harbour rat populations at Ark in the Park.

This study provides insight into the complexity of rat activity. There are many confounding variables that potentially influence rat activity levels, such as, seasonality, territoriality, food availability, baiting, edge effects and location. Our results indicate the importance of GIS in constructing accurate and efficient pest control systems on conservation land. Without appropriate monitoring and surveillance of bait station lines predator control projects run the risk of underperforming and exceeding financial budgets, this in turn will effect the longevity of such projects.

9.0 RECAMENDATIONS

9.1Further research

Further research in this field is needed, which (1) gains a full year's worth of data, (2) looks at a larger amount and range of control and divergent areas and (3), has a larger focus on the distances of bait stations regarding rat activity rather than entire areas. This would offer greater insight into rat activity rates and provide certainty, that differences in rat activity levels is a result of management (un-systematic gridding) and not other confounding factors.

Further research is needed in monitoring rats in tree tops as well as on ground level. Seasonal effect may cause rats to be largely canopy based feeders, thus ground monitoring techniques are meaningless. A comparison of tree and ground level rat activity could provide insight into rat behaviour, territories and many other measures.

Further research into other methods of measuring more specific rat activity measures would be beneficial. A categorisation of card activity levels could be useful (Figure 26).

Figure 26: *Possible rat density measure McGregor, 2011*

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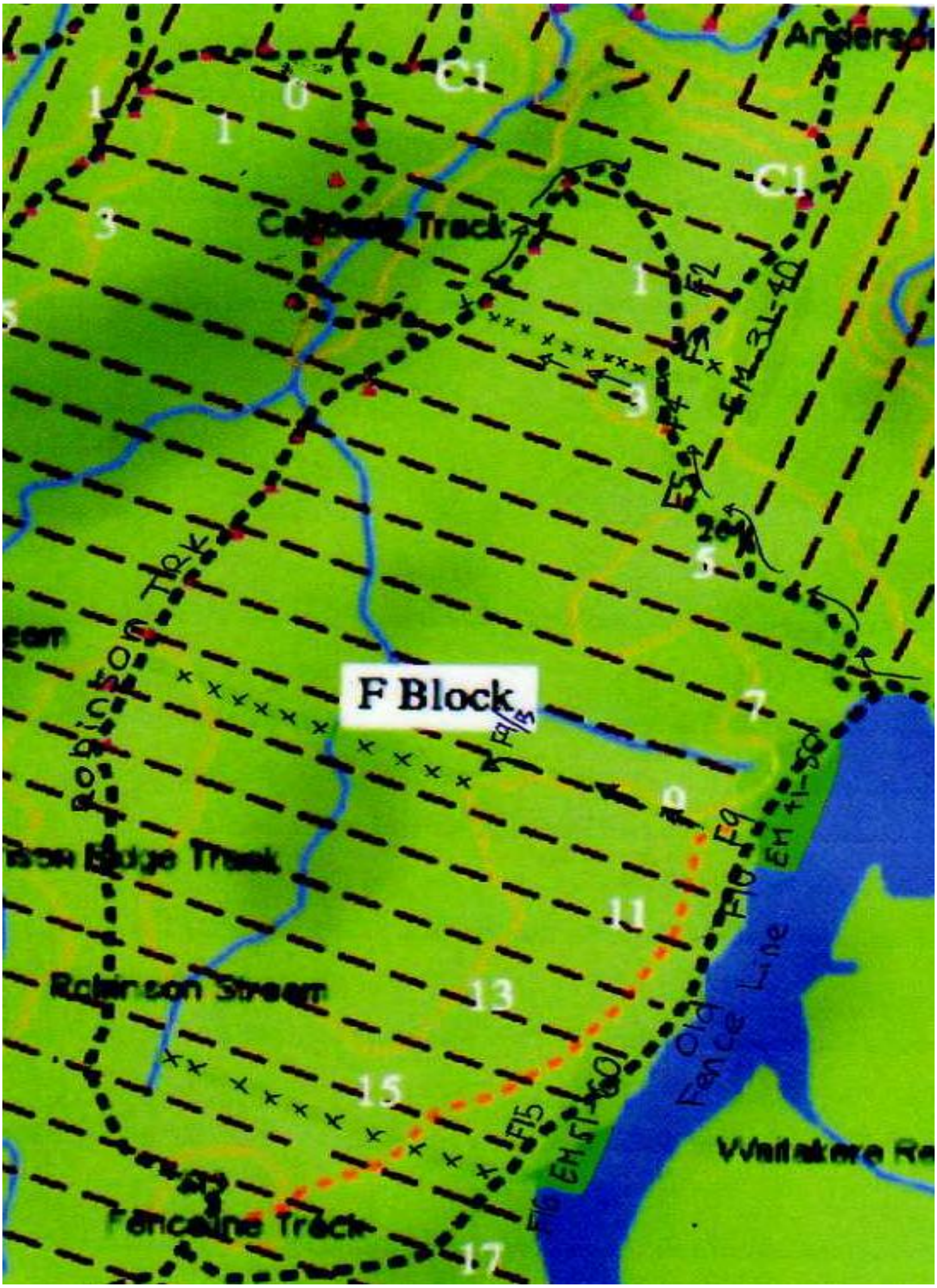
11.1 Figures

