Stoat Trap Tunnel Location: GIS Predictive Modelling to Identify the Best Tunnel Location

A Thesis

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Geographic information systems have become an important method in wildlife-habitat mapping as demand for predictive models that relate single species to measurable components of their habitats has been an influential tool used by nature resource managers and decision makers to manage wildlife (Quinlan, Moro and Lund, 2004).

Abstract

Stoats are recognised as one of the biggest threats to New Zealand's threatened species. They are difficult to control because of their biological characteristics. Currently trapping is the most common type of control technique that has a proven success rate. Research studies have shown that some traps catch more stoats than others, however the reason for this is not well documented. The effectiveness of a trap set is difficult to determine because not all trap locations are the same and not all people have the same ability to select the best location for a trap.

This study uses GIS to spatially analyse stoat capture data from a control operation on Secretary Island in conjunction with commonly available vegetation, habitat, diet and home range spatial data to see if there are consistent patterns that could be used as variables in a model that would predict the best place to locate a stoat trap tunnel. The model would then be tested against a similar dataset from Resolution Island. The Department of Conservation supplied the stoat capture data from the control operations on both islands. Standard spatial analysis techniques were used to generate surfaces that combined the capture data with the vegetation, habitat, diet and home range surfaces to produce predictive surfaces.

The key finding from the research was that it is possible to produce a predictive model, although one was not created because the spatial datasets were not of a high enough resolution to provide conclusive evidence that could be confidently used as a variable in a model. The spatial analysis also indicated that stoats on both islands were caught mainly in the warmer northwestern parts of the islands although the study could not determine why there was a preference for these areas. In rugged terrain like that found on both islands the location of the track network will influence where the majority of stoats will be caught.

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The windrose in Figure 2.6 was created using WindRose PRO, Enviroware srl. http://www.enviroware.com

The topographic maps were sourced from Land Information New Zealand, Topographic Map Series 260 - A44 Five Finger, A45 West Cape, B42 Secretary, B43 Dagg and B44 Resolution, Crown Copyright Reserved

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List of Abbreviations

DEM	Digital Elevation Model
DOC	Department of Conservation
DSIR	Department of Scientific and Industrial Research
FSMS6	Forest Service Mapping Series
GIS	Geographical Information Systems
GPS	Global Positioning System
GRID	
IUCN	International Union for the Conservation of Nature
LCDB	Land Cover Database (Versions 1 and 2)
LENZ	Land Environments of New Zealand
LRI	Land Resource Inventory
LUC	Land Use Capability
MMU	Minimum Mapping Unit
NAWAC	National Animal Welfare Advisory Committee
NRFA	National Rural Fire Authority
NVS	National Vegetation Survey Databank
NZMG	New Zealand Map Grid

Chapter One: Introduction

1.1: Context

New Zealand has a declining biodiversity and this is considered to be its most pervasive environmental problem, with nearly 1,000 indigenous species being threatened (Ministry for the Environment, 1997). Animal pests and weeds pose the greatest conservation threat on land and in freshwater, affecting landscapes, habitats and the survival of species, (Department of Conservation, 2001). The New Zealand Biodiversity Strategy (DOC and Ministry for the Environment, 2000) sets out the goals that must be achieved to halt the decline of biodiversity and the Department of Conservation is tasked with implementing projects that will meet these goals.

The Department must use all the tools currently available to it to carry out cost effective and efficient pest control programmes. Advances in technology and research enable existing techniques to be refined and new techniques to be tested. Small scale operations are used as training grounds for full scale operations. High priority sites that have high biodiversity values, including offshore islands, can provide a safe haven for threatened species. These sites are generally pristine and have not been heavily modified by human intervention and do not have a large range of introduced animal or weed pests. Isolated offshore islands are the ideal environment to test the techniques that will ultimately lead to meeting the goals in the New Zealand Biodiversity Strategy.

The very isolation that has preserved the islands also makes it very difficult to carry out pest control operations. Getting resources to the islands to carry out control operations becomes a logistical problem. Timing is critical to successful operations and in these isolated environments it is not always possible to reach the islands to make best use of the limited windows of opportunity that are available. There are also legal constraints which constrain operations.

The types of traps that can be used for pest control have to meet the guidelines as set out by the National Animal Welfare Advisory Committee (NAWAC). In 1994 the Department of Conservation only had one type of trap (The Fenn) that was approved by DOC's Animal Ethics Committee for use in mustelid trapping on public lands (King, 1994). At the time of writing the DOC 150™ and DOC 200™ had been approved by the NAWAC.

Stoats (*Mustela erminea*) were introduced into New Zealand in 1884 (Miller et al., 2001) in an attempt to control rabbit populations. As in similar liberations they quickly adapted to the new habitats and became a widespread predator of not only the intended prey but also a large number of New Zealand's native species. They are recognized as the biggest danger to our threatened species. They can be hard to control due to some of their biological characteristics (King, 1994). Stoats generally live alone within individual home ranges that can cover large areas, with males having larger home ranges than females. Females are able to produce litters of between 8 and 10 or more young when food is abundant. This happens in the summer and autumn following a beech mast. The young females mate before leaving the nest which means that most of them are pregnant with the following year's litter by November each year. To date the most common form of control is by trapping and this appears as though it will continue while current research attempts to find an alternative or a way of improving the trap catch ratio.

The research over the past few years has looked at monitoring techniques to assess the effectiveness of control operations (Brown and Miller, 1998, Christie et al., 2006), types of baits and lures (Clapperton et al., 2006; Henderson et al., 2002; Miller, 2003; Montague, 2002), toxins (Brown and Urlich, 2005; O'Connor, 2002; Spurr, 1999; Spurr et al., 2002), exclusion fencing (Clapperton and Day, 2001), the effect of different coloured trap tunnels (Hamilton, 2004), the effectiveness of different types of traps (Poutu and Warburton, 2003; 2005, Warburton et al., 2002), the use of sound lures (Spurr and O'Connor, 1999) and the use of viruses (Zheng and Chiang, 2006).

The Department of Conservation has even surveyed the public as to the social acceptability of stoats and stoat control methods (Fitzgerald et al., 2002; 2005). Most of this research was the result of a $6.6 million fund over five years, to identify long-term cost-effective approaches to controlling stoats. There has only been limited research into the actual location of the trap in control operations (Dilks et al., 1996; Lawrence and O'Donnell, 1999).

There have been studies that have looked at home range, habitat and diet but none of these have been combined and analysed to determine why some traps catch more stoats than others. In cat trapping operations at Pegusus on Stewart Island one particular trap caught more cats than any of the others (A Roberts, Department of Conservation 2007, pers. comm., 10 September). The reason for this was not investigated, but may well have been that all the factors such as home range, habitat and diet culminated at that particular point. It is this type of scenario that this study will look at creating a model for.

1.2: Research Objectives

The fundamental problem this research will attempt to answer is:

Is it possible to produce a Geographical Information System (GIS) model that will identify stoat trap locations to improve the trap capture rate of stoats?

The study intends to look at the viability of using vegetation classification, stoat habitat, diet and home range, and trap capture data to try and create a model using a Geographical Information System (GIS) that predicts the location for trap placement. The study covers two islands off the coast of Fiordland: Secretary Island and Resolution Island.

Data from the stoat trapping operation on Secretary Island will be used to create the model and it will then be tested against the data from the stoat trapping operation on Resolution Island.

1.3: Structure of Thesis

This thesis consists of nine chapters that are formatted so that they follow the research objectives with a final chapter providing discussion on the results of the analysis. Chapters one and two will introduce the study areas and provide background information that is relevant to the two islands, Secretary and Resolution. These islands are in a remote location off the Fiordland coast and provide unique logistical challenges for the conservation manager attempting to eradicate stoats from them.

Chapter three reviews trapping methodology and discusses different types of layouts and compares traditional grid layout to scientific layout. A scientific layout is based on variables generated from pre-existing data such as known home range within a certain vegetation type. A description of the methods used on Secretary and Resolution Islands are provided.

Traditional techniques tended to use a predefined system to locate tunnels in a rigid grid pattern or along a line or transect which did not provide the operator with much latitude when choosing the location for the tunnel. The rationale behind this method was to make sure that there were sufficient tunnels within the home range of the stoat so that a stoat would encounter a tunnel if it travelled a set distance in any direction. In the case of Secretary and Resolution Islands, this was 700 m.

Using the scientific approach the conservation manager takes into account a series of variables to target specific areas where the stoat is likely to be. This maximizes the effort in these areas and allows for efficiency gains. Although not necessarily scientifically proven, the fact that some tunnels catch more prey has been documented. Good operators know through experience where to place a tunnel so that the chances of it being successful are improved. Allowing the operator the latitude to select the most suitable sites within target areas increases the likelihood of catching the resident population.

Chapter four reviews some of the literature relating to the use of Geographic Information Systems (GIS) in wildlife habitat analysis. The literature is related to the definition of habitat which is one of the variables being investigated by this thesis. In general the studies reviewed are based on low resolution or large scale datasets covering large areas which produce an indication of where a particular species is more likely to be located. However the principle is the same for microanalysis where the study area is small and the datasets are at a high resolution and small scale. The GIS is used to extract known information about a species habitat from a series of datasets to produce a surface that depicts areas that are more likely to be suitable locations where a species will be found.

Chapter five reviews the datasets that will be used during the analysis process. A description of each dataset is provided along with a spatial representation with the stoat trapping results overlaid. The spatial datasets used in this thesis are available nationally from research organizations and therefore can be used in similar studies through the country. The trapping results from the Secretary Island eradication project were supplied by the Department of Conservation (DOC). The data from these results provided the coordinate references for all of the trapping tunnels and which tunnels were successful for each check period. This data is analysed here to see if there are any apparent patterns that can be used in conjunction with the other datasets in the following chapters.

Chapters' six to nine contain the spatial analysis of each of the datasets in relation to the trap capture data. The basis of these analyses is to try and identify patterns from each dataset that can be used in a model. The GIS is used to perform functions such as spatial queries, overlay analysis, hot spot analysis and slope and aspect generation. The technique used depended on the dataset being analysed and the information being extracted. Raster and vector datasets were used separately, in conjunction with each other, and converted into the same format to make analysis easier.

Chapter ten provides a discussion on the results from the Secretary Island analysis and the comparisons made with the Resolution Island analysis.

1.4: The Stoat

The stoat is a member of the family Mustelidae. They have long thin bodies, a smooth pointed head, short rounded ears and round black eyes. Males can grow up to 40 cm long and weigh 350 g. Females are smaller at up to 33 cm and 240 g in weight. They are mostly dark brown in colour with creamy white underparts. Their tail is bushy with a black tip. The stoat sheds and replaces its fur in the spring and autumn. Cold temperatures often cause the autumn fur to grow out white. Stoats can be found almost everywhere throughout the northern, temperate, Sub arctic and Arctic regions of Europe, Asia, and North America. In New Zealand they can be found from beaches to remote high country, at any altitude, up to and beyond the tree line. They are very adaptive and will live in any habitat where they can find prey.

Figure 1.1: Stoat (*Mustela erminea*), downloaded 24 January 2007, from http://www.targetpest.co.nz.

Their body shape allows them to move in a sinuous manner when pursuing their prey. The advantage of this body shape is that it is one of the few species that can follow burrowing animals into their own homes and exit the burrows without difficulty. Although stoats have short legs they can cover long distances quickly and they like to follow along lines such as natural vegetation boundaries, river banks, fence lines or roads. One reason stoats are so successful is that they are very mobile.

Even on short legs, one individual, tagged and recaptured in 1990 was found to cover more than 65 km in a direct line in one month (Murphy and Dowding, 1991). This mobility makes localised control very difficult (Hilhorst, no date).

Stoats can be active during any part of the day or night. King (as cited in Griffiths, 1999) states that they have a rapid metabolism that means that they need to eat frequently; this can be up to five or six times a day. They generally rest after eating before repeating the process.

Stoats are very good swimmers. Taylor and Tilley (1984) suggested that islands over 1200 m from the mainland should be stoat free. Since that time 1200 m has been seen in New Zealand as the maximum limit that a stoat could swim. In 1997 this was questioned by McKinlay, based on the fact that stoat trapping was being carried out on Moutapu Island (Loh, 1993) in the middle of Lake Wanaka which is according to the documentation 1650 m from the nearest shore. McKinlay (1997) suggests that due to the additional buoyancy, warmer water and the use of currents stoats can be expected to swim further in salt water than in fresh water.

Secretary Island is only 1000 m from the mainland at its closest point and only 200 m separates it from Bauza Island. Resolution Island is only 500 m from the mainland at its closest point with numerous islands at various distances between it and the mainland. Both Secretary and Resolution Islands are within the suggested swimming distance of the stoat. If the eradication of the resident populations are successful on these islands there is still a threat of reinvasion from the mainland from the stoat although Elliot et al., (2005, unpublished) suggests that islands that are greater than 500 m from the mainland are less susceptible to reinvasion.

Stoats are solitary animals (Hellstedt, 2005). They are territorial and intolerant of others in their range, especially others of the same sex. Within their range, they typically use several dens, often taken from prey species. Females mate between September and November and are pregnant for 8-11 months, with young being born the following September-October. The timing of the breeding is dictated by day length.

The embryo develops in a unique way. There is a c.8 to 9 month period of arrested development where the embryos lie dormant in the uterus. This means that more than 90% of females can be pregnant over the same nine month period between December and September. In August the embryos begin to grow again and the pregnancy continues as per normal in other mammals (O'Connor et al., 2006).

Chapter Two: Study Sites

2.1: Introduction

This study comprises two sites, Secretary Island and Resolution Island. Both islands lie off the west coast of the south island of New Zealand (Figure 2.1). Data recorded from a stoat eradication programme on Secretary Island will be integrated with other data sets in an attempt to develop a model that predicts the best location to place a stoat trap tunnel which will then be tested against trap capture data from Resolution Island.

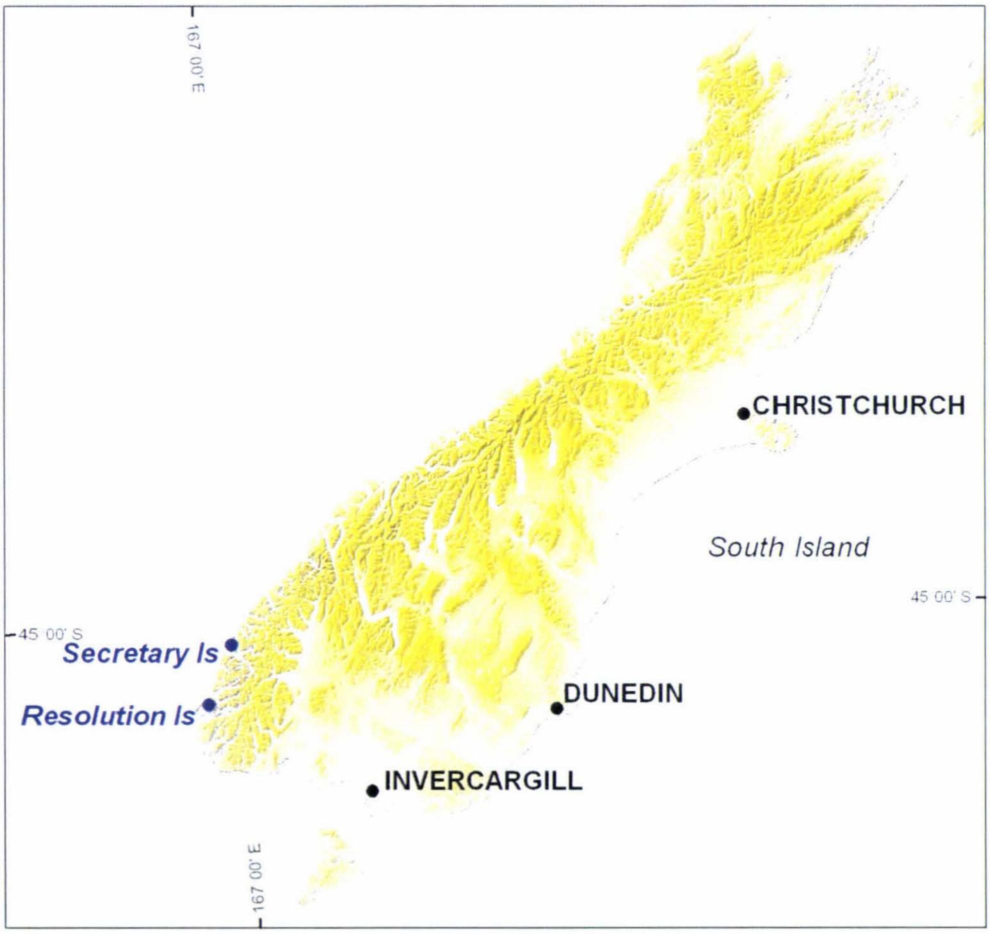

Figure 2.1: Location Map.

2.1.1: Secretary Island

Secretary Island lies off the west coast of the South Island of New Zealand. It is situated at approximately at 45° 13' 00" S and 166° 56' 00" E at the entrance to Doubtful Sound (Figure 2.2). The island is the second largest (8140 ha) island on the Fiordland coast and rises sharply to a height of 1196 m. It is separated from the mainland by Thompson Sound which runs up its eastern side in a generally north south direction (Figure 2.3). The sound varies in width from less than 1 km at the narrowest point at the head of the sound to 2 km at the southern end of the sound.

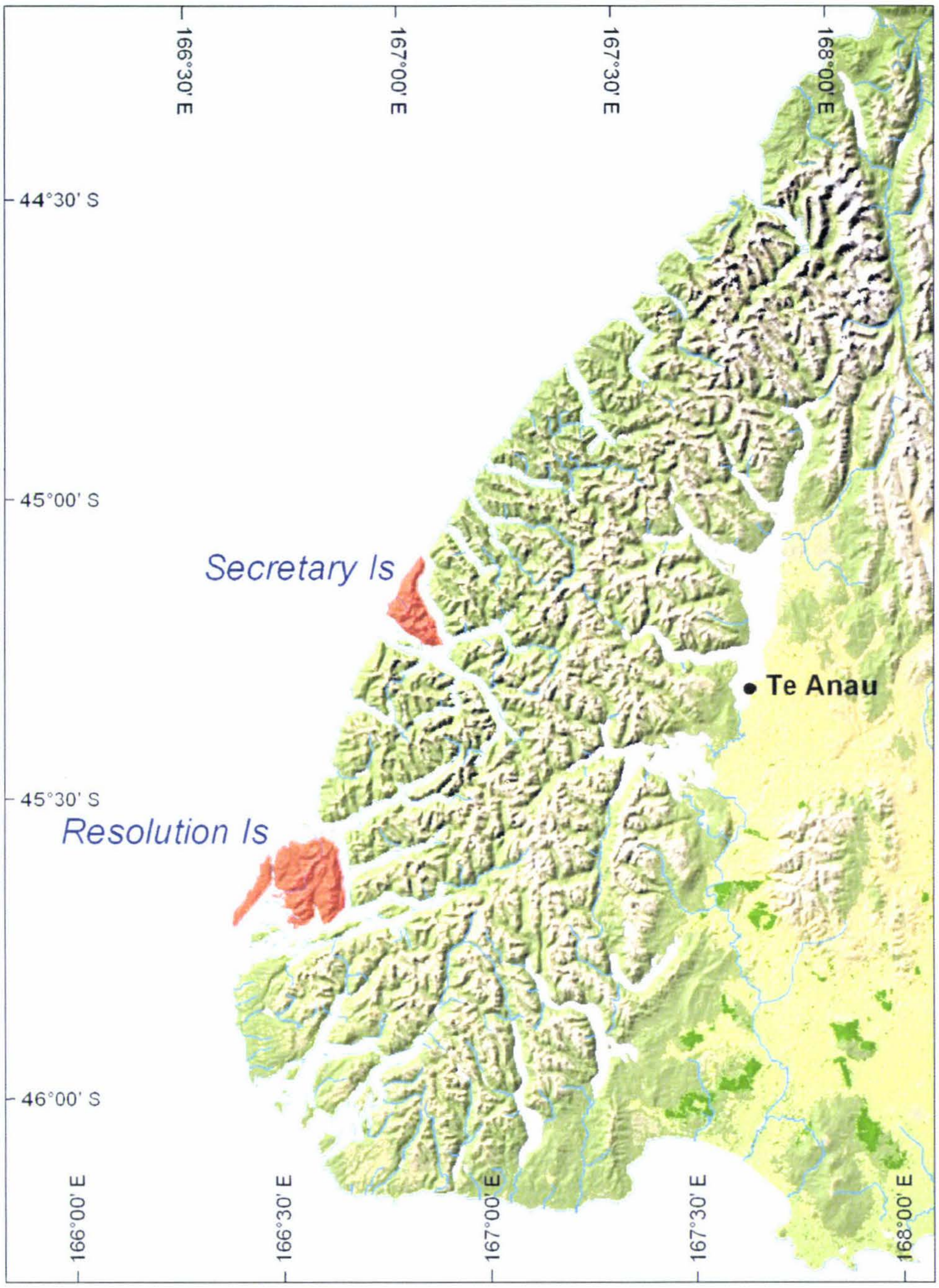

Figure 2.2: Study Area Location.

Figure 2.3: 1: 50 000 Topographic map of the Secretary Island Study Area *Sourced from Topographic Map 260-B42 Secretary and B43 Dagg. Crown Copyright Reserved.*

The island was originally notified as a Wilderness Area by New Zealand Gazette 1959 (page 1241). It was then subsequently set apart as a "Specially Protected Area" by New Zealand Gazette 1973 (page 1827). This was due to the pristine nature of the island's flora and fauna which was largely unmodified by browsing animals. This status was later revoked by New Zealand Gazette 1992 (page 2841).

It is part of Fiordland National Park and the South West New Zealand World Heritage Area which encompasses 2.6 million hectares within Westland Tai Poutini, Aoraki/Mount Cook, Mount Aspiring and Fiordland National Parks. The South West New Zealand World Heritage Area covers almost 10% of New Zealand's total land area.

The only mammalian pest species present on Secretary Island are deer and stoats. These animals are thought to have arrived on the island by swimming the short distance from the mainland. It is thought that deer arrived sometime in the late to mid 1960s (Mark and Baylis, 1975). Records show that stoats had colonised on Resolution Island, 35 km to the south of Secretary Island, in 1900 (Hill and Hill, 1987). It is possible that they were also present on Secretary Island at the same time. There are no records of possums or rodents which are found in many other areas of New Zealand being present on Secretary Island (Munn, 2001).

Secretary Island's unique ecosystem is home to a number of species that are susceptible to stoat predation. These include the Fiordland crested penguin (*Eudyptes pachyrhynchus*), titi or muttonbird (*Puffinus griseus*), northern tokoeka (*Apteryx australis*), weka (*Gallirallus australis*), karearea (*Falcon novaesseelandiae*), kakariki (*Cyanoramphus auriceps*) and Fiordland skinks (*Oligosomo acrinasum*) (Morrison and Moore, 1979; Munn, 2001; Goodman and Lettink, 2005).

The absence of rats and mice has meant that Secretary Island has provided refuge for an abundant and diverse range of invertebrates, such as the knobbled weevil (*Hadramphus stilbocarpae*), cave weta (*Gymnoplectron acanthocerum*) and tunnel web spider (*Porrhothele antipodiana*). Significant plant species which possums and deer like to eat, such as mistletoes (*Peraxilla tetrapetala, Peraxilla colensoi* and *Alepis flavida*), known as "beech mistletoe" because their primary host tree is southern beech (*Nothofagus* spp) and mountain lancewood (*Pseudopanax lineare*) are also found there.

2.1.2: Climate

Data extracted from the National Rural Fire Authority's (NRFA) Fire Weather Monitoring Station on Secretary Island from 1995 - 2007 shows that it has an average yearly temperature of 11.4 degrees Celsius, an annual rainfall of 1537 mm and the prevailing wind is from the south west quarter with an average speed of 35.8 km/hour. Baylis et al., (1963) quoted from the New Zealand Meteorological Service records (1959) that the island had an annual mean temperature of 50° F (10° C), annual mean rainfall of 150 inches (3810 mm) spread evenly throughout the year (Figures 2.4 and 2.5). The rainfall over the previous two years has increased compared to the previous 10 years.

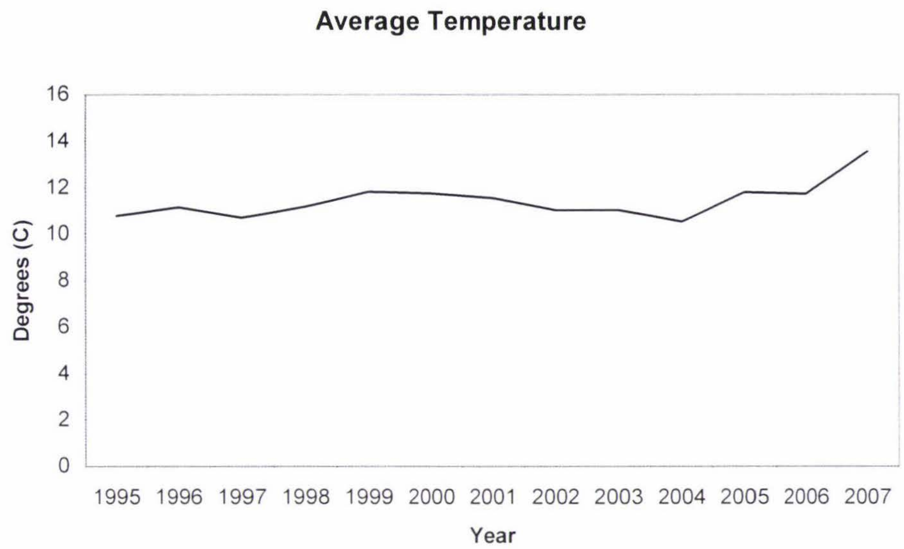

Figure 2.4: Average temperatures for Secretary Island from 1995 to 2007.

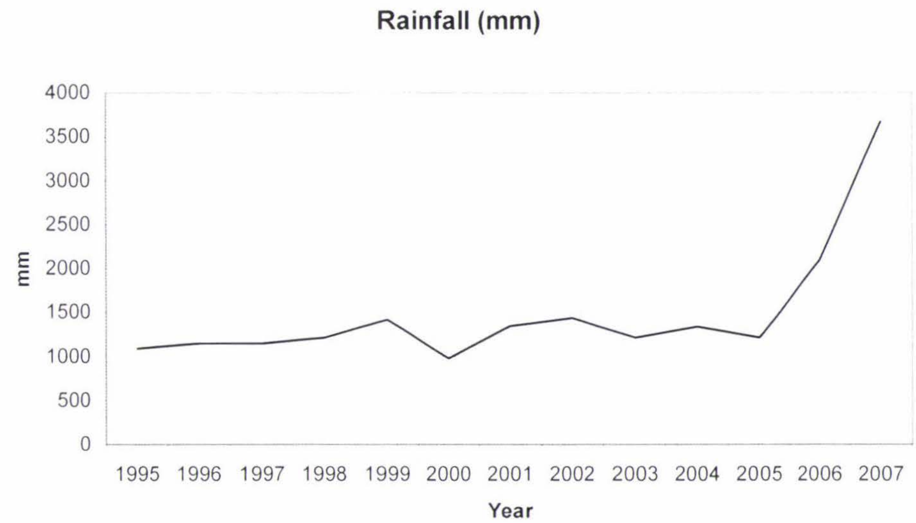

Figure 2.5: Yearly rainfall for Secretary Island from 1995 to 2007.

The prevailing wind was noted as being from the westerly direction. As compared to the Fire Authority data, the temperature is lower, the rainfall is 2.5 times greater and the wind direction is a further 45° to the north. The windrose (Figure 2.6) highlights the prevailing wind direction but the graphs of wind direction and speed (Figures 2.7 and 2.8) show that there has been a distinct change from 2005.

Admittedly the 1959 records were taken from recording stations situated throughout Fiordland which could explain the differences.

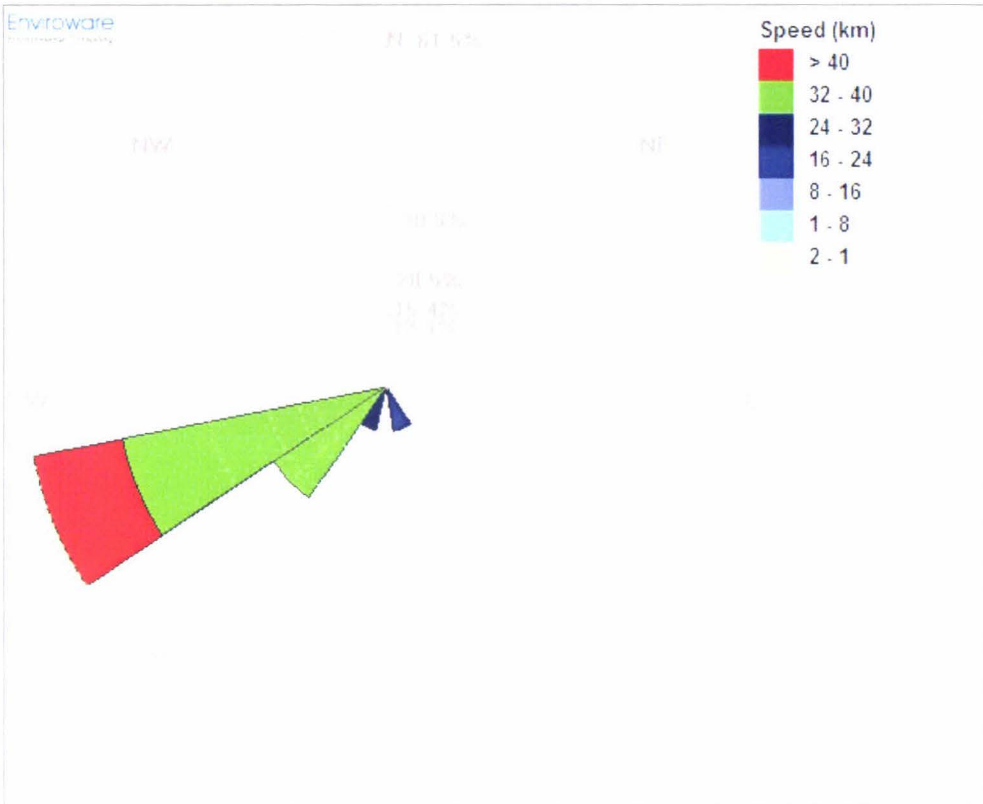

Figure 2.6: Windrose of the average wind data for Secretary Island from 1995 to 2007. Produced using WindRose PRO, Enviroware srl. http://www.enviroware.com

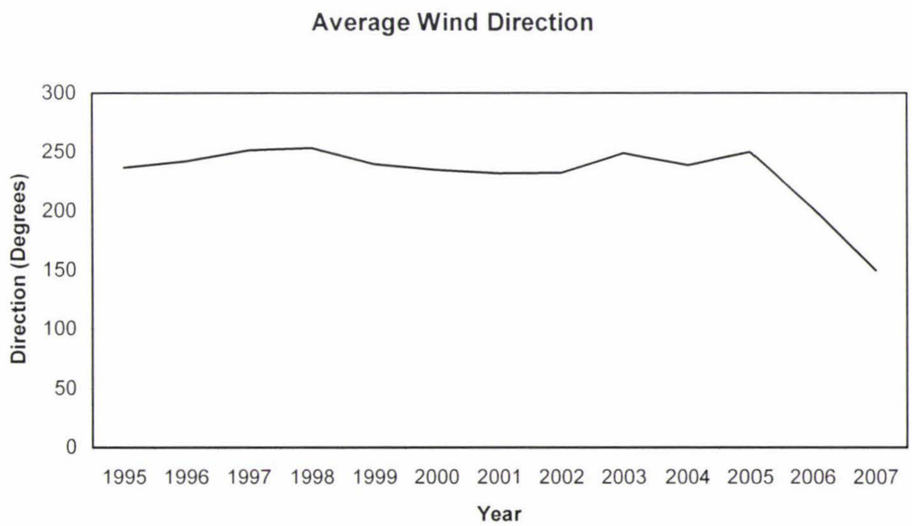

Figure 2.7: Average wind direction for Secretary Island from 1995 to 2007.

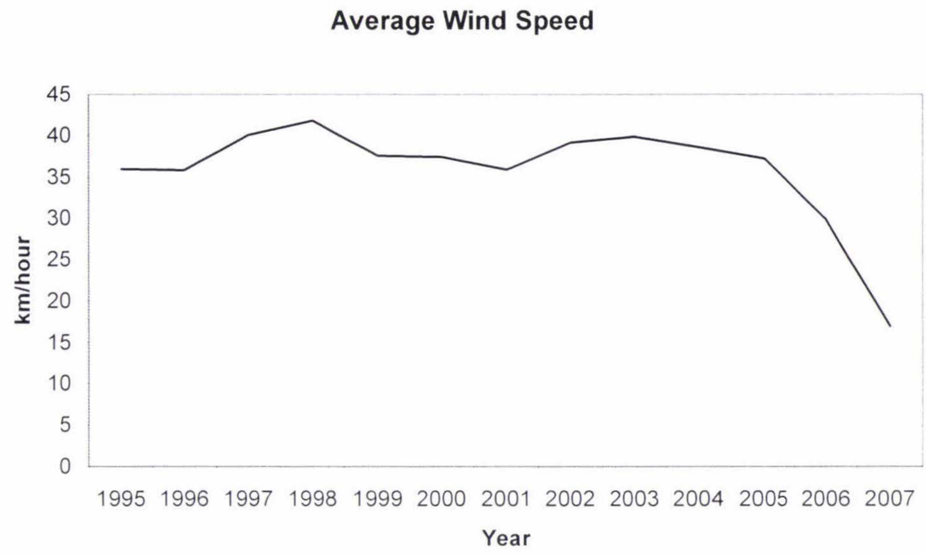

Figure 2.8: Average wind speed for Secretary Island from 1995 to 2007.

2.2: Resolution Island

Resolution Island is the largest uninhabited island in Fiordland. Captain James Cook named the island after his ship, the Resolution. During his second voyage in March 1773, he landed at Dusky Sound. At 20,860 ha, Resolution Island is the fifth largest offshore island in New Zealand. It is situated at approximately 45° 40' 00' S and 166° 38' 00" E and separated from the mainland by the Anchorage Passage.

The island lies at the entrance of Breaksea Sound to the north and Dusky Sound to the south. Wet Jacket Arm runs off to the east approximately halfway between these two sounds. The island is roughly rectangular, with the exception of a long narrow peninsula on the west coast known as Five Fingers Peninsula.

The island is closer to the mainland than Secretary Island. The closest point is only 500 m from shore to shore. The widest point is only a distance of 1500 m. There are also numerous small islands located around Resolution Island that provide stepping stones to the mainland that would enable pest reinvasion.

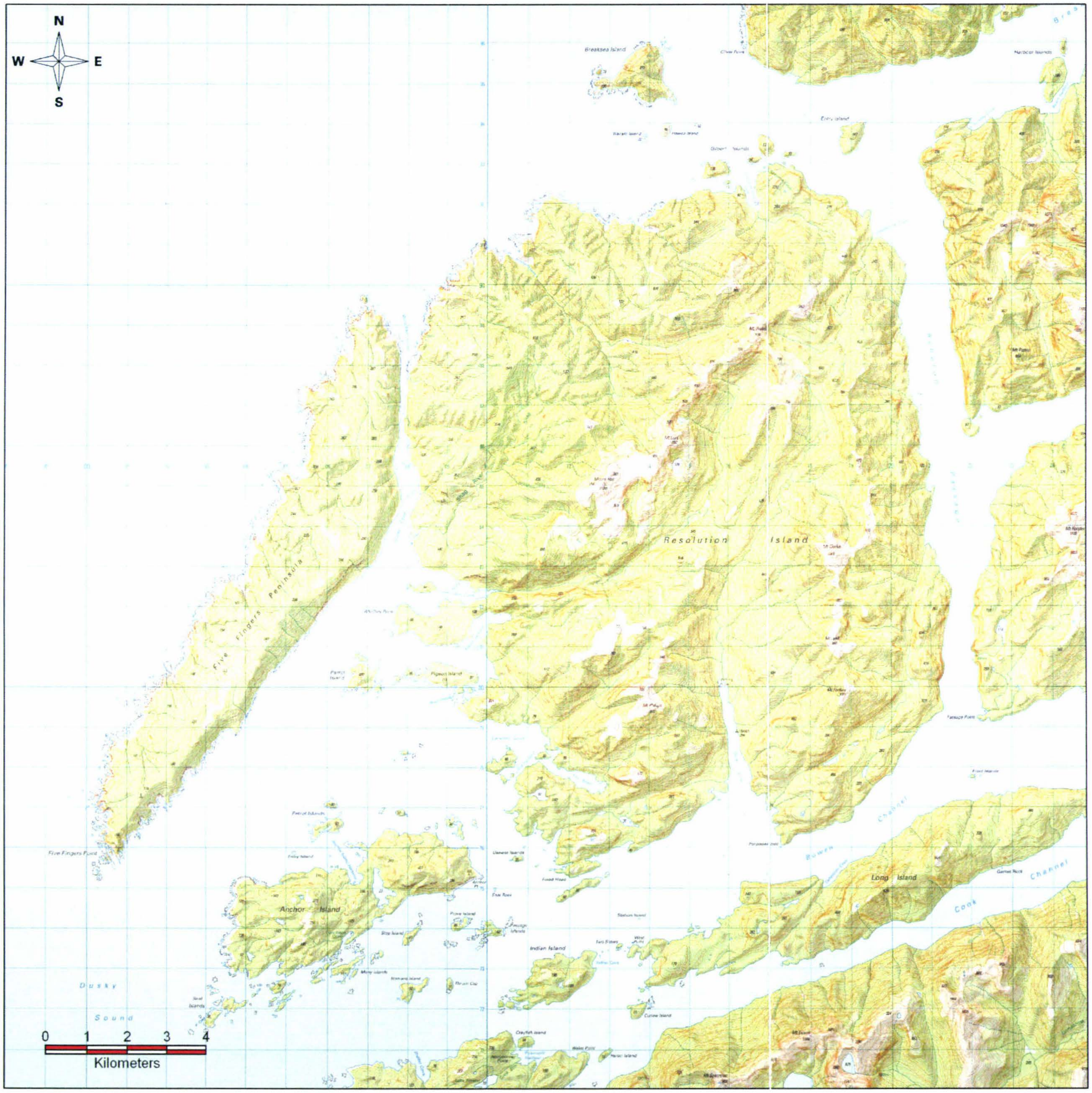

Figure 2.9: 1 : 50 000 Topographic map of the Resolution Island Study Area *Sourced from Topographic Map 260-A44 Five Finger, A45 West Cape and B44 Resolution. Crown Copyright Reserved.*

Together with Secretary Island, the Department of Conservation chose the island in 2004 to be one of New Zealand's offshore island reserves where introduced species would be removed to provide a sanctuary for the re-introduction of endangered native species. This follows a much earlier attempt, in 1894, when Richard Henry was appointed by the then Department of Lands and Survey as the curator of the island. Henry became aware of the threat that introduced predators were having on the native population and lobbied government to set the island apart as a reserve so that he could transfer kakapo (*Strigops habroptilus*) and kiwi (*Apteryx australis*) to the island. Unfortunately due to lack of funding and the arrival of the stoat on the island this initial attempt failed (Hill and Hill, 1987).

The island is populated with similar native species to Secretary Island. It is also inhabited by red deer (*Cervus elaphus scoticus*), stoats (*Mustela erminea*) and mice (*Mus musculus*).

2.2.1: Climate

Resolution Island is approximately 45 km to the south of Secretary Island and experiences similar weather patterns. Henry (Hill and Hill, 1987) described the climate as being "wet and tempestuous, but can be benign in unguarded moments. Westerly winds sweep across the Tasman Sea in an unrelenting succession of gales which deluge the mountains with rain".

His records showed an annual rainfall of about half way between the 90 inches (2286 mm) that was recorded at Puysegur Point, 30 miles (48 km) to the south, and the 250 inches (6350 mm) experienced at Milford Sound, 100 miles (160 km) to the north. This gives a rainfall of 4318 mm, which is significantly more than current records show for Secretary Island but is consistent with the figures recorded in 1959. The driest period is during the winter months, when frosts sometimes occur, giving way to fine settled days.

Chapter Three: Trapping Methodology

3.1: Introduction

The ability to successfully target a pest species relies on trap tunnels being located in a place where they are likely to encounter the tunnel. Depending on the nature of the operation and the area being targeted the layout selected may differ. Choosing the correct layout that ensures the success of an operation can be difficult; however the Department of Conservation provides a set of guidelines for their conservation managers that are based on research carried out throughout New Zealand.

3.2: Trapping Layouts

Two types of layout are generally used for control operations, grid and transect or line configurations. Grid trapping requires that the trap tunnels are set out in a grid layout. The spacing is predetermined depending on the target species. Transects for the grid are defined on the ground using a compass and tape or a global positioning system (GPS). The transect intersections are where the trap tunnels are located. This produces a semi rigid layout that is aimed at having a particular number of tunnels per area so that stoats do not have to travel any further than a specified distance to encounter a trap tunnel.

Transects or lines can follow a compass bearing, or be natural or man made features. They can be as rigid as a grid layout requiring the tunnels to be located a precise distance apart or flexible, where the operator has some discretion in where the tunnel is located e.g. 200 m apart (± 5 m). This gives the operator the chance to select the best possible location for the tunnel that will maximise the success rate for the set.

The main objective of trapping is to capture a target species. When designing the layout of tunnel locations the intensity of the tunnels is defined by the distance between them.

Flowerdew (1976) suggests that tunnels should be positioned such that all animals have sufficient opportunity to approach a tunnel. Irrespective of species differences, this opportunity decreases as the spacing between tunnels increases. This is one factor that can determine the proneness to capture or trappability of a species.

Both types of layout rely on there being sufficient trap tunnels covering a control area so that a stoat will encounter one in its normal daily routine. In this type of trapping unless the tunnel is located on or next to a stoat's run there has to be something that will attract the stoat to the tunnel.

In general grid layouts are easier to establish and require less effort to maintain and check. They are better suited to small control areas. Stickel (1948), (as cited in Read et al., 1988) notes that they are too laborious and time consuming and are not practical for sampling a large number of habitats. Because of the structured layout and the close proximity of each tunnel it is less likely that tunnels will be missed when checking is done. Buckland et al., (2004) found that transects required about 50% more effort (in person hours) to set up than a grid layout but less effort was required for each tunnel setup because of the close proximity of each tunnel. Transects required more attention to detail when setting up and checking because tunnels were set in a non-uniform and less predictable manner.

The rigid layout of the grid does not allow for positioning of the tunnel in the best possible location. This can be detrimental to the success of the operation although it may be countered by the density per area of tunnels. This was demonstrated by Stewart (1979) who set two parallel trap lines. One had the traps set at precisely 20 m intervals and the other at intervals of roughly 20 m (± 2 m) with the trap in the best possible position. The second line caught many more animals. This is an important difference and indicates that correct tunnel placement has more effect on the success of a capture operation than the number of tunnels available. Increasing the number of tunnels may not necessarily increase the capture rate.

Laudenslayer and Fargo (2002) suggested that the results of their study indicated that trap capture success rates for small mammals could be influenced by trap type and trap location. The variation was attributed to differences in microhabitat and travel corridors. In a similar study, Murray (1957) concluded that small differences in trap placement in similarly structured and composed vegetation could cause variations in trapping results. These variations have been documented in Kirkland and Griffin (1974), Price (1978), Sakai and Noon (1993), and Tietje (1995).

In a study that compared grid and transect trapping for assessing small-mammal community composition and relative abundance in two types of forest cover the transect method yielded more total captures, more individual captures and more species than the grid layout in both forest cover types (Pearson and Ruggiero, 2003).

When using a grid layout the ability to put a tunnel in an area where the target species is likely to encounter it is limited. Read et al. (1988) suggests that animal movement is intersected better by a transect rather than a grid as it passes through the home ranges of more animals and is not complicated by a two dimensional, multiple choice of traps.

3.3: Scientific Trapping

Dilks et al. (1996) and Lawrence and O'Donnell, (1999) cited by King et al. (2001) suggest that kill trapping with the Fenn trap or the new DOC traps, set in tunnels and baited with hen's eggs or meat, is still at present, the only proven and safe method applicable over wide areas for the control of stoats.

King (1994), O'Donnell and Phillipson (1996) and Griffiths (1999) cited by King et al. (2001) conclude that effective control operations with current technology are labour intensive, and therefore costly, so it is important to maximise trap efficacy by selecting the correct trap type, bait, layout, seasonal timing and length of operation to suit the purpose of the operation. The other important issue to consider when setting a tunnel is that it is imperative that "what goes in does not come out". Ineffectual trapping leads to trap-shy animals. When the aim is to eradicate a species this only makes the success of the operation harder to achieve.

When a conservation manager is able to pick or select the best place to set a tunnel the chances of the tunnel being successful are enhanced. "Set" is the term used by trappers that refers to the position, camouflage and lead-in of a tunnel (King, 1973). Scientific trapping uses information gathered from previous studies that have identified factors common to successful tunnels to aid in the location of the tunnels in future operations. This could be as simple as setting the tunnels at a particular time of year or as complex as identifying individual territories and prey species habitat.

Parkes and Murphy (2004) suggest that there could be significant gains in stoat control effectiveness if trapping is used strategically. When interviewed on 16 September 2007, A Cox (Department of Conservation) suggests that if you could predict how stoats moved around their home ranges then tunnels could be concentrated in those areas.

However males tend to travel over wider home ranges than females and apart from radio tracking stoats prior to an operation this would be almost impossible to predict. It is therefore important to make sure that there are sufficient tunnels on the ground to make sure all stoats will encounter at least one within their home range. If this is within their core home range then the likelihood of them encountering the tunnel is increased.

Decisions on the best placement and configurations of traps are usually based on trappers' opinions and experiences (Cameron et al., 2005). Experienced trappers have always known that some sites are more productive than others, assuming this is because sites must vary in their positions relative to the normal runways used by resident animals. Results suggest that, in habitats where stoats and rodents are patchily distributed, the need for a trapper to find a good trap position within a good patch may be less important than the need to identify and avoid bad patches (Purdey et al., 2004).

Tunnel location has a large impact on the effectiveness of the tunnel to catch the prey species. King (1994) suggests that trap location is the most important factor within human control that can to a large degree dictates the success of a stoat operation. Dilks et al. (1996) and Ratz (1997) found that tunnel position had a major effect on catch rate. If the conservation manager is able to determine where the best places are to run the tunnel grids or lines using a set of known variables the effort required to achieve the desired result is reduced. Areas that are known to be non-productive can be avoided and conversely areas that are known to be favoured habitat can be strategically targeted.

3.4: Secretary Island Trapping Methodology

The methodology used on Secretary Island is fundamentally different from some of the other projects that have been carried out to protect endangered species. The objective of the Secretary Island project is:

"To totally eradicate the resident stoat population and manage the possible re-invasion by reducing stoat density on the adjacent mainland and stepping-stone island" (McMurtrie, 2005).

On Secretary Island the idea is not to control the stoats in a cost effective manner, but to get rid of the stoats in a cost-effective manner and then control the reinvasion. Mainland projects have concentrated on reducing the stoat population to protect a breeding population of endangered species at critical times (O'Donnell et al., 1996 and Dilks et al., 2003). To make sure that the operation was successful the use of more rather than less tunnels was acceptable.

The eradication of stoats from Te Kakahu (Chalky Island) in 1999 (514 ha) and Anchor Island in 2001 (1130 ha) (Willans, 2000; 2001) have been planned and implemented in such a way that the methods used on these islands can be transferred to much larger islands such as Secretary and Resolution Islands (Golding et al., 2005). In an effort to reduce the variable associated with the human factor a lot of effort was put into making sure that everyone managing a line of tunnels used the same techniques when setting and checking them. The tunnels were set in such a way to encourage the stoat to enter the tunnel.

Three criteria were developed for the location of the trap tunnels on the island:

1. locate a practical track network (Figure 3.1),
2. have reasonable even coverage (Figure 3.2),
3. tunnel placement closely approximates a grid layout.

A 135 km (approx) network of tracks was cut by contract staff between October 2004 and April 2005. Some of these were originally created by the New Zealand Forest Service in 1970 when deer control operations were started on the island (Brown, 2005). This provides for approximately 1 km of track per 81 ha of land area.

Figure 3.1: Secretary Island track network.

During the planning stages of the operation the GIS was used to generate a 700 m buffer around each track to estimate the level of effective coverage that the network would provide. Apart from a portion of the eastern coast the majority of the island would be covered effectively. Additional tunnels were placed along the coastline in the areas outside the effective coverage area.

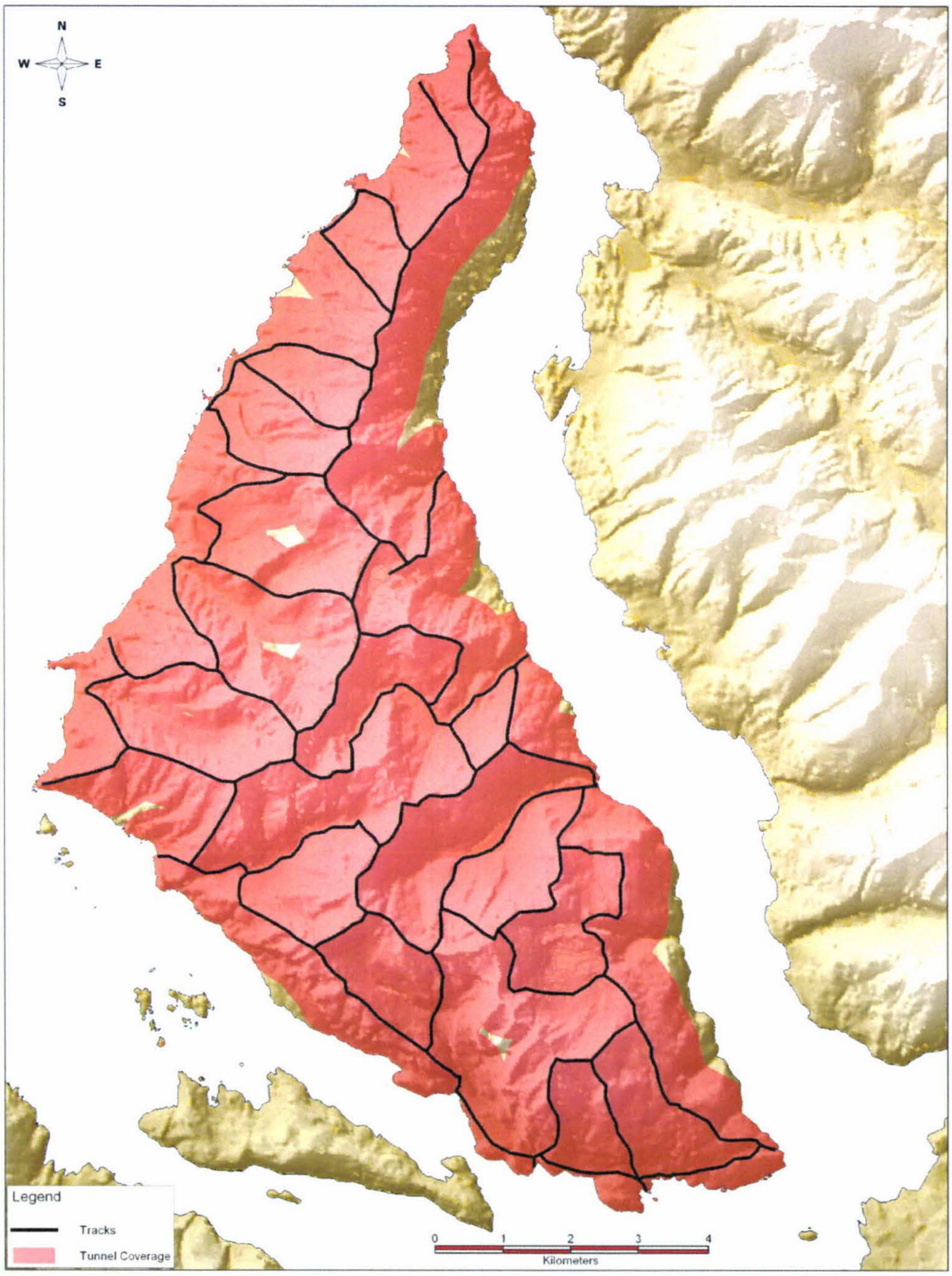

Figure 3.2: Secretary Island track layout and effective tunnel coverage.

Tunnels (Photo 3.1 and Appendix 11) were placed at intervals of approximately 100 - 150 m along the tracks and in several places along the coastline. The coastal tunnels were located to serve two purposes, help with the initial eradication and protect against re-invasion. Tunnels were uniquely numbered and their location captured using a Global Positioning System (GPS) unit.

This level of coverage provided approximately one tunnel every 8.6 ha with lines being a maximum of 1 km apart. This tunnel density is lower than other island eradication projects partly because of the size of the island but also because of the length of time it will take to remove the resident stoat population.

Photo 3.1: Double set tunnel with DOC 150 traps similar to those used on Secretary Island. Photo taken by Darren Peters, Department of Conservation National Predator Advisor.

Current guidelines (www.predatortraps.com, 27 April 2005) suggest that for large scale operations tunnel lines should be 1 km apart and tunnels spaced between 100 - 200 m (maximum). A line will protect an area approximately 400 m either side of the line. Small scale localised operations should have the tunnels spaced closer together (www.predatortraps.com, 27 April 2005). The prescription for this operation falls within these guidelines. Tunnel spacing varies greatly over recorded operations. Spacings from 25 m to 800 m have been recorded but 100 - 200 m spacings seem to be the most common (Parkes and Murphy 2004).

Two types of tunnels were used: wooden and wire (Photos 3.2 and 3.3). The tunnel serves three purposes:

1. orientate the animal relative to the trap,
2. protect the trap,
3. keep out non target species.

The wire tunnels had a coreflute lid on them to stop heavy rain from setting off the traps and birds poking their beaks through the mesh.

Photo 3.2: Wooden tunnel and Fenn traps like those used on Secretary Island. Photo taken by Keri-Anne Edge, Department of Conservation.

Photo 3.3: Wire tunnel with coreflute cover and Fenn traps like those used on Secretary Island. Photo taken by Kerri-Anne Edge, Department of Conservation

Two Fenn Mk IV traps (Photo 3.4) were used in each tunnel. DOC 150 traps (Photo 3.5) were initially used on the mainland but were later replaced with Fenn Mk IV traps when it was found that they could not withstand the harsh coastal climatic conditions.

Photo 3.4: Fenn Mk IV trap, Downloaded 2 February 2008 from www.philproof.co.nz

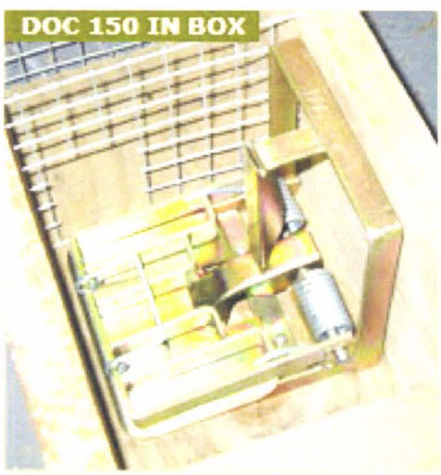

Photo 3.5: DOC 150 trap, Downloaded 2 February 2008 from www.predatortraps.com/

The Fenn traps are now being replaced with an improved version of the DOC 150. This is because these and the DOC 200 are the only traps that meet the National Animal Welfare Advisory Committee (NAWAC) guidelines for use as a stoat kill trap.

Before the traps were set in the tunnels they were pre-baited twice to assess initial bait take. These were done over a one week period each, in June and July 2005. Rabbit and venison were used for the pre-baiting. Rabbit, venison and beef were then used to bait the traps. The traps were then set over a three day period and each trap was checked twice over a seven day period. This provided for an initial intensive knock down of the resident stoat population. This was followed up with a further three checking periods in November 2005, February and June 2006. The operation has continued with twice yearly checks there after.

It is expected that there will be a level of reinvasion from the mainland because of the stoats swimming ability. The distance between Secretary Island and the mainland is generally greater than 1200 m although this is reduced by the number of smaller stepping stone islands that lie between the island and the mainland. A current study (Stoat eradication from islands in Fiordland, Department of Conservation, Investigation Number 3406, Elliott et al., unpublished), that is looking at stoat reinvasion suggests that the re-invasion will be low and therefore manageable using the current trapping methodology (Golding et al., 2005).

3.5: Resolution Island Trapping Methodology

The eradication of stoats on Resolution Island, if successful, will be the largest island eradication of its type in New Zealand. At 20,860 hectares, Resolution Island is a major undertaking that poses huge logistical issues for the conservation managers. The lessons learnt and experience gained from previous island eradications will be invaluable to the success of the operation.

The programme has three objectives:

1. To enhance the existing ecological values of Resolution Island by eradicating stoats.
2. To minimise the risk of stoat and rat re-establishment by:
   (a) reducing stoat density on the adjacent mainland and stepping stone islands;
   (b) ongoing surveillance and contingency operations for stoats and rats that do reach Resolution Island.
3. To reintroduce threatened species to Resolution Island (McMurtrie et al., 2008).

A track network will underpin the success of the operation. Due to the nature of the terrain and the sheer size of the island the only way to effectively move around it is via a network of tracks. Approximately 230 km of tracks were constructed between September 2007 and April 2008 to DOC standards. The proposed track network is shown in Figure 3.3 but the actual final layout may differ from this due to a lack of detailed knowledge of the terrain on the island. Generally, tracks will follow main ridge lines, spurs and valley floors.

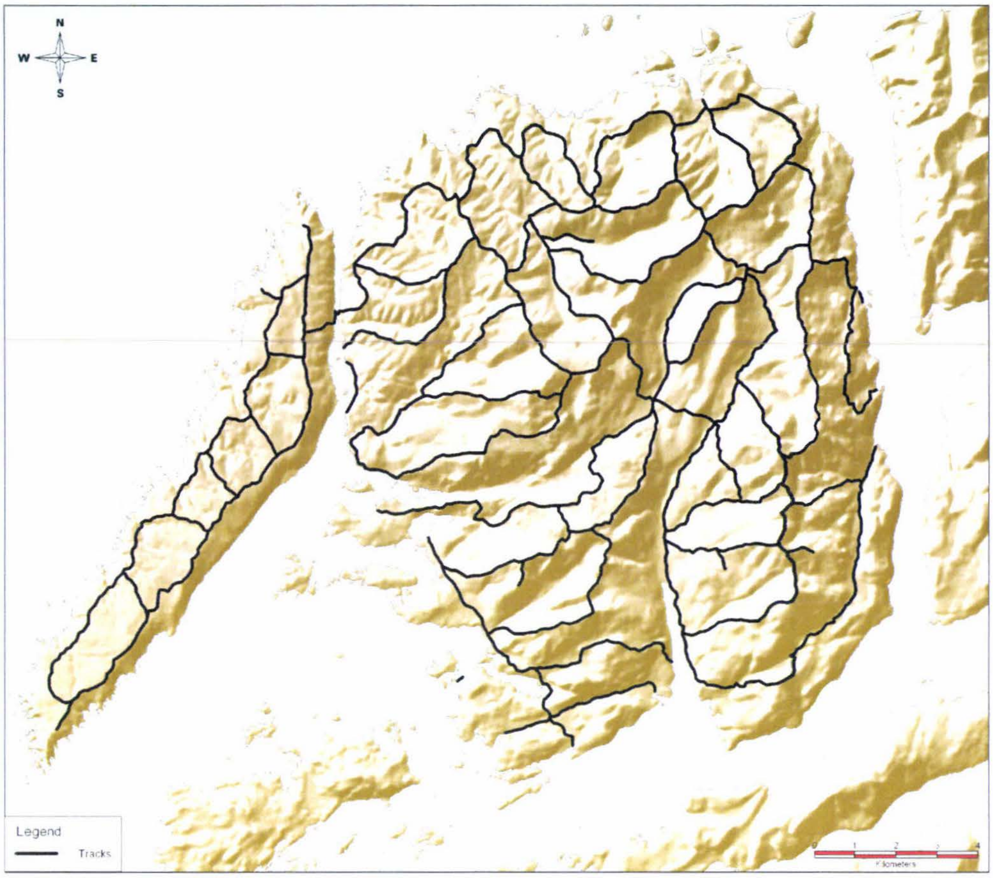

Figure 3.3: The Resolution Island track network.

The network was designed so that a stoat would have to travel no more than 700 m to encounter a tunnel. Using the same methodology as Secretary Island a 700 m buffer was applied to all the tracks to ensure that full coverage of the island was achieved Figure 3.4. This identified approximately 31 locations averaging less than 35 hectares in size that were outside the buffer. In most cases these are in areas that are very steep and difficult to access (McMurtrie et al., 2008).

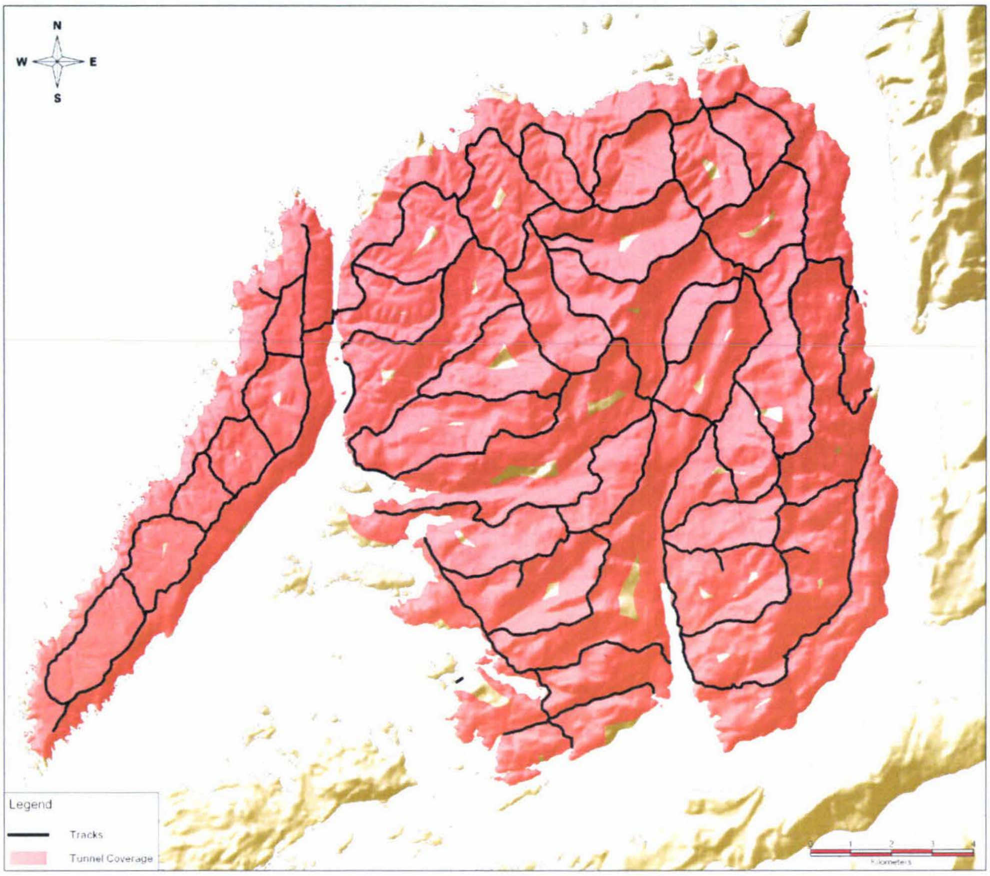

Figure 3.4: Resolution Island track layout and effective tunnel coverage.

Tunnels will be placed along the track network at a spacing of approximately 105 m. A minimum of 2315 tunnels will be used giving a density of 1 tunnel per 9 hectares which is similar to that achieved on Secretary Island. The distance between tunnels will be measured using a hip chain and operators will locate the tunnel in the most appropriate site available to achieve this spacing. Tunnels will also be located at likely invasion points along the coast with additional tunnels being placed along the mainland and adjoining stepping stone islands.

Two types of tunnels will be used, wooden and wire (Appendix 12 and 13). The wire tunnels will only be used below the bush line to avoid interference from birds (kea (*Nestor notabilis*) and kaka (*Nestor meridionalis)*) and weather which caused traps to be sprung on Secretary Island. All tunnels will be pegged to the ground or nailed to trees to avoid kea and kaka associating rolling a tunnel with obtaining an egg from the tunnel. The island has been split into two blocks in a north-south direction; the western half will contain wooden tunnels and the eastern half will contain a mixture of wooden and wire tunnels. This is being done to see if there is any significant difference between using different types of tunnels on the success rate. Some stoats may have an aversion to a particular type of tunnel and therefore if only one type of tunnel is used it will take longer to capture all of the stoats on the island.

Tunnels will be placed by the operator on level ground alongside the track in a position that is makes it easy to be serviced. They are to be in a sheltered position especially in exposed sites. The location of each tunnel will depend on the operator. This may cause some variation as a number of operators will be employed to locate the tunnels due to the size of the operation and each operator will have a slightly different approach to the positioning of a tunnel. The human variable is one that can be controlled to a certain extent. All operators will be experienced trappers and will be briefed prior to the start of the eradication operation. The quality of the initial layout of the tunnels and the subsequent trapping is seen as being crucial to the success of the operation.

A single DOC 150 stainless steel trap per tunnel will be used for the operation. This differs from the Secretary Island operation where two Fenn Mk IV traps were used. This means that the tunnels do not have to be as big, the trap release is preset at the factory eliminating operator error and there is a substantial cost saving by halving the number of traps required.

Double captures on Secretary Island were very low, only three during the initial knock down period. The traps require less maintenance and can be left out for a longer period before needing to be replaced. The disadvantage of only having a single trap in each tunnel is that if a stoat is caught then the tunnel is out of action until the next service. With a double set the tunnel is still active. This could have an effect during the initial knock down phase but may not be an issue thereafter due to the low level of captures (A Cox, Department of Conservation 2007 pers. comm. 17 September).

Trapping will be preceded by two pre-baiting periods, scheduled for June and July 2008. Bait will consist of one fresh hen's egg and a cube of salted meat, being one of beef, rabbit or venison. An egg will also be placed outside the tunnel, but only those that are below the bush line or where the egg is not visible from the air so as not to attract the attention of birds. Tunnels will be rested for two weeks after the second pre-bait period and then trapping will re-commence in August 2008. Trapping is timed to coincide with low levels of prey species. Natural prey species populations start to increase at the end of August so the first knock down is scheduled to be completed before this happens.

The Resolution Island methodology is largely the same as that used on the Secretary Island project. The major difference is the change from double set tunnels to single set and use of DOC 150 traps instead of Fenn Mk IV traps. One of the reasons for this was that there were only a small number of tunnels on Secretary Island that caught two stoats at the same time. The ability of the trap to catch the stoat once it enters the tunnel is more important. The DOC 150 traps appear to be more reliable in this harsh environment. In terms of this study, which is investigating suitable tunnel location, it should not have any affect on the outcome. If different operators are being used, this may have a larger impact as they ultimately have control over selecting the tunnel location which appears to have a larger influence on the success of a tunnel.

Chapter Four: Geographic Information Systems

4.1: Introduction

Generating the spatial extent of a variable relies on the use of maps. Prior to the advent of Geographic Information Systems (GIS) applications this was carried out manually. This was a time consuming process that required multiple transparent overlays to be generated to produce an outcome. Making changes to simulate different scenarios was laborious and time consuming. The GIS simplifies this process and allows complex sets of data to be manipulated to generate numerous scenarios.

4.2: GIS and Wildlife Habitat Analysis

Geographic Information Systems have become an important method in wildlife-habitat mapping. The application provides decision makers with the ability to generate predictive models that relate single species to measurable components of their habitats. The main objectives for applying models to infer wildlife-habitat relationships are to develop spatially explicit habitat maps that show areas that may support a species, predict which environmental factors affect the distribution and abundance of a species, as well as predicting the possible future distribution of the species (Qunilan et al., 2004).

There are various models available for habitat modelling. The type of habitat model to use is dependant on the nature of the species, eco-region and purpose of the study (Ashraf, 2003). Ashraf discusses some examples of habitat models used to identify such things as snow leopard habitat, evaluate the impact on fish and wildlife from changes in water and land use and habitat manipulation. The type of data available will also have an impact on what type of model is used and what type of results will be generated.

Some of this data can be produced using the GIS. An example would be that the species being controlled may favour certain altitudes and a particular aspect. By spatially manipulating a Digital Elevation Model (DEM) these criteria can be identified and combined with other known data sets. In this study the intention is to model habitat, prey species and existing trap capture records and combine the results into a single trap location model.

In a study that looked at the potential habitat of moths in boreal forests in North America the authors used geo-statistics to convert male moth counts, at point locations, to complete spatial coverage maps for use in a GIS. The authors suggested that the resultant maps could be used to predict incipient outbreaks and potential defoliation (Lyons et al., 2002). In this particular study the authors used a geostatistical technique known as kriging to interpolate point data. The process relies on autocorrelation to provide a weighting to nearby points in the estimates.

Vismara et al. (2001) suggests that habitat suitability indices are an effective method of building predictive models of species occurrence but they require specific information about the biology and autecology of a species in order to develop a suitability index used in the model. An alternative to this may be to combine habitat measurements with total count data for the taxon captured over past census periods (Smith and Connors, 1986). In a study looking to improve trapping success for rare species Quinlan et al. (2004) used a GIS in combination with habitat information to identify potentially suitable habitat for the heath mouse *(P. shortbridgei)*, and to focus future trapping effort, within one reserve in Western Australia.

The role of GIS in pest management is discussed by Gillgren (1999) in relation to all phases of possum control. During the planning phases the author used the GIS to identify potential trap line locations, calculate control areas, identify potential preferred vegetation types and find adjoining property owners for legal notification purposes.

The 3D capabilities of the GIS in conjunction with a digital elevation model (DEM) can be used to give operators a better understanding of the terrain they are likely to encounter as well as assisting with new track placement.

During the actual operation the GIS can be used to plot data from a Global Positioning System (GPS) to make sure that bait is being placed within the operational area and that the correct coverage is being achieved to avoid leaving holes that may contain the target species. The author concluded that environmental control operations involve spatial data. The GIS is an efficient way of storing and manipulating this data. By manipulating data from historical control operations there is the possibility of identifying trends that will enable improvements in the way control operations are managed.

An important criteria that helps to identify where a target species is located is home range. Kernohan, et al. (1998) investigated the use of a GIS to calculate habitat use by white tailed deer (*Odocoileus virginianus*) in Sand Lake National Wildlife Refuge, South Dakota. In the study the author used an adaptive kernel home range estimator and data collected from radio tracking collars on forty-five white-tailed deer. He was able to identify ten habitats and home ranges and thus calculate the percentage of each habitat within each home range. This provides valuable information for control operations as the most favoured sites can be targeted, which means that valuable resources are being utilised to their full potential.

The GIS was used to identify the ecological impact a road corridor had on the ecosystem it bisected. GIS analysis enabled the author to manipulate data from road-kill, track surveys, mark-recapture and telemetry to evaluate road impacts on different taxa. This was used to determine the effects the road had on the presence and movement behaviour for different suites of wildlife.

The Department of Conservation has used GIS to assist with pest control operations throughout New Zealand. GIS has been used as a planning tool to identify potential control areas, developing control strategies and monitoring the results of control operations. GIS has been used successfully to manage 1080 (sodium monofluoroacetate) possum control operations so that the correct area is targeted. This utilises the GIS in the planning stage to identify the area to be controlled, location of flight lines and monitoring sites. Data from GPS units mounted in the aircraft used to distribute the toxic bait is then downloaded into the GIS to monitor bait distribution and make sure that the correct area is completely covered and no bait is dropped outside the control area. Pre and post control data from the monitoring sites is then analysed in the GIS to determine the success rate of the operation.

In the Secretary Island stoat eradication project GIS was used to record the ocation of the track network from data downloaded from GPS units. These features were then used to carry out buffer analysis to determine the effective area that would be covered using the recommended guidelines. Once the trap tunnels were located, their location was recorded using GPS units and this data was then added to the GIS.

To get an accurate measurement of the length of the tracks 3D analysis was used. This provided the operation managers with profile information for each track so they could then work out relative times for tunnel checking and therefore the amount of person hours required for each tunnel check period. Apart from recording the location of stoat captures for reporting purposes no GIS analysis has been done on the data that has been recorded during the control operation.

In one of their most successful control operations to date, the eradication of rats (*Rattus norvegicus*) from Campbell Island, one of New Zealand's largest subantarctic islands, GIS was used in the planning stages and then during the operation to monitor bait application. This was done in one of the harshest environments in the world using laptop driven GIS and shows the potential for using GIS to assist with pest control operations. Further examples of GIS being used in pest control operations can be found in Cleland et al. (2006) and Sancha et al. (2007).

Chapter Five: Data Sources

5.1: Introduction

To create a predictive model the analyst requires a set of data from which a set of variables can be extracted. The data sets available for this study have been used in past studies to produce predictive models of wildlife habitat. Some of the data sets are used in their raw form and others are manipulated to produce derived data. In one case a data set is refined based on data extracted from a written study. The data recorded from the Secretary Island stoat eradication project is used as the basis for extracting potential variables to be used in the predictive model. This is compared using various GIS analysis techniques to the other data sets to try and determine stoat habitat and home range. Combining the results of this with the stoats dietary requirements would attempt to answer the second of the research objectives.

5.2: Data Sources Used

5.2.1: Secretary Island Trap Capture Data

Having access to trap capture data from control operations that have been carried out in similar environments to proposed control operations provides useful information during the initial planning stages. If the location of the traps has been accurately geo-referenced then they can be used to extrapolate a habitat model based on the number of stoats caught at each trap. The more stoats caught at a trap would tend to suggest that there is a good correlation between the surrounding habitat and high stoat numbers. This can then be used as a planning tool to identify similar areas in the proposed control operation site.

Similarly, if the gut content of the trapped stoats has been examined, the relationship between prey species and habitat can be combined to further narrow the potential sites for trap location. The prey species of stoats have varied habitats, ranging from podocarp/broadleaved forest (possum (*Trichosurus vulpecula*)) to fallen logs and damp ground litter (Large cave weta (*Gymnoplectron* spp.)). There is even evidence that stoats prey on freshwater crayfish (*Paranephrops* spp.) which tend to be resident in the streams throughout the stoats home range (King and Moody, 1982).

Not all of the areas where stoat control is going to be carried out will have all of the potential combinations of prey species and habitats so the control effort can be targeted at those that are present. Using a Geographic Information System (GIS) and spatial analysis techniques to identify these sites is an example of what these applications were designed for.

The trap capture data was supplied by the Department of Conservation, Te Anau Area Office. The data came as a Microsoft Excel spreadsheet with separate sheets for each tunnel check period (Appendix 1 - 7). The data included the location, check period, operator, tunnel reference and type, bait type, weight and sex of stoats captured.

This data provided the location of each trap which was then able to be imported into the GIS application by geo-coding the New Zealand Map Grid (NZMG), Datum 1949 coordinates for each trap location (Figure 5.1). A total of 945 trap tunnels were located on Secretary Island and a further 180 tunnels were located on the adjoining mainland. Another 46 tunnels were also placed on Bauza, Utah, Seymour and Shelter Islands.

Figure 5.1: Tunnel locations on Secretary Island, adjoining islands and the mainland, June 2005. *Map base sourced from Topographic Map 260-B42 Secretary and B43 Dagg. Crown Copyright Reserved.*

The trap catch data was then analysed to determine:

1. Which tunnel locations caught stoats.
2. Which tunnel locations caught multiple stoats.

These results were then mapped, Figures 5.2 and 5.3.

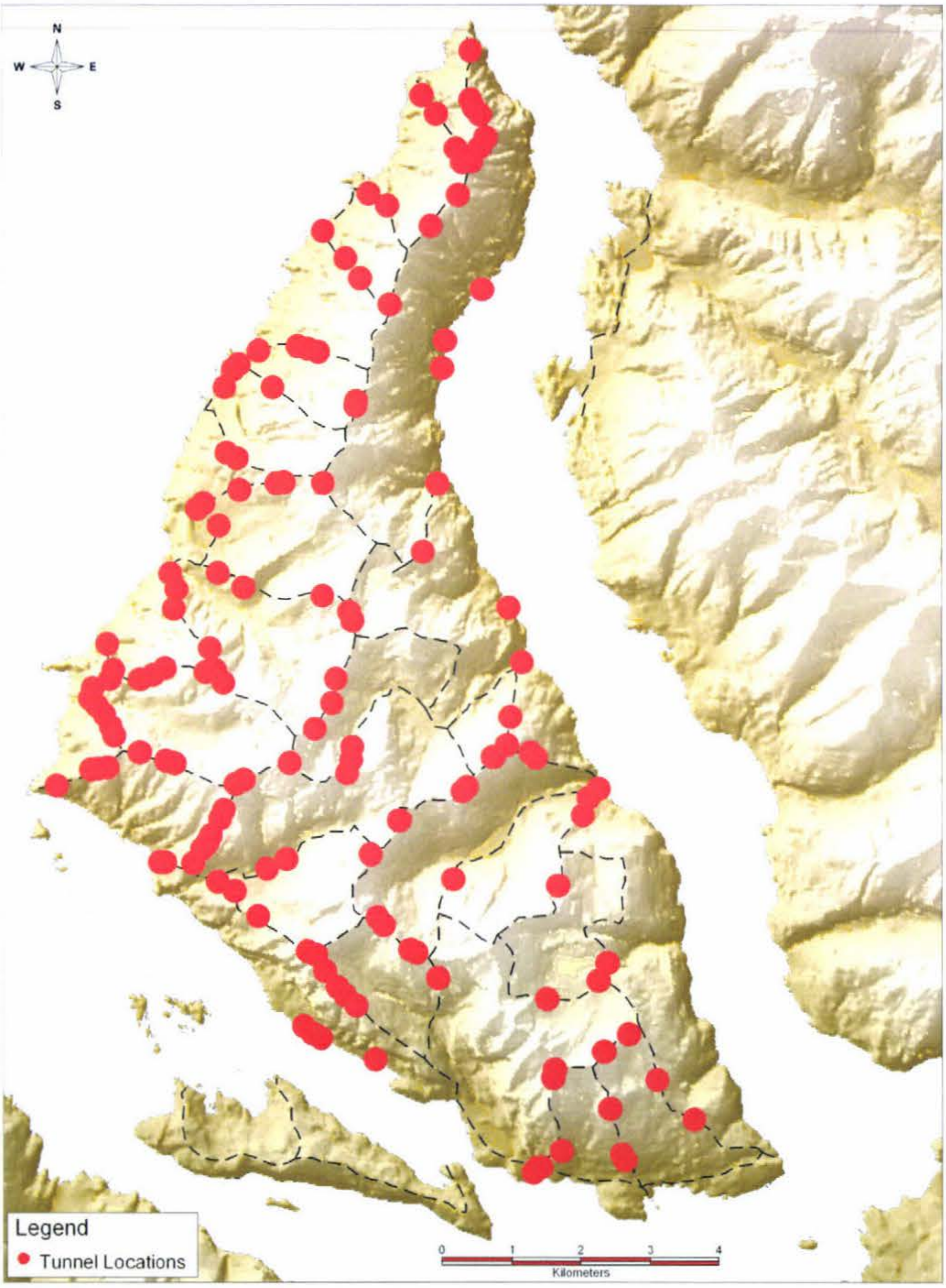

Figure 5.2: All successful tunnel locations on Secretary Island from July 2005 until January 2008.

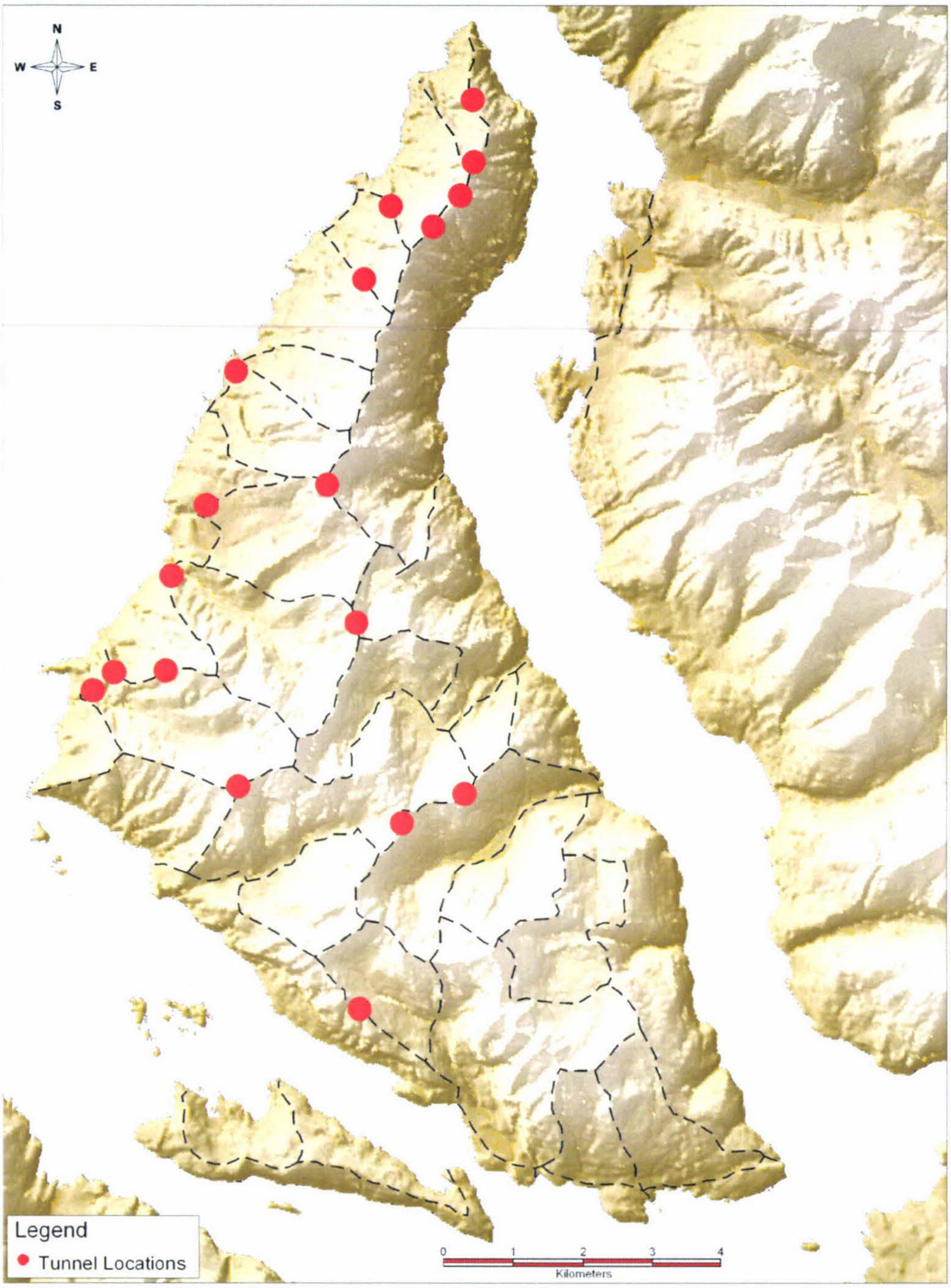

Figure 5.3: Multiple catch tunnel locations on Secretary Island from July 2005 until January 2008.

The single and multi capture tunnel locations formed the basis of the analysis for the tunnel location model. There were a total of 167 stoats caught at 144 tunnel locations. From these there were only 18 tunnel locations that caught more than one stoat. These accounted for 38 out of the 144 stoats, or 26.4% of the total. There were no stoats caught during the November 2006 check period (Figure 5.4). The successful tunnel locations are spread evenly over the entire island with no real pattern evident. McMurtrie (2005) suggested that the majority of stoats in the initial knock down period were caught on the western and northern parts of the island.

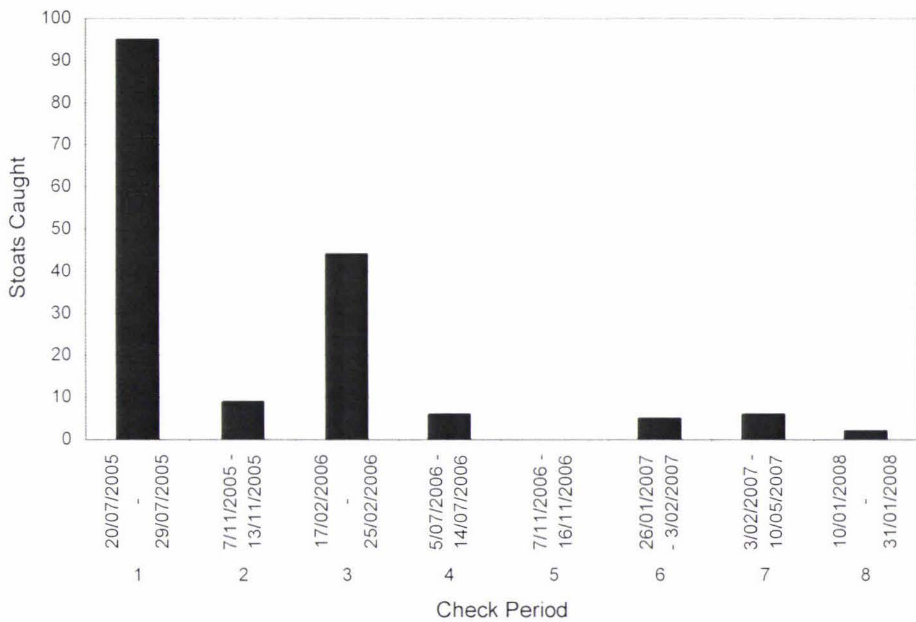

Figure 5.4: Stoat captures on Secretary Island by check period.

The fact that the tunnels are located on cut tracks may add some bias to the prediction model, although the current guidelines for stoat control suggest that tunnel lines should follow habitat perimeter, ridges, tracks, altitudinal contours and waterways (www.predators.com, 2 July 2007). However due to the isolated and rugged terrain that these eradication programmes are carried out on, tracks will generally be used as a means of access and therefore the tunnels will normally be placed on or beside them.

	Check Period						
	July 2005	Nov 2005	Feb 2006	July 2006	Jan 2007	May 2007	Jan 2008
Tunnels	93	9	41	6	5	4	2
Stoats	95	9	44	6	5	6	2
Multi Catch	2		2			1	

Table 5.1: All stoat captures and multi-catch captures by check period between July 2005 and January 2008 for Secretary Island.

Figures 5.5 to 5.11 show the successful tunnel locations on Secretary Island for check periods between July 2005 and January 2008.

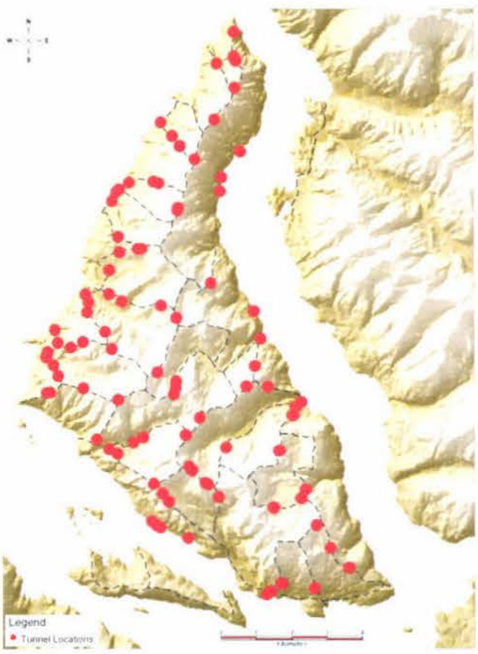

Figure 5.5: July 2005 Captures

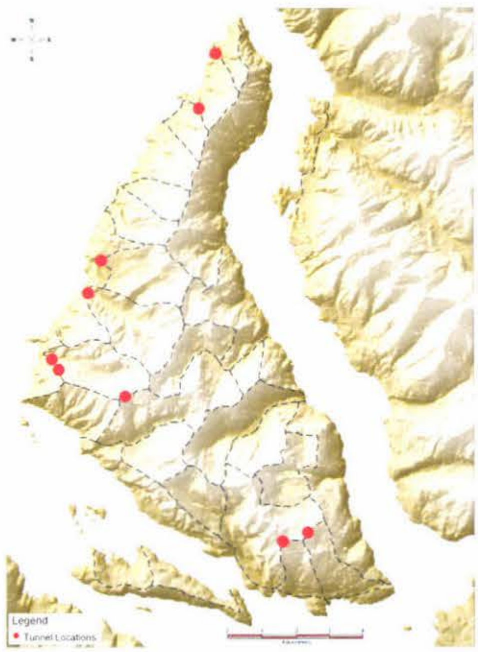

Figure 5.6: November 2005 Captures

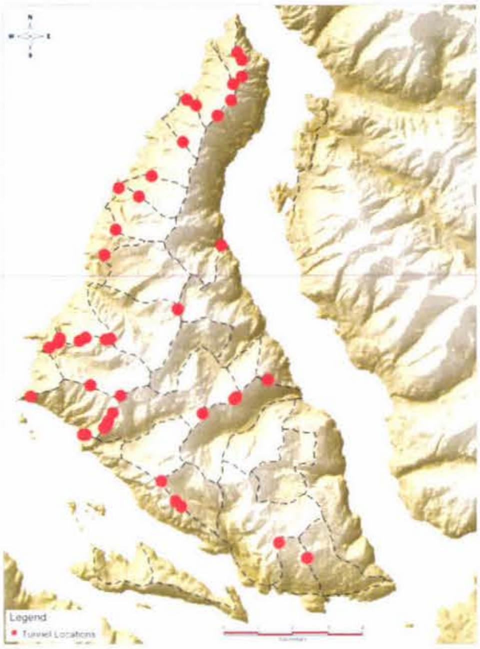

Figure 5.7: February 2006 Captures

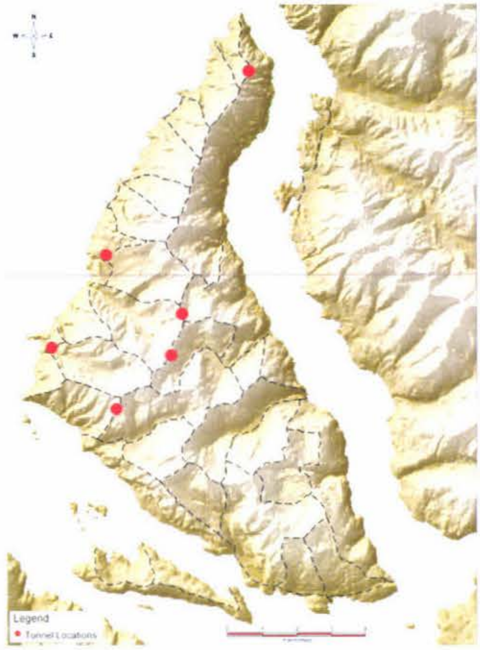

Figure 5.8: July 2006 Captures

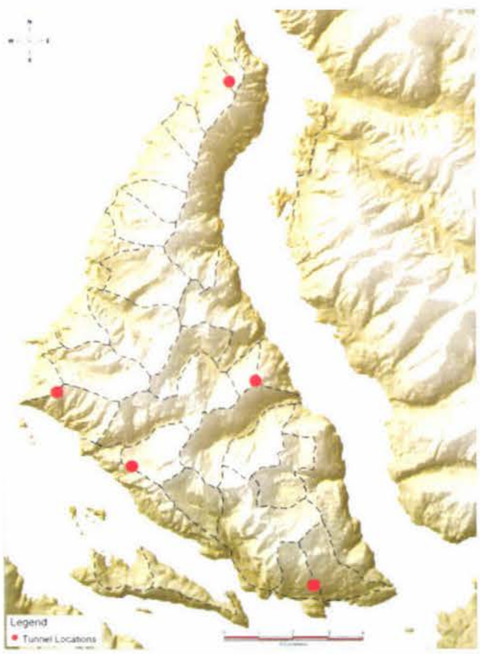

Figure 5.9: January 2007 Captures

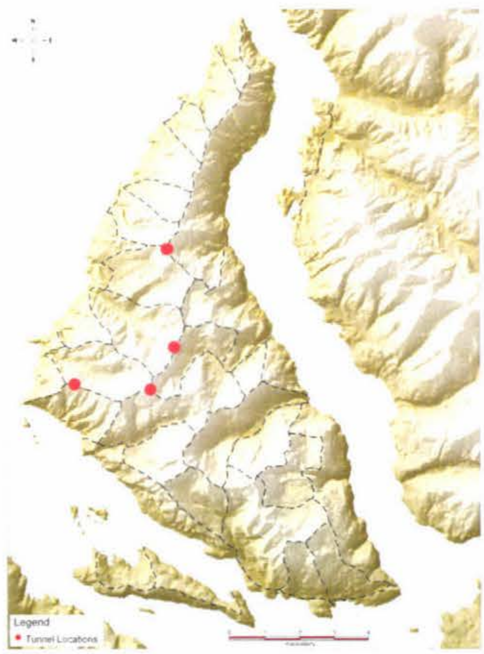

Figure 5.10: May 2007 Captures

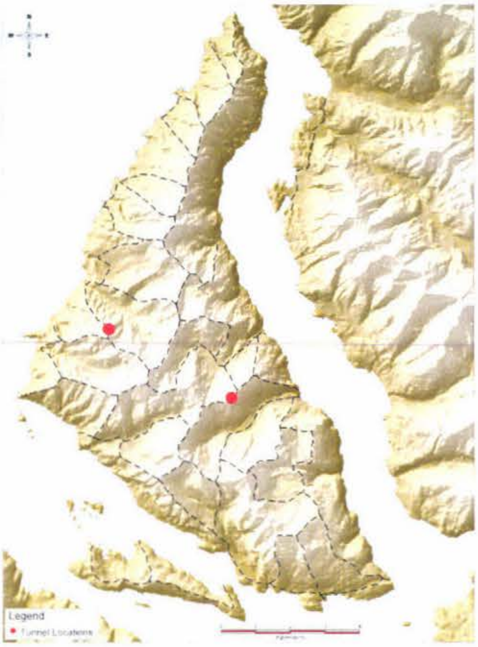

Figure 5.11: January 2008 Captures

When the multi catch tunnels (Table 5.2) are analysed a pattern (of sorts) appears. The north-west facing slopes from the centre of the island to the top of the island have a higher density of successful tunnel locations. The area south-west from Hub Creek had no multi catch tunnels. Apart from one tunnel at Rocky Point on the west coast the remainder of the tunnels were all on main ridges.