11.2 Tables

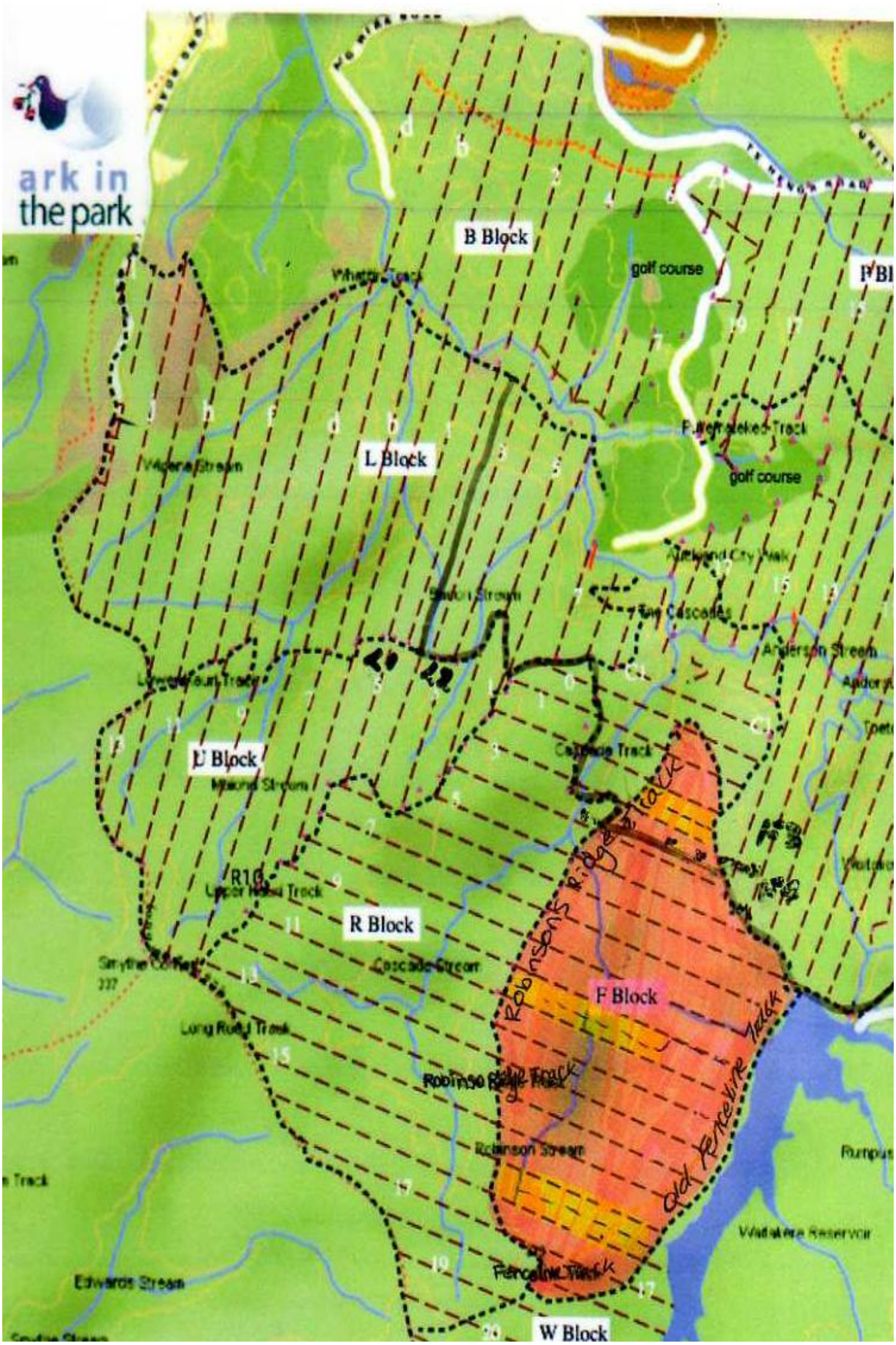
12.0APPENDICIES

12.1 Maps

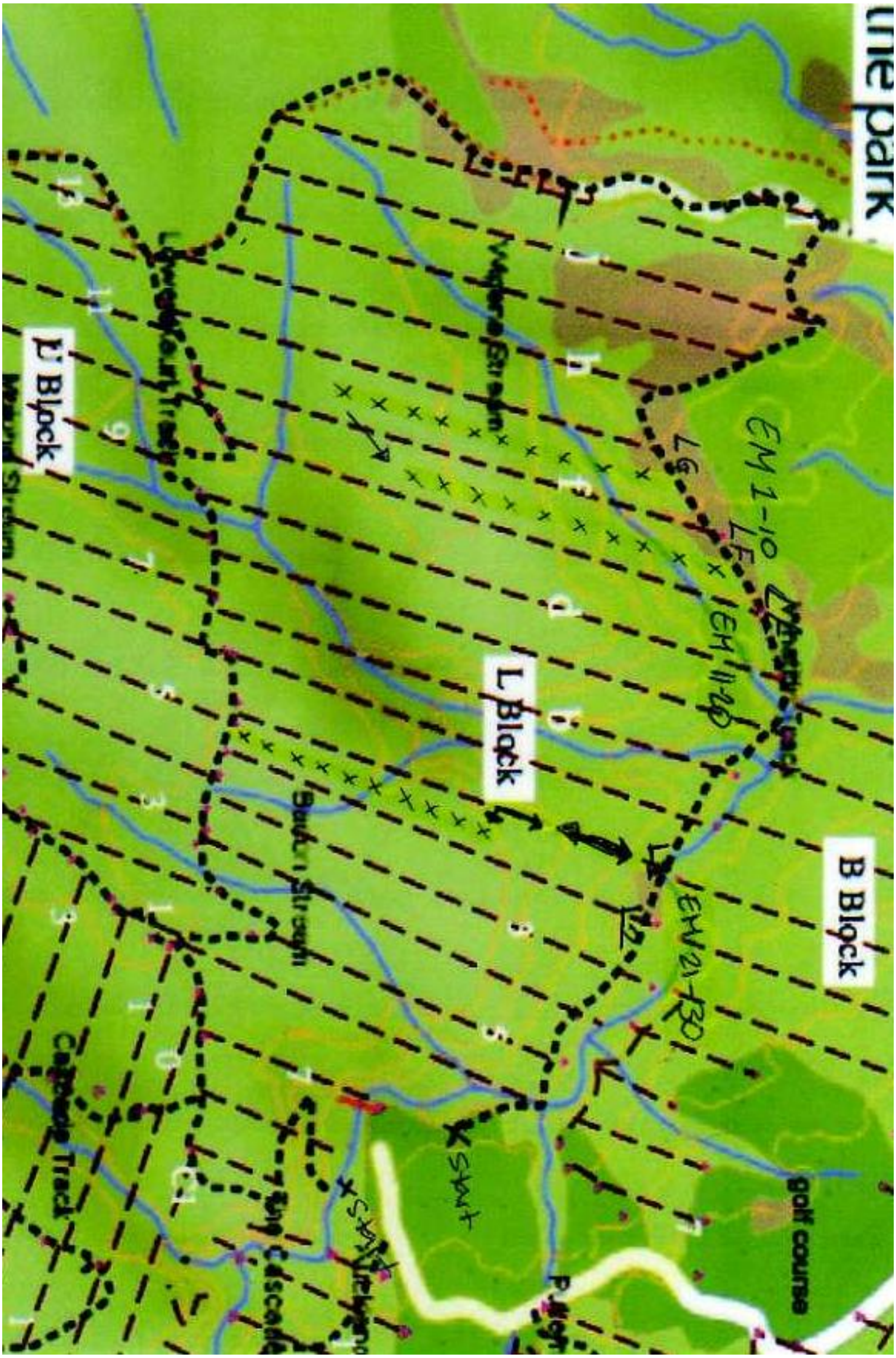