The majority, 14 or 77.7% of multi catch tunnels were in the first, second and third check periods. This would be expected due to the declining population from successful trapping and by the time of the January 2008 check period it appeared that there had been no further breeding on the island.

The three stoats caught in tunnel 702 during the May 2007 check period were two females and one male. One of the females and the male were both juvenile. These were sent to Iso-trace New Zealand Limited for genetic analysis and were found to be genetically unrelated. Additional tunnels were located around tunnel 702 due to the higher number of stoats caught in this area but no more stoats have been caught since their placement. This may slightly distort the results due to the small size of the sample used in the analysis.

Trap Ref.	July 2005	Nov 2005	Feb 2006	July 2006	Jan 2007	May 2007	Jan 2008
300			1				1
313	1	1					
347			2				
514	1	1	1				
537	1		1				
566	1		1				
571	1		1				
604	1			1			
627	1		1				
658			1	1			
702						3	
727	1		2				
811	2		1				
816			2				
820	2						
828	1		1				
841	1		1				
856		1	1				

Table 5.2: Multi-catch tunnel locations on Secretary Island by check period.

Further analysis of this data provided some interesting statistics when viewed in the context of the effectiveness of this control method. There were a total of 945 tunnels set on Secretary Island, of these only 144 caught stoats. This is only a 15.2% success rate. The wire tunnels were removed during the July 2006 check period (Figure 5.12). They were removed due to the amount of tunnel interference from weka (*Gallirallus australis*) and kea (*Nestor notabilis*) which resulted in sprung traps (McMurtrie, 2006). This left 645 wooden tunnels on the island.

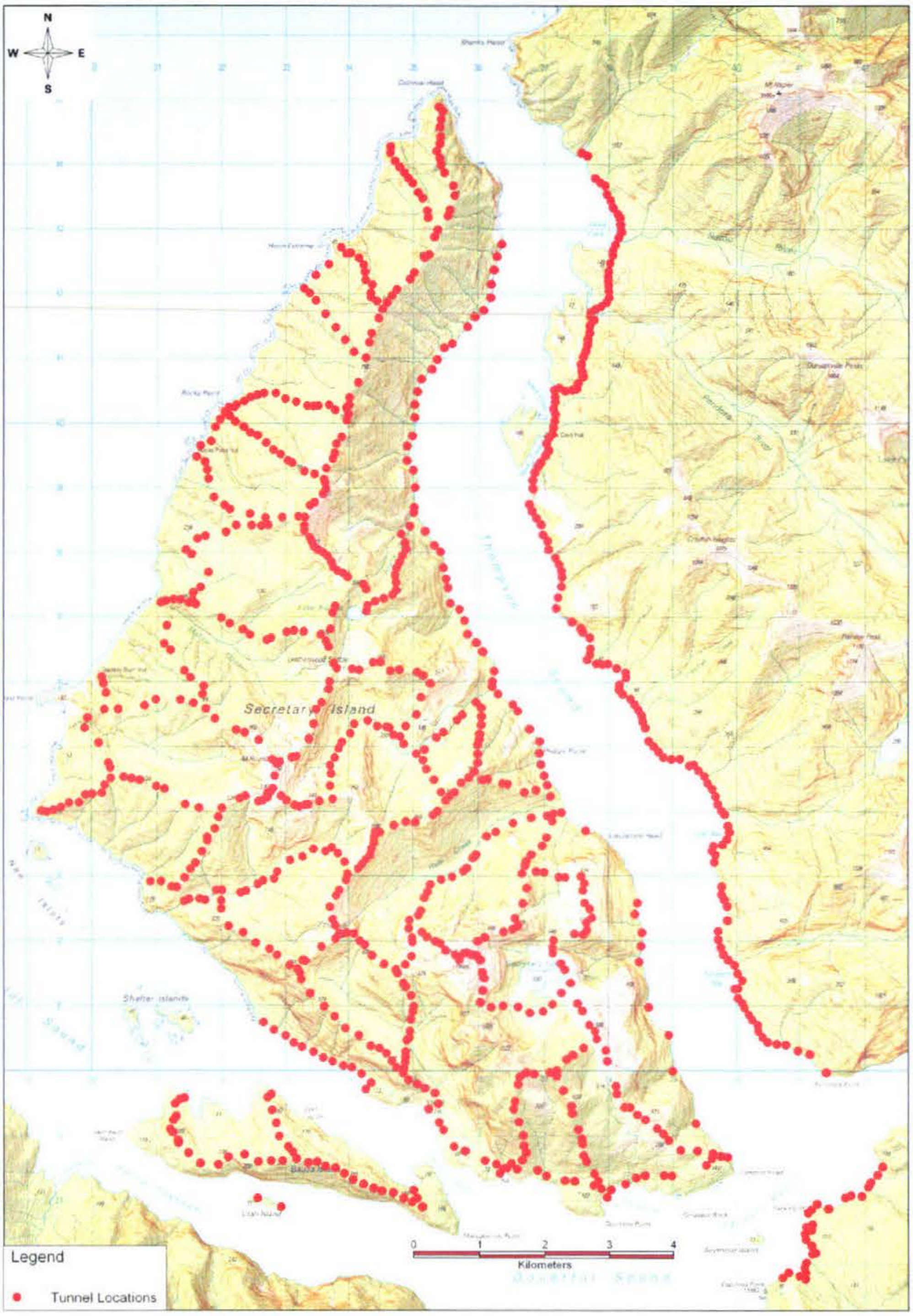

Figure 5.12: Location of remaining wooden tunnels on Secretary Island after the removal of the wire tunnels in July 2006. *Map base sourced from Topographic Map 260-B42 Secretary and B43 Dagg. Crown Copyright Reserved.*

Wire tunnels caught 49 or 33.6% of the total number of stoats caught. This also equates to the multi catch tunnels where 6 or 33.3% of the 18 tunnels were wire. The effect on the continued success of the operation of removing these successful tunnels is unknown. King (1973; 1980; 1994) and King and Edgar (1977) suggest that tunnels that are not catching animals should be removed or repositioned to increase the chances of a stoat finding the tunnel. This would indicate that rather than removing the wire tunnels completely it may have been more beneficial to at least replace the successful wire tunnels with wooden tunnels providing continued opportunity to capture any possible remaining stoats in a tunnel set that had a proven success history.

5.2.2: Resolution Island Trap Capture Data

The eradication project started on Resolution Island in August 2008. The traps were set in the tunnels for the first of two initial trapping periods in July 2008. The second period was in the first week of August 2008. Data from these two trapping operations was provided by the Department of Conservation in a format similar to the Secretary Island data (Appendices 8 and 9). There were a total of 2562 tunnels set on Resolution Island, surrounding islands and the adjacent mainland (Figure 5.13).

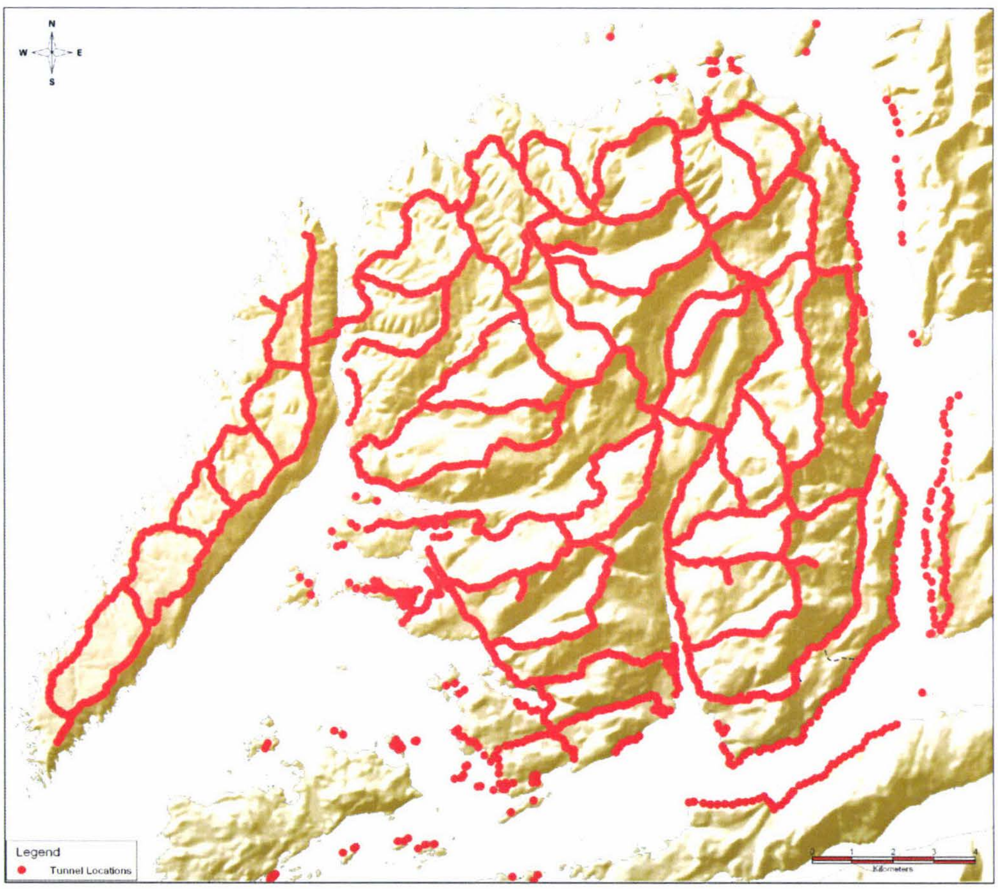

Figure 5.13: Tunnel locations for the Resolution Island stoat eradication project.

The initial knockdown period accounted for a total of 307 stoats on Resolution Island and the adjoining mainland (Figure 5.14). There were 290 caught on Resolution Island. This compares to 95 stoats caught on Secretary Island for the initial knockdown. There was a higher percentage of females (76%) caught than males on Resolution Island compared to Secretary Island (59%). Resolution Island is approximately 2.6 times larger than Secretary Island so it would be reasonable to expect that at least 247 stoats would be caught during this initial knockdown period. The fact that for each stoat caught on Secretary Island there were 3.3 stoats caught on Resolution Island suggests that the initial knockdown was more successful than on Secretary Island. It may also indicate that stoat densities were higher on Resolution Island which may be due to the fact that mice, a staple food source for the stoat, are present on Resolution Island but not on Secretary Island.

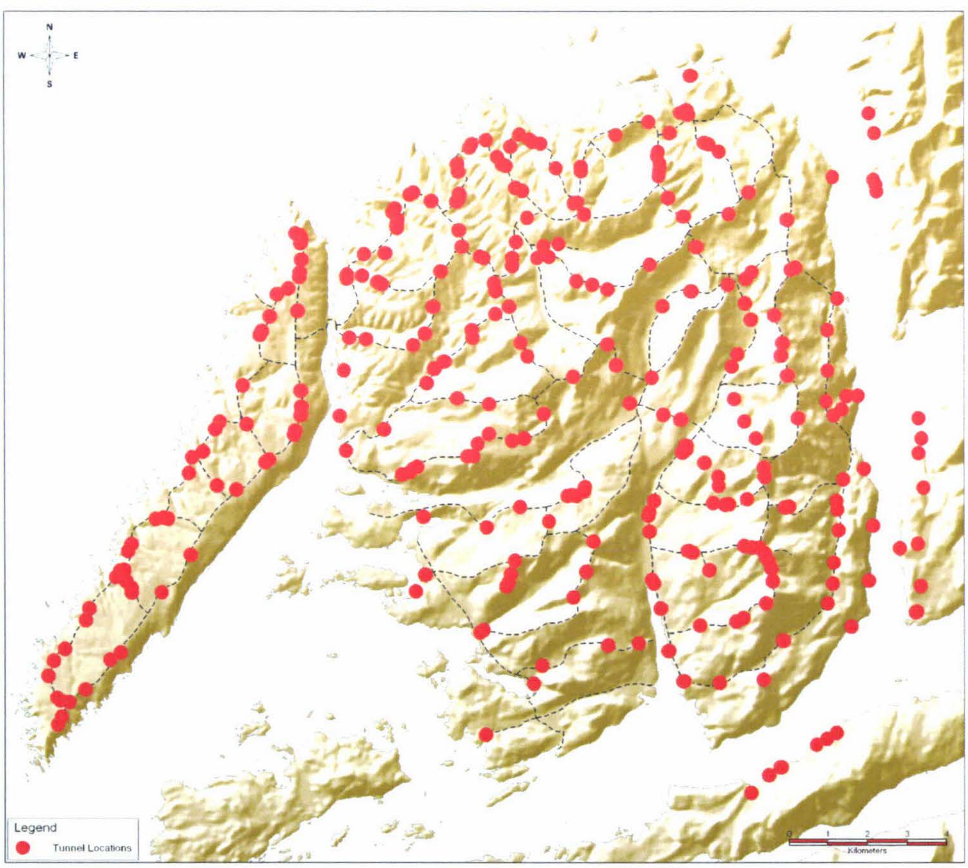

Figure 5.14: All successful tunnels on Resolution Island for the initial knockdown period.

The first check period resulted in 278 stoats being caught, with 258 of these on Resolution Island (Figure 5.15). The second check period resulted in 34 stoats being caught, with 32 of these on Resolution Island (Figure 5.16).

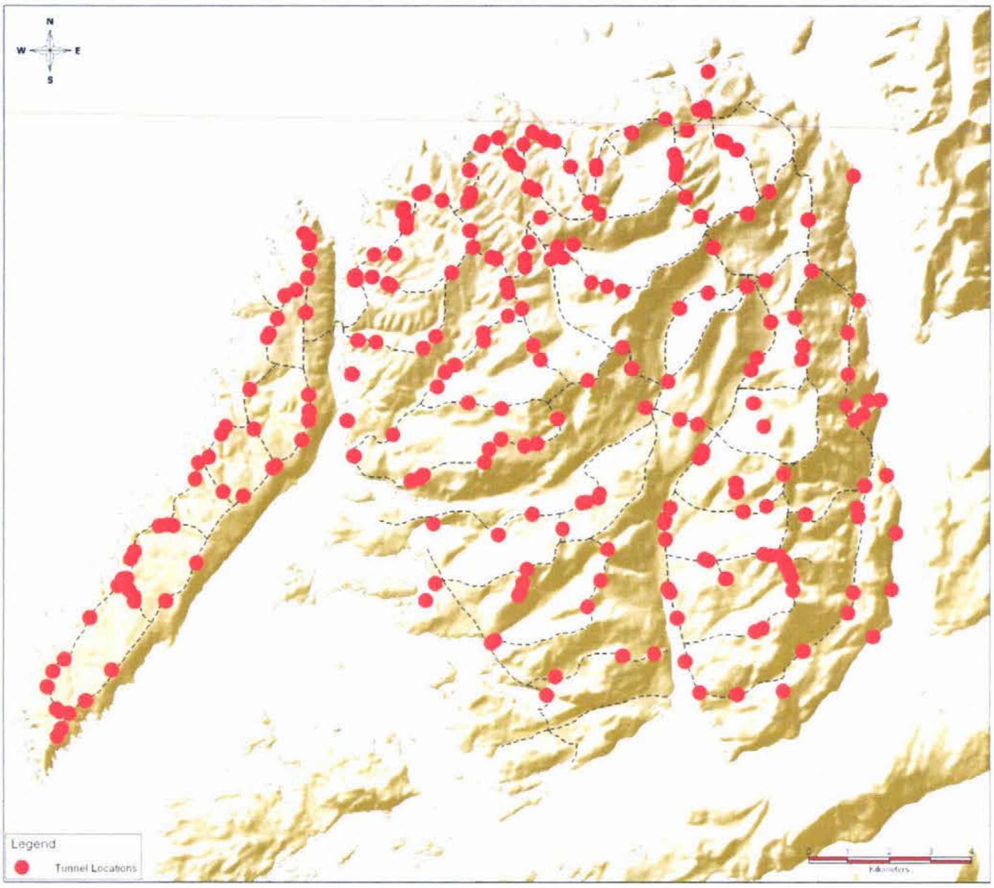

Figure 5.15: Successful tunnel locations on Resolution Island for the July 2008 check period.

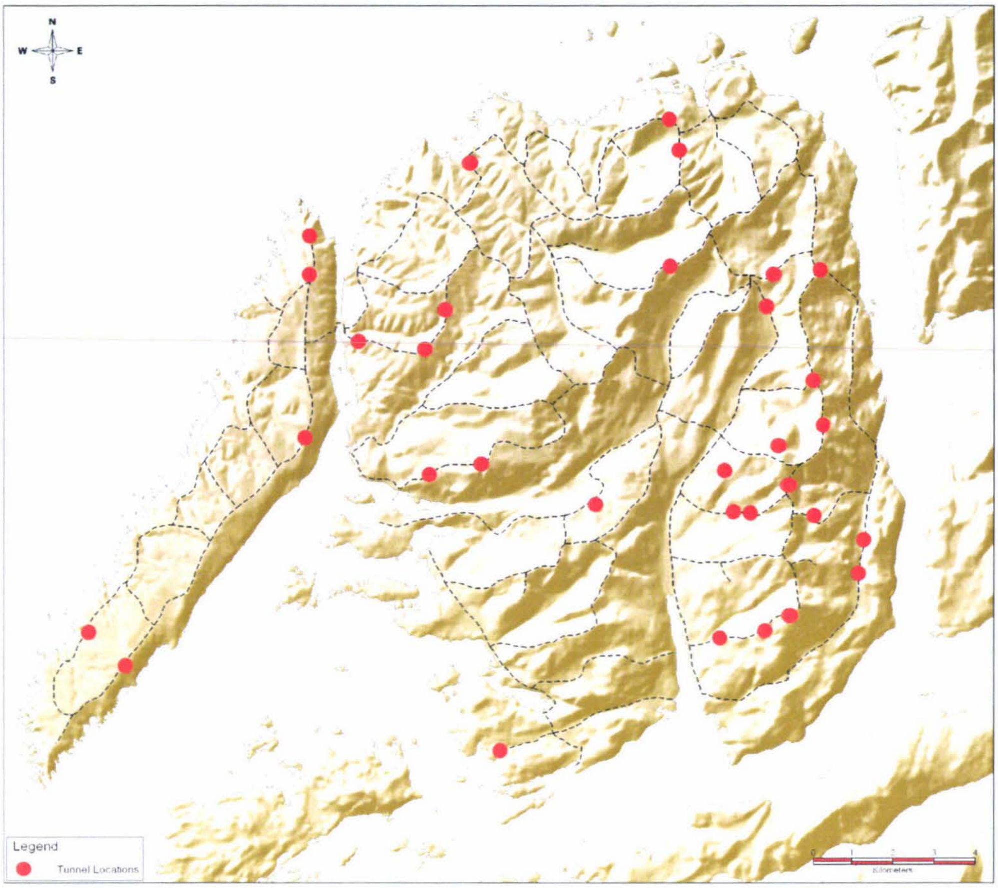

Figure 5.16: Successful tunnel locations on Resolution Island for the August 2008 check period.

There were nine (0.35%) tunnels (Figure 5.17) that caught more than one stoat. This compares with two (0.17%) for the same period on Secretary Island. On the same assumption stated above that Resolution Island is approximately 2.6 times larger than Secretary Island you would expect to have at least five multi-catch tunnels. Considering that the tunnels were all single set (only one trap per tunnel) this would imply that the success rate for this initial phase is higher than that on Secretary Island. This poses the question: why is there such a difference in the two sets of results?

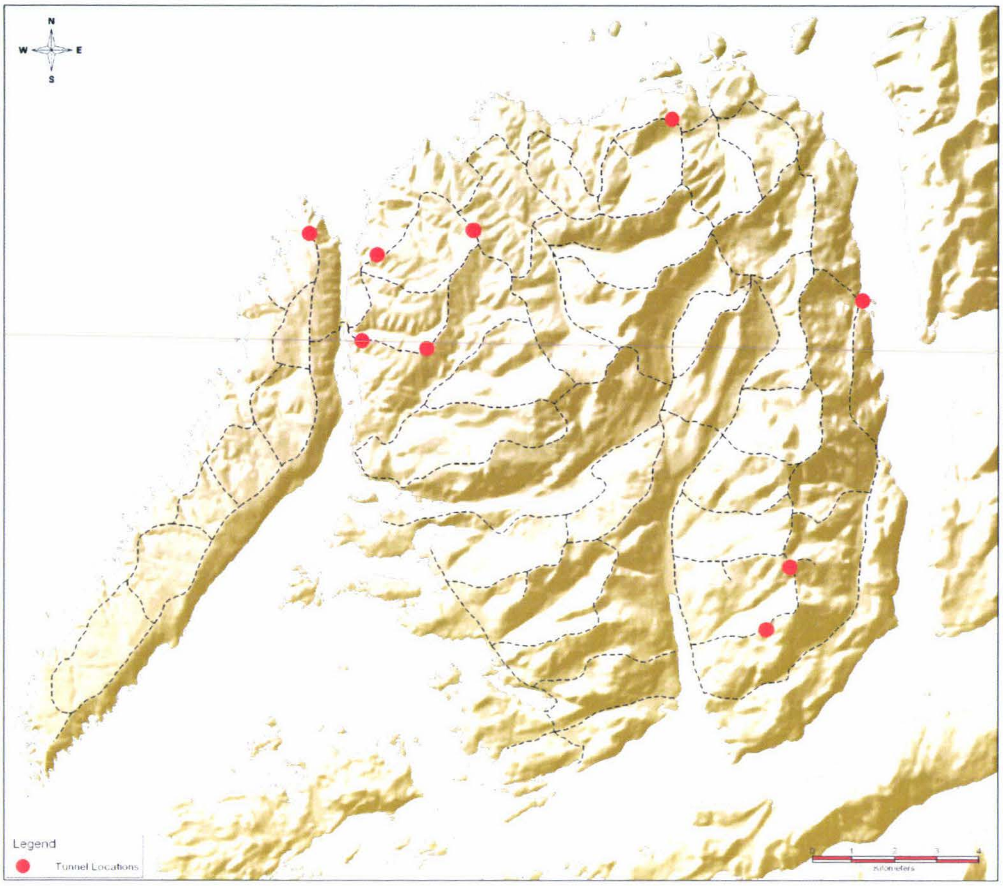

Figure 5.17: Location of Resolution Island multi-catch tunnels.

5.3.1: Land Cover Database

The Land Cover Database (LCDB) is a digital thematic representation of land cover specifically designed for use in a GIS. The original land cover database (LCDB1) was derived from Spot II satellite imagery taken in 1996 - 1997. The compilation of the database was completed in June 2000. The spatial resolution of the data is 20 m with a positional accuracy of ± 2 5 m. A total of 16 land cover classes, covering artificial, cultural and natural classes were identified. These had a classification accuracy of 93% and the smallest area represented was one hectare.

The land cover or 'target' classes are hierarchical (Table 5.3). There are eight first level classes and sixteen more detailed second level classes. The top level classes are based on the physical characteristics of the land cover (i.e. grassland, shrubland and forest). The second order level of classes are based on other characteristics such as phenology (i.e. evergreen / deciduous) and floristic composition (i.e. broadleaved / needleleaved). Downloaded 12 June 2008 from (www.mfe.govt.nz/).

1st Order Class	2nd Order Class
Artificial surfaces	Urban Area
	Urban Open Space
	Mines and Dumps
Bare or Lightly Vegetated Surfaces	Coastal Sand
	Bare Ground
Water Bodies	Inland Water
Cropland	Primarily Horticulture
Grassland	Primarily Pastoral
	Tussock Grassland
	Inland Wetland
Sedgeland Saltmarsh	Coastal Wetland
Scrub and Shrubland	Scrub
Forest	Major Shelterbelts
	Planted Forest
	Willows and Poplars
	Indigenous Forest

Table 5.3: LCDB1 Classifications. Downloaded 12 June 2008 from www.mfe.govt.nz/

The LCDB has a five yearly update frequency. In 2001-2002 Landsat7 imagery was used to refine the original LCDB1. The land cover classification scheme for Land Cover Database Version 2 (LCDB2) is a hierarchical development of the target classes used for Land Cover Database Version 1 (LCDB1). Of the original 16 second order level classes, 6 remain unchanged and 10 have been expanded. LCDB2 has 61 classes. The database retains the one hectare Minimum Mapping Unit (MMU) used for LCDB1. This is necessary to ensure valid change analysis between LCDB1 and LCDB2.

LCDB2 uses data from the FSMS6 (Forest Service Mapping Series) database to provide a more detailed indigenous forest classification. The FSMS6 data has 18 forest classes which were defined using black and white aerial photography (1948-1955) and ground truthed using plot detail from the National Forest Survey (1946 - 1952) and the Ecological Survey (1962 - 1965).

The spatial resolution of the LCDB2 has been increased to 15 m. The Landsat7 satellite imagery was ortho-rectified and then sharpened to achieve a spatial resolution of 15 m. In the context of this study the second generation dataset provided the potential to identify a more detailed representation of the grass, indigenous forest and scrub and shrubland classifications.

1st Order Class	LCDB1 Class	LCDB2 Class
	Primarily Pastoral	40. High Producing Exotic Grassland
		41. Low Producing Grassland
Grassland	Tussock Grassland	43. Tall Tussock Grassland
		44. Depleted Grassland
	Inland Wetland	45. Herbaceous Freshwater Vegetation
	Scrub	50. Fernland
		51. Gorse and or Broom
		52. Manuka and or Kanuka
Scrub and Shrubland		53. Matagouri
		54. Broadleaved Indigenous Hardwoods
		55. Sub Alpine Shrubland
		56. Mixed Exotic Shrubland
		57. Grey Scrub
		60. Minor Shelterbelts
	Major Shelterbelts	61. Major Shelterbelts
	Planted Forest	62. Afforestation (not imaged)
		63. Afforestation (imaged, post LCDB 1)
		64. Forest - Harvested
Forest		65. Pine Forest - Open Canopy
		66. Pine Forest - Closed Canopy
		67. Other Exotic Forest
	Willows and Poplars	68. Deciduous Hardwoods
	Indigenous Forest	69. Indigenous Forest
		70. Mangrove

Table 5.4: LCDB2 Classifications, Downloaded 12 June 2008 from www.mfe.govt.nz/

5.3.2: Land Resource Inventory

The New Zealand Land Resource Inventory, commonly known as the LRI is a national dataset of rock type, soil, slope, vegetation, and erosion. It was developed by Ministry of Works and Development during the 1970s, with some areas having vegetation updates in the early 1990s. The LRI was developed from existing soil/rock maps, aerial photographic interpretation and field work.

The aim of the LRI was to produce a national Land Use Capability (LUC) classification to help land managers to choose appropriate landuse options for sustainable production. The LUC was originally designed as a tool that could be used to facilitate soil conservation and erosion control work. The first edition of the LRI was released in the 1970s and covered all of New Zealand except for Stewart Island. The original product was based on the one inch to one mile (1 : 63,360) map series grid and produced as hard copy maps. Subsequent revisions were based on the 1 : 50,000 metric map series grid and were made available in digital format.

The LRI divides the New Zealand landscape into land use capability units (map polygons) and provides a national database of physical land-resource information, based on two sets of data:

1. An inventory of five physical factors basic to the assessment of land resources:
   - (a) rock type
   - (b) soil type
   - (c) slope
   - (d) erosion degree and type
   - (e) vegetation

2. A Land Use Capability (LUC) rating of each unit (map polygon) based on an assessment of the ability of that unit to provide sustained agricultural production. This included an assessment of:

   (a) the five physical factors above
   (b) climate information
   (c) effects of past land use
   (d) potential for erosion

While the units are relatively 'homogeneous' at the scale of mapping (i.e. 1 : 63,360 and later 1 : 50,000), they (polygons) were defined firstly on rock type and slope. This means that there is often variability for some factors, especially vegetation, within the units.

Each unit contains information about:

   (a) each of the five physical factors
   (b) the LUC classification

The inventory and capability classification mapping process included aerial photograph interpretation and field work. The assessments of the five physical characteristics were based on relatively objective field and other measurements, while the LUC class identifications were interpreted from a range of information sources. Downloaded 12 June 2008 from (www.mfe.govt.nz/). Landcare Research is the custodian of the LRI.

The soil classification is based on the New Zealand Soil Classification system (Hewitt, 1998). Some of the soil data was based on 1 : 250,000 DSIR Soil Bureau maps and expanded to 1 : 63,000 and 1 : 50,000 scale. This could introduce inaccuracies into the data and is not generally recognized as best practice. The intention of this study was to use the soil data from the LRI in conjunction with the vegetation data from the 1963 Baylis et al. (1963) and Wardle (1963) survey to generate an improved indigenous forest class. However, the resolution of the LRI data proved to be too coarse to be of any use in this analysis. Baylis et al. (1963) and Wardle (1963) identified soils that were not included in the LRI data set for Secretary Island. Reference was also made to the PH levels and fertility of the soil.

5.3.3: Land Environments of New Zealand

The Land Environments of New Zealand (LENZ) data is a new way of looking at environmental factors in New Zealand but it is based on an amalgamation of previous survey data that was meticulously transferred from manual systems so that it could be analysed in a computer. This process was started by the New Zealand Forest Service in the 1980's and came to fruition in the early stages of the new century. Landcare Research is the custodian of LENZ.

With new legislation in the form of the Environment (1986), Conservation (1987) and Resource Management (1991) Acts being passed into law in the late 1980s there was a need for a national environmental classification that could be used by the managers who had to implement the requirements of the new Acts. LENZ consists of four different levels with each one being comprised of multiple environmental classifications. The new classification was designed so that it could be used from a national level (Level I - 20 environments) through to a local level (Level IV - 500 environments, nationally). The number of environments may vary depending on what region is being analysed.

The digital data is supported by two volumes of text; Land Environments of New Zealand and Land Environments of New Zealand: LENZ Technical Guide. The first volume is designed as an overview of LENZ and provides valuable background information on the reasons for developing the classifications; the techniques used descriptions of the four levels, several case studies using LENZ and some map examples. The technical guide is designed as a guide for managers who intend to use LENZ to develop solutions to conservation and environmental issues.

LENZ gives a new insight into the rich diversity of New Zealand's ecosystems by merging traditional approaches to ecology with powerful modern spatial analysis tools. The classification of New Zealand's landscapes provides a powerful tool that will profoundly change the way we manage biodiversity and land-related issues (Downloaded 12 June 2008 from (www.landcareresearch.co.nz/).

Although this dataset is seen as a new way of looking at environmental data some of the data that it was derived from is still at a relatively coarse scale (1 : 250,000). This means that in some cases the actual effective cell resolution at which the data can used is 200 m. For example, the soil layer was based on two major data sources, the Land Resource Inventory (LRI), described earlier in this study and the New Zealand Soils Database. In particular, in more inaccessible areas, the soil data in the LRI was derived from national soil maps produced at a scale of 1 : 253,440.

5.3.3.1: Secretary Island LENZ

Secretary Island is broken down into six LENZ level IV classifications. These are shown in Figure 5.18 with a breakdown by proportion of area listed in Table 5.5.

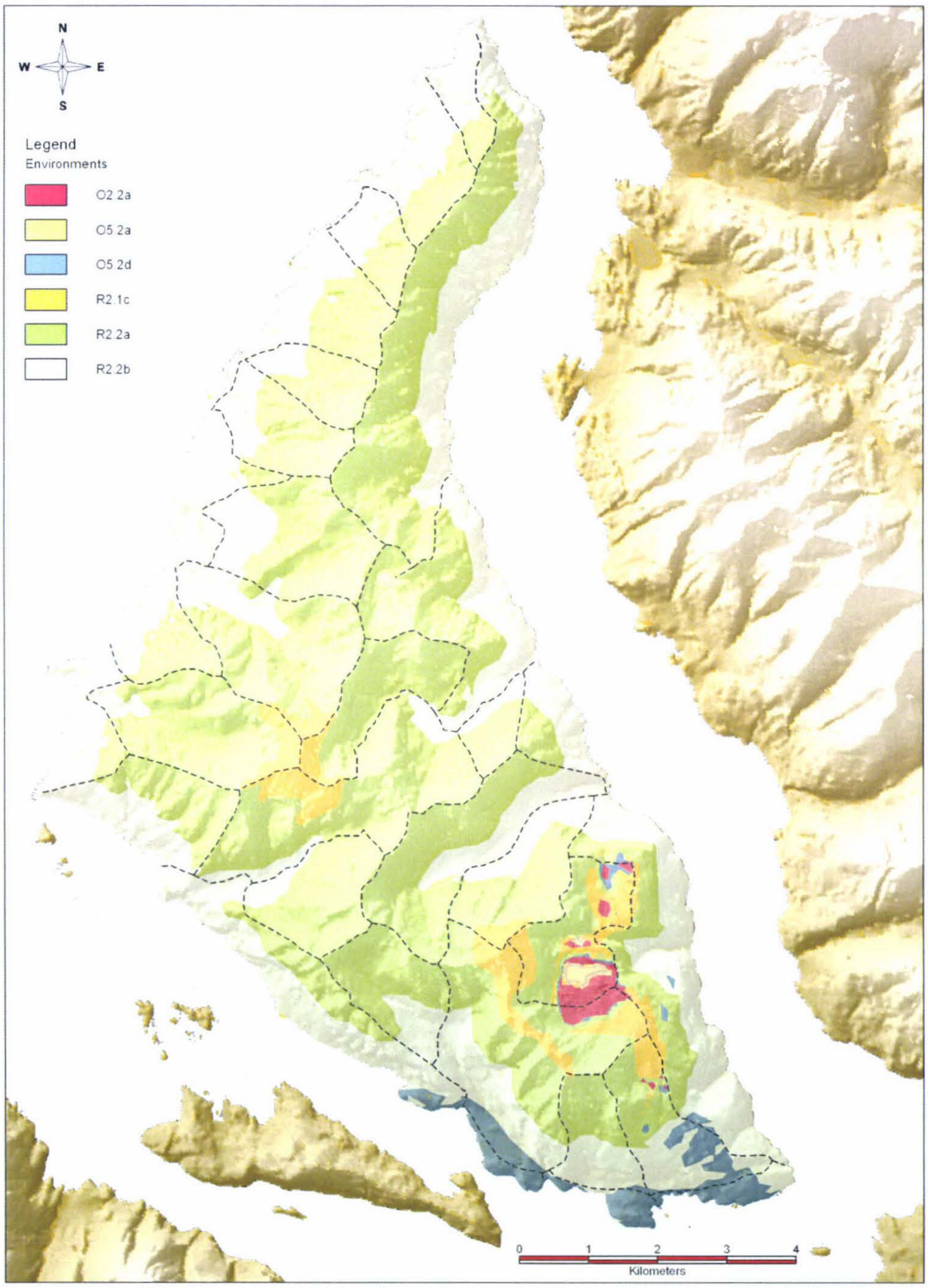

Figure 5.18: Secretary Island LENZ level IV classifications.

LENZ Class	Land Form	Soil	Average Elevation	Average Slope	Area(ha)
O2.2a	Easy Rolling Hills	Well drained soils - low fertility	404	8.7	64
O5.2a	Easy rolling hills	Imperfectly drained soils - low fertility from fresh granite and intermediate igneous rocks	90	6	1
O5.2d	Strongly Rolling Hills	Slightly imperfectly drained soils - very low fertility	177	13.1	224
R2.1c	Steep Mountains	Imperfectly drained soils - very low fertility from granite and basalt	1085	33.2	368
R2.2a	Steep Mountains	Imperfectly drained soils - very low fertility from granite and older basalt and gneiss	645	32.7	4526
R2.2b	Steep Mountains	Imperfectly drained soils - very low fertility from granite and older basalt and gneiss	304	27.5	2763

Table 5.5: Secretary Island LENZ level IV classifications.

Although the table (Table 5.5) does not reflect a difference between R2.2a and R2.2b there are other variables associated with the classification that differentiate these two classifications. R2.2a has cooler temperatures and higher monthly water balances than R2.2b. Apart from this the classifications are the same. The O5.2a classification only comprises 0.7 ha out of the total area of the island which equates to 0.009%.

If the LENZ classifications were going to be used as part of a model all five classifications identified in Table 5.5 would have to be used. Considering that these classifications cover the majority of Secretary Island (only excluding 0.009% of the total land area) they could only be used at a coarse level or as a starting point, if used in isolation. It may be that by combining one or more of the other variables described with the LENZ classifications (such as slope or elevation) that an indicator does emerge. This will be discussed further in the following data analysis chapters.

5.3.3.2: Resolution Island LENZ

Resolution Island has ten level IV classifications with the predominant class being R2.2a (Figure 5.19 and Table 5.6). The island has several classifications that are not found on Secretary Island. These are: M4.1a, M4.1e, O5.1a and O5.2b. They classify areas of valley floors, U-shaped valleys and rolling hills as opposed to step hills.

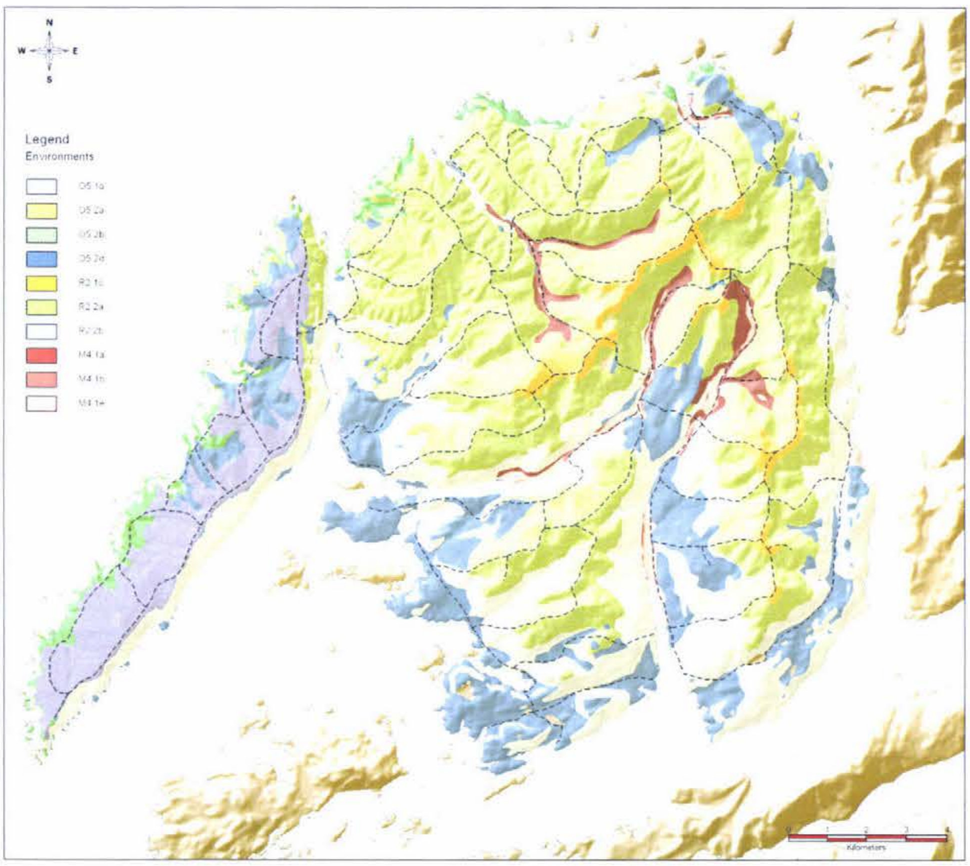

Figure 5.19: Resolution Island LENZ level IV classifications.

LENZ Class	Land Form	Soil	Average Elevation	Average Slope	Area (ha)
M4.1a	Rolling u-shaped valley floors	Recent well drained soils - very low fertility from Fiordland alluvium	346	17.9	434
M4.1b	Rolling u-shaped valley floors	Recent well drained soils - very low fertility from Fiordland alluvium	439	15.3	3.5
M4.1e	Undulating u-shaped valley floors	Recent well drained soils - very low fertility from Fiordland alluvium	206	5.1	229
O5.1a	Easy rolling hills	Imperfectly drained peaty soils - very low fertility	236	6	1420
O5.2a	Easy rolling hills	Imperfectly drained soils - low fertility from fresh granite and intermediate igneous rocks	90	6	5
O5.2b	Strongly rolling hills	Imperfectly drained soils - high fertility from fresh granite and intermediate igneous rocks	267	15.4	479
O5.2d	Strongly rolling hills	Slightly imperfectly drained soils - very low fertility	177	13.1	3510
R2.1c	Steep Mountains	Imperfectly drained soils - very low fertility from granite and basalt	1085	33.2	639
R2.2a	Steep Mountains	Imperfectly drained soils - very low fertility from granite and older basalt and gneiss	645	32.7	9058
R2.2b	Steep Mountains	Imperfectly drained soils - very low fertility from granite and older basalt and gneiss	304	27.5	4906

Table 5.6: LENZ level IV classifications on Resolution Island.

One of the classification, O5.2a only accounted for a total of 5.3 ha (0.02%) out of the total island area. The O5.2a classification was generally located around the coast of the island including Five Finger peninsula. This is consistent with the classifications for Secretary Island.

5.3.4: National Vegetation Survey (NVS) Databank

The National Vegetation Survey (NVS) databank contains data from over 6000 sample plots that have been established over the last 40 years. Each plot is a 20 x 20 m plot that has been established and a reconnaissance (RECCE) survey carried out that forms the baseline from which future surveys can be compared against. The plots location, site data and vegetation are all recorded. The surveys are very detailed and other data such as soil types, non vascular plants and animal browse is also recorded.

The data is an important source of information that has been used to quantify such things as the impact of introduced animals on indigenous forest species, the impact of exotic weeds on indigenous forest species and monitoring die-back caused by coastal salt spray. It has also been used in conjunction with other environmental data sets to determine where endangered species may be found.

Secretary Island contained 42 individual plots that are recorded in the NVS databank. Because of the detailed nature of the data recorded at these locations there was a possibility that it could be used to enhance the LCDB2 data set to produce a refined vegetation cover surface. However the fact that all of the plots were located on the western side of the island meant that if the data was included in a vegetation model it would be on the assumption that all species identified were also present on the eastern side of the island. The NVS data was analysed for its detailed vegetation information but was not used in this study. It is however an important data set and should not be discounted from future studies of this nature if the plots are distributed evenly throughout the study area.

Chapter Six: Data Analysis - Habitat

6.1: Introduction

In the following chapters the datasets described in the previous chapter are analysed in conjunction with the Secretary Island stoat capture data to determine if there are any patterns or similarities between successful tunnels that can be used as an indicator of where and possibly why a tunnel has a higher success rate. If it is possibly to identify commonalities in the Secretary Island data using the GIS then the same process can be used to identify similar sites on Resolution Island.

6.2: Data Analysis

The purpose of the following chapters is to use the analytical techniques available in the GIS to manipulate the datasets. The datasets that are available for analysis are often not in a common format and have to be manipulated before they can be used. The datasets that were used in this study were supplied in different software application formats, different coordinate systems and either raster or vector data.

Intergraph's suite of GIS applications was used to carry out the analysis. The initial process was to translate all of the datasets into the same GIS environment. Bringing the various layers of data into GeoMedia Professional meant that the original datasets remained untouched and could be referred back to if the imported data was corrupted during processing. The next step was to carry out a coordinate translation so that they could all be related to each other in the same spatial environment. All of the point data from spreadsheets had to be geo-coded using the coordinate data supplied. A digital elevation model for both islands was extracted from a 10 m South Island model for the slope and aspect analysis and to form a background image for the other datasets.

With the datasets all in the same format they could then be spatially analysed. The vegetation datasets were first to be analysed to create a surface depicting stoat habitat.

6.3: Habitat

Habitat encompasses a range of elements that together form an environment that supports a species. A definition for habitat from The American Heritage Science Dictionary 2005 is:

"The area or natural environment in which an organism or population normally lives. A habitat is made up of physical factors such as soil, moisture, range of temperature, and availability of light as well as biotic factors such as the availability of food and the presence of predators".

In relation to this study vegetation, topography, physiography, home range and diet will be used in an attempt to identify any common factors in relation to trap capture data that might provide sufficient data to generate a model that identifies potential locations for tunnel placement. Ashraf (2003) used five parameters: distribution, elevation, land cover, slope and aspect to predict potential species habitat using GIS software. Although the author was investigating the potential of GIS as a tool for developing a habitat prediction model the concept is the same for this study. By using a set of known or derived parameters, is it possible to predict the best location for a stoat trap tunnel.

6.3.1: Secretary Island Vegetation

Vegetation can be used as one indicator of species habitat. The reliability of the resulting data is dependent upon the detail of available information. There must be enough detail to be able to identify the preferred vegetation types of the target species. This is also dependant on the extent of the study area. Large scale studies utilise generalised data that can be used to provide an indication for future investigation, but micro studies require detailed data to make accurate predictions. The available datasets for this study include the Land Cover Database (LCDB2), the Land Resource Inventory (LRI), and the National Vegetation Survey (NVS). Both the LCDB2 and LRI data would be considered to be datasets that would be used as a first cut to provide a general indication of the presence or absence of a species. The National Vegetation Survey is detailed individual plot level data that is suitable for micro habitat identification. Individual field reports also provide valuable data that can be used as a basis for analysis.

An intensive study was carried out by Wardle (1963) and Baylis et al. (1963) that recorded the vegetation on Secretary Island over the altitudinal range from sea level through to the highest point, Mt Grono. Wardle (1963) suggested an eight class classification for the vegetation on Secretary Island (Appendix 10). This was based on climatic and edaphic factors (Figure 6.1). The edaphic classes were a representation of decreasing soil fertility. The climatic factors were affected by altitude. He suggests that soil characteristics primarily determine the horizontal sequence of communities, but differences in aspect also play a part. Weather extremes and the duration of the growing season impact communities even when they are on similar soil types. Baylis et al. (1963) suggest that the vegetation on the exposed headlands and summits are severely affected by the prevailing winds in contrast to the tall forest trees growing at sea level on sheltered sites.

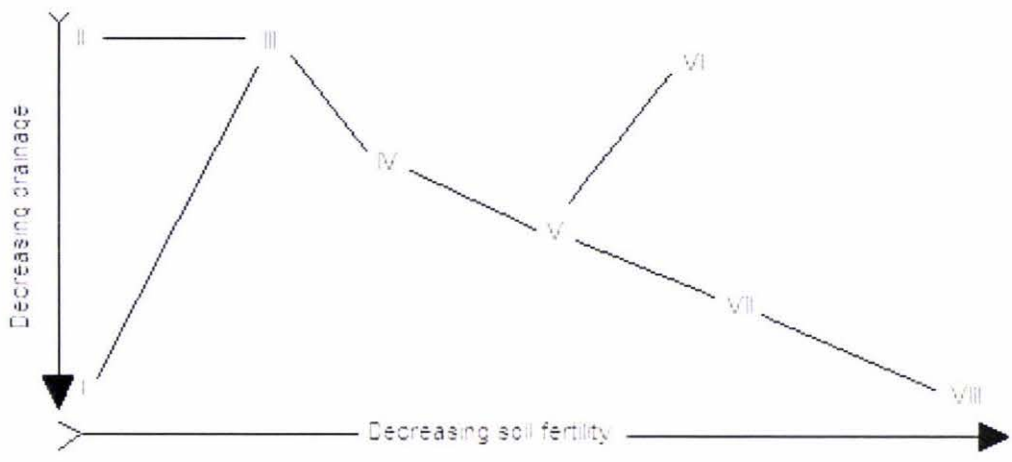

Figure 6.1: Plant community distributions by climatic and edaphic factors (P Wardle 1963).

The island is dominated by *Nothofagus* and *Podocarpus* forest. *Nothofagus solandri* var. *cliffortioides* (mountain beech) forms most of the canopy. The canopy is broken by scattered trees of *Dacrydium cupressinum* (rimu) below 60 m and *Podocarpus dacrydioides* (Kahikatea) up to 380 m. *Weinmannia racemosa* (kamahi) and *Cyathea smithii* (Soft or Golden Tree Fern) forest grows from 60 m to 490 m. *Nothofagus menziesii* (silver beech) is the other dominant species and is present through the altitudinal range (Photo 6.1). The various canopy types and soil classes support differing understory communities. At the lower altitudes this is dominated by *Dacrydium cupressinum* (rimu), giving way to *Hoheria glabrata* (mountain ribbonwood).

Photo 6.1: Vegetation cover on Secretary Island. Photo by G Harper, Department of Conservation.

The subalpine scrub belt at around 915 m is made up of *Nothofagus cliffortioides* (mountain beech), *Dacrydium biforne*, *Dracophyllum longifolium* (turpentine scrub) and *Olearia Colensoi* (leatherwood). The alpine areas support snow tussock grasslands (Photo 6.2). These are dominated by Chionochloa species with low shrubs present, especially on northerly aspects. The snow tussock is generally on southerly aspects where they dominate above 900 m.

Photo 6.2: Alpine environment, Secretary Island. Photo by S Lake, Department of Conservation.

Ground cover is dependent on the dominant vegetation class and the soil fertility. Under the *Nothofagus* and *Podocarpus* canopy there is a continuous ground cover of bryophytes. In the *Weinmannia racemosa* and *Cyathea smithii* community the shrub, herb and moss storey are usually relatively sparse. The *Nothofagus, Weinmannia* and *Podocarpus* community supports a well developed small tree and shrub storey.

Monks et al. (2005) suggest that the ground cover on Secretary Island has been modified by tracking and general ground damage which has been caused by the resident red deer population. Between 1988 and 2003 the extent of exposed rock, soil and litter appeared to be constant. Vegetation cover showed a slight increase but moss coverage showed a significant (nearly half) decline.

The LCDB2 (Land Cover Database Version 2) describes the island as having six vegetation classes. These are:

1. Alpine Grass/Herbfield
2. Broadleaved Indigenous Hardwoods
3. Indigenous Forest
4. Manuka and or Kanuka
5. Subalpine Shrubland
6. Tall Tussock Grassland

The area and the percentage of the island that is covered by each class is listed in (Table 6.1).

LCDB2 Classification	Area (ha)	% Coverage
Alpine Grass/Herbfield	108.44	1.36
Broadleaved Indigenous Hardwoods	13	0.16
Coastal Sand and Gravel	13.67	0.17
Indigenous Forest	7350.91	92.39
Lake and Pond	23.24	0.29
Landslide	31.76	0.39
Manuka and or Kanuka	13.36	0.17
River and Lakeshore Gravel and Rock	0.5	0.01
Subalpine Shrubland	28.69	0.36
Tall Tussock Grassland	372.32	4.68

Table 6.1: Land Cover Database 2 Classifications for Secretary Island.

Indigenous forest is the dominant vegetation class, contributing to 92% of the total area of the island. The LCDB2 definition for this class is:

"Indigenous forest is defined as vegetation dominated by indigenous tall forest canopy trees".

The classification is based on the data gathered during the 1948 - 1955 National Forest Survey. Figure 6.2 shows the extent of the indigenous forest class.

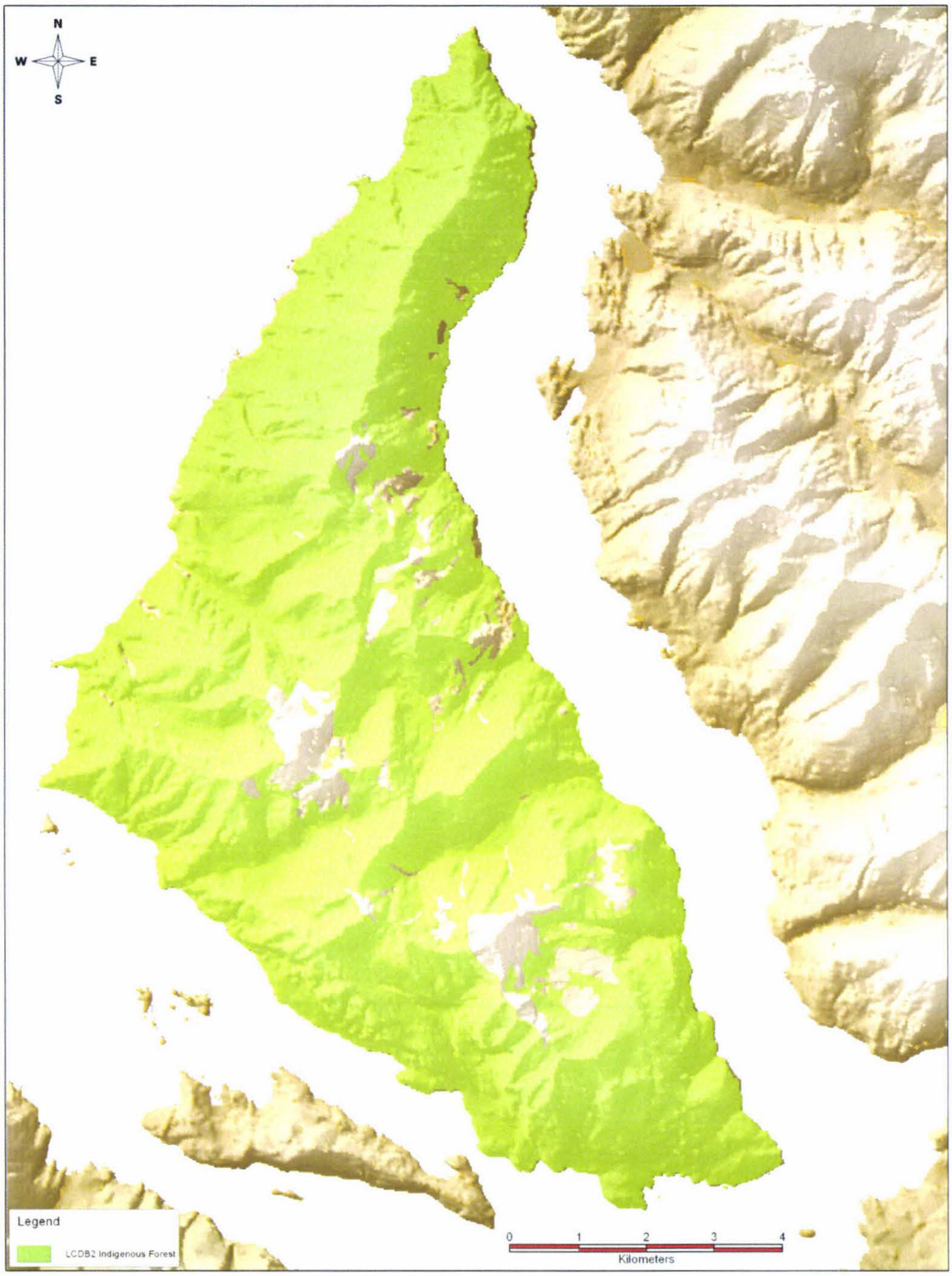

Figure 6.2: The extent of the LCBD2 Indigenous Forest Type on Secretary Island.

The NVS database also provides valuable data from 42 individual plots located on Secretary Island (Figure 6.3). These plots range in altitude from 23 m to 883 m and are located on the south west and western slopes of the island with a transect running parallel to Te Awaatu Channel, two groups in the catchment below The Hub. There are also four transects running from the shoreline up ridges between South West Point and Rocky Point. The plots range in size from 1000 m^2 to 4000 m^2 and were last surveyed in 2003-2004. The vegetation data recorded at each plot is very comprehensive and is broken into different height tiers starting at the top of the canopy and working down to ground level. Slope, altitude, aspect, drainage, exposed soil and rock are also included.

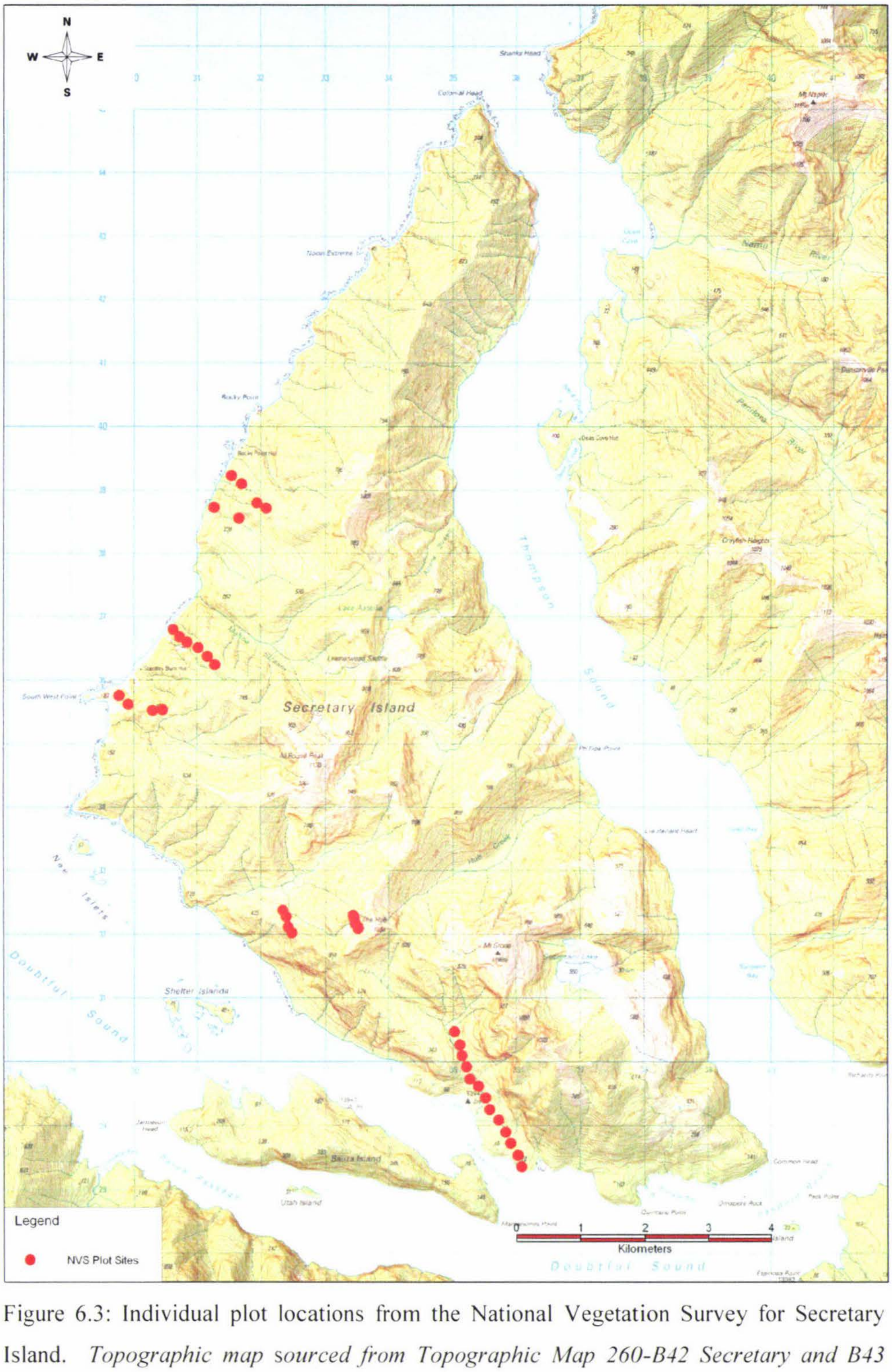

Figure 6.3: Individual plot locations from the National Vegetation Survey for Secretary Island. *Topographic map sourced from Topographic Map 260-B42 Secretary and B43 Dagg. Crown Copyright Reserved.*

This data could be used to generate a vegetation cover surface but it would have to either be only for the western side of the island or the assumption made that what was recorded at the plots on the western side was consistent on the rest of the island. The data also details the physiography of the plot location. This is recorded as ridge, face, gully or terrace and as the location of the tracks generally follow valleys and ridges the vegetation species from the plot data that are located on ridges and in gullies could be extracted and used to generate a vegetation surface for these two topographic features. The same assumption as stated above would have to apply due to the limited number of plot locations on the island.

6.3.2: Refined LCDB2 Indigenous Forest Classification

Although the LCDB2 data is a more recent data set it was not detailed enough to determine if there was a difference in vegetation type between tunnel locations when they were located within the indigenous forest class. Although the studies by Baylis et al. (1963) and Wardle (1963) were older, they were far more detailed and there was the possibility of generating a land cover surface that incorporated this detailed classification to split the LCDB2 indigenous forest class. The studies included references to altitudinal limits, slope, aspect and soil types which could be used to generate a new classification.

The altitudinal range, slope and aspect were extracted from the Baylis et al. and Wardle (1963) reports and formatted into a table so that the different surfaces could be generated by the GIS and then combined to create a new vegetation classification for the LCDB2 Indigenous Forest class (Table 6.2).

Vegetation Class	Elevation (m)	Slope Class	Slope (Degrees)	Aspect	Surface Value
IA	20 - 60	Gentle	0 -15		1 - 16
IIA	420 - 900	Steep	30 - 45		31 - 46
IIB	900 - 920	Steep	30 - 45		31 - 46
IIIA	60 - 500	Moderate	15 - 30		16 - 31
IIIB	500 - 540	Moderate	15 - 30		16 - 31
IVA	0 - 60	Gentle	0 - 15		1 - 16
IVB	300 - 460	Moderate	15 - 30		16 - 31
IVC	600 - 980	Moderate to Steep	15 - 45		16 - 46
IVD	920 - 1200	Steep	30 - 45	SE to SW	31 - 46
VA	60 - 480	Moderate to Precipitous	30 - > 60		> 31
VB	720 - 860	Moderate to Steep	15 - 45		16 - 46
VC	860 - 980	Moderate to Steep	15 - 45		16 - 46
VIA	180 - 480	Gentle	0 - 15		1 - 16
VIB	480 - 760	Moderate to Steep	15 - 45		16 - 46
VIIA	300 - 700	Moderate to Steep	15 - 45		16 - 46
VIIB	700 - 980	Steep	30 - 45		31 - 46
VIIIA	300 - 320	Moderate	15 - 30		16 - 31
VIIIB	720 - 740	Steep	30 - 45		31 - 46

Table 6.2: Data extracted from the Baylis et al. (1963) and Wardle (1963) report and used as the basis for the new indigenous vegetation class.

The LRI soil data was analysed at this point to determine whether it could be linked to the work that Baylis et al. (1963) and Wardle (1963) did during their survey (Figure 6.4).

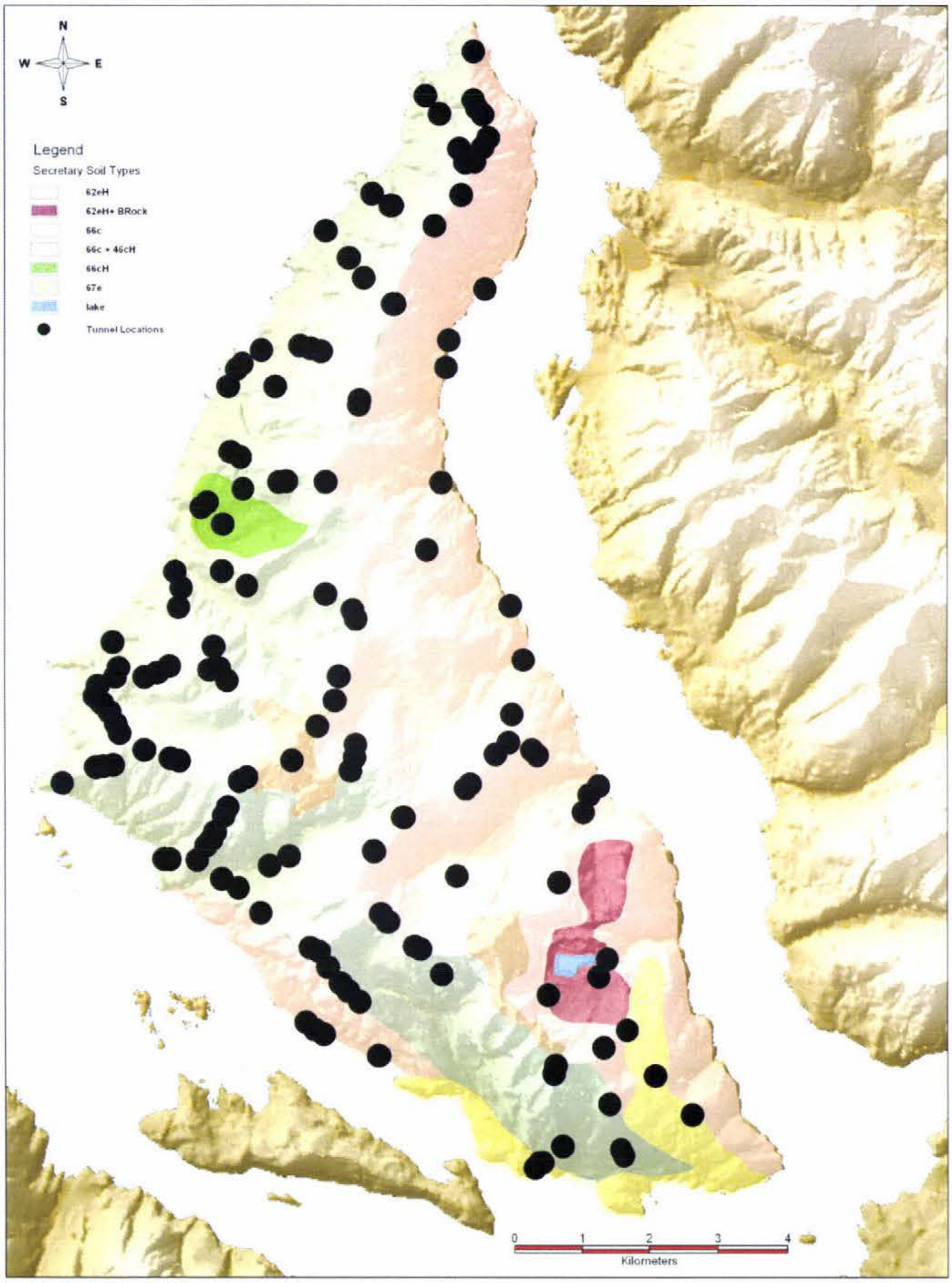

Figure 6.4: Location of successful tunnels on Secretary Island in relation to soil types.

Soil	Series	Phase	Rock	Slope	Erosion	No of Tunnels	Stoats Caught
66c + 46cH	Titiraurangi	steepland	Gs+St2	F + G	1Ss Da	85	98
66c	Titiraurangi	steepland	Gs+St2	G + F	1Da Ss	38	46
66cH	Titiraurangi		Gs+St2	D + E	1Sh	4	5
67e	Resolution	steepland	Gs+St2	G + F	1Sh	4	5
62eH +BRock	Fiordland	hill soils	Gn	C + D	1Sh	3	3
66c	Titiraurangi	steepland	Gs+St2	G	1Da Ss	4	4
62eH	Fiordland	hill soils	Gs+St2	D + E	1Sh	3	3
62eH	Fiordland	hill soils	Gs+St2	E + C	1Sh	3	3

Table 6.3: Soil data available from the LRI for all successful tunnels on Secretary Island.

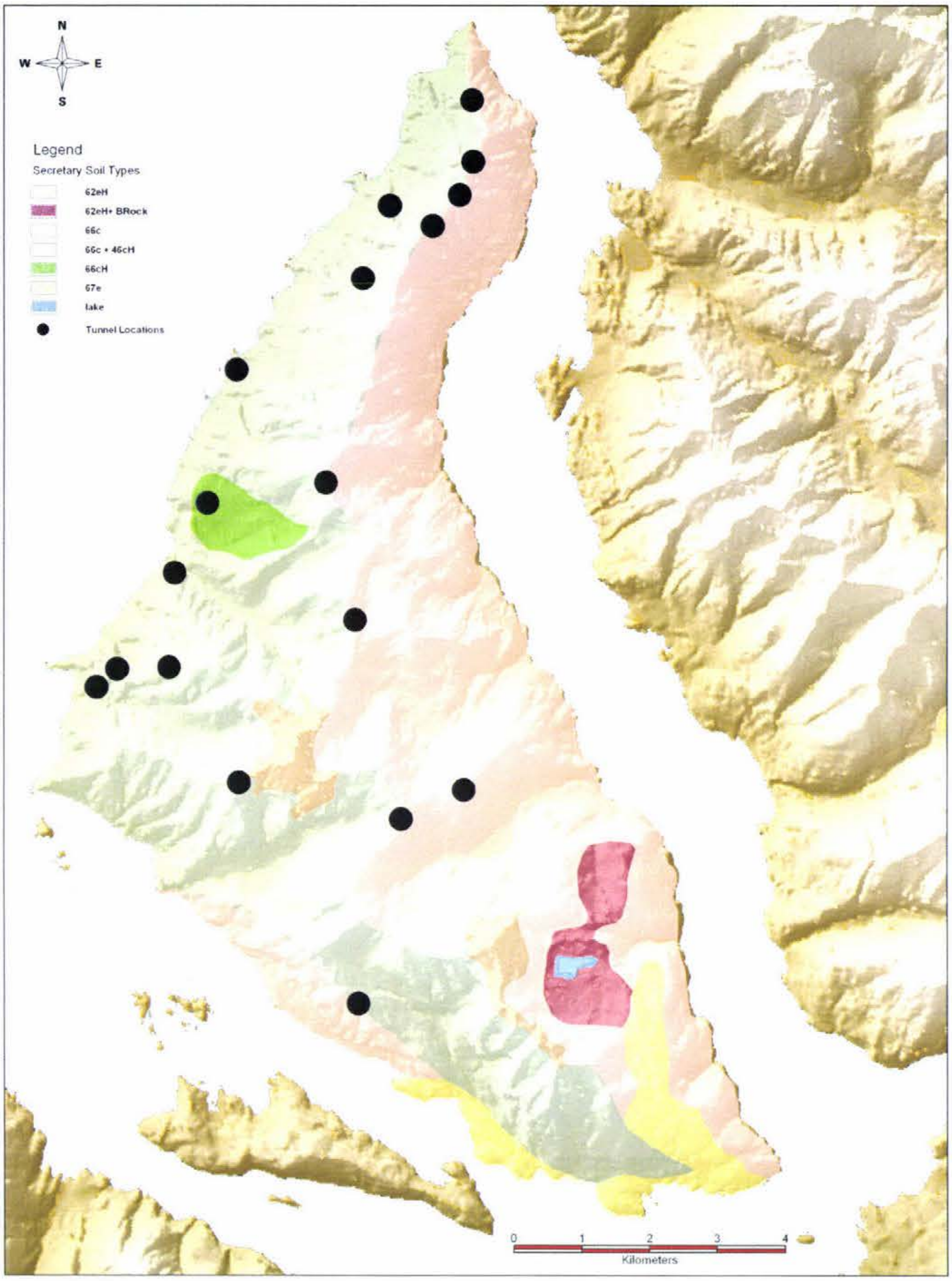

Figure 6.5: Location of multi-catch tunnels on Secretary Island in relation to soil type.

Soil	Series	Phase	Rock	Slope	Erosion	No of Tunnels	Stoats Caught
66c + 46cH	Titiraurangi	steepland	Gs+St2	F + G	1Ss Da	10	23
66c	Titiraurangi	steepland	Gs+St2	G + F	1Da Ss	6	13
66cH	Titiraurangi		Gs+St2	D + E	1Sh	1	2
67e	Resolution	steepland	Gs+St2	G + F	1Sh	1	2

Table 6.4: Soil data available from the LRI for the multi-catch tunnels on Secretary Island.

Slope values for the codes in Tables 6.3 and 6.4.

D = 16 - 20°
E = 21 - 25°
F = 26 -35°
G = > 35°

LUC Values
8e 5 = mainly high mountainous country that is erosion prone
8c 1 = mainly high mountainous country that has climatic extremes and salt laden onshore winds

The soil information from the LRI was not used in the analysis because the soil data that was available was at the same resolution as the LCDB2 data and did not provide the level of detail to determine where the soil types that Baylis et al. (1963) and Wardle (1963) had reported were located.

With the information derived from Baylis et al. (1963) and Wardle (1963) the GIS was used firstly to generate the classes by altitudinal range. The 1: 50, 000 topographic vector contour data was used to create area representations of each class. An attribute query was used to extract the contours relating to the lower and upper limits for each vegetation class. The query result was then converted from a linear feature to an area feature. These were then converted to raster surfaces using GeoMedia GRID. GRID was then used to generate a slope surface from a digital elevation model (DEM) that was classified into the five ranges listed in Table 6.5. An aspect surface was generated from the same DEM for the areas that were within the range from the south east to the south west (135° - 245°).

Slope Class	Slope Range
Gentle	0 - 15 degrees
Moderate	15 - 30 degrees
Steep	30 - 45 degrees
Very Steep	45 - 60 degrees
Precipitous	> 60 degrees

Table 6.5: Slope classes used to generate the slope surface for Secretary Island.

Each vegetation class was assigned a value of 1 so that when it was combined with the other surfaces the values that would represent the combination of the vegetation class and the correct slope class could be identified. The altitudinal, slope and aspect surfaces were then added together for each class, resulting in a surface that identified the original classes in relation to altitude, slope and aspect. These were then grouped by surface value to only show the vegetation/slope/aspect combination.

In light of the fact that only one vegetation class (IVD) had a reference to aspect, this was also not used in the final analysis.

To identify the areas where the classes overlapped, i.e. where there were multiple classes overlapping and therefore multiple vegetation types, the results of the altitude, slope and aspect process were reprocessed based on the combinations in Table 6.6 and the original altitudinal ranges.

Vegetation Class	Elevation Range	Possible Class Combinations
IA	20 - 60	IVA
IIA	420 - 900	VB, VC, VIB, VIIA, VIIIB
IIB	900 - 920	IVC, IVD, VIIB, VC
IIIA	60 - 500	IVB, VIA, VIB, VIIA, VIIIA
IIIB	500 - 540	VIB, VIIA
IVA	0 - 60	IA
IVB	300 - 460	IIIA, VIIA, VIIIA
IVC	600 - 980	IIA, IIB, IVD, VB, VC, VIB, VIIA, VIIB, VIIIB
IVD	920 - 1200	IIB, IVC, VC, VIIB
VA	60 - 480	IIA, VIIA
VB	720 - 860	IIA, IVC, VIB, VIIB, VIIIB
VC	860 - 980	IIA, IIB, IVC,IVD,VIIB
VIA	180 - 480	IIIA
VIB	480 - 760	IIA, IIIA, IIIB, IVC, VB, VIIA, VIIB, VIIIB
VIIA	300 - 700	IIA, IIIA, IIIB, IVB, IVC, VA, VIA, VIB, VIIIA, VIIIB
VIIB	700 - 980	IIA, IIB, IVC, IVD, VB, VC, VIB, VIIIB
VIIIA	300 - 320	IIIA, IVB, VIIA
VIIIB	720 - 740	IIA, IVC, VB, VIB, VIIB

Table 6.6: Vegetation class combinations used to determine overlapping vegetation types on Secretary Island.

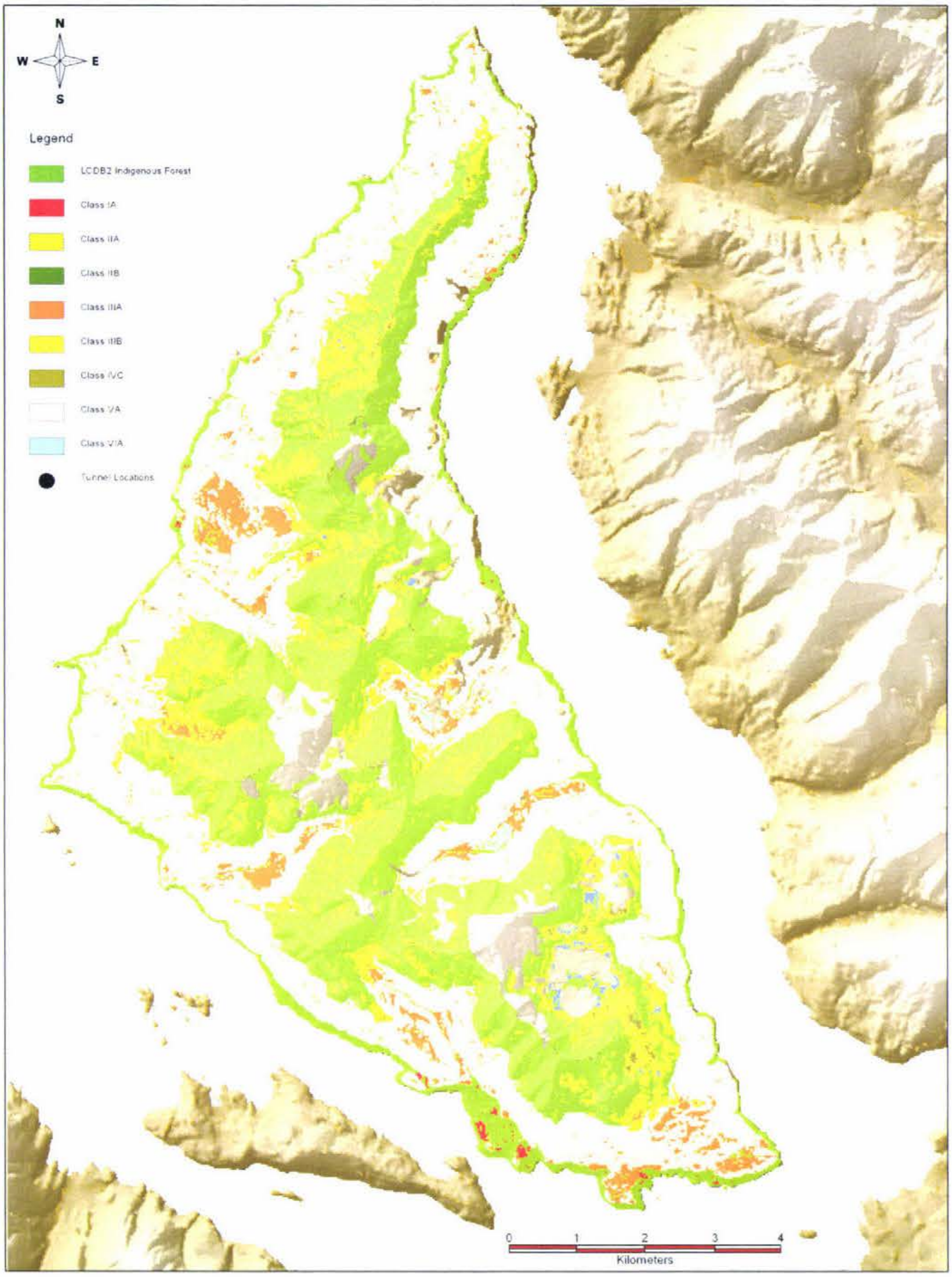

Figure 6.6: Refined indigenous forest type extracted from Baylis et al. (1963) and Wardle (1963) survey data for Secretary Island.

The new vegetation classification (Figure 6.6) did not completely replace the LCDB2 indigenous forest classification. Although the altitudinal criteria provided full coverage the slope classifications had a significant bearing on the final extent of each new vegetation class.

Further work would be needed to improve the assumptions that were made based on Baylis et al. (1963) and Wardle's (1963) survey data, specifically to the slope classes that were used. Changes to these and the addition of aspect and soil data would probably increase the percentage area that was covered by the refined classifications.

Spatial analysis was then used to determine the vegetation class at each successful tunnel and then at each multi catch tunnel to see if there were any patterns suggesting that vegetation was a determining factor in tunnel success rates.

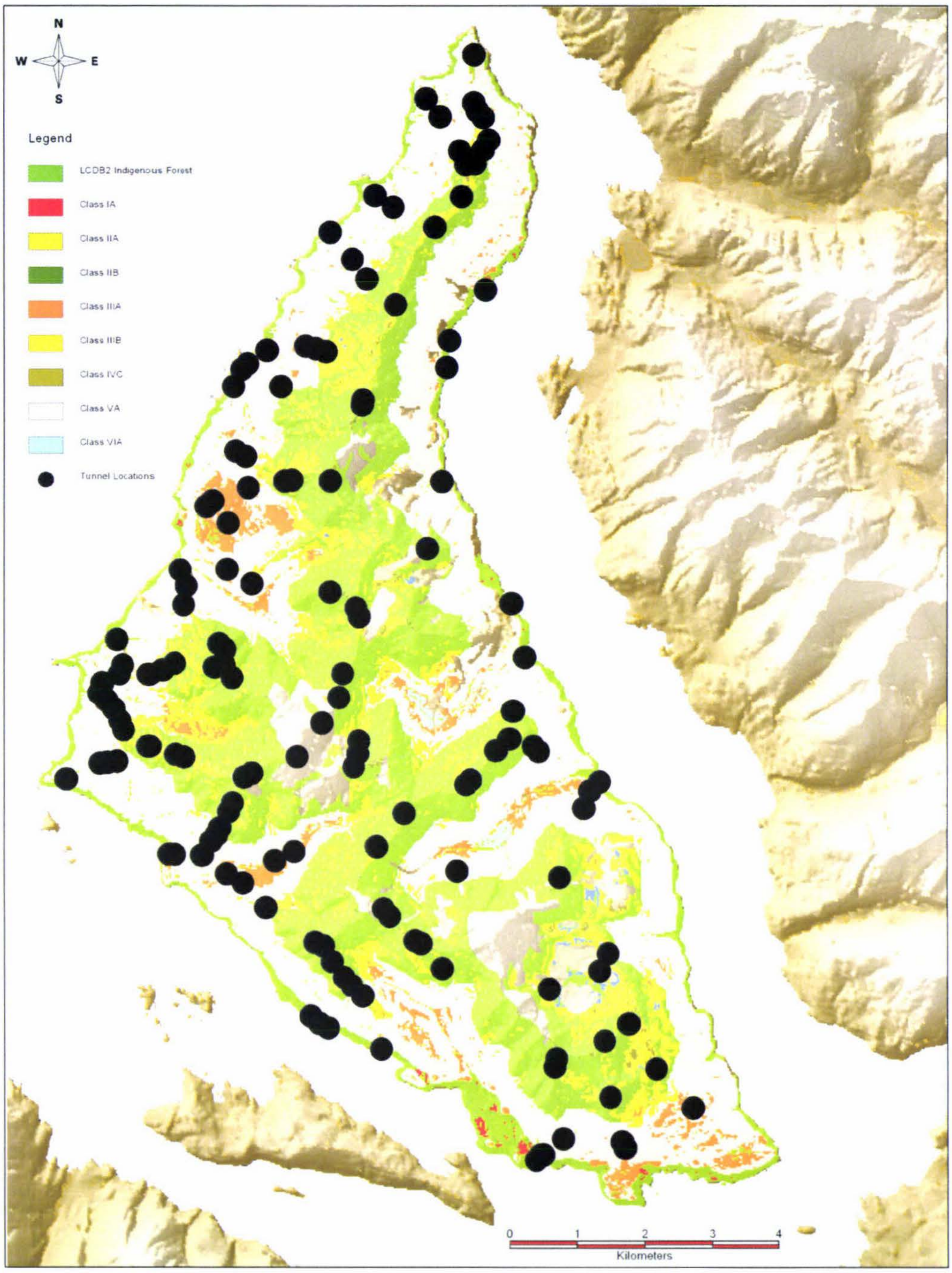

Figure 6.7: Location of all successful tunnels on Secretary Island in relation to the new indigenous vegetation class.

Table 6.7 shows the spread across the different vegetation classes for all successful tunnel locations. If the classes are amalgamated based on the primary class then tunnels located in vegetation classes II and V are significantly higher than classes I, III and IV. There were 50 (34.7%) out of the 144 tunnels that are located in the class V vegetation type and 23 (15.9%) located in the class II vegetation type.

If the 48 tunnels that are located in the original LCDB2 indigenous forest classification are removed from the calculation then the results would alter to: 52.1% and 24% respectively.

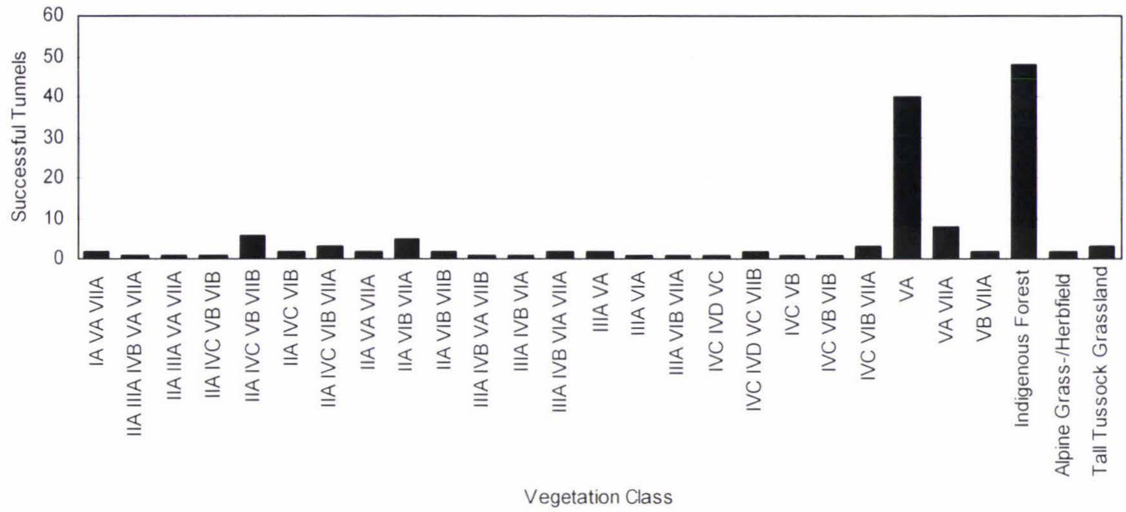

Table 6.7: Successful tunnels on Secretary Island by new indigenous vegetation class.

A similar pattern can be seen in the multi catch tunnel locations (Table 6.8) where 5 (33.3%) are in vegetation class II and 6 (40%) are in vegetation class V. Although this is a significantly smaller sample set the fact that the pattern is similar means that it there is consistency in the results. If it was possible to reclassify the entire LCDB2 indigenous forest classification then the results may provide definitive proof that there is a preference for tunnels that are located in these two vegetation class combinations.