12.1.1 ‘F’ block monitoring lines



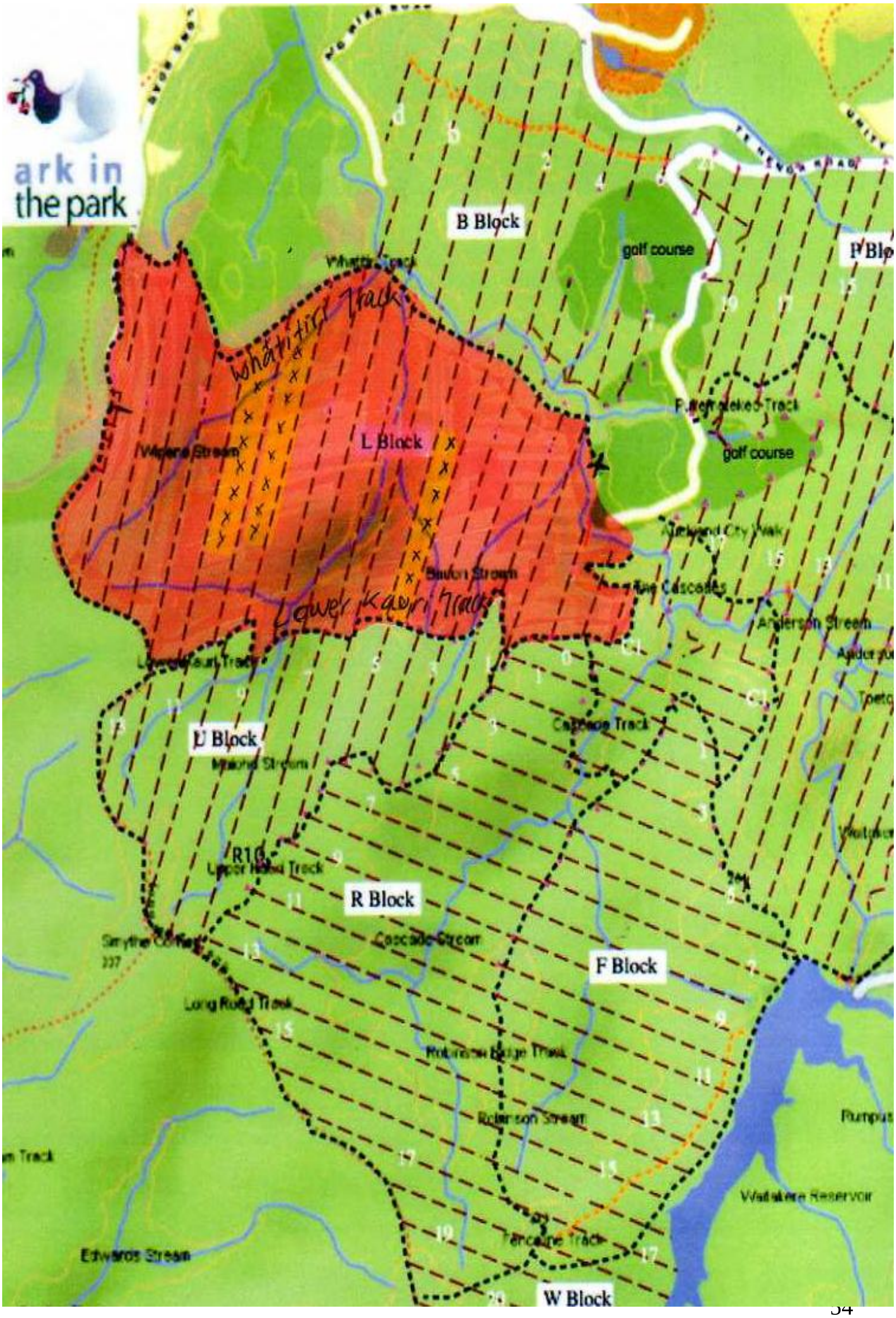
12.1.2 'F' block location and surrounding tracks



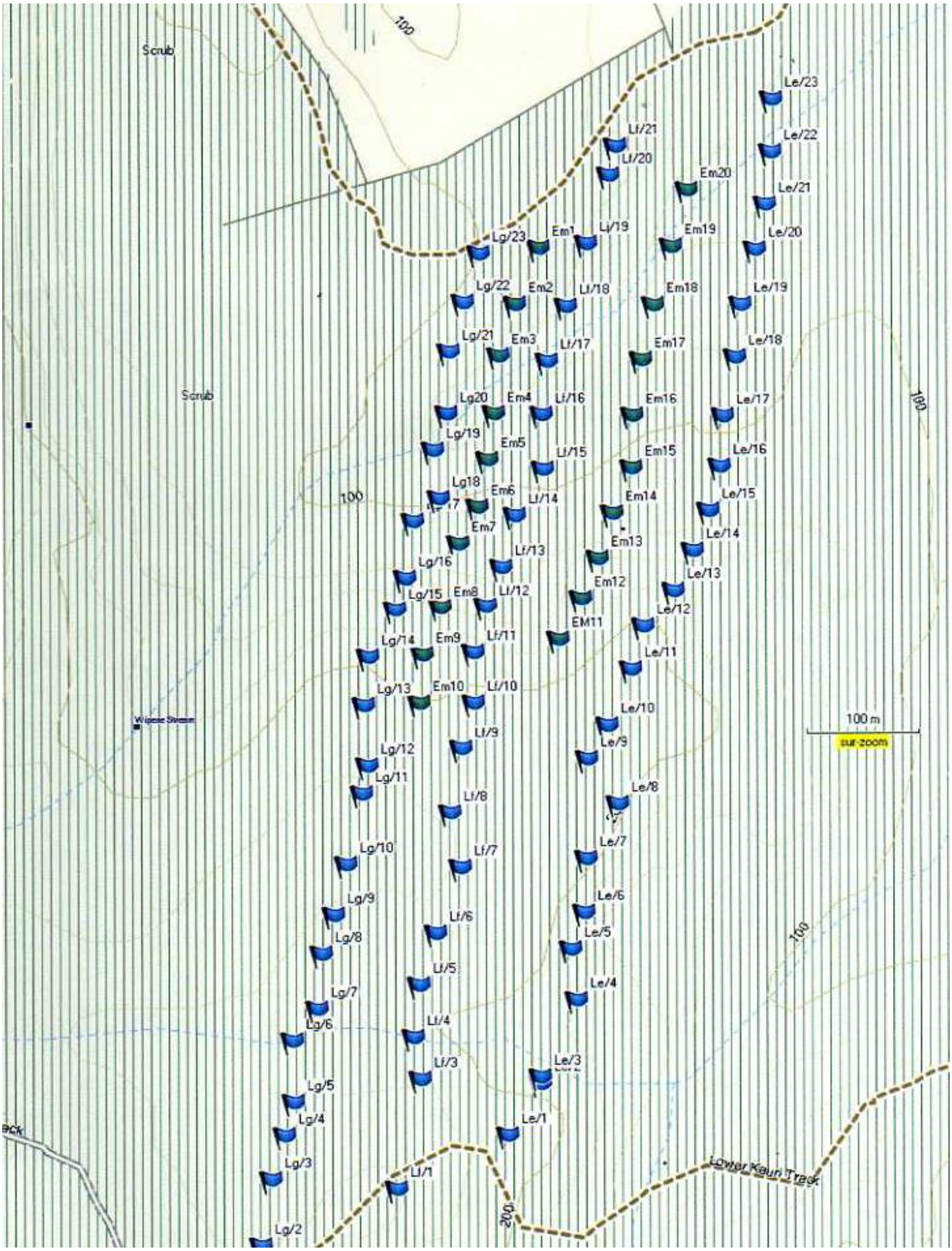
12.1.3 'L' block monitoring lines