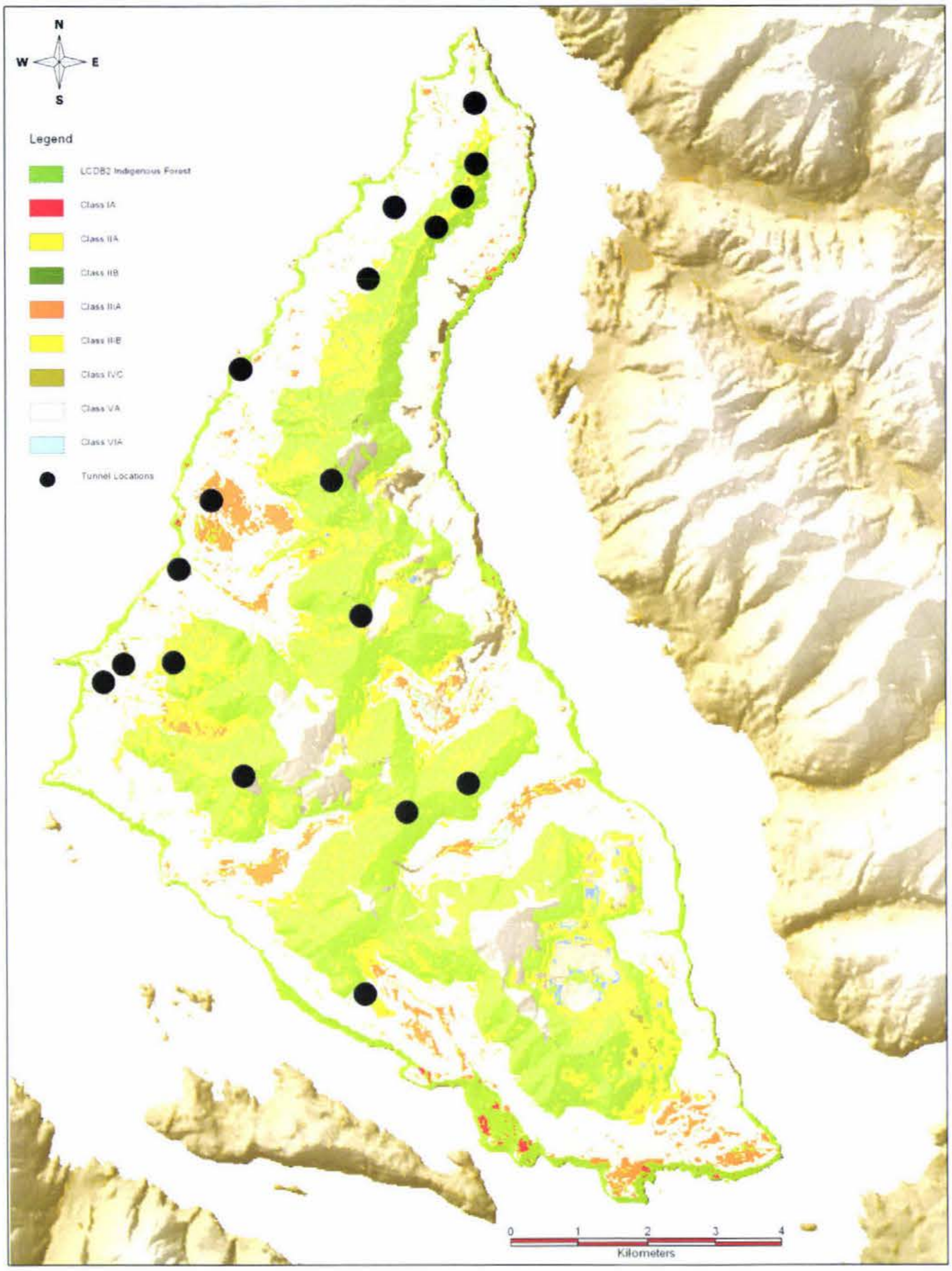

Figure 6.8: Location of the multi-catch tunnels on Secretary Island in relation to the new indigenous vegetation class.

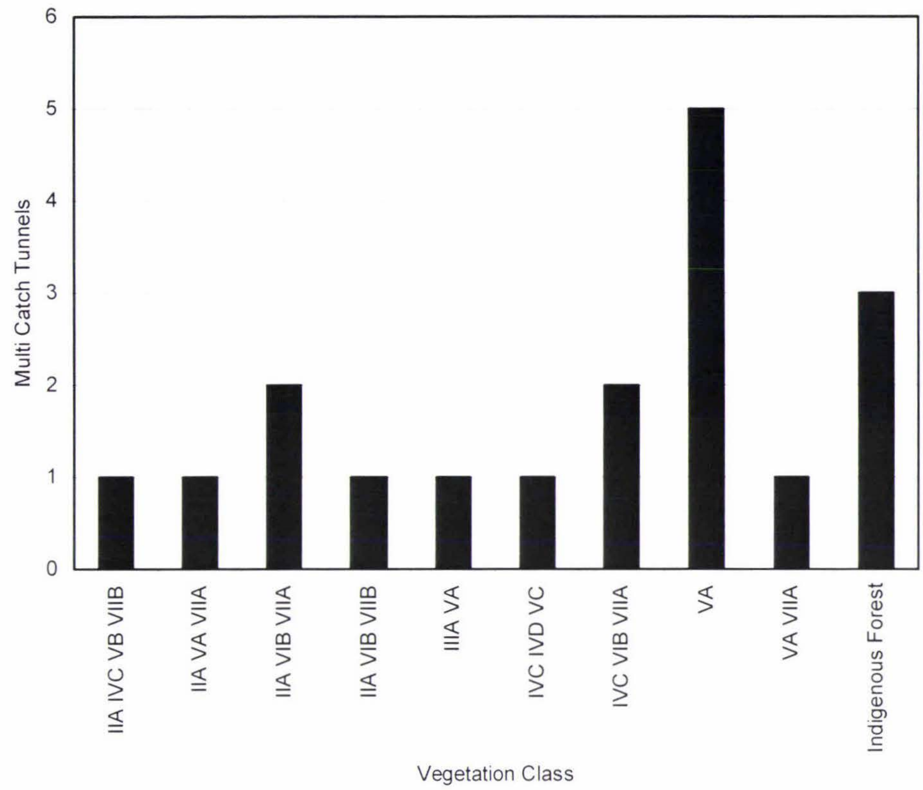

Table 6.8: Successful tunnels on Secretary Island by new indigenous vegetation class.

This would require further field work to determine a more robust set of slope and aspect criteria that could be applied to the altitudinal data that has been extrapolated from Baylis et al. (1963) and Wardle's (1963) study. The specific composition of each vegetation combination could then be investigated to see which classes dominate. This information could be extracted based on the percentage of area each class occupies when there are multiple overlapping classes. However, considering the resolution of the base data (25 m) the results will still only be very coarse and would only provide an indication towards a preference for a particular vegetation type.

Due to the fact the stoat is generally a ground dwelling mammal (although they are very good climbers, King et al., 2001), it may be more important to look at the vegetation types between ground level and 500 mm above the ground as this is where they would spend the majority of there time.
Baylis et al. (1963) and Wardle (1963) provide a list of other species that are also present within the eight main classifications. These could be

analysed and split into vegetation classes based on height. Those that form the ground cover and the "understorey" to 500 mm could be used to generate a new vegetation classification.

The NVS data could be used in conjunction with the data from the studies done by Baylis et al. (1963) and Wardle (1963) to create a height restricted vegetation surface. The NVS data has two tiers at this level that would be suitable. These are from ground level to 0.3 m, and 0.3 m to 2 m. The data also provides an indication of the percentage of ground cover. This is split into five categories: vegetation, non-vascular, litter, bare ground and rock, which would possibly enable potential sites to be identified in the planning stages based on the percentage of vegetation cover compared to bare ground i.e. a high percentage value for vegetation would mean that it would be more likely to be densely vegetated. Sites that had high values for non-vascular, litter and bare ground could potentially be good sites for tunnel location.

This may provide a completely different indication as to their preferences for particular types of habitat. Rosenzweig and Winakur (1969) (as cited in Dueser and Shugart, 1978) observed that several habitat variables, including foliage height diversity, vegetation density and soil structure, significantly influenced species distribution both between and within habitats. In their study that investigated small mammal microhabitat Dueser and Shugart (1978) gathered six strata at each capture site.
These were:

1. Overstorey
2. Understorey
3. Shrub level
4. Herbaceous level
5. Forest floor
6. Litter-soil level

From this data they were able to conclude that 3 of the 4 forest-floor small mammal species resident in the study area exploited microhabitats which differed significantly in structure or configuration.

King et al. (1996) recorded altitude, aspect, slope, physiography, drainage and the relative contribution to ground cover of live vascular vegetation, forest litter, exposed soil and exposed rock within a 15 m diameter plot centred on the trap location. This data was combined with trap capture data to generate ordination plots displaying the correlations between the two sets of data for the different habitat areas that were being surveyed. In this study stoats were caught most often in older exotic plantations and least often in young pines. Indigenous unlogged and indigenous logged forest produced results within these extremes.

6.3.3: Resolution Island Vegetation

A refined vegetation surface was not generated for Resolution Island as there was no additional survey data to base it on at the time of the study. Intensive vegetation surveys had been carried out on other islands in the vicinity but Resolution Island had not been surveyed to the same level. A vegetation survey has since been carried out to provide a higher level of vegetation information than was currently available to assist conservation managers with the ongoing management of the island (Ledgard and Rance, 2008).

The capture data was spatially analysed with the LCDB2 classifications and compared with the Secretary Island results to see if there were any inconsistencies between the two islands. There LCDB2 classifications are the same for both islands except for the Manuka and Kanuka class which is present on Secretary Island but not on Resolution Island (Table 6.9).

LCDB2 Classification	Area (ha)	% Coverage	No. of Tunnels	Captures
Broadleaved Indigenous Hardwoods	194.69	0.94	2	
Coastal Sand and Gravel	14.52	0.07	2	2
Indigenous Forest	19498.79	94.04	254	268
Lake and Pond	37.6	0.18		
Landslide	13.02	0.06		
Low Producing Grassland	7.49	0.04		
River and Lakeshore Gravel and Rock	0.92	0.00		
Sub Alpine Shrubland	48.14	0.23	1	1
Tall Tussock Grassland	918.98	4.43	19	19

Table 6.9: LCDB2 Classifications for Resolution Island.

As this class only accounted for 0.17% of the total area and there were no successful tunnels within the class it would not have any bearing on any comparisons made between the two islands. The indigenous forest class makes up 94% of the total area of the island which compares with 92% for Secretary Island.

Captures for both islands are consistent and as would be expected the majority of successful tunnels on Resolution Island are also located within the indigenous forest class. A comprehensive vegetation survey would have to be undertaken on Resolution Island to provide additional data so that a refined vegetation surface could be generated. The level of detail required for a predictive model would mean that the cost to do this would possibly be prohibitive.

6.3.4: Secretary Island LENZ

Figure 6.9 shows the successful tunnels in relation to the LENZ level IV classifications. These results are summarized in Table 6.10.

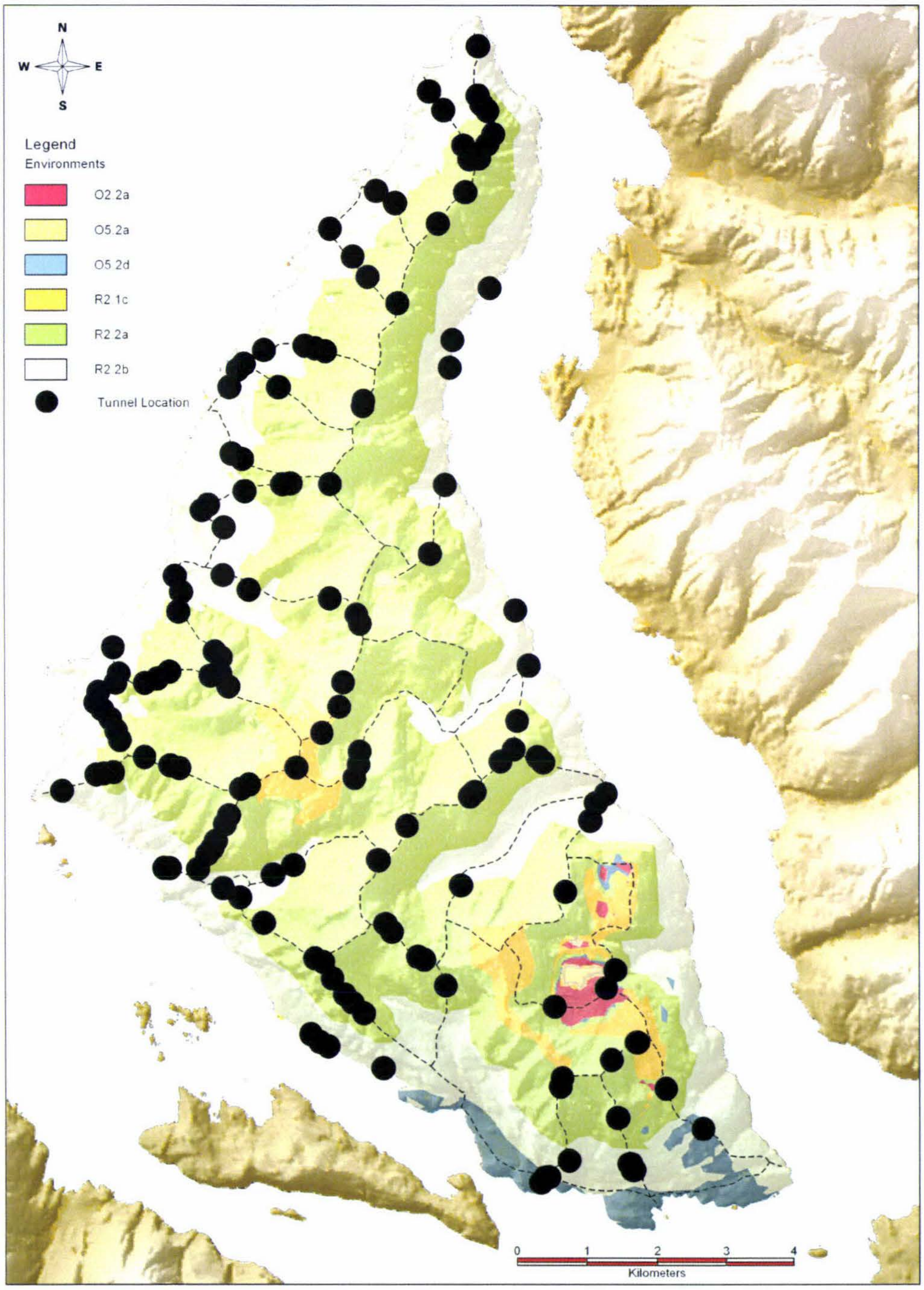

Figure 6.9: Location of successful tunnels on Secretary Island in relation to the LENZ level IV classifications.

The majority of the successful tunnels (133 or 92.4%) were located in the R2.2a and R2.2b classifications. These two classifications account for the largest proportion of the total area of the island. The remaining 11 tunnels were spread across the other three classifications fairly evenly.

LENZ Class	**Land Form**	**Soil**	**Average Elevation**	**Average Slope**	**Total Tunnels**
O2.2a	Easy Rolling Hills	Well drained soils - low fertility	404	8.7	3
O5.2d	Strongly Rolling Hills	Slightly imperfectly drained soils - very low fertility	177	13.1	3
R2.1c	Steep Mountains	Imperfectly drained soils - very low fertility from granite and basalt	1085	33.2	5
R2.2a	Steep Mountains	Imperfectly drained soils - very low fertility from granite and older basalt and gneiss	645	32.7	81
R2.2b	Steep Mountains	Imperfectly drained soils - very low fertility from granite and older basalt and gneiss	304	27.5	52

Table 6.10: LENZ level IV classifications for successful tunnel locations on Secretary Island.

The results found for the successful tunnels are repeated when the multi-catch tunnels are analysed with only one of the tunnels not in either of the R2.2a or R2.2b classifications (Figure 6.10 and Table 6.11).

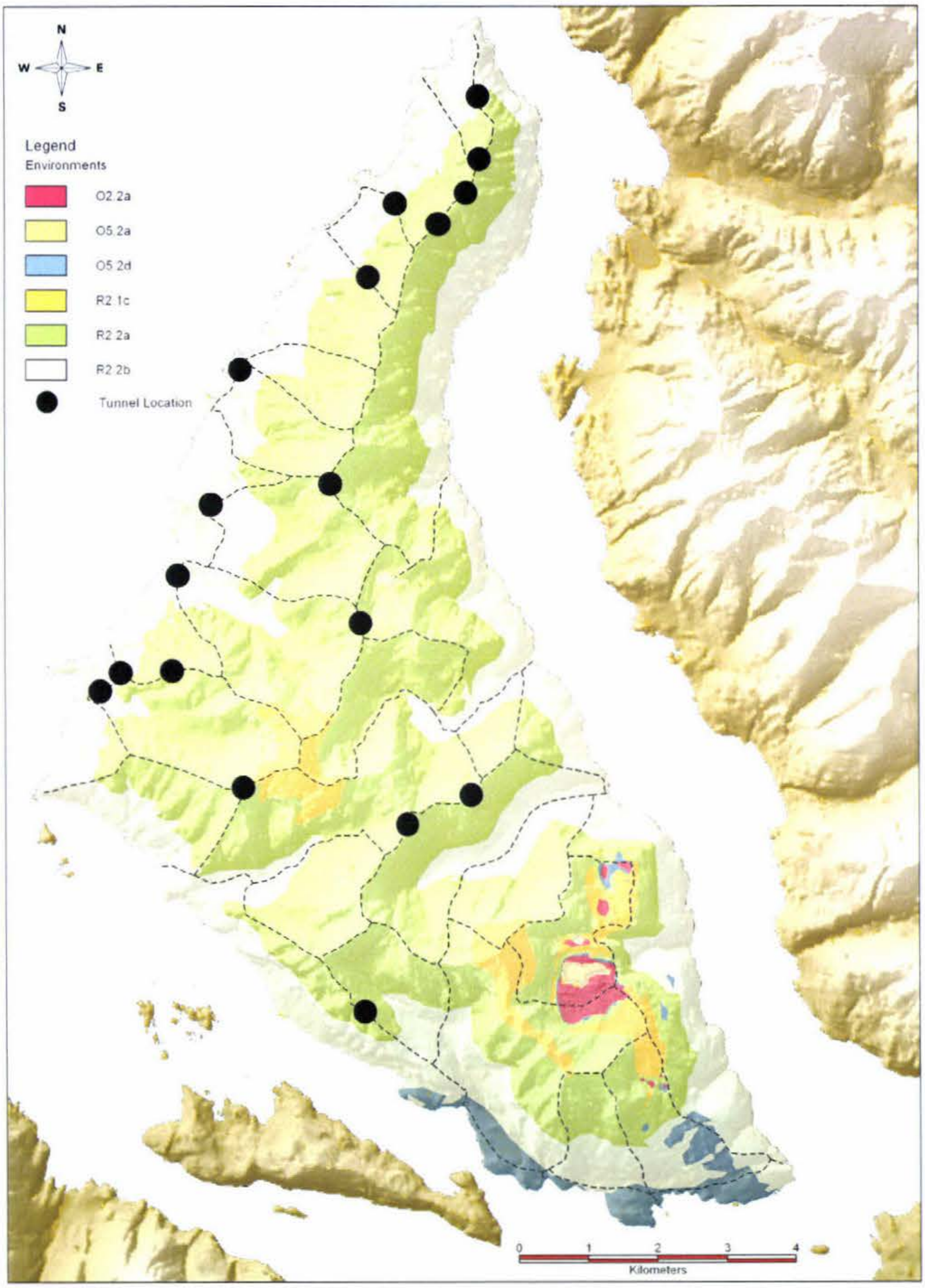

Figure 6.10: Location of multi-catch tunnels on Secretary Island in relation to the LENZ level IV classifications.

LENZ Class	Land Form	Soil	Average Elevation	Average Slope	Total Tunnels
R2.1c	Steep Mountains	Imperfectly drained soils - very low fertility from granite and basalt	1085	33.2	1
R2.2a	Steep Mountains	Imperfectly drained soils - very low fertility from granite and older basalt and gneiss	645	32.7	10
R2.2b	Steep Mountains	Imperfectly drained soils - very low fertility from granite and older basalt and gneiss	304	27.5	7

Table 6.11: LENZ level IV classifications for multi-catch tunnel locations on Secretary Island.

6.3.5: Resolution Island LENZ

Figure 6.11 shows the successful tunnels in relation to the LENZ level IV classifications. These results are summarized in Table 6.12. The majority of successful tunnels (121 or 42.2%) on Resolution Island were located within the R2.2a classification.

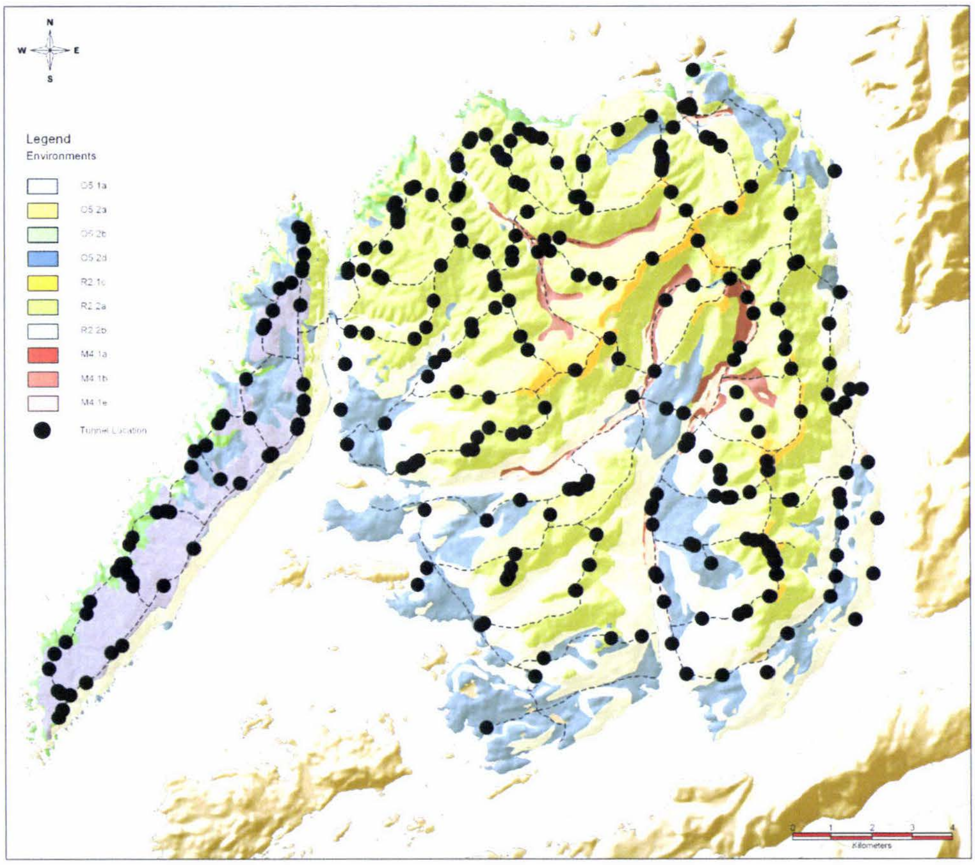

Figure 6.11: Location of successful tunnels on Resolution Island in relation to the LENZ level IV classification.

These results are consistent with all of the results from Secretary Island. However, due to the more rolling nature of the topography on Resolution Island, the O5.1a classification contained the second highest number (42 or 14.6%) of successful tunnels. Secretary Island does not have any of this classification. This was followed closely by O5.2d (38 or 13.2%) and R2.2b (36 or 12.5%) which is similar to the Secretary Island results.

LENZ Class	Land Form	Soil	Average Elevation	Average Slope	Total Tunnels
M4.1a	Rolling u-shaped valley floors	Recent well drained soils - very low fertility from Fiordland alluvium	346	17.9	12
M4.1e	Undulating u-shaped valley floors	Recent well drained soils - very low fertility from Fiordland alluvium	206	5.1	8
O5.1a	Easy rolling hills	Imperfectly drained peaty soils - very low fertility	236	6	42
O5.2b	Strongly rolling hills	Imperfectly drained soils - high fertility from fresh granite and intermediate igneous rocks	267	15.4	9
O5.2d	Strongly rolling hills	Slightly imperfectly drained soils - very low fertility	177	13.1	38
R2.1c	Steep Mountains	Imperfectly drained soils - very low fertility from granite and basalt	1085	33.2	21
R2.2a	Steep Mountains	Imperfectly drained soils - very low fertility from granite and older basalt and gneiss	645	32.7	121
R2.2b	Steep Mountains	Imperfectly drained soils - very low fertility from granite and older basalt and gneiss	304	27.5	36

Table 6.12: Land Environments of New Zealand level IV classifications for successful tunnel locations on Resolution Island.

Level IV	M4.1a	M4.1e	O2.2a	O5.1a	O5.2b	O5.2d	R2.1c	R2.2a	R2.2b
Secretary Successful			3			3	3	46	38
Resolution Successful	12	8		42	9	38	21	121	36
Secretary Multi								2	
Resolution Multi						2	1	5	1

Table 6.13: Comparison of Level IV classifications and results from the initial knock down period from Secretary and Resolution Islands.

The initial knock down period on Resolution Island provided nine tunnels that caught more than one stoat (Figure 6.12 and Table 6.14). There were only two tunnels on Secretary Island during the initial knock down period that caught more than one stoat. The tunnels on Secretary Island were located within the R2.2a classification and correspond to the Resolution Island results (5 tunnels) although three other classifications had multi-catch tunnels as well (Table 6.13). The multi-catch tunnels on Resolution Island (Figure 6.12 and Table 6.14) provided similar results to the successful tunnels and apart from the O5.2d classification are the same as the Secretary Island results.

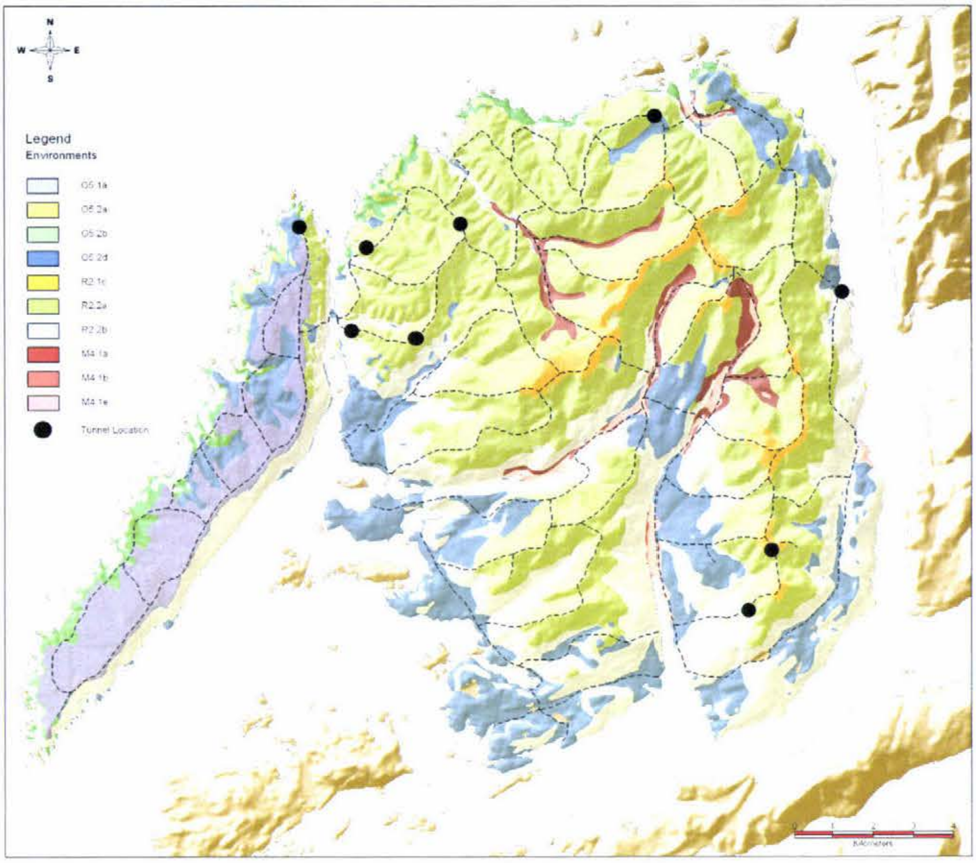

Figure 6.12: Resolution Island LENZ level IV classes and multi-catch tunnels.

LENZ Class	Land Form	Soil	Elevation	Slope	Total Tunnels
O5.2d	Strongly rolling hills	Slightly imperfectly drained soils - very low fertility	177	13.1	2
R2.1c	Steep Mountains	Imperfectly drained soils - very low fertility from granite and basalt	1085	1	1
R2.2a	Steep Mountains	Imperfectly drained soils - very low fertility from granite and older basalt and gneiss	645	32.7	5
R2.2b	Steep Mountains	Imperfectly drained soils - very low fertility from granite and older basalt and gneiss	304	27.5	1

Table 6.14: Land Environments of New Zealand level IV classifications for multi-catch tunnel locations on Resolution Island.

The Level IV classifications are similar for both sets of results but there are sufficient differences to create bias if a model was based on them. The results are probably more indicative of the fact that both islands have a large proportion of their total areas covered by a single classification (R2.2a) and the majority of the tunnels are located within this classification.

The data that provides the basis for the LENZ classifications are similar to those used for the LCDB2 and the LRI. Because of this the resolution of the data is such that there are only small variations in the classifications in isolated locations such as Secretary Island and Resolution Island. To make more than a generalized use of the LENZ level IV classifications would require further work to break down the R2.2a and R2.2b classifications similar to what was done with the LCDB2 indigenous class in Section 6.3.2 of this chapter.

6.4: Discussion

The datasets that describe the vegetation on Secretary and Resolution Island's are derived from surveys that were undertaken at a very coarse level. Intense vegetations surveys have been done on Secretary Island but only on the western side of the island. Similar surveys have only just been completed on Resolution Island (Ledgard and Rance 2008).

The datasets in their current form do not provide enough detail to extract an indicative vegetation type or classification that could be used to identify successful tunnel locations. The work done on modifying the LCDB2 indigenous vegetation classification does however show that if sufficiently detailed data is available a stoat's preference for a particular vegetation environment may become apparent. There is enough evidence to suggest that further work in this area would be warranted.

Chapter Seven: Data Analysis - Topography

7.1: Introduction

Secretary Island is roughly triangular in shape and runs generally north-south from Colonial Head in the north to Blanket Bay in the south. The island's topography is made up of ice worn benches and steep ridges that rise to nearly 1200 m. Mount Grono at the south end of the island is the highest point at 1196 m. The northern part of the island is divided by one main ridge with the eastern face rising sharply from sea level. The coastal faces are precipitous and bear the scars of numerous landslides, both old and some more recent.

The centre of the island is split by a number of streams that run generally in an east-west direction. This creates a very broken landscape of steep sided valleys and ridges. The south west facing slopes at the southern end of the island are very steep with bluff systems. The south east facing slopes are generally the darker colder faces. Figure 7.1 gives an indication of the steep broken topography that forms Secretary Island and graphically depicts the problems imposed by the rugged topography for the conservation managers attempting to successfully eradicate the stoat from the island.

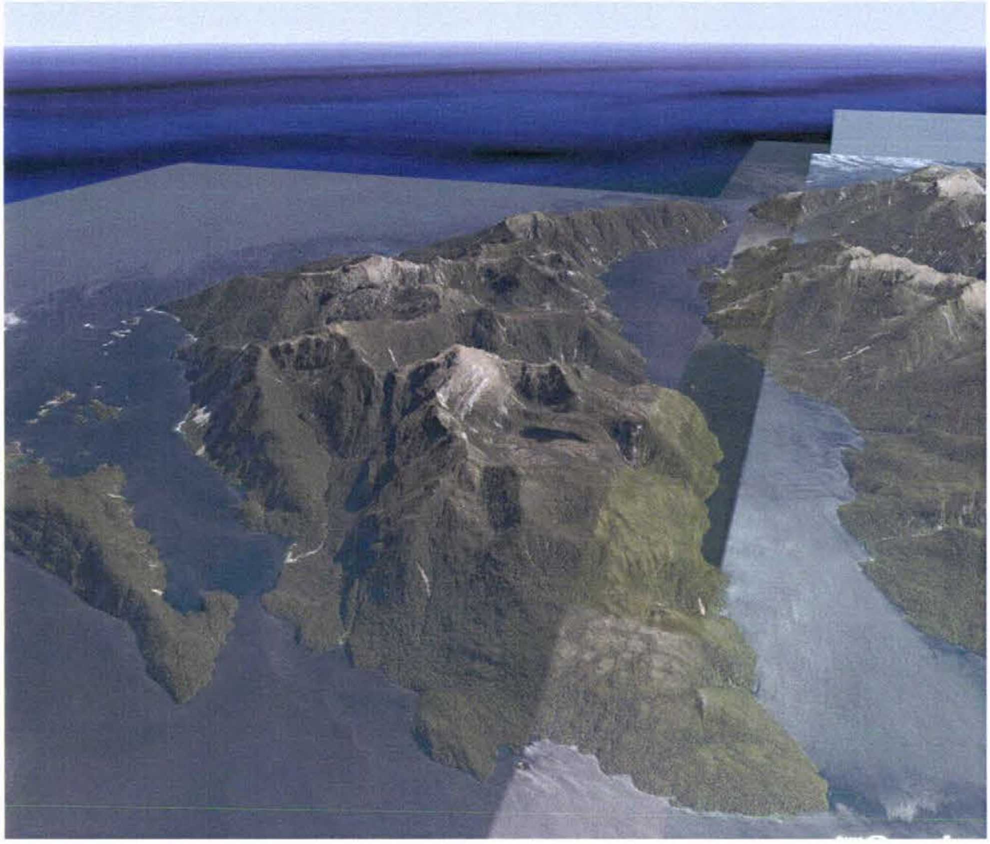

Figure 7.1: Secretary Island viewed from the south looking northwest. Thompson Sound and the main Fiordland coast are on the right hand side with Bauza Island and Doubtful Sound in the lower left corner. Mount Grono, the highest point on the island is visible in the centre of the image with All Round Peak behind it. The image was generated from Google Earth Professional.

7.2: Topographic Analysis

Brabyn (1998) suggests that terrain can be used as an indication to identify micro, meso and macro terrain indices by varying the neighbourhood radius during an analysis process that subtracts the mean elevation from the actual elevation. At a macro level broad relationships can be seen, such as the difference between broad river flats and mountains. When this is developed at the micro level, depressions which may indicate micro climates and specific soil types can be identified.

By combining terrain with climatic, soil and land cover data, it is feasible to determine species habitat (Tivy, 1993). Brabyn (1998) proposes that the availability of the 20 m contour interval terrain data enables analysts to automatically generate differences in terrain that could provide useful indicators to a particular species potential habitat. Terrain impacts on various features such as soil, drainage and climate which all have a bearing on a species habitat. This could be as simple as identifying all slopes that are greater than a known steepness because a plant species that a particular animal species feeds on will not grow means that these areas could be excluded from a study.

In a University of California (Shortridge, no date) paper students are provided with the following criteria to identify potential habitat in a region in northern New Mexico for the Wyoming Mountain Stoat:

1. Stoats prefer altitudes between 2500 and 3000 m.
2. Stoat dens are always on south and west facing slopes.
3. Stoats cannot live on slopes steeper than 35°, but they also suffer on slopes below 25°.

All of this information can be generated from terrain data using a GIS. By identifying altitudes between 2500 and 3000 m, south and west facing aspects and slopes between 25° and 35°, a macro level surface showing potential habitat can be generated. The value of terrain data and the level of information that can be extracted from it can be demonstrated by this simple example. Combining the results of this initial macro level analysis with other known factors such as preferred prey species extent, land cover and climatic data the macro surface can be refined down to a micro level providing a more definitive indication of suitable habitat and where to concentrate project resources.

7.2.1: Secretary Island Slope and Aspect Analysis

Due to the difficult terrain on Secretary Island and the fact that a track network is required to provide access this type of analysis could be used to identify micro habitats that are located within a given radius of successful tunnel locations. Identification of these areas prior to tunnel placement may indicate priority areas for trap location. For example, two micro habitat sites might be identified on opposite sides of a ridge. This could indicate that stoats may travel between the micro habitats and therefore if a tunnel was placed on the ridge between the two sites one would expect that there would be a high probability that a stoat or stoats would be caught. An intensive study of these sites may reveal stoat den sites or preferred prey species habitat that would provide useful information for future control operations.

There are two elements of topography that can be derived from a digital elevation model (DEM), slope and aspect. As indicated in the scenario described above they can be used to identify possible habitat. When they are combined with the trap capture data it is possible that a trend may be revealed. This by itself may not be significant but when combined with the results of analysis on datasets it could reveal consistencies that are then able to be modelled.

GeoMedia GRID has within its Visualisation toolbox two functions: Grade and Aspect. Using the Secretary Island DEM as the input surface, slope and aspect surfaces were generated (Figures 7.2 and 7.3). The slope surface shows slope values in degrees of slope, light brown refers to low slopes, with the colour getting darker as the slope increases i.e. the dark brown represents steep slopes. The colours used in the aspect surface are designed to reflect the difference between warm and cold orientated faces. The warm colours, red, orange and yellow define the northerly faces, while the blues define the southerly slopes.

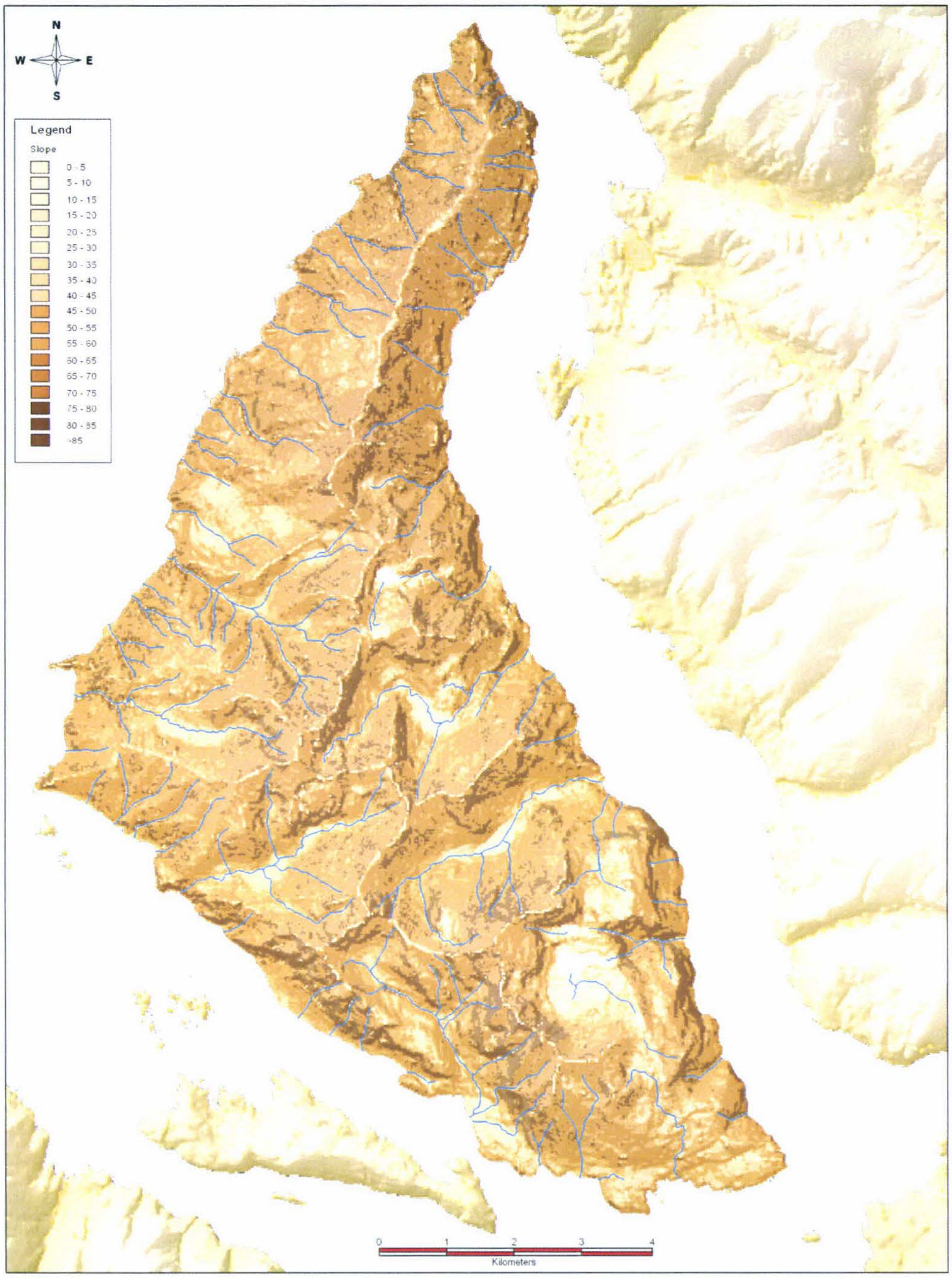

Figure 7.2: Secretary Island slope map.

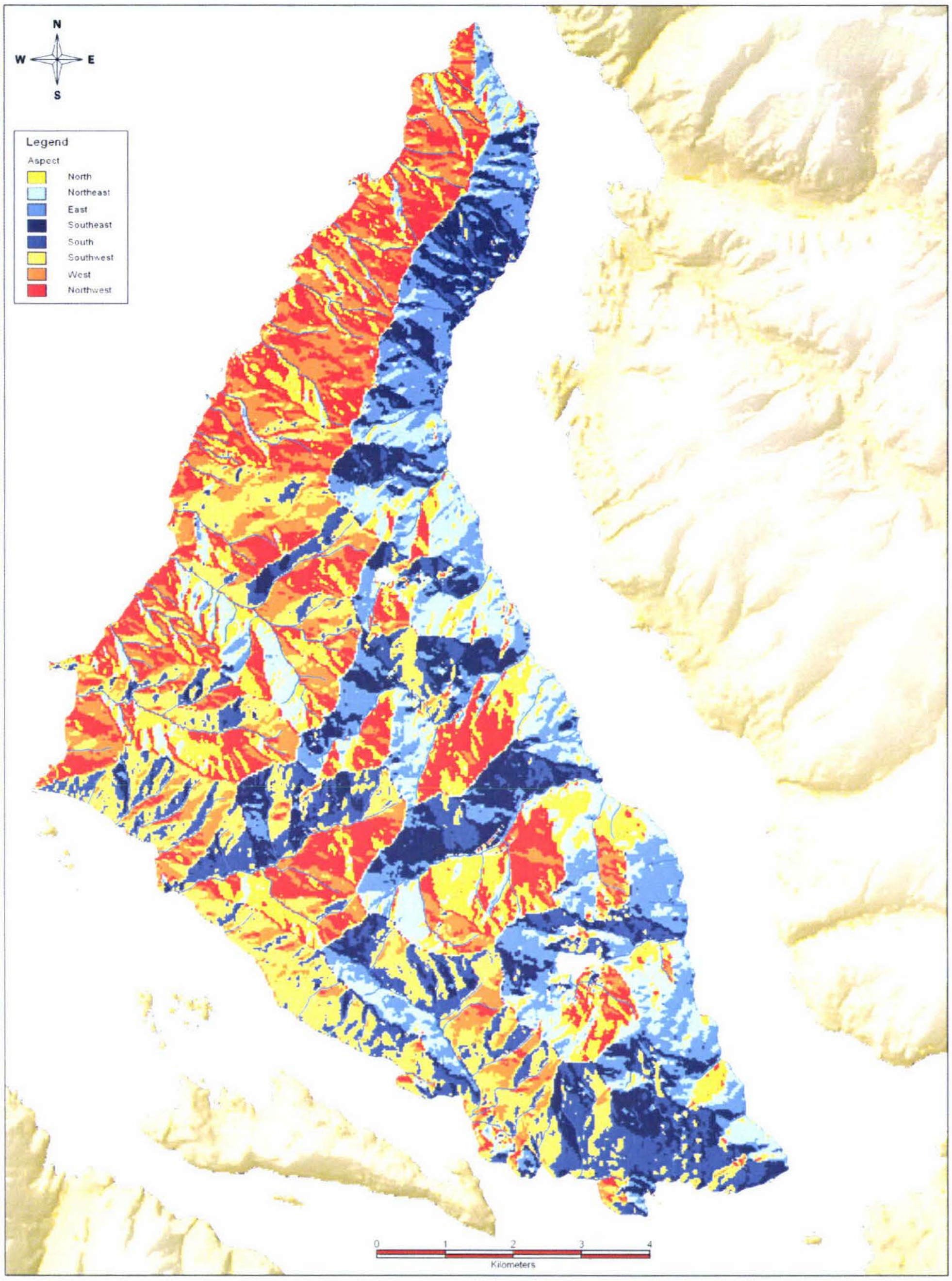

Figure 7.3: Secretary Island aspect map.

To extract the slope and aspect values for the successful tunnel locations they first had to be converted to a raster. Once this was generated it was reprocessed to apply a zero value to each valid cell. This meant that when it was combined with the slope and aspect surfaces the resulting values replicated exactly the slope and aspect values. This negated the need for further processing to extract the values required for the graphical analysis. Once the tunnel surface had been prepared the Calculation function within

GRID was used to add it to firstly the slope surface and then the aspect surface. These were separate operations and resulted in two new surfaces. The histograms for each were viewed and the data extracted out to MicroSoft Excel for charting (Figures 7.3 and 7.6).

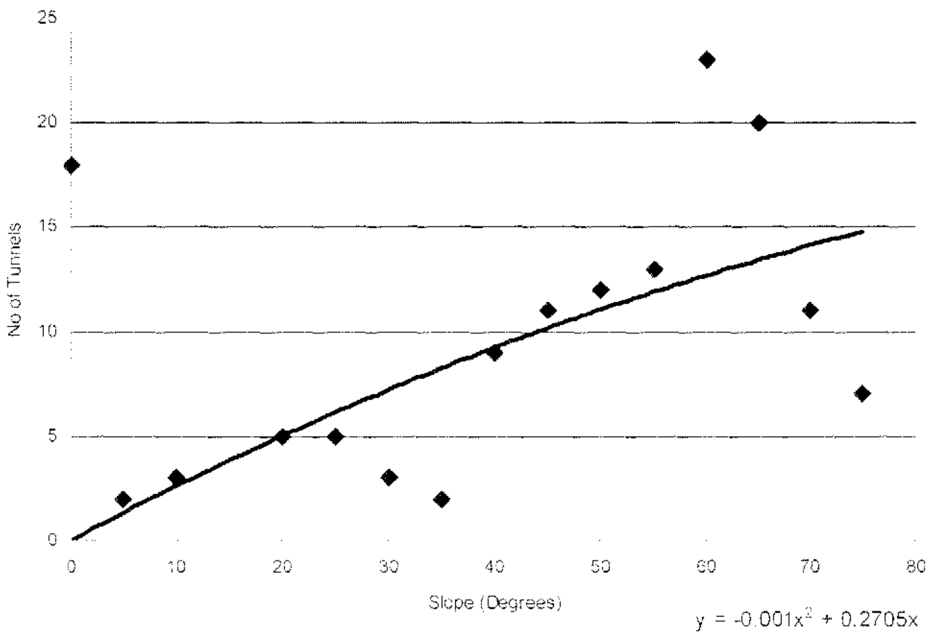

Figure 7.3: Slope values for successful Secretary Island tunnels.