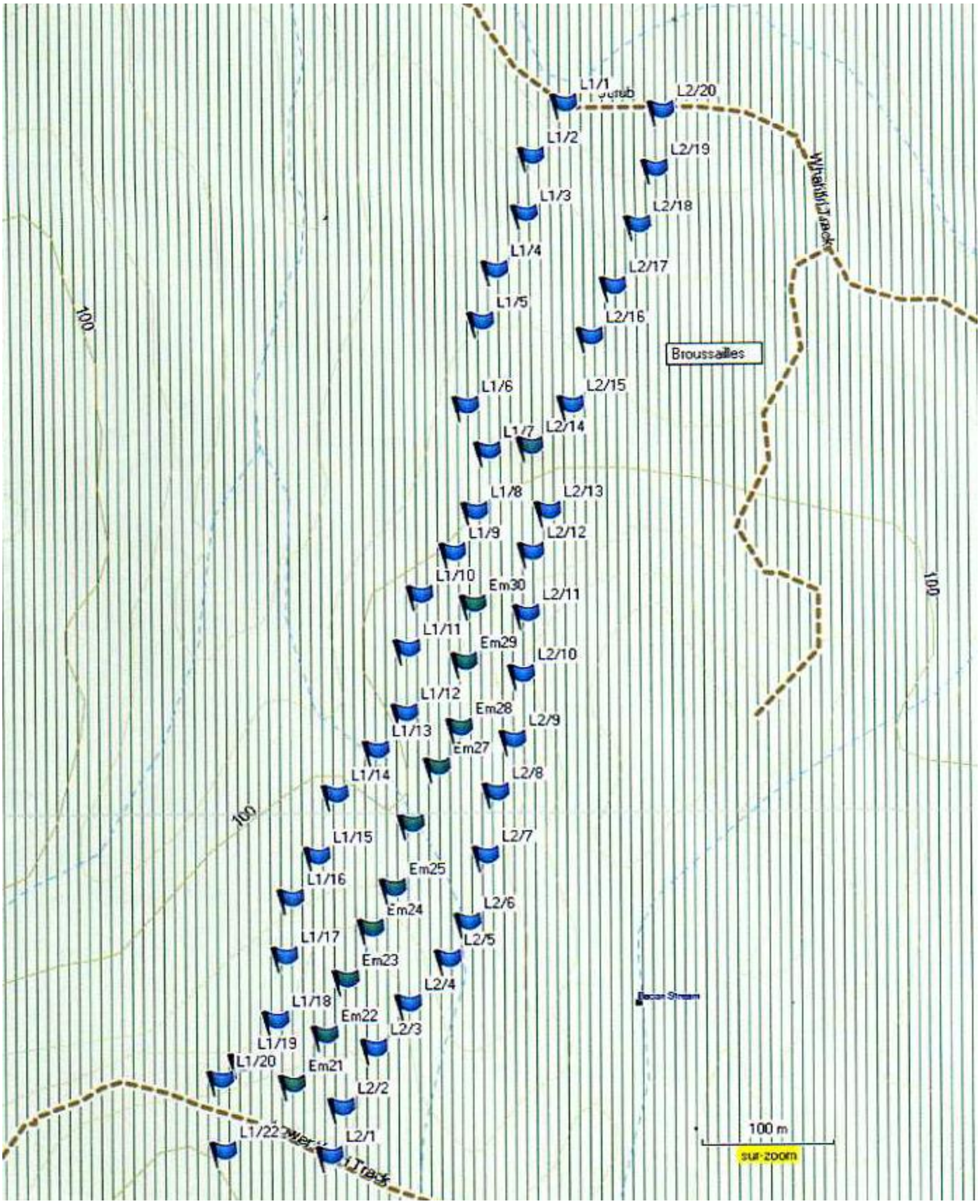
12.1.4 ‘L’ block location and surrounding tracks



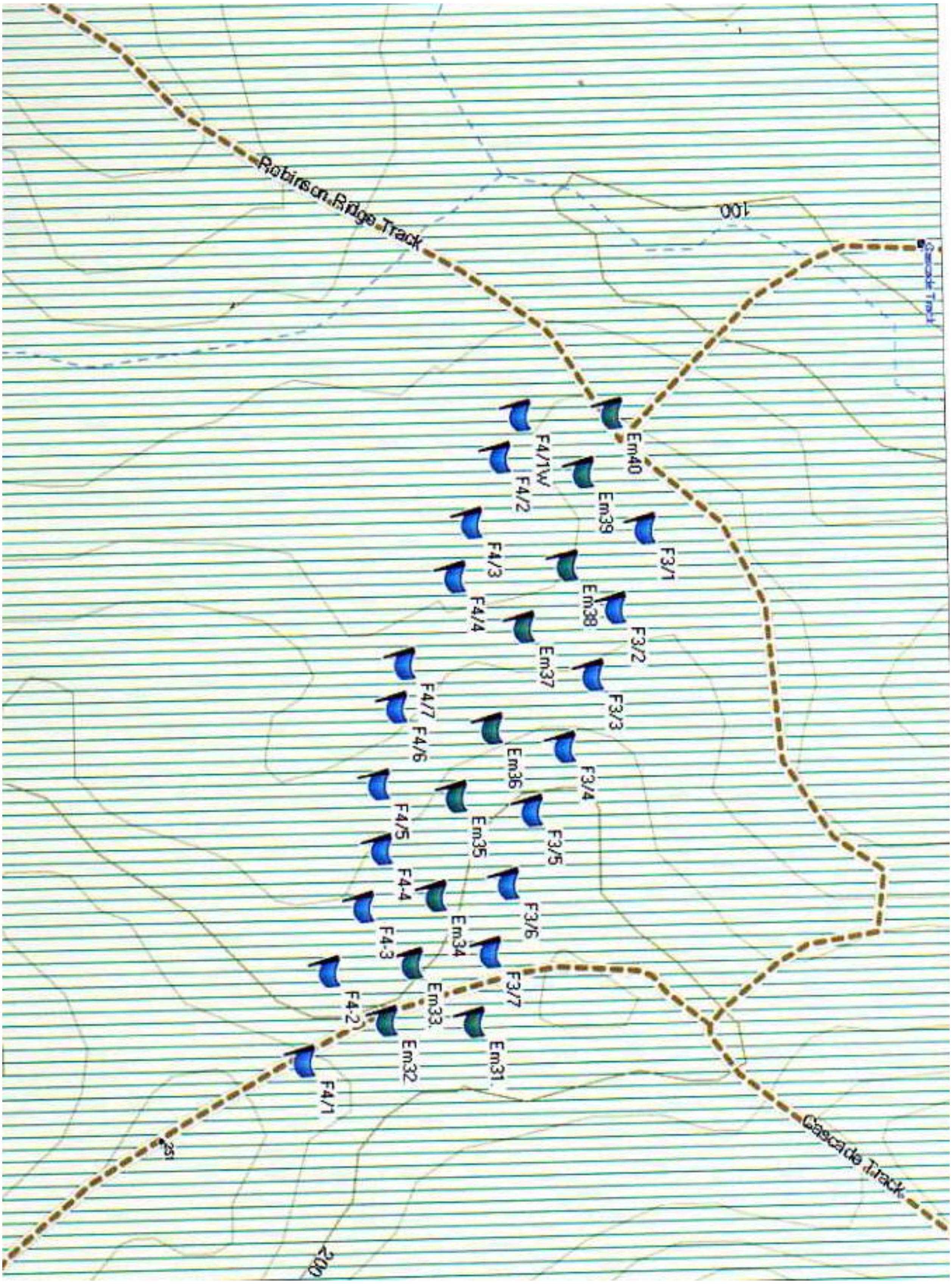
12.1.5 'L' block control and divergent line 1, general location and bait-station/tracking tunnel locations.