The slope graph shows four distinct clusters of tunnels. Because a large proportion of the tunnels were located on ridges the number that have a slope value of zero or flat is relatively high. These are clearly visible in Figure 7.2 as the lightest coloured areas and in Figure 7.3 as the single point on the zero slope line. The mid range slopes from 5 to 35° have the least number of successful tunnels. Although when viewed in relation to the trendline, the tunnels at 30° and 35° drop well below the line and could be discounted.

Proportionally, there were more successful tunnels at slopes greater than 40^{o}. Within this range there were a total of 106 tunnels, of these there were 61 tunnels that were at slopes of greater than 60^{o}.

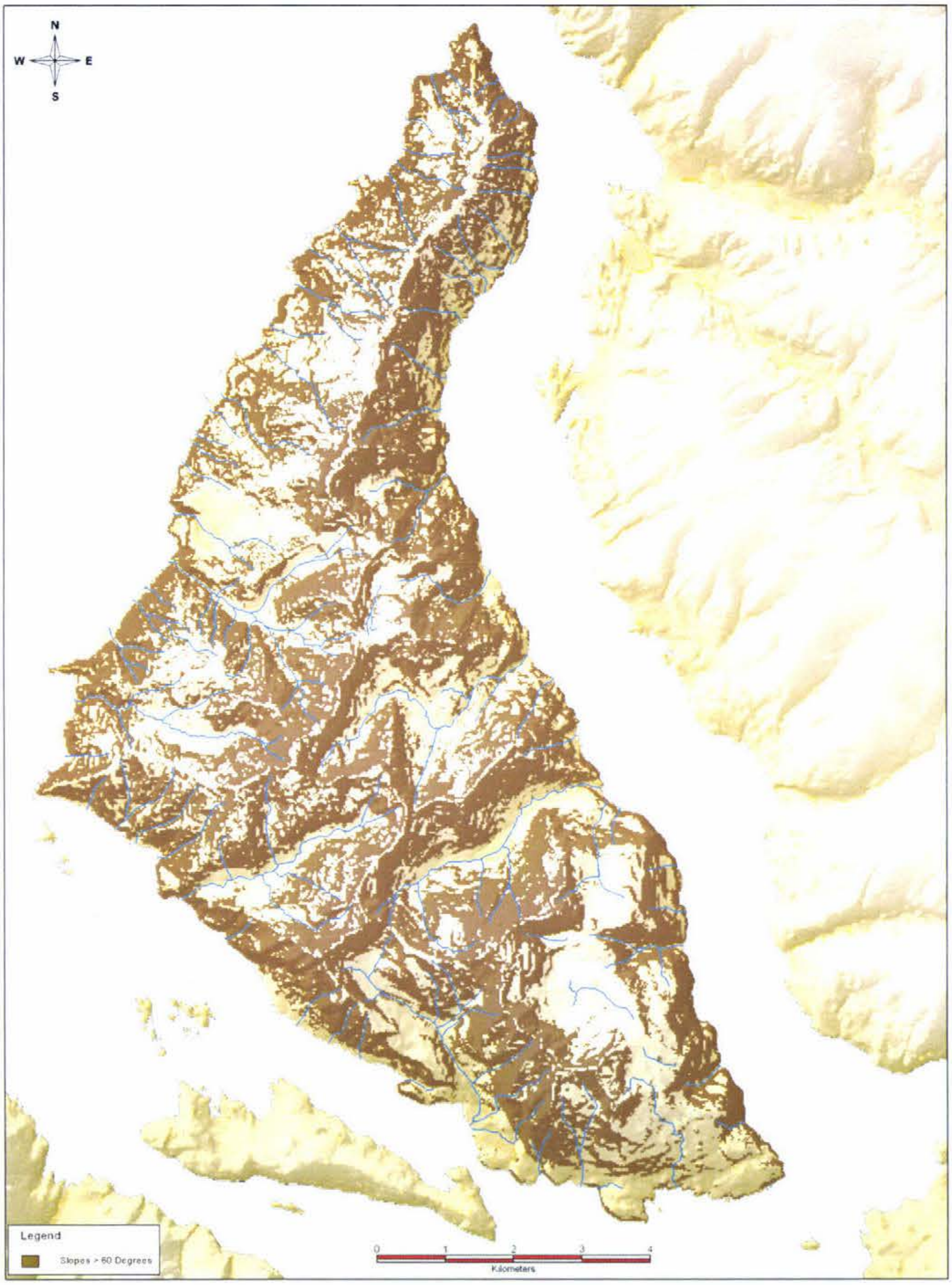

Figure 7.4: The extent of slopes that are greater than 60 degrees on Secretary Island.

Considering the extreme nature of the topography of Secretary Island where a large proportion of the island has slopes that are greater than 60^{o} (Figure 7.4), these results are probably not surprising but may be due to the positioning of the tunnel locations in relationship to the DEM.

The fact that the tunnel locations were captured using a GPS and the DEM is only at 15m resolution could mean that the slope value assigned to a tunnel location may not accurately reflect the actual slope at that location. This is due to the difference in the accuracy of the two sets of data. However, the difference is significant and possibly worth further investigation. The trend line indicates that as slope increases the likelihood of a tunnel being successful increases. The tunnels in the two slope ranges (5^{o} to 25^{o}) and (40^{o} to 60^{o}) closely follow the trendline with the ones at zero and greater than 60^{o} showing the most variation. Based on this a new slope map was generated using the following values.

Slope	Tunnels
0 - 20^{o}	28
20 - 40^{o}	10
40 - 60^{o}	45
> 60^{o}	61

Table 7.1: Slope values used to generate new slope map for Secretary Island.

The results of this are displayed below in Figure 7.5.

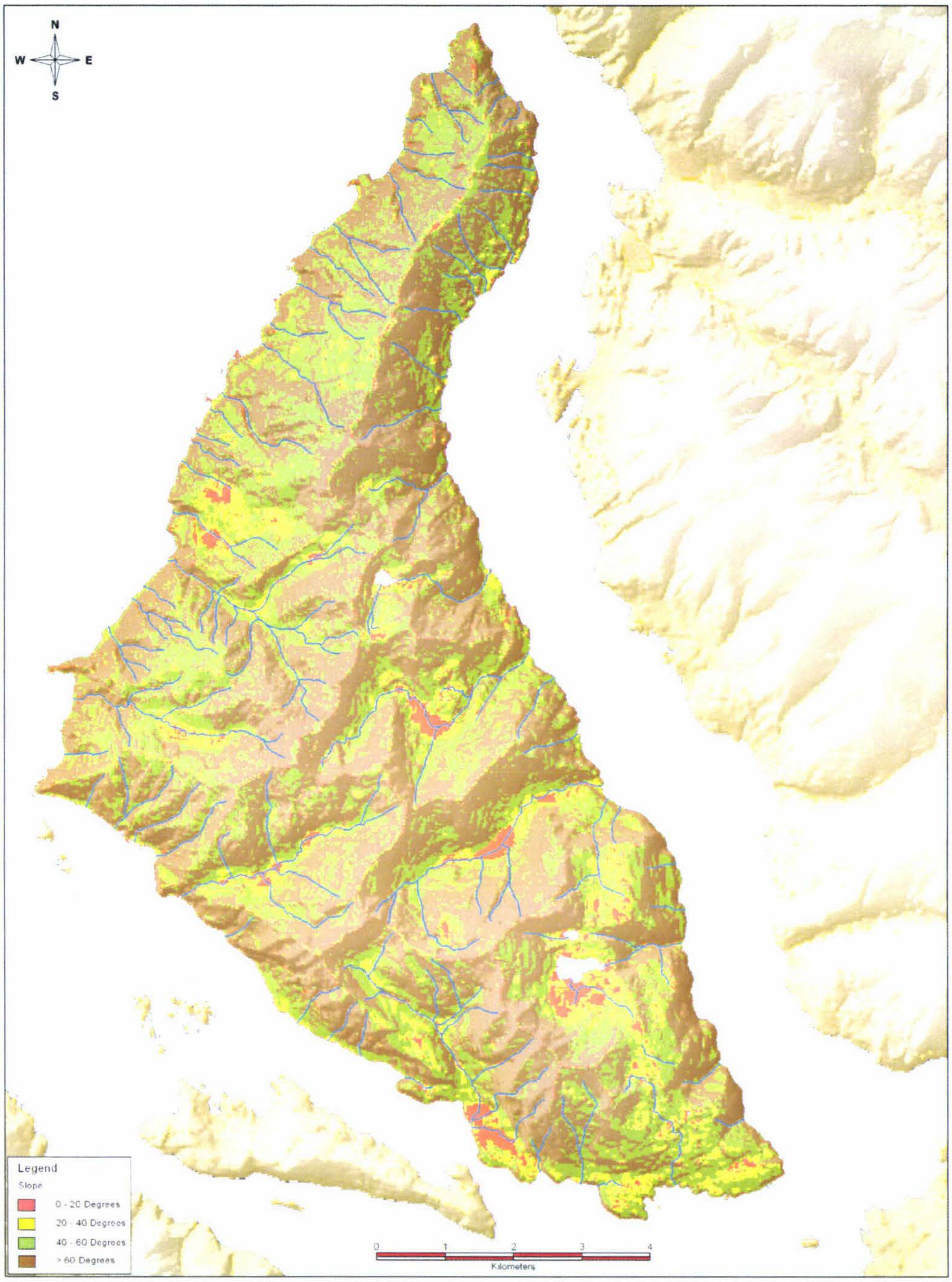

Figure 7.5: Secretary Island slope values classified into four slope ranges to reflect the slopes identified by the successful tunnels

The direction or aspect of the successful tunnel locations could indicate a preference for a particular site in combination with other factors such as vegetation. However, apart from the three points at 10°, 220° and 310°, the successful tunnels are evenly distributed around the points of the compass. These three exceptions only account for 40 tunnels out of the total and as such would not warrant further investigation. There are two clusters in the south-west and north-west directions but these are not significantly different that they would suggest a preference for these sites.

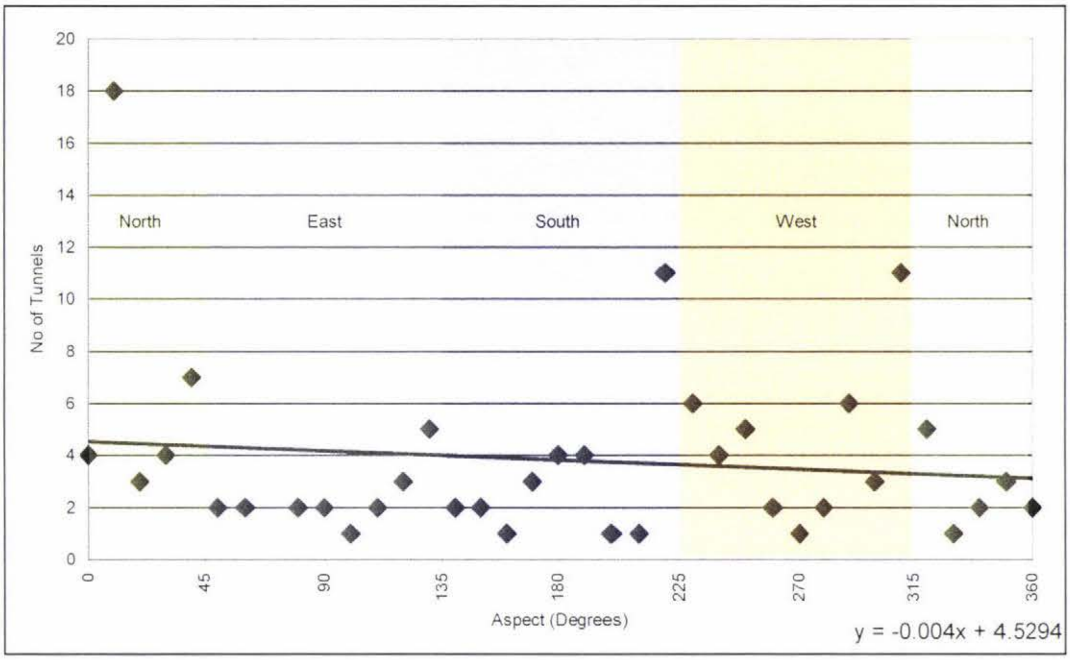

Figure 7.6: Aspect values for successful Secretary Island tunnels.

Topography on Secretary Island is a determining factor on the success of the control operation. Although this may not be evident in the results from the control operation, it certainly needs to be considered due to the extremes across the island. The ability to locate sufficient tunnels over the island to provide effective coverage is severely impeded by the nature of the terrain, restricting track placement to accessible ridges and gullies. In this situation the terrain is controlling where tunnels can be located which may not necessarily be in the most suitable position.

The conservation manager is then required to select a location for the tunnel that has to a certain degree been predetermined. They are limited to choosing the best position within this constraint and hoping that the tunnel is in a location that may be frequented by the prey species. This may explain to a certain extent why some tunnels are more successful than others.

7.2.2: Secretary Island Elevation Analysis

Elevation is another topographical factor that can be used to indicate patterns when analysing data. Due to the steepness of Secretary Island and the fact that the majority of the tunnels are located on ridge tracks it would be feasible to assume that the successful tunnels would be at the higher elevations. This however is not the case and the successful tunnels are spread from sea level to the almost the highest point on the island (Figure 7.7) with no preference for a particular elevation evident.

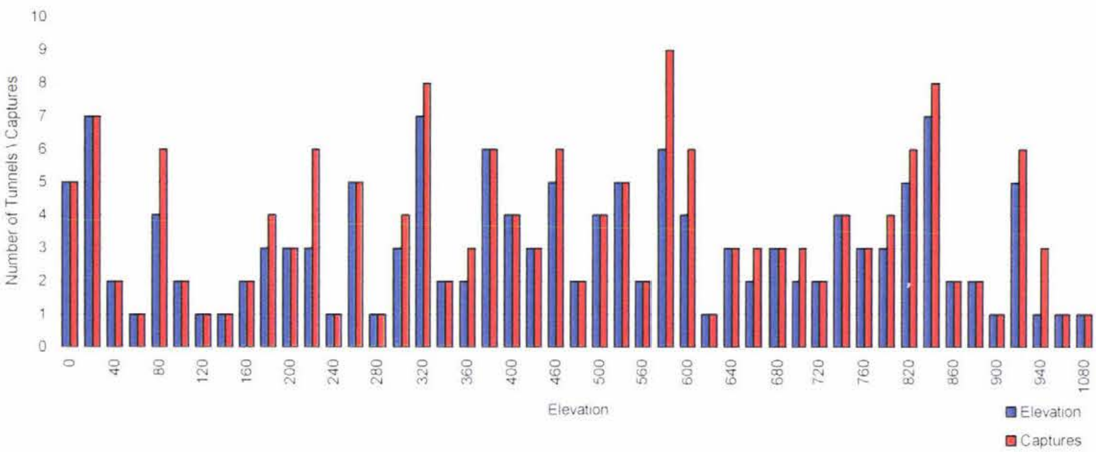

Figure 7.7: Successful tunnels on Secretary Island by elevation and frequency of stoat captures.

The multi-catch tunnels are also spread through the elevation range with the exclusion of some elevations below 80 m and above 940 m (Figure 7.8). Tunnels below the 80 m elevation accounted for 16 stoats and those above the 940 m elevation, 2 stoats. The 16 stoats caught at the lower elevations is 9.6% of the overall captures so is significant considering that these stoats may be arrivals from the mainland. With no clear preference in either set of results the use of elevation in a predicative model could only be used if there were further criteria that indicated a particular elevation level, such as warm facing slopes, with highly productive vegetation that contained a particular prey species.

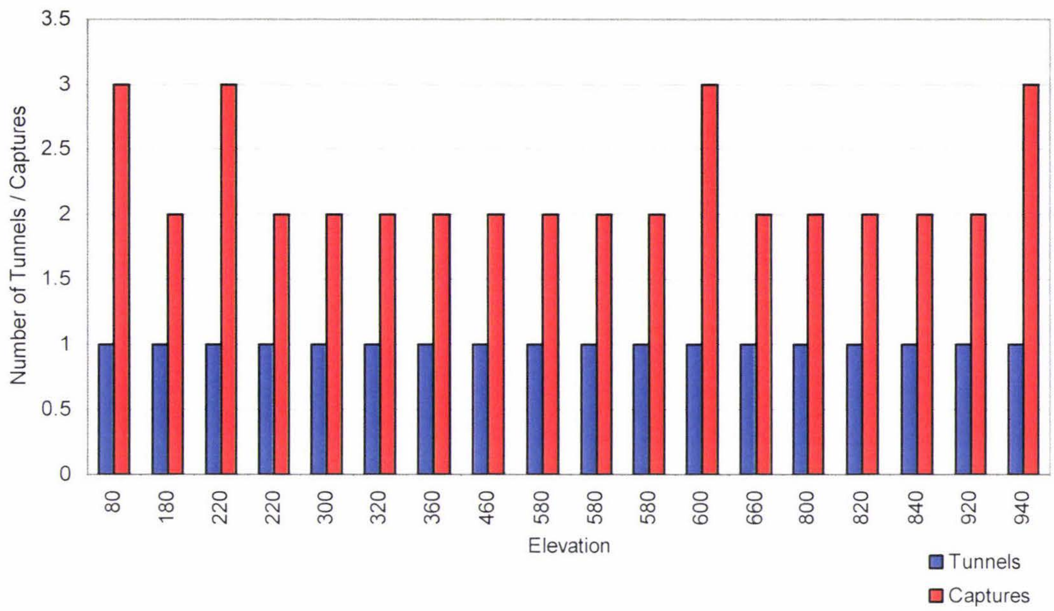

Figure 7.8: Multi-catch tunnels on Secretary Island by elevation and frequency of stoat captures.

7.2.3: Resolution Island Slope and Aspect Analysis

The highest point on Resolution Island is Mount Clarke at 1069 m. This is only 127 m lower than Mount Grono on Secretary Island; however there is a distinct difference in the slope ranges between the two islands. Where Secretary Island is dominated by very steep sided valleys and sharply defined ridges, Resolution has a more rolling appearance (Figure 7.9). The main island has two main ridges, one running generally north-south through Mount Clarke and the other generally southwest-northeast from Mount Roa to Mount Wales (Refer Figure 2.9). Five Finger Peninsula has a ridge running its entire length. The western side rises reasonably gently from the coastline to the top of the ridge but the eastern slopes drop steeply back down to the coastline.

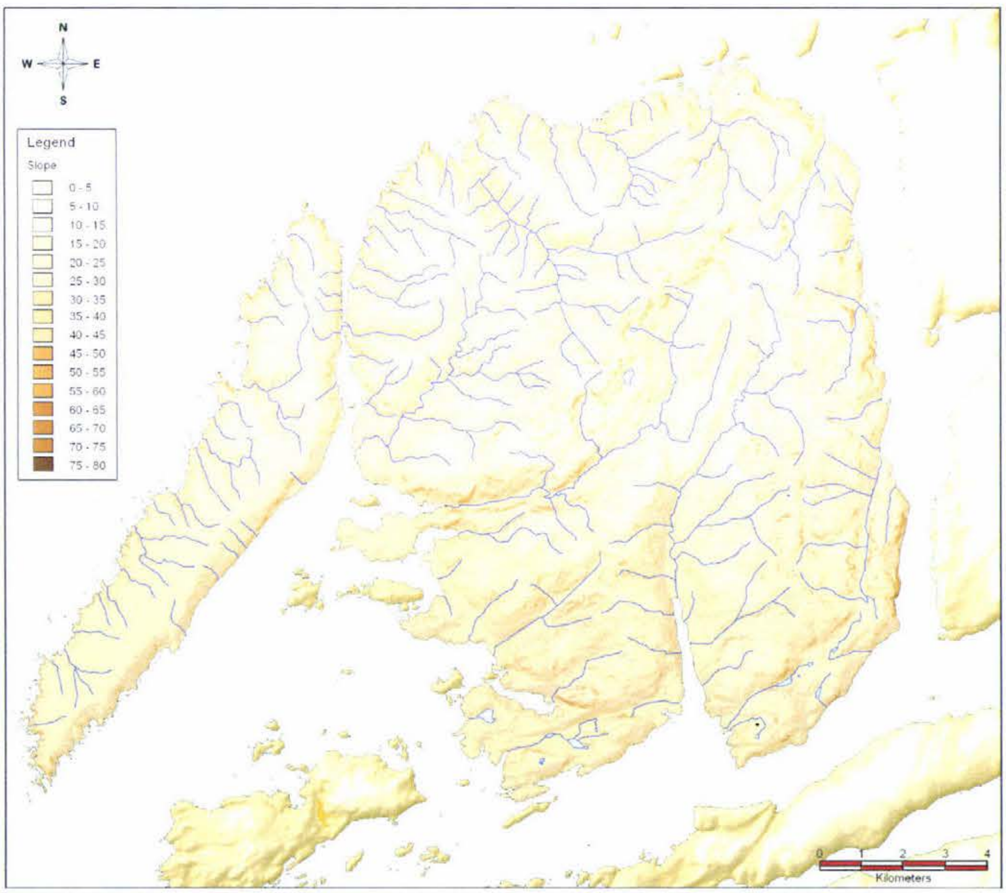

Figure 7.9: Resolution Island slope map.

The slopes on Resolution Island range between 0° and 75°, whereas Secretary Island's range between 0° and 85° (Figure 7.10). The difference between the two islands is evident with the majority of the slopes on Resolution being around the 10° to 25° range compared to Secretary, where they are in the steeper ranges of 55° to 75°.

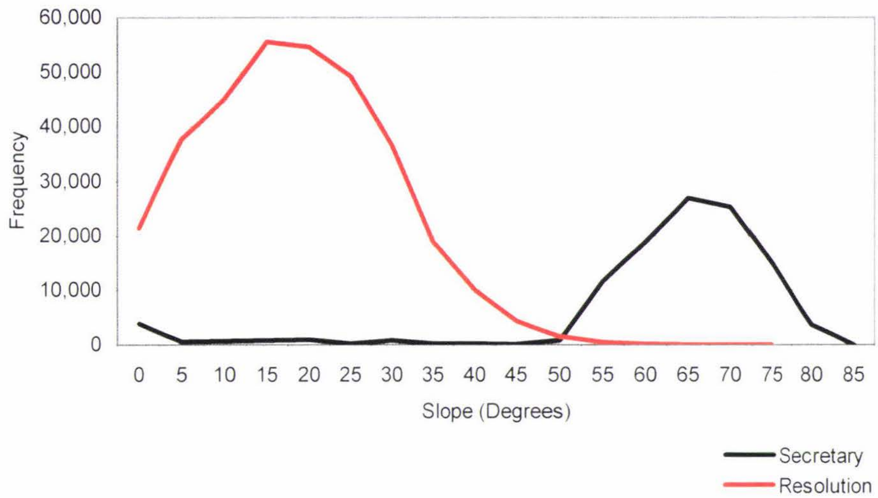

Figure 7.10: Slope comparison between Resolution and Secretary Islands.

The successful tunnels are plotted against the slope values in Figure 7.11 and form an even polynomial curve starting at 0° and finishing at 40° with the majority of tunnels (265 out of the total 277) within the 0° to 25° slope range. This is the reverse of what happened on Secretary Island where the curve started at 0° and rose consistently through to 75° with the majority of tunnels being on the steep to very steep slopes (97 out of the total 144 tunnels). Figure 7.12 provides a graphic depiction of the comparison between the two islands with the lower slope ranges of Resolution Island dominating the right hand side of the radar chart. Although the successful tunnels on Resolution Island are on gentler slopes compared to Secretary Island, this is consistent with the variation in the slope ranges between the islands and the location of the track networks.

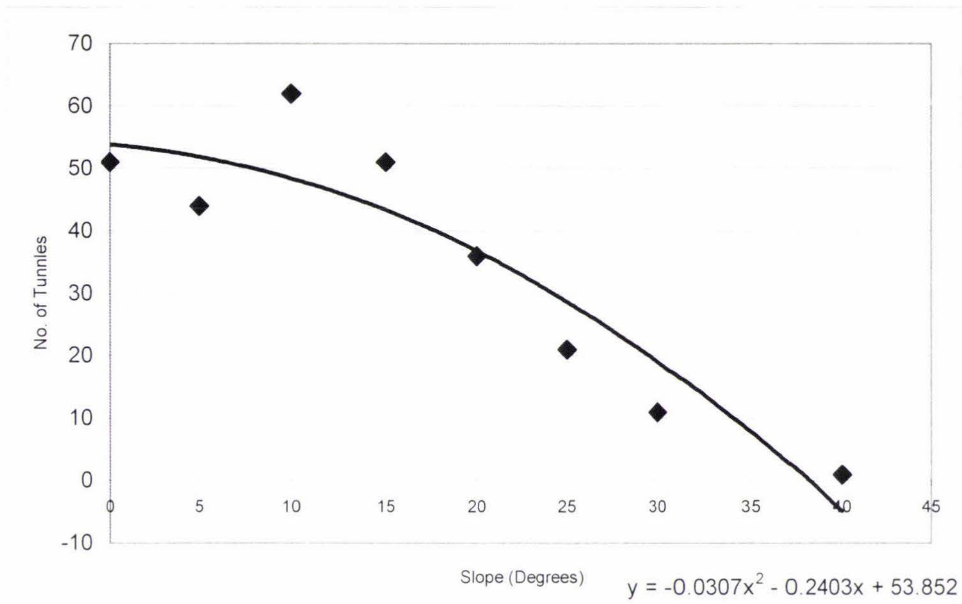

Figure 7.11: Slope values for successful Resolution Island tunnels.

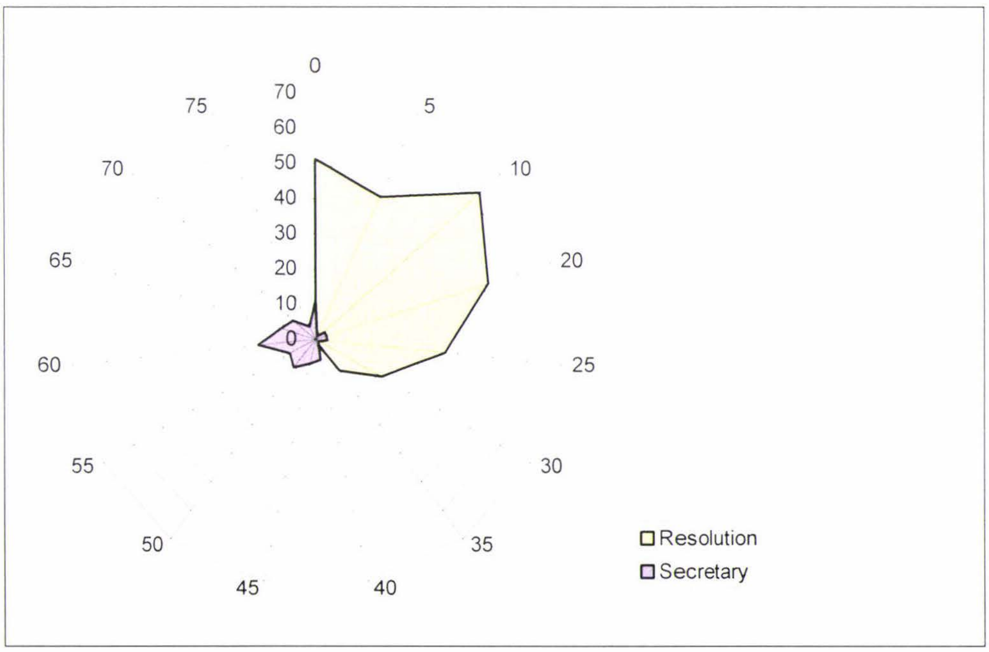

Figure 7.12 Slope comparisons of successful tunnels on Resolution and Secretary Islands for the initial knockdown period.

The successful tunnels on Secretary Island were evenly spread around the points of the compass and did not highlight any preferences for a particular aspect. Figure 7.13 shows the aspect values by cardinal points for Resolution Island. The island is fairly evenly split between the warm (11,232 ha or 54.2%) and cold (9483 ha or 45.8%) facing slopes. This is similar to Secretary Island where the warm facing slopes accounted for 53.5% and the cold facing slopes accounted for 46.5% of the total area.

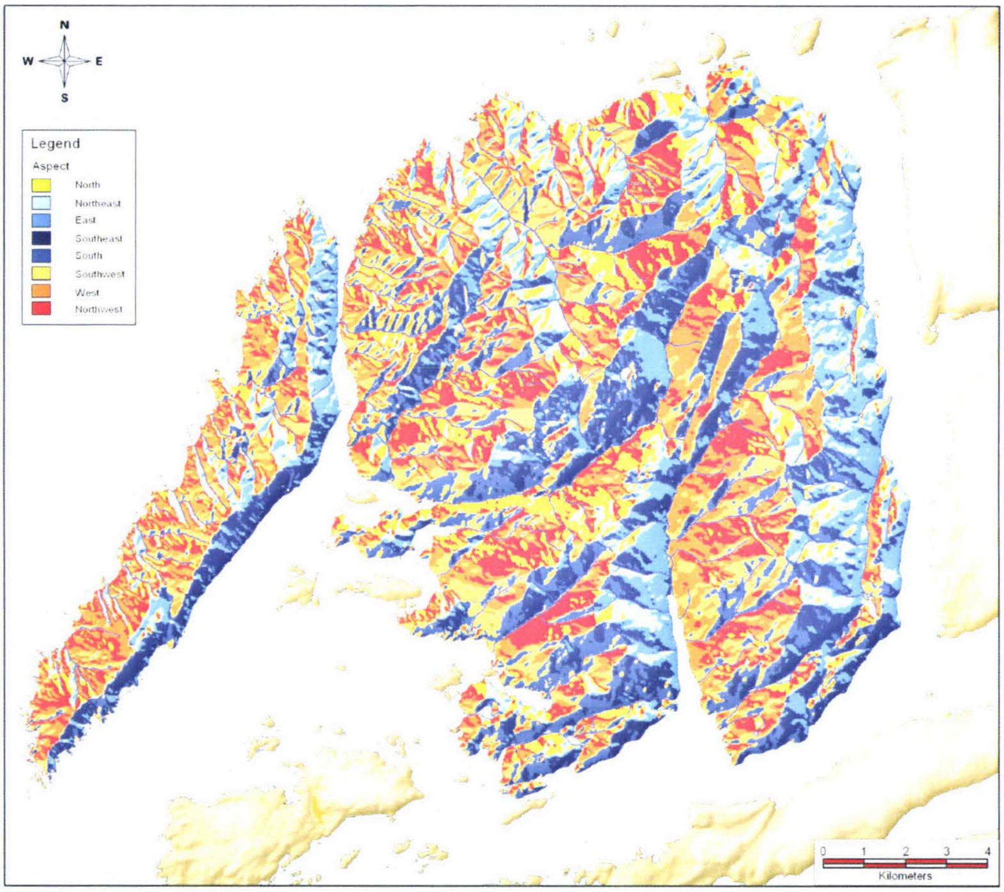

Figure 7.13: Resolution Island aspect map.

The same analysis was carried out using the Resolution data and graphed (Figure 7.14). Although the tunnels are spread around the compass there appears to be a preference for the warmer sites between the west and northwest quarter (Figure 7.15). The successful tunnels on Resolution follow the trendline (Figure 7.14) more evenly than on Secretary Island (Figure 7.6) without any distinct departures.

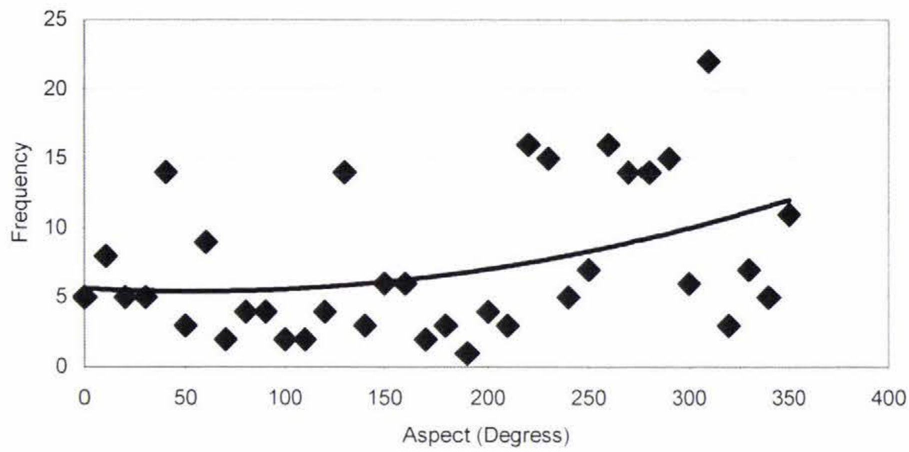

Figure 7.14: Aspect values for successful Resolution Island tunnels.

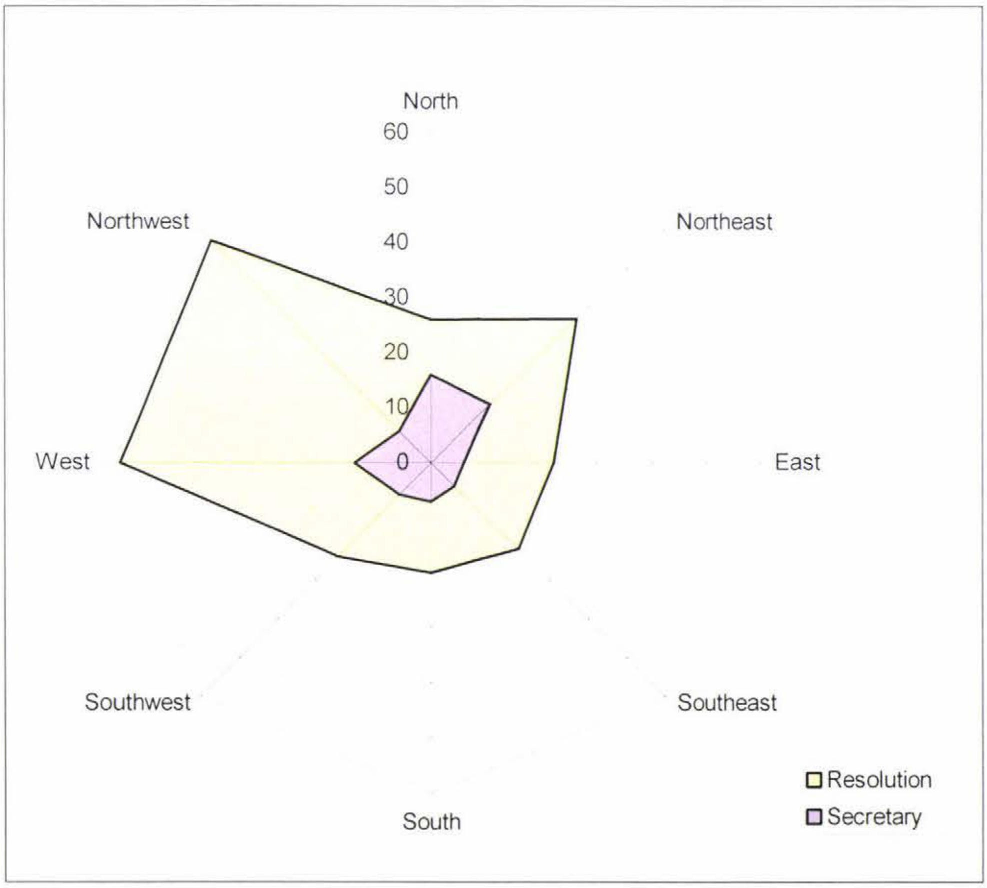

Figure 7.15: Comparison of successful tunnels in relation to aspect between Resolution and Secretary Islands for the initial knockdown period.

The results of the two sets of data differ with Resolution results have a preference for the warmer slopes and the Secretary results tending more to the colder slopes. When you compare the Resolution results with the full set of data from Secretary Island the pattern is very similar (Figure 7.16).

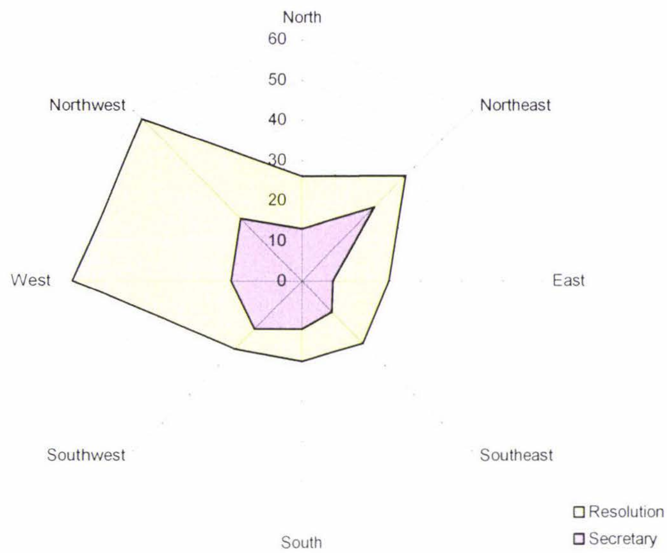

Figure 7.16: Comparison of successful tunnels in relation to aspect between Resolution's knockdown period and Secretary Island's full set of data.

The results do show a preference for the warmer slopes; however there are too many successful tunnels on the remaining colder slopes to disregard these from any model. Control efforts could be maximized in these areas and reduced on the colder facing slopes. These areas may have higher producing vegetation which in turn may mean that there are higher concentrations of food and therefore draw the stoats to them whereas the stoats caught in the colder areas may just be travelling through to the more productive areas.

7.3: Track and Physiography Relationship

7.3.1: Introduction

The track network that was established to provide access for the eradication operation on the island also operates as an attractant to the stoats. Stoats like to travel along lines and they have been provided with a network of highways that they can use to move throughout their home range. The relationship between track location and the number of successful tunnels may provide an indication of preference for a particular track type i.e. ridge or gully.

7.3.2: Secretary Island Track Analysis

Out of the total 113 km of tracks on the island, tracks that were located on ridges made up 74% (84 km). With almost three quarters of the track network located along ridgelines it could be expected that a high proportion of the successful tunnels would be located on these tracks. Figure 7.14 shows the number of tunnels for each track compared with all successful and multi-catch tunnels.

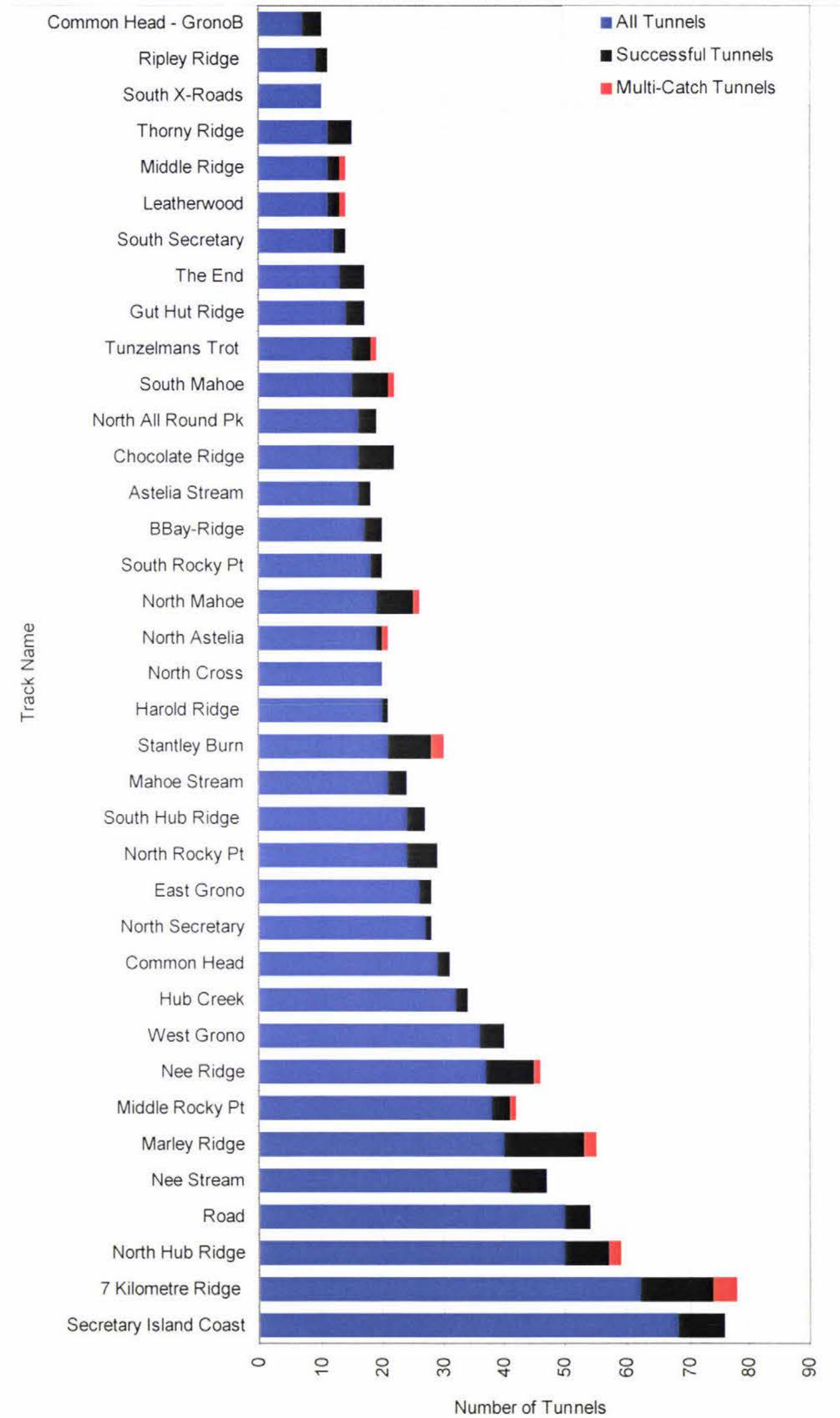

Figure 7.17: The total number of tunnels on Secretary Island by track compared to successful and multi-catch tunnels.

Two tracks had very high success rates. 7 Kilometre Ridge and Marley Ridge tracks, with 17 and 16 stoats caught respectively (Figure 7.18). This is repeated in the multi-catch tunnels where 7 Kilometre Ridge tunnels caught 9 stoats and Marley Ridge tunnels caught 5 stoats. There was obviously a preference for the tunnels on these two tracks. The Marley Ridge track runs generally in an east-west direction, with one face to the north dropping into a gully and the southerly face dropping to the coast line. The 7 Kilometre Ridge track runs generally north-south with both faces running down to the coastline.

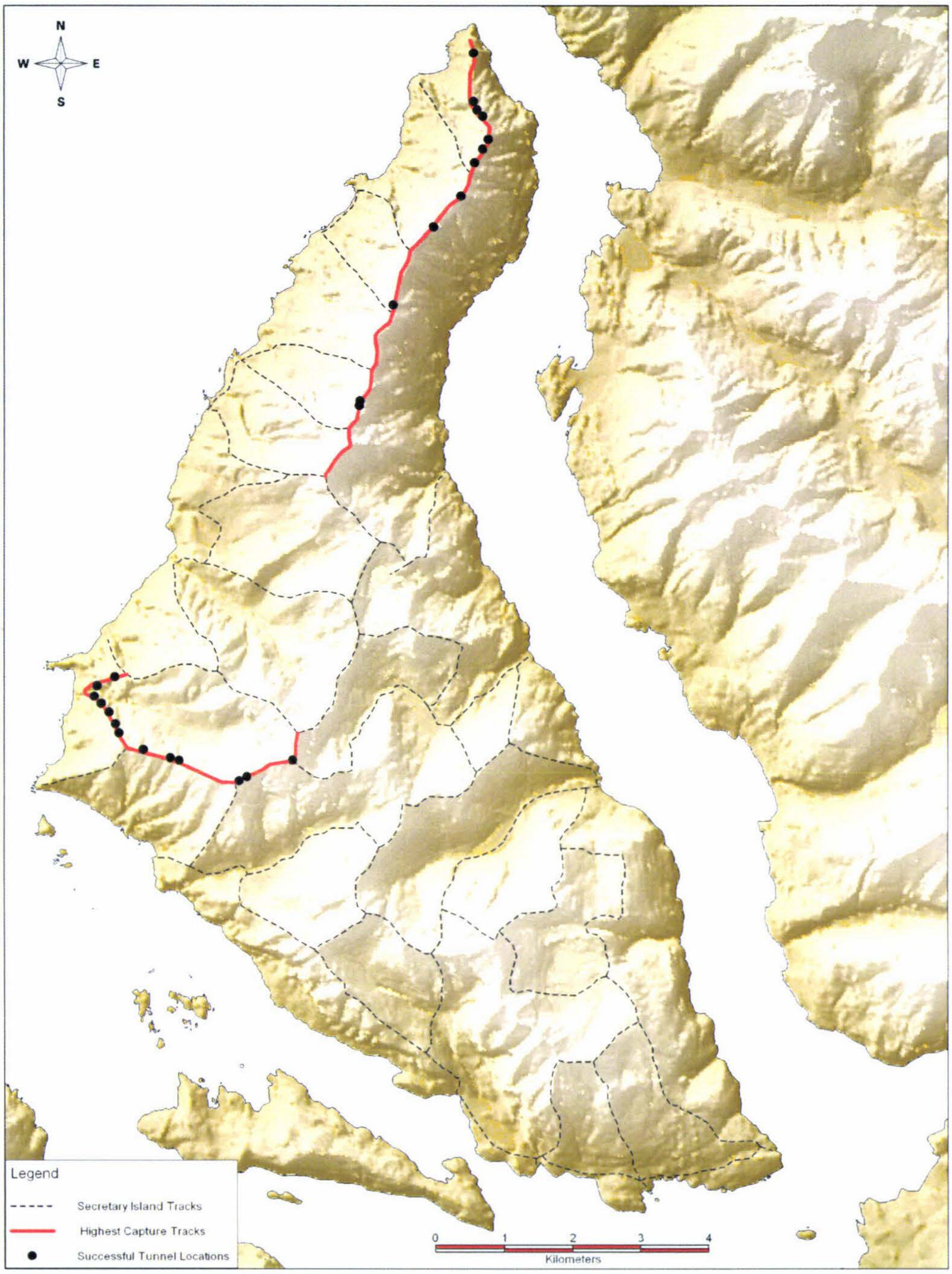

Figure 7.18 Tracks on Secretary Island with the highest number of stoat captures.