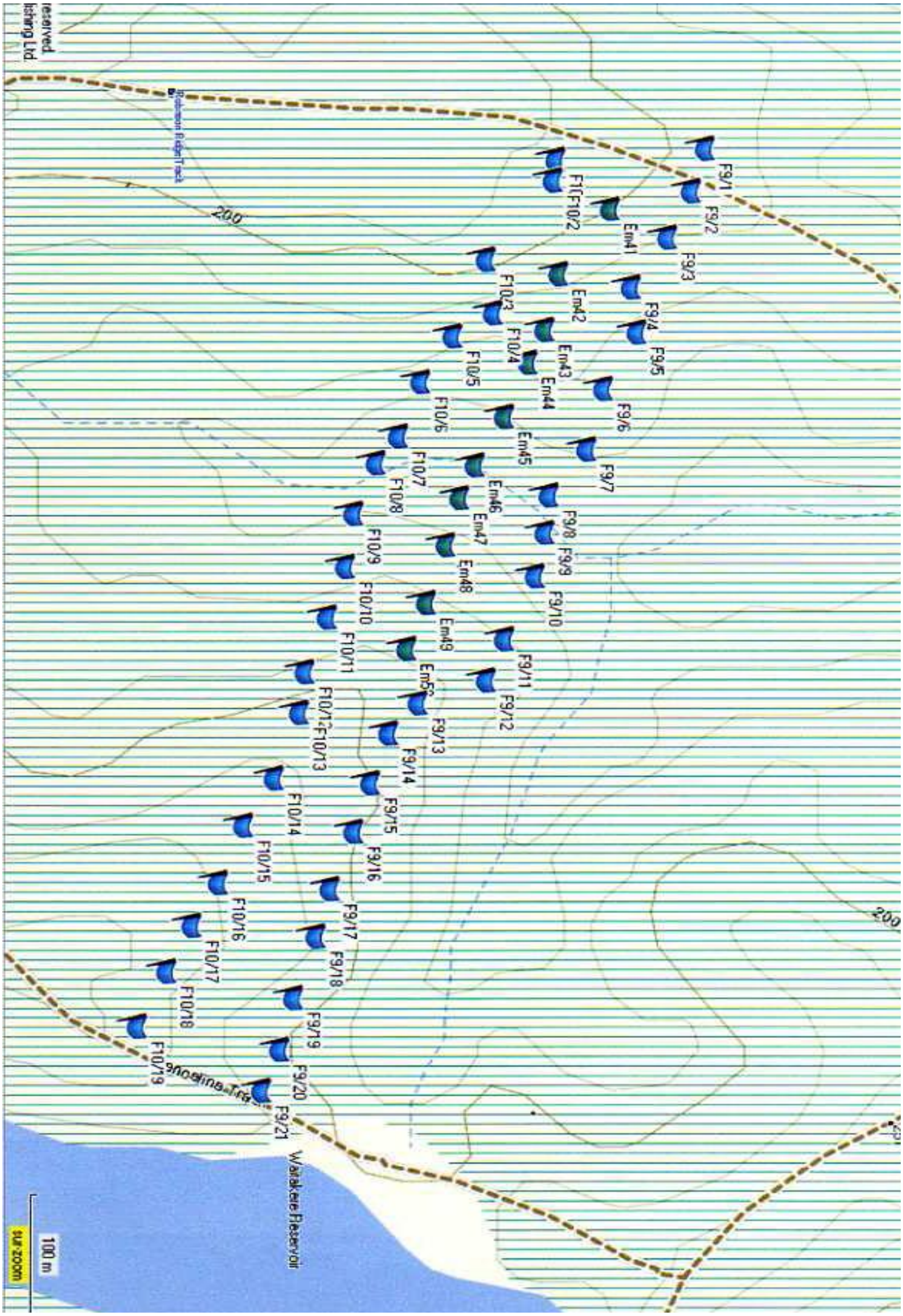
12.1.6 'L' block divergent line 2, general location and bait-station/tracking tunnel locations.