The tracks that had successful tunnels on them were analysed and recorded in a spreadsheet with the results being graphed (Figures 7.19 and 7.20).

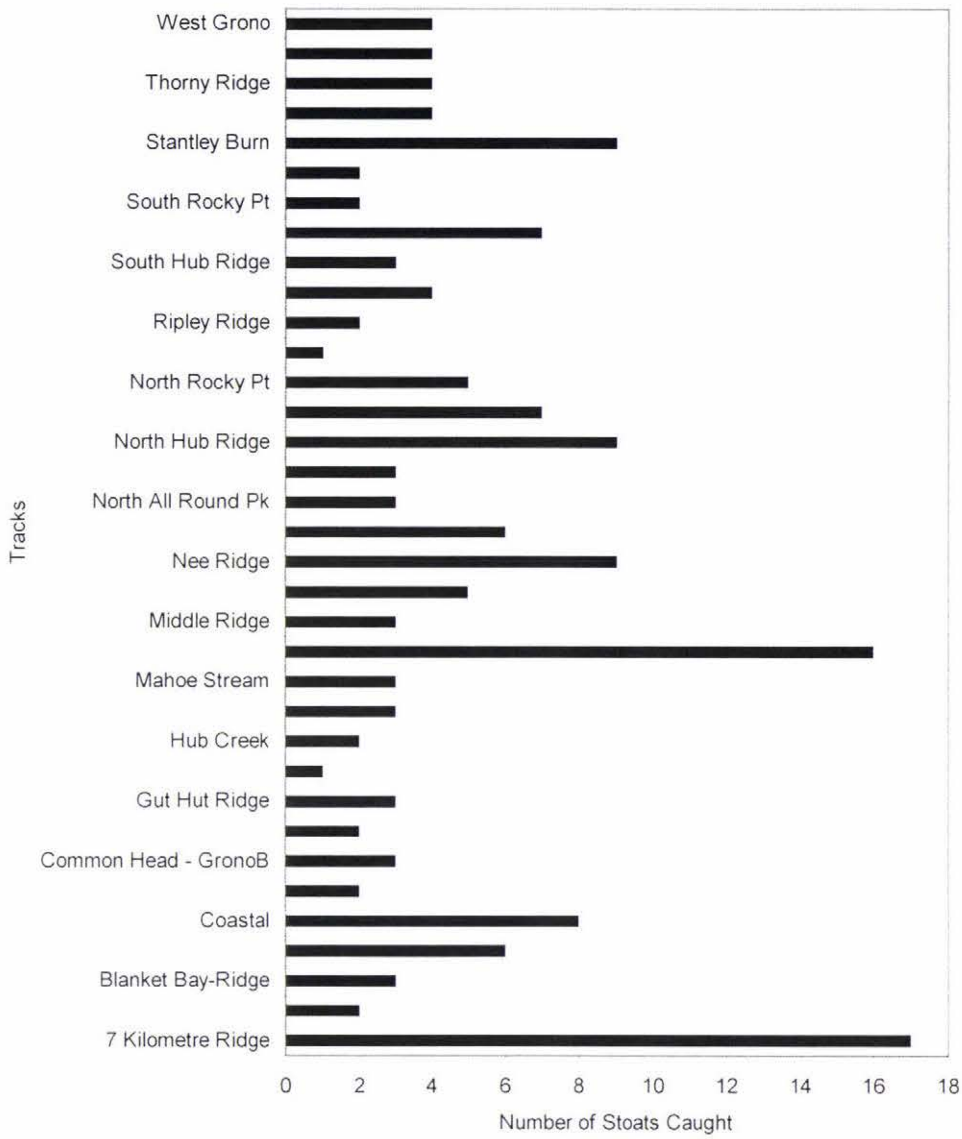

Figure 7.19: Secretary Island successful tunnel captures by track.

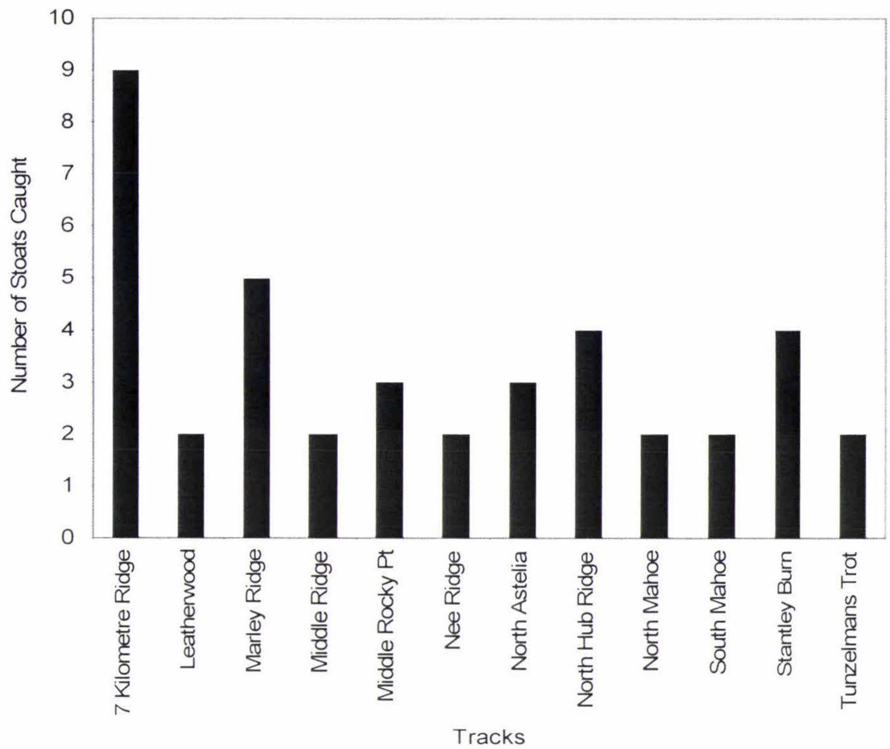

Figure 7.20: Multi-catch tunnels on Secretary Island by track.

The length of each track may have some bearing on the number of successful tunnels. One would expect that due to the fact that a long track would pass through more home ranges than a short track that there would be more successful tunnels along its length. This may be correct but I would suggest that there are other factors such as physiography, aspect, slope and tunnel location that will also have an influence on the success rate of each tunnel. Figure 7.21 shows the number of stoats caught compared to the lengths of each track. There does not appear to be any correlation between these two factors.

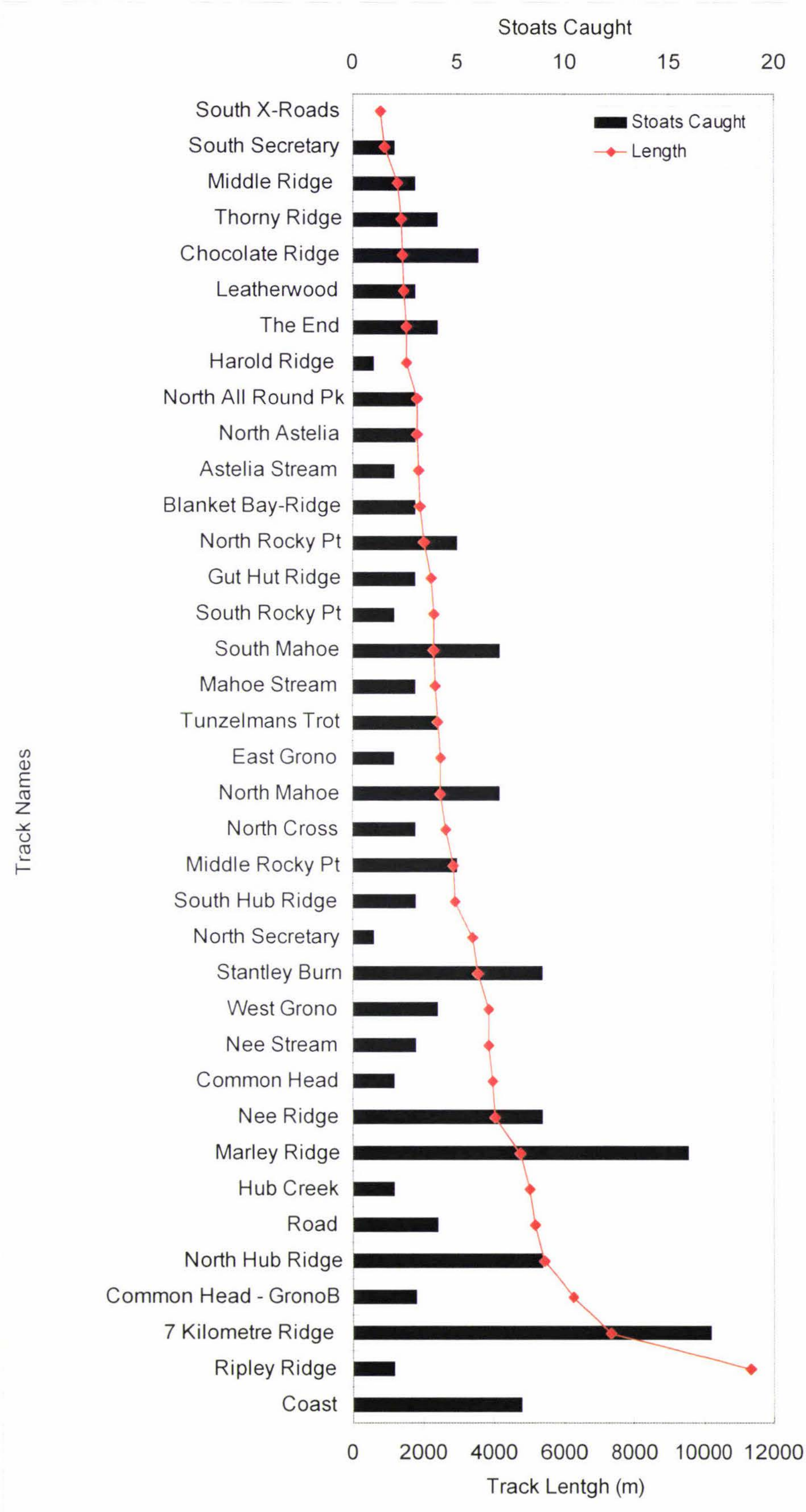

Figure 7.21: Frequency of stoats caught by track length on Secretary Island.

7.3.3: Resolution Island Track Analysis

The level of tracking on Resolution Island is similar to that on Secretary Island providing effective tunnel coverage over the whole island. The coastal tunnels are all serviced by boat and have not been used in length calculations although they are shown on the maps to indicate where the coastal tunnels are located. There are eighty tracks with a total distance of approximately 233 km on the island. The average track length on Resolution Island is 2.9 km which is almost the same as Secretary Island at 3 km. Tracks that followed ridges dominate the total network at 72% (169 km), with tracks running along faces making up 17% (39 km) and those in gullies the remaining 11% (25 km) of the total. This is similar to the track network on Secretary Island where 74% of the tracks are on ridges.

Figure 7.22 provides a comparison between the number of tunnels per track and the number of successful and multi-catch tunnels. As with the Secretary Island results it is feasible to expect the longer tracks with a greater number of tunnels to catch more stoats. These results do not support this theory with one of the smaller tracks number 49 catching the same number of stoats as the longest track.

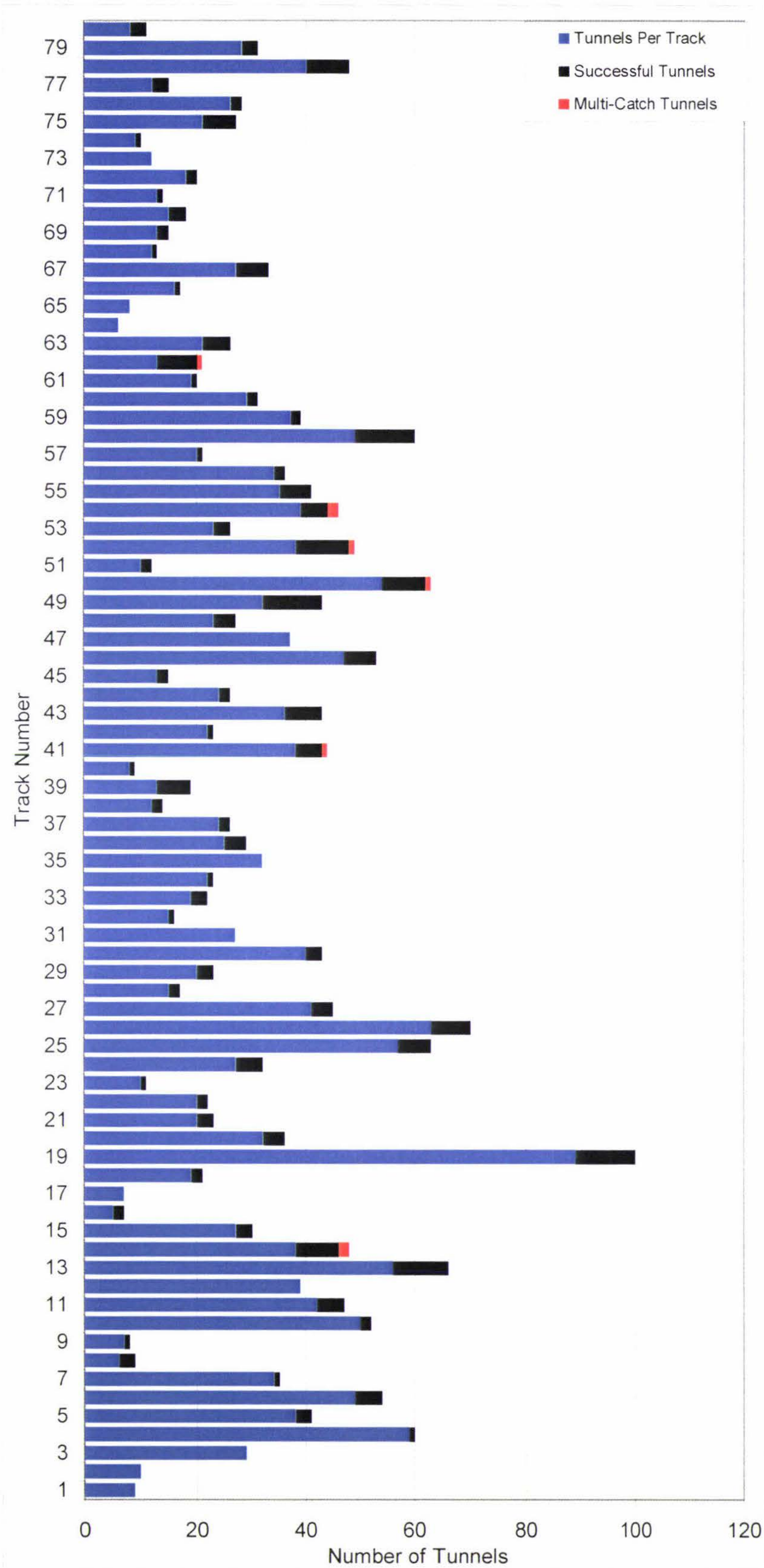

Figure 7.22: The total number of tunnels on Resolution Island by track compared to successful and multi-catch tunnels.

There were only eight tracks out of the total of eighty tracks (10%) that did not have tunnels that caught stoats. Four tracks (Numbers 19, 49, 52 and 58, Figure 7.23, red coloured bars) all caught eleven stoats; three of these were on ridges. The 17 stoats caught (Figure 7.23, blue coloured bar) are a cumulative total for all the coastal tunnels. Secretary Island had one track (7 Kilometre Ridge) that caught more stoats (10) than any of the other tracks. The coastal tunnels were the next highest with 8 stoats caught. This may indicate that these tracks pass through more stoat home ranges, stoats are encountering the tunnels as they travel along the tracks, or they are encountering the tunnels while travelling to areas of high prey presence or while looking for potential mates.

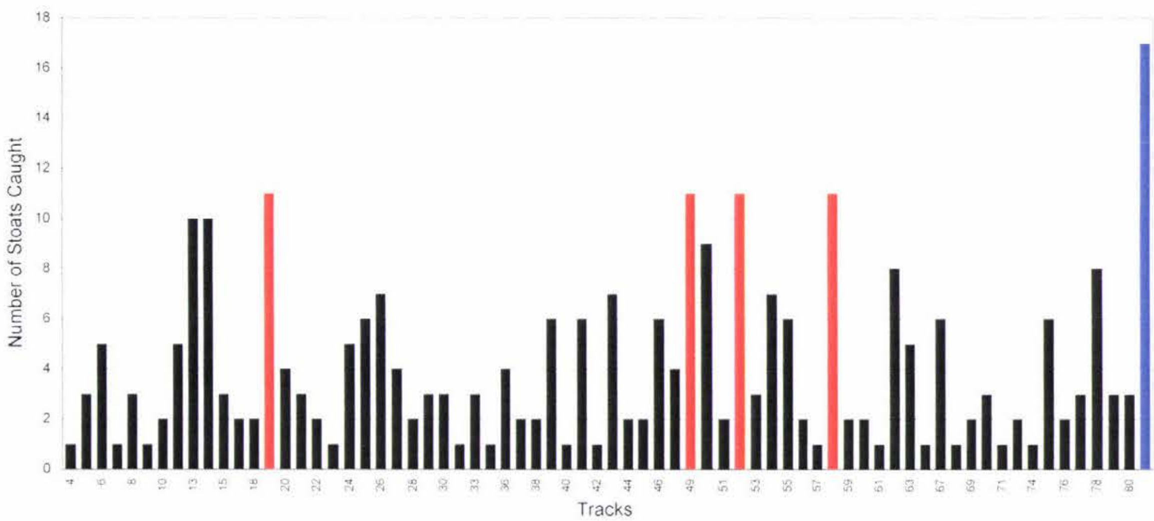

Figure 7.23: Total number of stoats caught by track on Resolution Island.

Resolution Island had more tracks that caught more stoats than Secretary Island but it also had considerably more tracking due to the size of the island. It also appears to show that the stoats are well spread over the whole island apart from one area at the south western end of the island (Figure 7.24). This area is well tracked by three tracks but none of them had any successful tunnels.

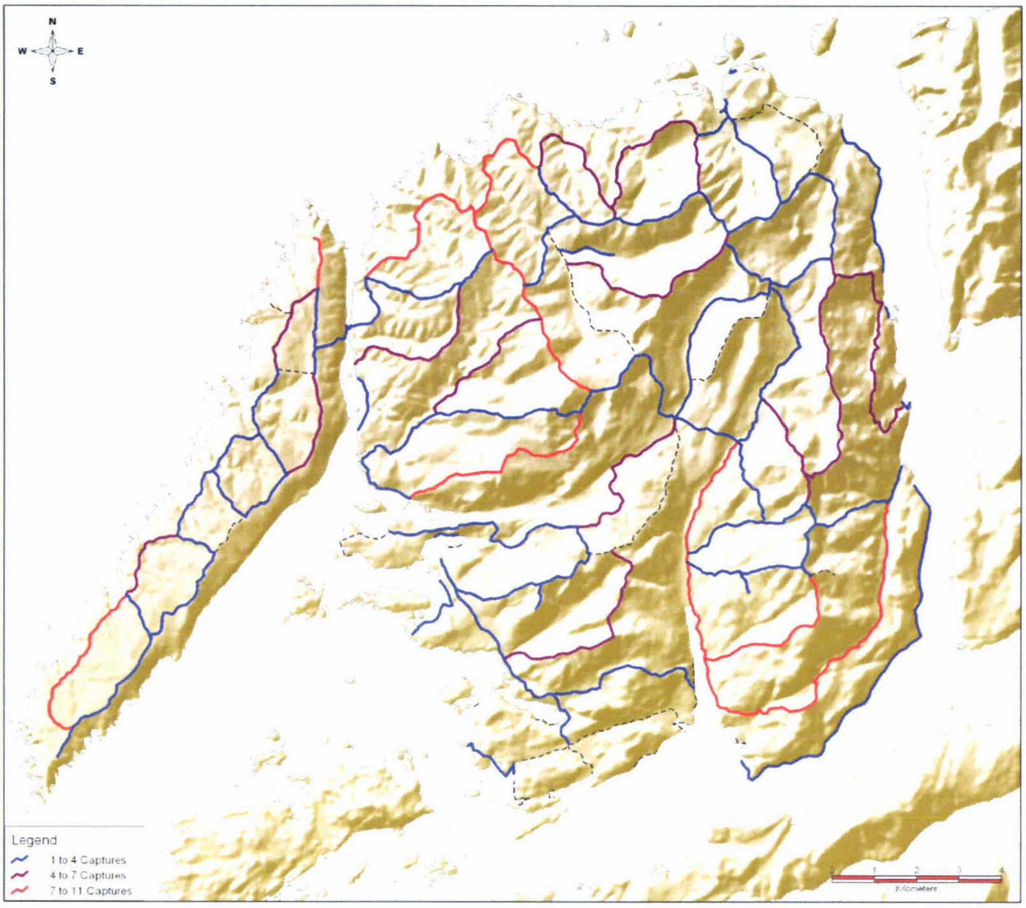

Figure 7.24: The number of stoats caught by track on Resolution Island.

The stoat captures were compared to track length to determine if there was any correlation but as was the case with Secretary Island the results did not provide any pattern that linked track length to higher stoat captures (Figure 7.25). There appear to be other factors that influence the success of a tunnel, and the fact that a track runs through a variety of habitats does not appear to increase the success rate. It may be that a short track just happens to be in a highly populated area and only a small portion of a long track runs through a similarly populated area.

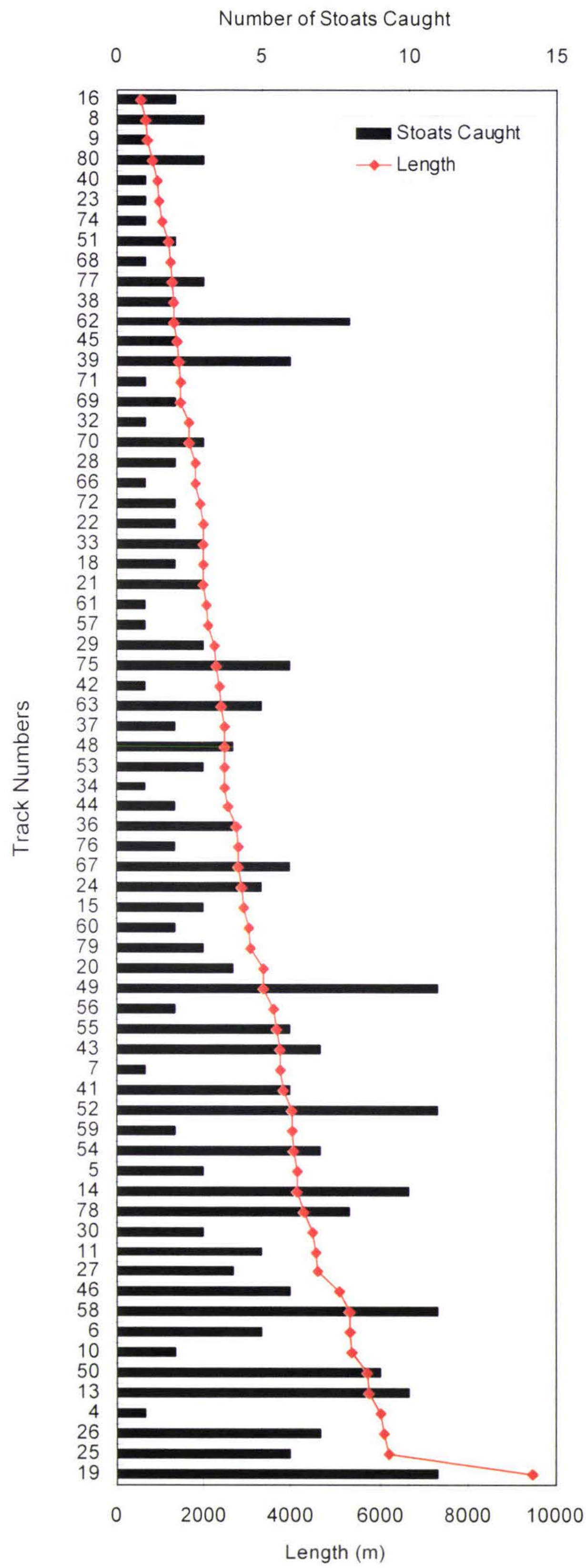

Figure 7.25: Frequency of stoats caught by track length on Resolution Island.

There were six tracks and one coastal tunnel on Resolution Island that caught more than one stoat compared to twelve tracks and no coastal tunnels on Secretary Island (Figure 7.26). Two of these caught four stoats each and both tracks were approximately 4 km long. Of the other four, two were also 4 km long while one was only 1.3 km and the other was 5.7 km. The average length of these tracks was 3.8 km, which was 1 km longer than the overall average.

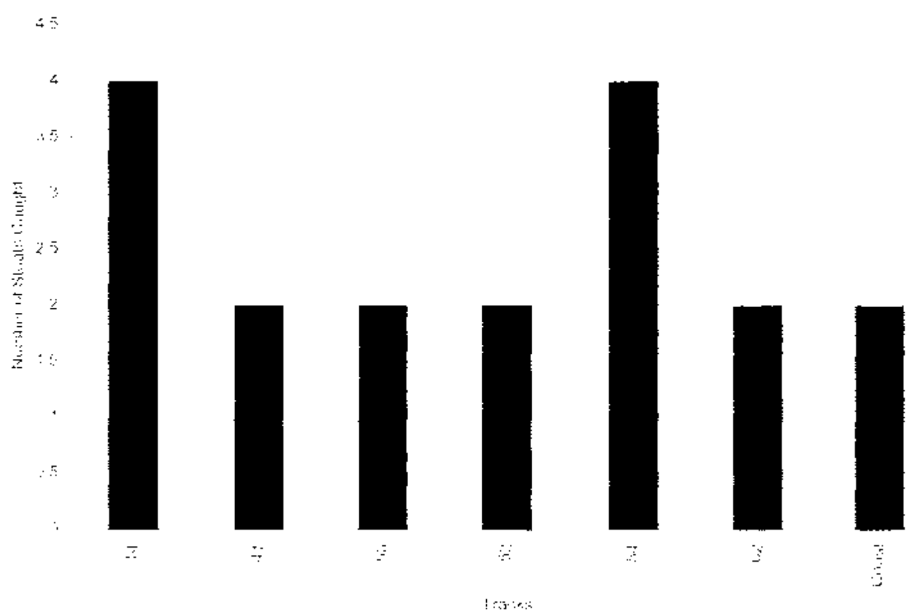

Figure 7.26: Multi-catch tunnels on Resolution Island by track.

7.3.4: Secretary Island Physiography Analysis

The National Vegetation Survey (NVS) standard uses four definitions for physiography: ridge, face, gully and terrace. The topographic data was used to apply one of the four definitions to each of the tunnels. The criteria used to determine tunnels that were on a face were if a track traversed a slope as opposed to running up, down or along a ridge. Gully tunnels were those that followed streams. The physiographies of the successful and multi-catch tunnels were compared with all of the tunnels on the island (Figure 7.27). The tunnels located on ridges made up 69.6% of all tunnels and accounted for 77.8% of all stoat captures.

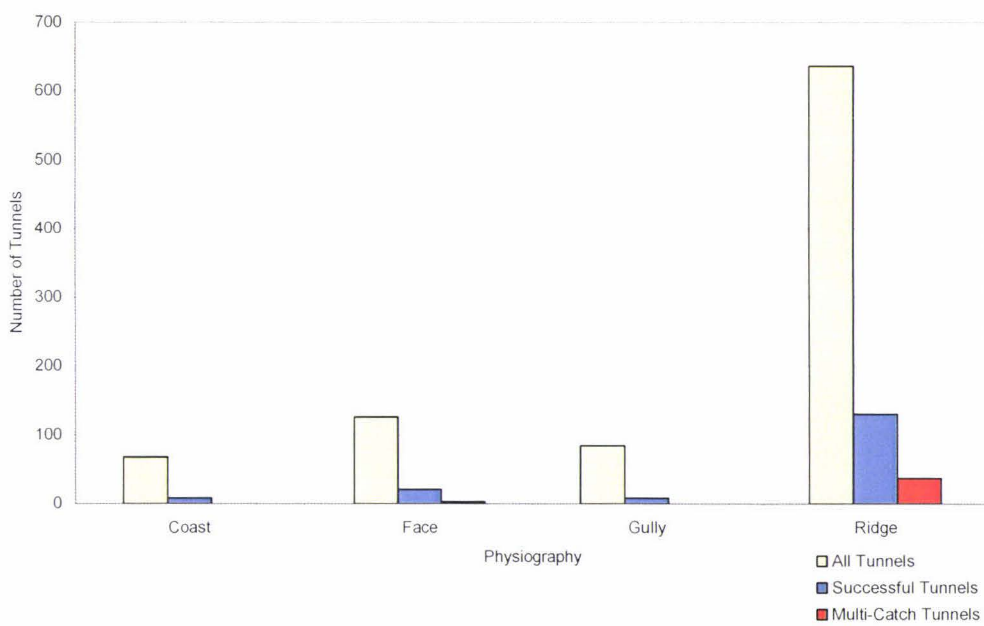

Figure 7.27: Physiography of all Secretary Island tunnels compared to successful and multi-catch tunnels.

Successful tunnels located on ridges accounted for 130 out of 167 (77.8%) of the stoats caught on the island (Figure 7.28) which is similar to the percentage of tunnels located on ridges. This means that there is a relationship between the number of stoats caught and the tunnels that are located on the ridges. However if the majority of tunnels were located on the faces or gullies would this relationship be the same.

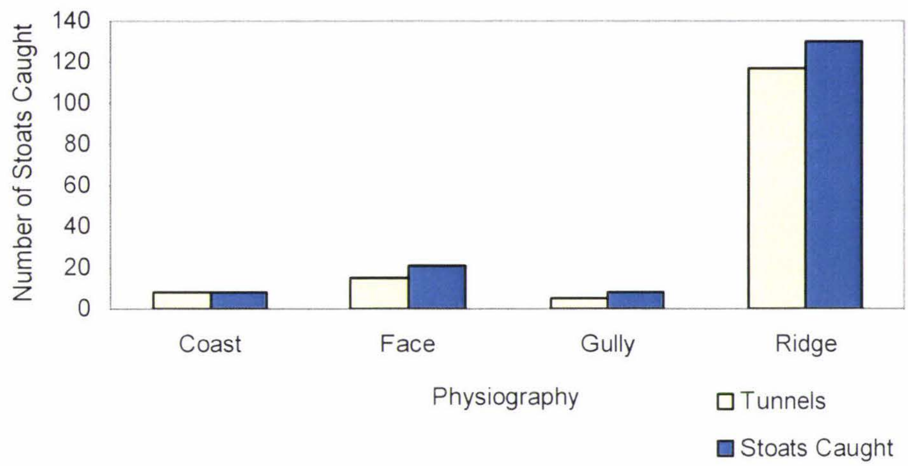

Figure 7.28: Secretary Island successful tunnel captures by physiography.

The multi-catch tunnels were almost all 37 out of the total 40 stoats caught located on ridge sites (Figure 7.29). The multi-catch tunnels show a distinct relationship between tunnels located on ridges and successful captures at 92.5%. This is significantly higher than the successful tunnel results.

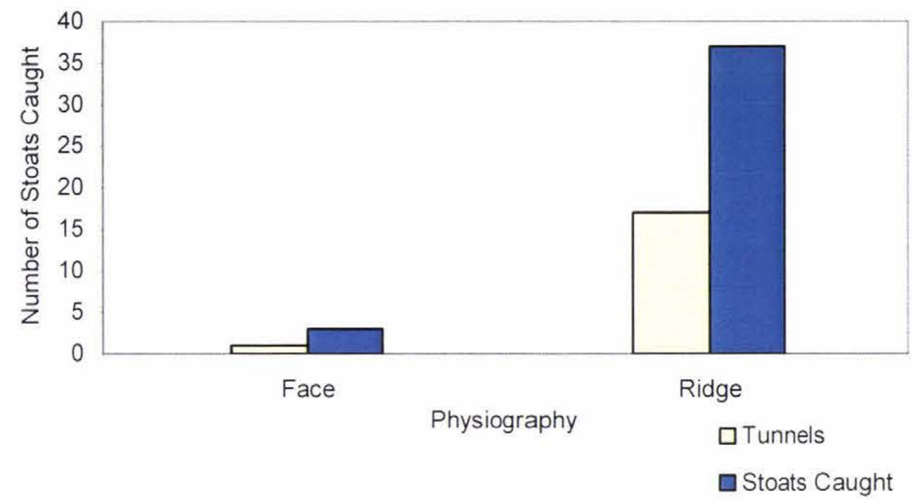

Figure 7.29: Secretary Island multi-catch tunnel captures by physiography.

With ridge tunnels accounting for the majority of captures, both overall and for multi-catch tunnels there is evidence that in further control programmes effort could be concentrated in these areas. Depending on the topography of the control area for an operation this could alleviate the need to cut tracks up the sides of streams as long as the track network still effectively provides the coverage required in the current stoat control guidelines.

7.3.5: Resolution Island Physiography Analysis

The topography of both islands dictate to a certain extent where tracks can be located, and steep mountainous terrain ridges often provide the easiest and most open routes. Because of the high proportion of tracks located on ridges on the two islands (Resolution 69.6%, Secretary 74%) the results displayed in Figure 7.30 are to be expected.

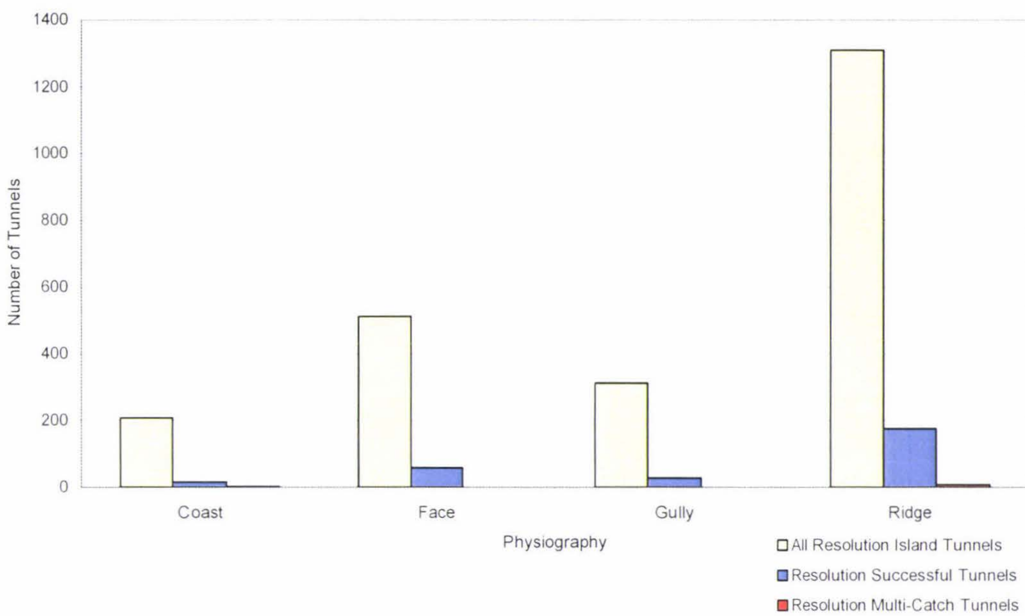

Figure 7.30: Physiography of all Resolution Island tunnels compared to successful and multi-catch tunnels.

The ridge tunnels on Resolution accounted for 63.3% of all stoats caught which is a lower success rate than on Secretary Island where 74% of the tunnels accounted for 77.8% of the stoats (Figure 7.31). The graph almost mirrors the same one for Secretary Island (Figure 7.22) which shows all successful tunnels in relation to physiography. Apart from the higher number of successful tunnels on Resolution Island for the initial knockdown period the physiography for tunnels on both islands follows the same trend.

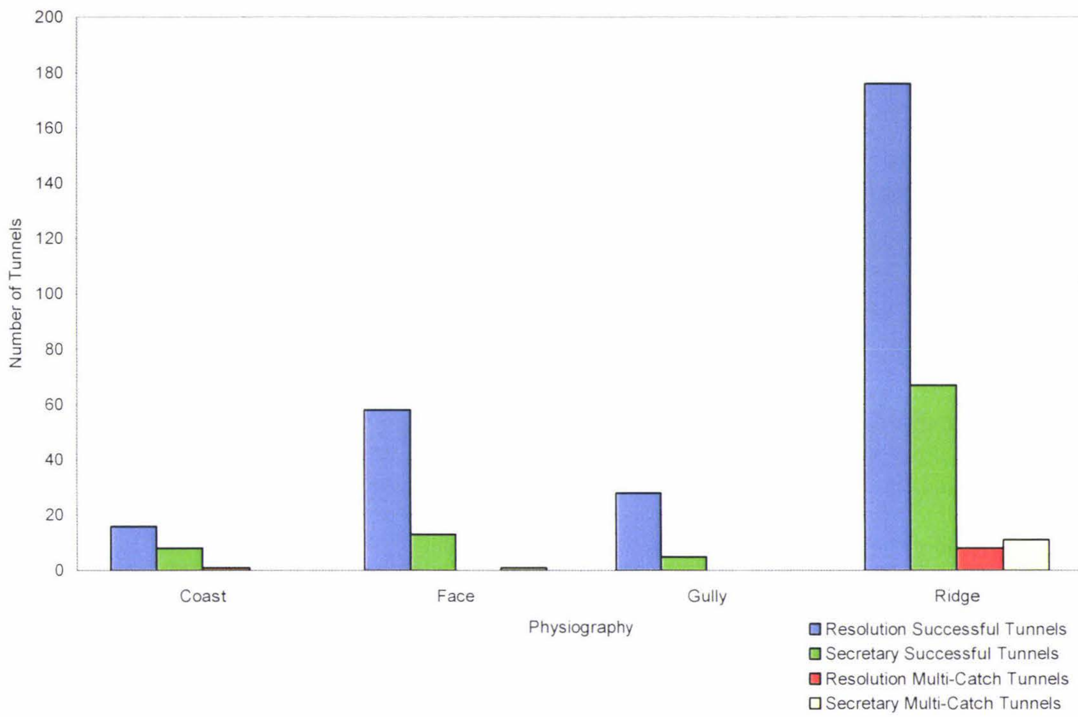

Figure 7.31: Physiography comparison between successful and multi-catch tunnels on Secretary and Resolution Islands.

This is to be expected considering the majority of tunnels are located on ridges and could not be used as an indicator of tunnel success for other control operations unless the track layout followed the same pattern. Due to the erratic nature of the stoat, the results in other areas may differ from those found here.

7.4: Discussion

The topography on both islands makes it very difficult to undertake stoat eradication projects. Due to the extreme nature of the topography and the size of the islands the only plausible way to navigate around the islands and get effective tunnel coverage was to construct a track network. The track network generally followed ridges and streams as these provided the path of least resistance and provided natural features that partitioned the islands.

Because of the very nature of the topography on the islands a high percentage of the tracks were on ridges which subsequently meant that there were more tunnels on ridges than in gullies or on faces. This is reflected in the capture data where more stoats were caught in tunnels located on ridges than any of the other physiographical classes. There is obviously some bias in these results and any conclusions drawn from them could only be applied to control operations undertaken where the topography and the tracking network were similar.

The study does however provide some interesting questions on how the stoat travels around its home range before and after the tracking network is installed. If they naturally use the ridges and streams then the possibility of encountering a tunnel in their normal travels would be very high. However if they only intersect the ridges a certain points travelling to productive food sources either side of a ridge then the probability of encountering a tunnel is reduced considerably. Further research using satellite tracking of stoat's movement patterns may provide answers to these questions and could be used when planning future operations.

Although stoats can be found in most environments, like most animals they will spend more time in preferred areas. The results of the aspect analysis showed that a high proportion of the successful tunnels were located in the warmer north-western facing areas of both islands. This would indicate that the stoats prefer the warmer facing slopes.

Chapter Eight: Data Analysis - Home Range

8.1: Introduction

Home range, as applied to mammals, has been defined by Burt (1943) as

"That area traversed by the individual in its normal activities of food gathering, mating and caring for young".

Food supply, cover, population density, territoriality and other factors may be reflected in size of range. Home range can be considered to represent the living area of the animal; its size is related to the living requirements of the animal. Occasional sallies outside the area were specifically excluded (Stickel, 1954).

If the habitat that the target species frequents is known then by identifying those areas of habitat that they do not frequent you are able to reduce the area of control operations considerably. Inversely by identifying known habitat and concentrating control operations in these areas the chances of improving the success rate of the operation will increase.

Stoats have large home ranges that vary worldwide from 2 to 368 ha (King, 1989; Alterio, 1994; Murphy and Dowding, 1994). In a New Zealand study nearly all of the stoat home ranges were in the upper part of this range (Murphy and Dowding, 1995). Miller et al. (2001) states that the average size of a stoats home range, varies from 69 to 206 ha. This was based on studies carried out in two different ecosystems, New Zealand beech (*Nothofagus*) forest and grassland. Alterio (1998) found that extensive home range overlap was observed between sexes.

Male stoats tend to range further in search of prey and receptive females. Cuthbert and Sommer (2002) suggest that the home range size and territorial behaviour of stoats has important implications for the conservation of wildlife in New Zealand. Dominant male and female stoats mark their territories by either rubbing or an anal drag (Erlinge et al., 1982).

Due to the large home ranges experienced in New Zealand stoats move through various types of vegetative habitats within their home range. Stoats will range through any areas that contain prey species although they still show some preferences to some habitats and avoid others. Murphy and Dowding (1995) found that stoats tended to avoid open areas within their home range. Studies looking at stoat home range tended to coarsely define their habitat into a small number of classifications such as forest, forest margin and open areas (Murphy and Dowding, 1995).

King et al. (1996) used a modified reconnaissance plot of roughly 15 m in diameter centred on the trap location, to describe the vegetation at each trap site. The study covered both podocarp-hardwood forest, logged native forest and exotic plantation forest. The relationship between trap location, capture rate and vegetation was correlated. In this study the largest proportion (50%) of stoats were caught in exotic plantation forest, with 32% in the cutover native and 18% in the podocarp-hardwood forest. There was also a preference for older aged exotic forest stands. Murphy and Dowding (1994) found that all stoats that were tracked in a study in the Eglinton Valley avoided open areas within their home range. This type of information can provide valuable data in the planning stages of a control operation in similar vegetative habitats.

In a patchy environment, where the density of potential prey varies greatly between habitats, stoats and other mustelids have been shown to concentrate their habitat use into areas with the highest density of prey, even though their home range include surrounding areas of relatively barren ground (Oksanen et al., 1992).

Kriton et al. (1996) in a study that looked at the distribution of tsetse flies in the Lambre Valley, Kenya found that there was a correlation between vegetation type and soil moisture. They found that this could be used to predict favourable fly sites in inaccessible sites, and to determine the number and location of fly suppression traps in a local control programme.

By combining this type of known information with other types of stoat specific data such as diet a better picture of how and where the stoat carries out its daily routine can be built up.

Stoats can be active any part of the day or night. King (as cited in Griffiths, 1999) states that they have a rapid metabolism that means that they need to eat frequently, this can be up to five or six times a day. They generally rest after eating before repeating the process.

8.2: Home Range Analysis

The ability to completely understand the biology and habits of the target species is paramount when a control operation is being planned. The identification of the home range of a target species can provide valuable information to the manager of a control operation. Home range analysis provides the area that is covered by the target species during its normal daily routine. Continued observation provides information on favoured areas (core home range), periods of activity and inactivity, preferred vegetation habitat, prey species and habitat, nesting sites and interactions with other members of the same species. In conjunction with this there is also the concept of utilisation distribution which takes the form of a two dimensional probability function that represents the probability of finding an animal in a defined area within its home range.

The home range of an animal is generally constructed from a set of location points that show its position over a period of time. Points can be gathered using visual observation, tracking tunnels, live trapping, telemetry or satellite tracking. The most common method of calculating the home range is to use a method called Minimum Convex Polygon.

The International Union for the Conservation of Nature (IUCN 1994, 2001) rules define the extent of occurrence as the area contained within the shortest continuous boundary that encompasses all sites of present occurrence of a taxon. To measure habitat area, the IUCN (1994) recommended a minimum convex polygon (also called a convex hull). It is the smallest polygon in which no internal angle exceeds 180 degrees and which contains all sites. The minimum convex polygon is easy to compute from coordinate data and it is appropriate for presence only data (Burgman and Fox, 2003).