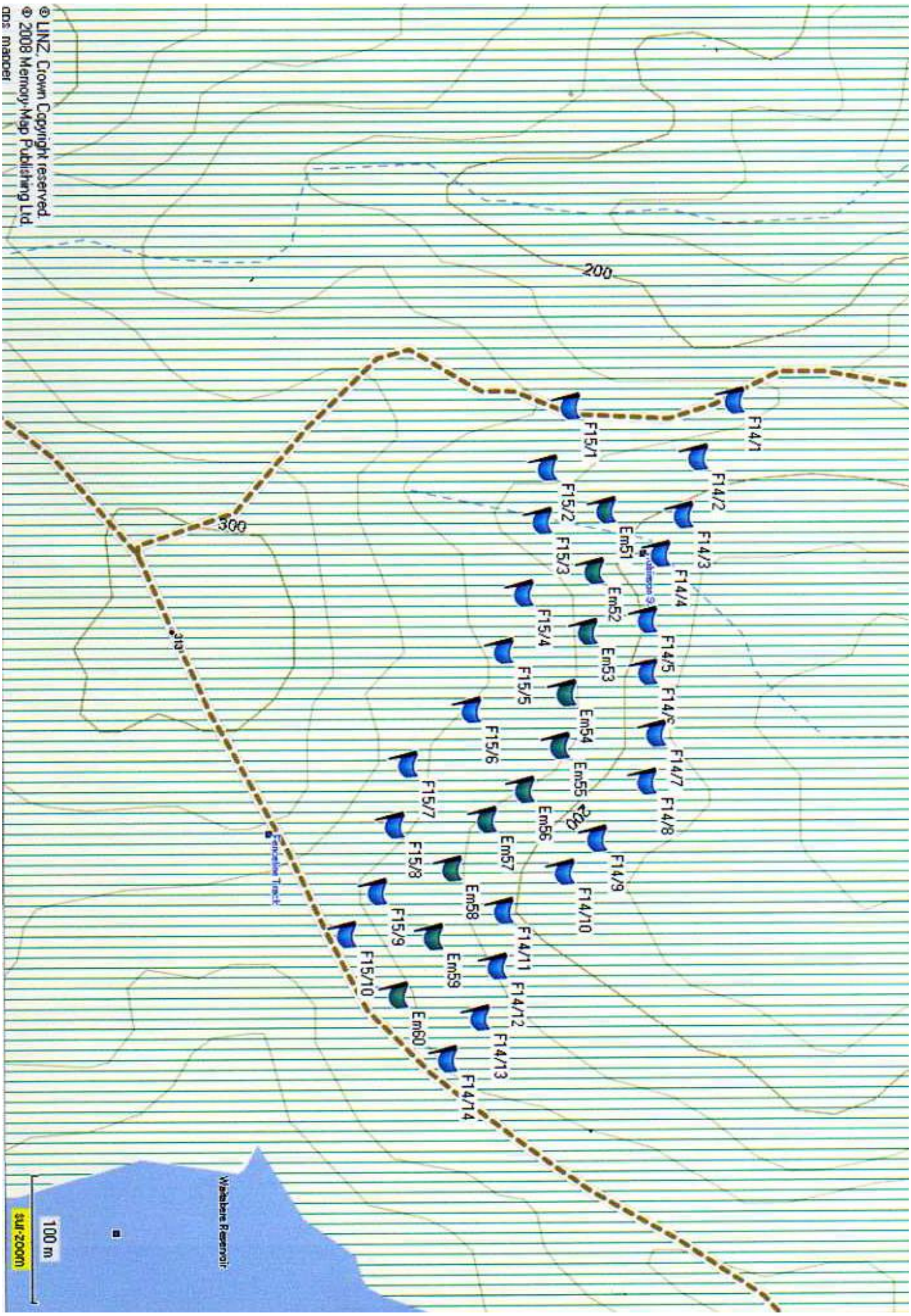
12.1.7 ‘F’ block controls, general location and bait-station/tracking tunnel locations.



12.1.8 ‘F’ block divergent line one, general location and bait-station/tracking tunnel locations.



12.1.8 ‘F’ block divergent line two, general location and bait-station/tracking tunnel locations.



12.2 Permit

Auckland Council

Te Kaunihera o Tāmaki Makaurau

Applicant

Signed [signature]

Name: Elizabeth McGregor

Date: 21/12/10

Delegation (Principal Ranger, Western Sector Parks, Auckland Regional Council)

Signed [signature]

Name: Stephen Bell

Date: 9-12-10