The method has known drawbacks, the main one being the overestimation of the size of the home range. There are other methods such as the Harmonic Mean, Fourier, Tessellation and Kernel. The one thing they all have in common is that they require a set of point data that represents the location of the animal over a period of time.

Cuthbert and Sommer (2002) used the minimum convex polygon method to determine the home range area of stoats in a colony of Hutton's shearwater. They found that because of the availability of prey the home range sizes revealed were far less than those calculated in studies carried out in *Nothofagus* forest. Prey species tended to be more widespread in *Nothofagus* forest and so stoats had to travel further to find them, hence larger home range areas.

The data available for this study only provided one point for each stoat caught. A single point could not be used with any of the abovementioned methods to generate the stoat's home range. This meant that the only option available to generate home range was to buffer each successful tunnel using a radius measurement that would approximate the home range area. Jennrich and Turner (1969) suggest that circular home ranges tend to give a smaller estimate than a long narrow one encompassing the same area.

Home range size for this study was based on data from a study by Miller et al. (2001) of between 69 and 206 ha. The minimum, average and maximum areas were used as a basis for a circular buffer around the successful and multi-catch tunnels. The following radii were calculated using the calculation πr^2. In this case the area of each home range was known so the radius had to found. This provided a radius of 468, 663 and 810 m respectively for the representation of each home range.

When the maximum circular home range was generated for the successful tunnels the result approximated the original 700 m track buffer coverage (Figure 8.1). The area covered by the circular home range was 7269 ha compared to 7675 ha for the track buffer or 94.7% (Figure 8.2). This means that theoretically a smaller number of tunnels could effectively cover the same amount of area but does not provide any indicators as to habitat preference which could be used in a model. The effective area covered reduced to 6497 ha (84.6%) using the average home range and down to 4674 ha (60.9%) with the minimum home range. Although the effective area that would be covered by the smaller circular home range areas was reduced, all types of habitat, terrain, aspect, slope and altitudinal levels were encompassed.

When interviewed on 16 September 2007, A. Cox (Department of Conservation) suggested that when considering the tunnel layout for a control operation the home range of the female stoat should be used because they are the driver for breeding potential and if the female population is dropped by, say, 70%, then this will drop the breeding potential by 70%. The same does not apply if the male population is dropped by 70.

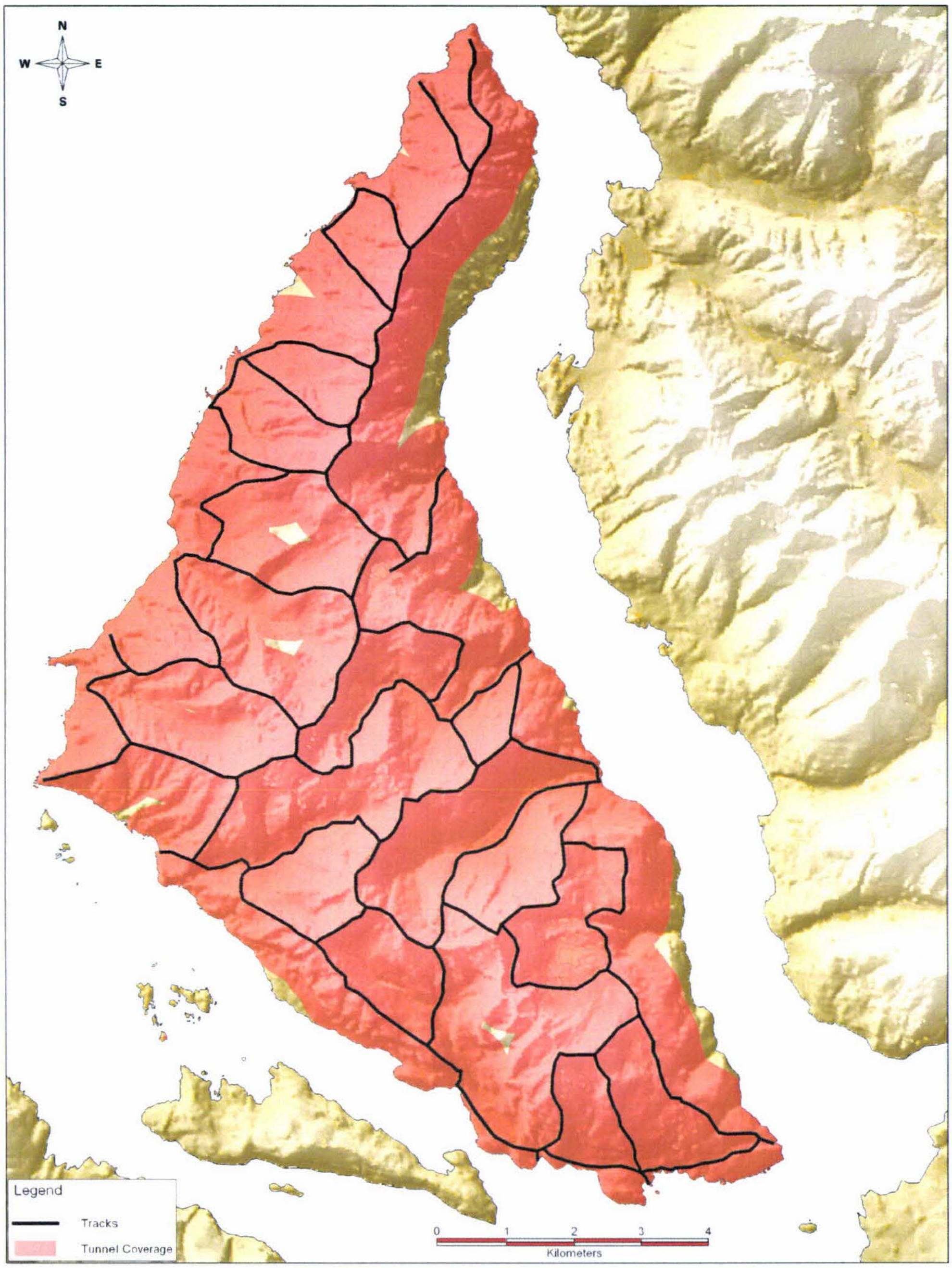

Figure 8.1: Predicted tunnel coverage on Secretary Island based on a 700 m buffer either side of the track network.

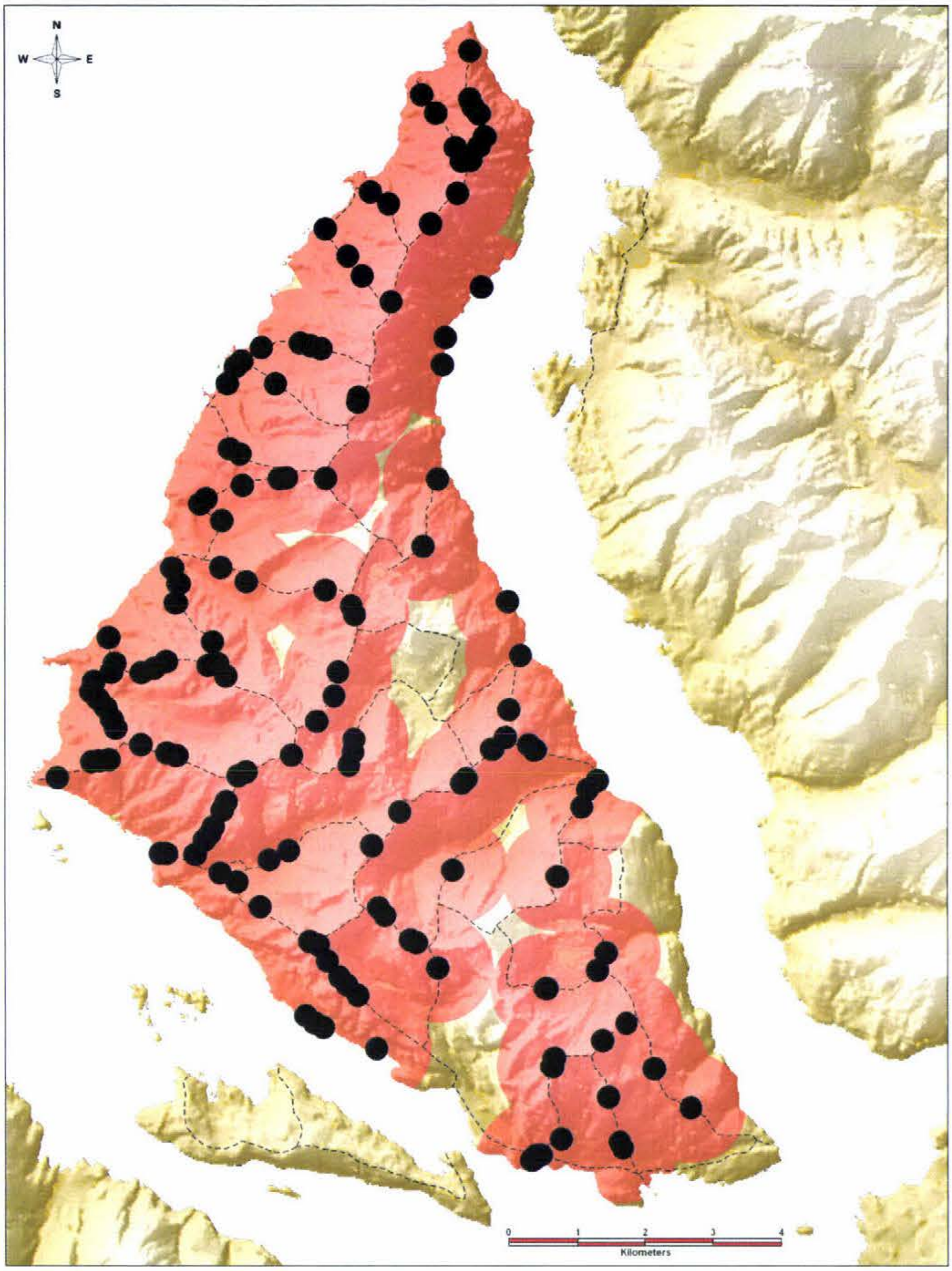

Figure 8.2: Maximum circular home range of all successful tunnels on Secretary Island.

8.3 Hot Spot Analysis

8.3.1: Introduction

Hot spot analysis is a process that identifies clusters of related incidents or areas of high concentrations. It is widely used as a tool in crime analysis and disease informatics applications (Chen et al., 2004). Several typologies of cluster analysis have been developed as cluster routines; they typically fall into several general categories (Everitt, 1974; Can and Megbolugbe, 1997). One of these, Point Locations, is the most intuitive type of cluster routine involving the number of incidents occurring at different locations. Locations with the most number of incidents are defined as 'hot spots'. This is an area of larger activity within an area of lower activity. This type of analysis can be applied to any type of point data to provide an indication of preferred (hot spot) sites.

8.3.2: Secretary Island Hot Spot Analysis

Hot spot maps depict features that are used to generalize and simplify isopleth (continuous surface) maps. This is a map that shows a continuous distribution of data such as density values or surface elevations. They are very useful for displaying very complex information in a way that is easily understandable by a wide audience. The GeoMedia GRID application extracts hot spots from isopleth maps. To generate a hot spot map from the trap capture data the point data firstly had to be converted to an isopleth surface. The "Density" command is used to achieve this. Points are aggregated together within a specified search radius to create a smooth surface that represents the density of events across the area. The kernel density method used by GRID identifies the location, the spatial extent and intensity of hotspots. During this process the ability to use a weighting is available. This has to be a numeric value that is an attribute of the point feature being used to generate the density surface.

In this exercise the following values were applied to both the successful tunnels and the multi-catch tunnels (Table 8.1).

Stoats Caught	Weight Value
1	1
2	5
3	8

Table 8.1 Density weightings used in the generation of the density surfaces for Secretary Island and Resolution Island.

Figure 8.3 shows the result of producing a density map based on all successful tunnels. The density surface was blended (draped) with the relief model to create the completed map. In doing this the low density areas which were originally light red now appear translucent. The high density areas are thus highlighted by the darker red areas. This provides a graphical depiction of the areas that had higher densities of captures. The bottom third of the island has very low densities with the higher densities concentrated along the northwest facing slopes and the central east-west running ridge. If the tunnels in the bottom third are removed this relates to 127 out of the total 167 captures, or 86%. Looking at the captures on the northwestern slopes only, there were 87 out of the total of 167 captures, or 52%.

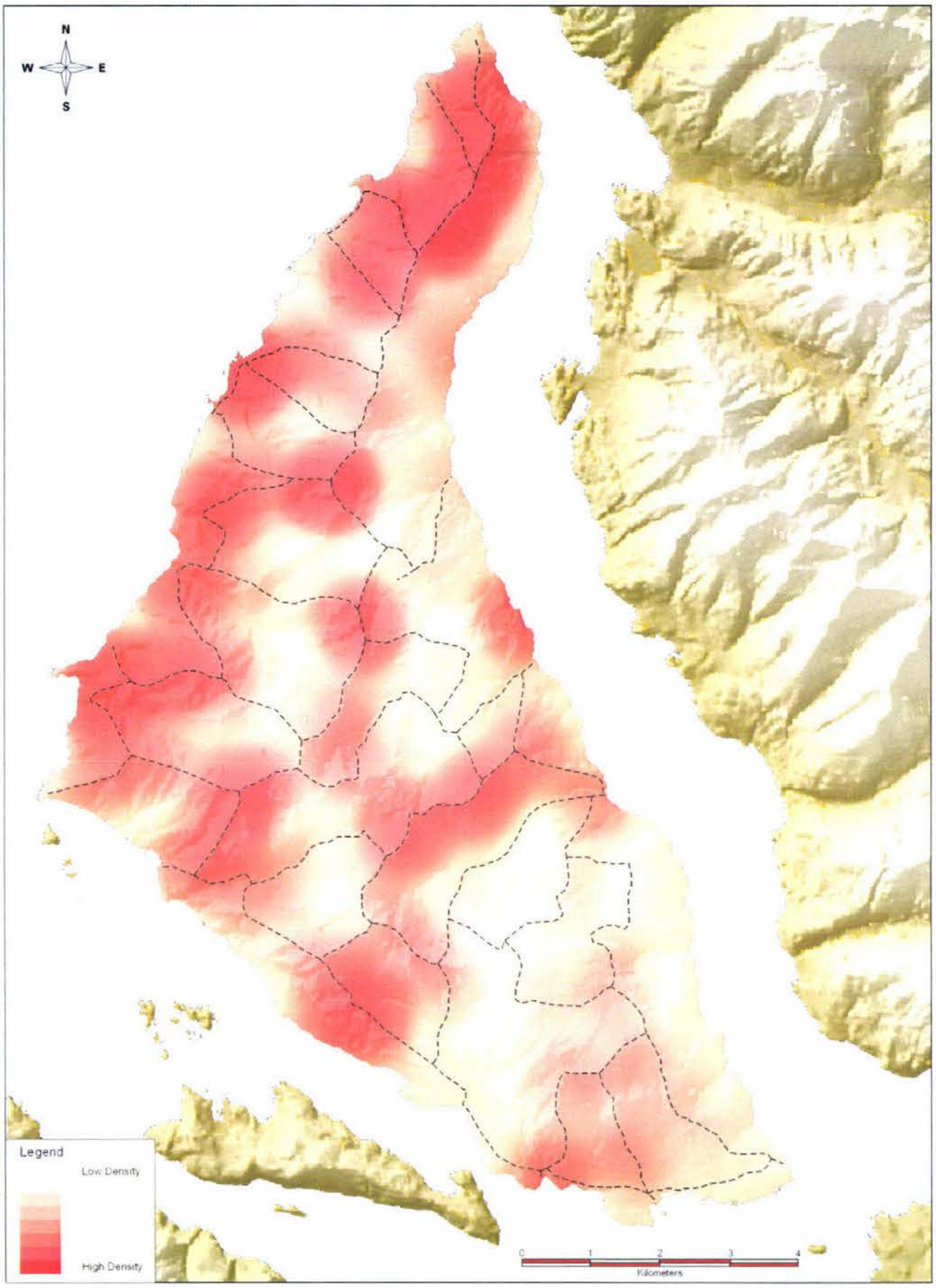

Figure 8.3: Density map of all successful tunnels on Secretary Island.

The preference for the northwestern slopes becomes even more obvious when the multi-catch tunnels are used to generate a density map. The highest densities are concentrated on the northwest side and northern tip of the island with the area at the top of the island having the highest density as shown in Figure 8.4.

These tunnels accounted for 27 stoats out of the total of 40 stoats caught, or 67.5%. This could provide conservation managers planning similar operations in similar environments with useful information. Based on this they could choose to have higher concentrations of tunnels on ridges and gullies that are facing northwest and reduce the number of tunnels elsewhere.

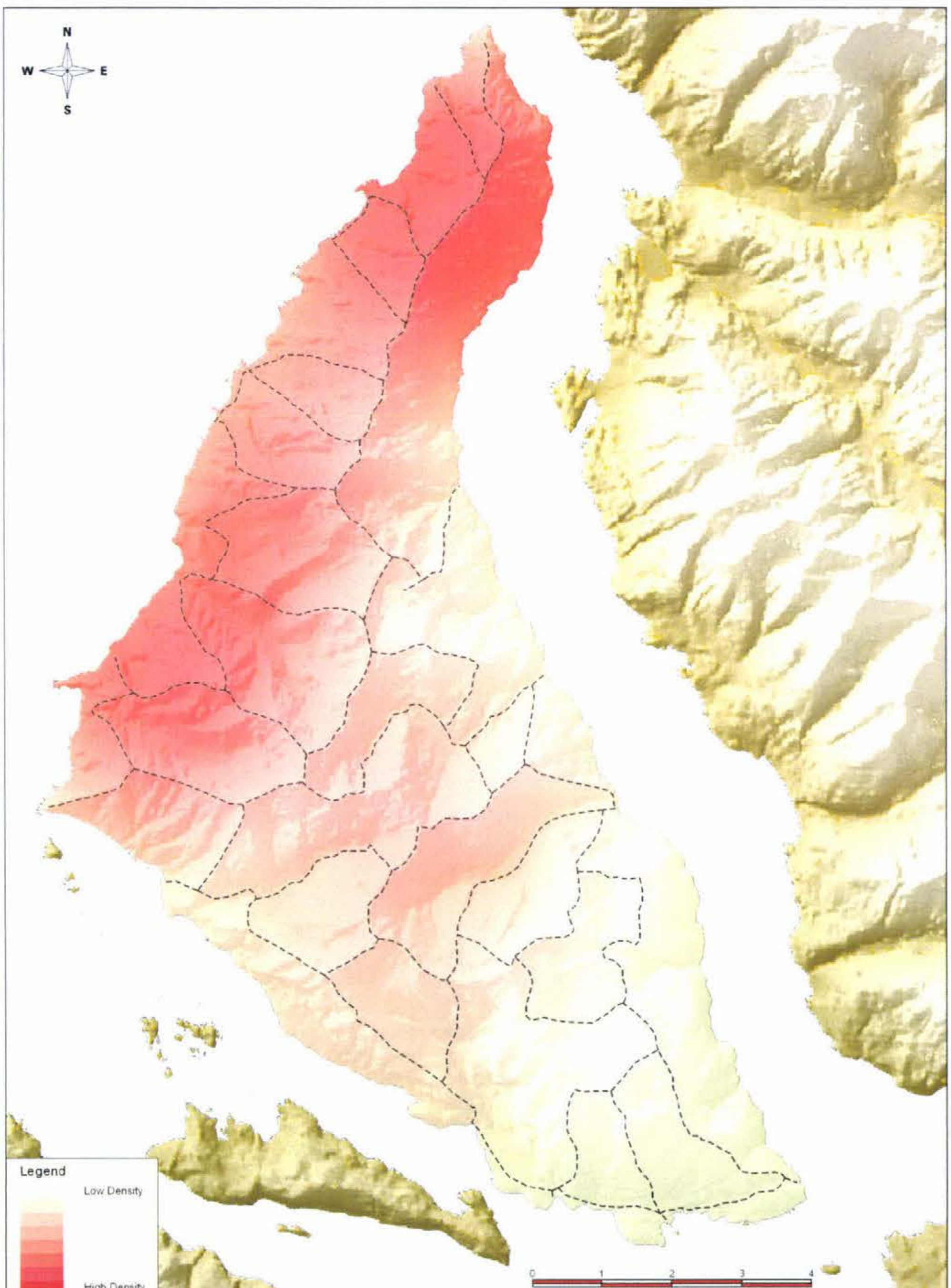

Figure 8.4: Density map of all multi-catch tunnels on Secretary Island.

With the density surfaces generated the hotspot classification could be carried out. This provides a graphical representation based on the density surface of where the areas of highest stoat capture occurred (Figure 8.5).

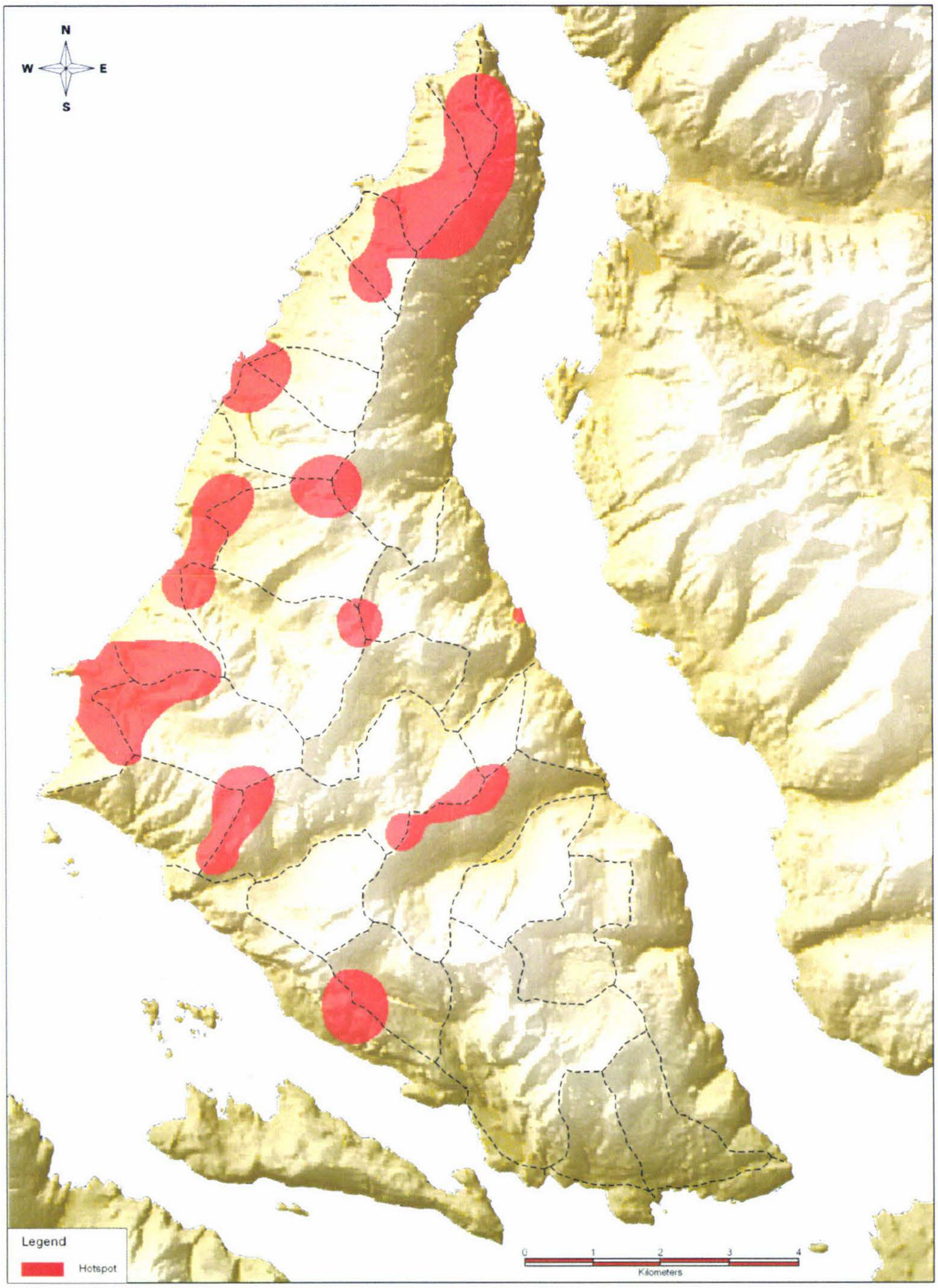

Figure 8.5: Hot spot classification of successful tunnels on Secretary Island.

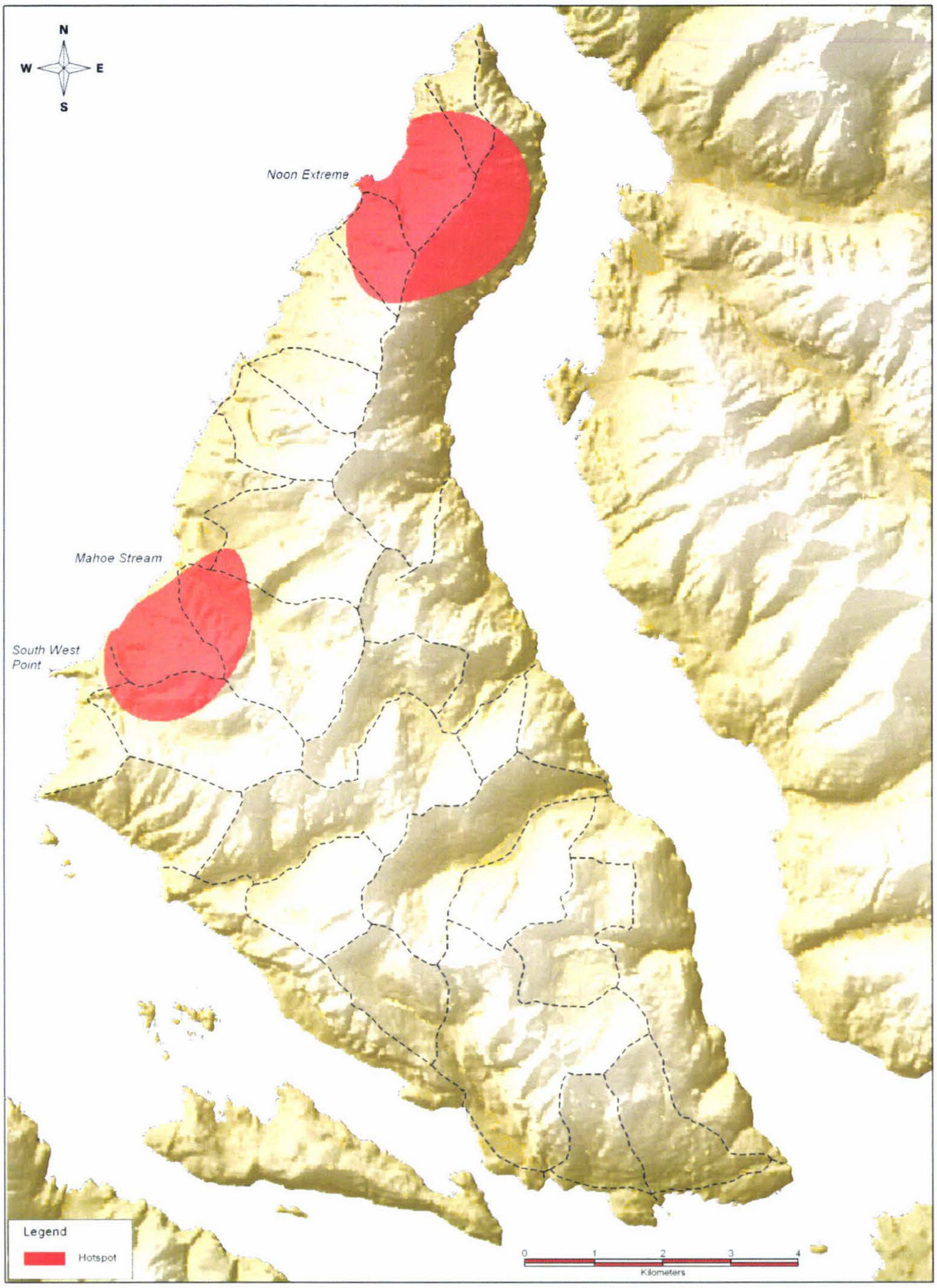

Figure 8.6: Hot spot classification of multi-catch tunnels on Secretary Island.

Using the multi-catch tunnel density surface for the hotspot classification further refines the areas on the north-western side of the island (Figure 8.6). Two distinct areas are generated by the analysis, one covering the northern end of the island around Noon Extreme and the other in the area between South West Point and Mahoe Stream.

The area at the northern tip of the island encompasses both the north-west and south-west facing slopes with the main ridge running through the middle while the area above South West Point is an area of broken country dominated by gully and ridge systems that run from the main north-south ridge down to the coastline. Although these are two distinct areas, they encompass all terrain and vegetation associations on the island which does not provide any possibilities for identifying specific tunnel characteristics that could be used in a model.

8.3.3: Resolution Island Hot Spot Analysis

The same analysis was applied to the initial knockdown data for Resolution Island and compared with the results for the same period for Secretary Island. The density surface for Resolution Island (Figure 8.7) shows a pattern similar to Secretary Island (Figure 8.3) with higher densities in pockets over the island. The northwestern area of the island has the highest densities, as does one ridge area in the southeast portion of the island.

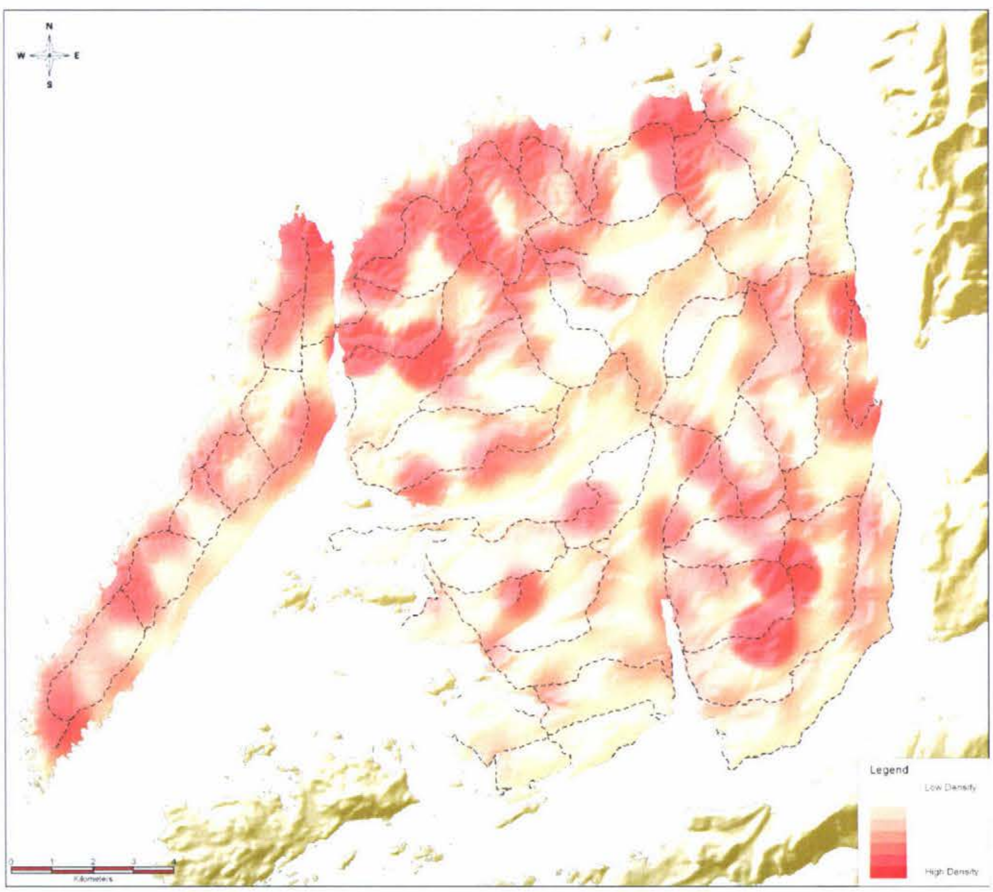

Figure 8.7: Density map for all successful tunnels on Resolution Island.

The density map of the multi-catch tunnels shows this trend more dramatically with the north western part of the island displaying the highest densities (Figure 8.8). The concentration in the northwest of the island is comparable with those for the multi-catch tunnels on Secretary Island (Figure 8.4).

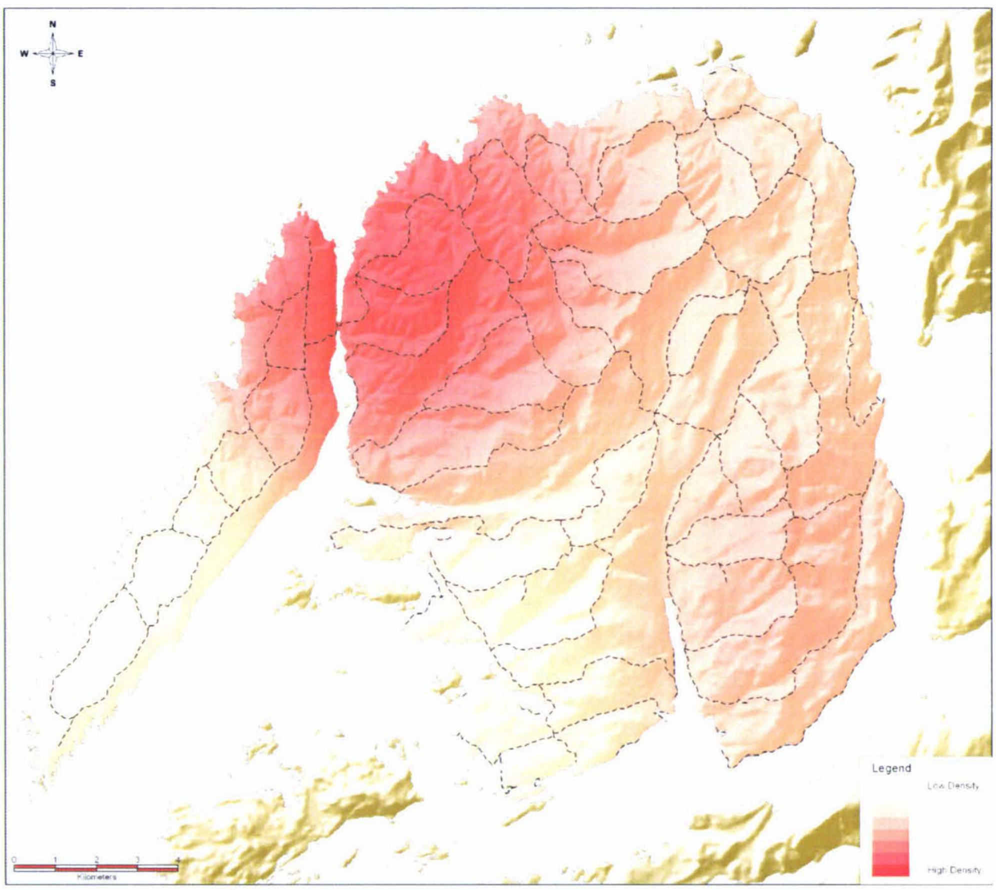

Figure 8.8: Density map of multi-catch tunnels on Resolution Island.

The two isopleth surfaces generated by the density process were then used to create a hotspot surface for all of the successful tunnels and then the multi-catch tunnels. The successful tunnels produced a surface that had multiple hotspot areas mainly concentrated in the northwest of the island but with some interesting deviations (Figure 8.9). Two of these were around two of the higher peaks in the southeast of the island, Mount Lyall and Mount Forbes, with the other two by the coast on opposite sides of the island. The one on the west of the island is where a track coming down a ridge intersected with a track running along parallel with the coast. The one on the east of the island is where two tracks start on the coast.

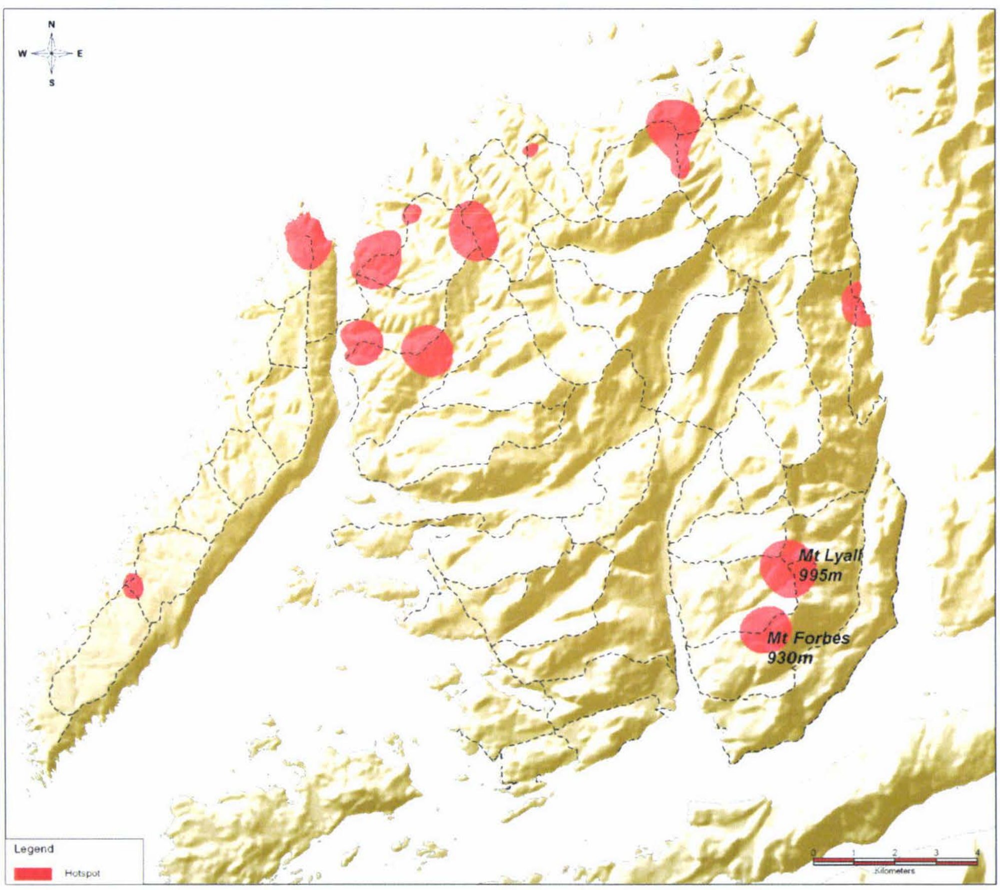

Figure 8.9: Hot spot map of all successful tunnels on Resolution Island.

The hot spot surface for the multi-catch tunnels reflect the same trend as the successful tunnels, with concentrations in the northwestern part of the island and one other area around Mount Lyall and Mount Forbes (Figure 8.10). This is an interesting deviation from the pattern seen on Secretary Island where all of the multi-catch tunnels in the hot spot surface were in the northwest of the island. The other interesting comparison is that this area is one of the colder areas on the island when you analyse the aspect map in chapter 7 (Figure 7.13). The hotspots in the northwestern part of the island are on the warmer faces whereas the ones around the two mountains have steep cold faces on the eastern side. This may act as a natural barrier which concentrates the stoats from the western slopes along the ridge at this point.

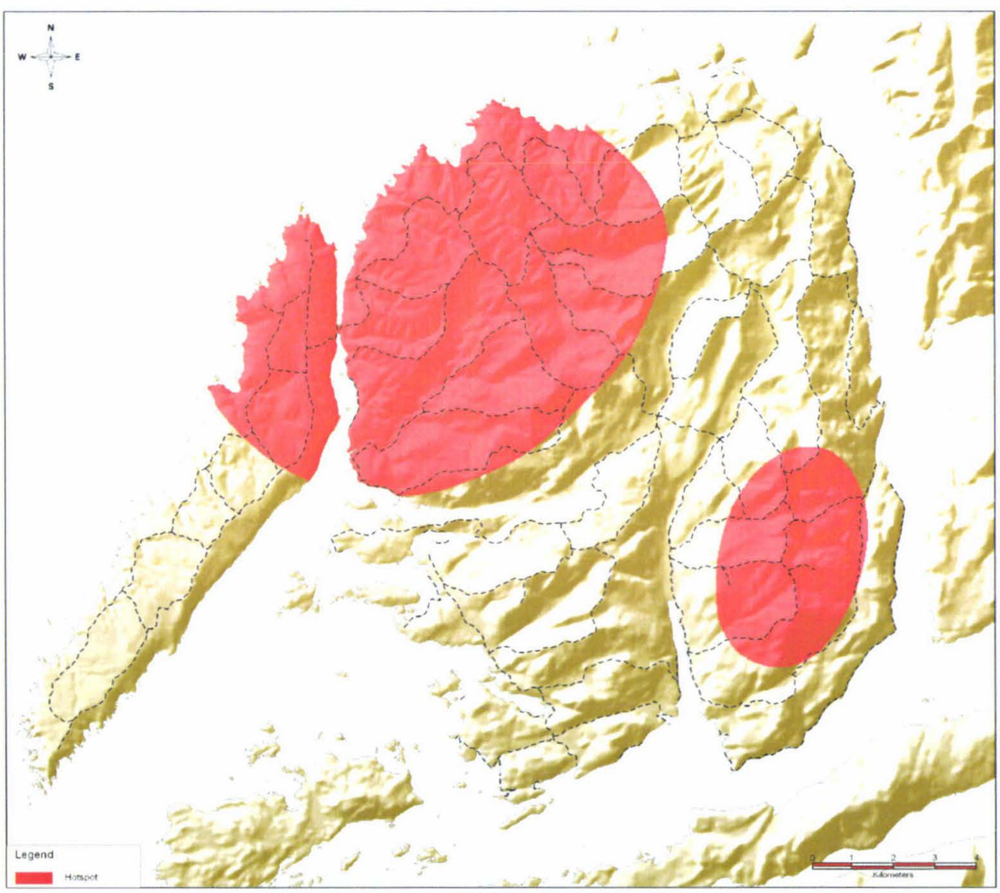

Figure 8.10: Hot spot map of the multi-catch tunnels on Resolution Island.

8.4: Discussion

There are similarities between the initial knockdown data for the two islands. The warmer facing slopes in the northwest of both islands appear to be the areas where the higher concentrations of stoats have been caught. This is certainly the case when the multi-catch tunnels are used in the analysis. However the deviation from this pattern around the two mountains on Resolution Island would worth further investigation to try and determine what might influence the higher capture rates. The results for Resolution Island are only for the initial knockdown, and may change when there is more data from subsequent check periods. It is, however, interesting to see that there is a commonality between the two sets of data and this may provide the basis for a spatial model if higher resolution data becomes available.

Chapter Nine: Data Analysis - Diet

9.1: Introduction

The general food habits of the stoat are described in detail by King and Moody (1982). Stoats are flexible and opportunist in their diet (Murphy and Dowding 1995). A change in abundance of prey may cause a diet shift (Murphy and Bradfield 1992; Murphy et al., 1998). In New Zealand rats, birds, lagomorphs (rabbits and hares (*Lepus europaeus occidentalis*)) and mice are major items of prey in habitats where they are available. Female stoats tend to eat smaller prey species than males. Males will eat more lagomorphs, rabbits *(Oryctolagus cuniculus L.)* and hares (*Lepus capensis L.*) and possums (*Trichosurus vulpecula*), while females will eat smaller prey such as rats (*Rattus rattus*), mice (*Mus Musculus*) and invertebrates.

Invertebrates, such as weta (Order: Orthoptera) make up a large percentage of frequency of occurrence but, because each item is small, a much smaller proportion of diet by weight frequency (Griffiths, 1999). Ground weta (*Hemiandrus* spp.) were the most common prey for stoats inhabiting alpine grasslands in the Borland Burn (Smith, 2007) and the Murchison Mountains (Smith et al., 2005). Cuthbert et al. (2000) found that the majority of invertebrates found in stoat scats were identified as those of weta.

9.2: Diet

Stoat numbers are related to prey species. When there is an increase in the number of a prey species the stoat population increases. When the prey species numbers drop, stoat numbers drop but more slowly. At this stage other prey species come under threat of predation. This scenario has been tested when the mouse population increases dramatically during a beech mast year. These happen every three to five years (Wardle, 1984) and the beech trees produce increased amounts of seed.

In the summer following a beech seed mast, first insect numbers, then mice and then stoat numbers erupt (O'Donnell, Dilks and Elliot, 1996). When the increased populations of prey species drop off, the stoats look at alternative food sources. This is when threatened species are most at risk.

King and Moody (1982) suggest that if stoat control operations in New Zealand's national parks are to be successful then a precise description of the food habits of stoats and the associated habitat is required. In a study they carried out, the gut contents of 1514 stoats were examined and the prey species identified. These were identified and grouped by: feathers, eggshells, hairs, fragments of exoskeleton, fragments of lizard skin and other. The habitats the stoats were caught in were classified as beech forest *(Nothofagus spp.)*, podocarp/broadleaved forest, mixed forest, scrub, grassland and alpine. The study concludes that the most frequently eaten prey of the stoat are birds, feral house mouse, lagomorphs, rats, possums and insects. By studying the relationship between prey species and habitat you can start to form a picture of the types of habitats where stoats will look for a particular prey species.

Lagomorphs are rare or absent in many New Zealand forests, where their place as large mammalian food for stoats is taken by possums. Lagomorphs prefer grasslands and are not generally found in forested areas, whereas possums prefer forest areas. You would expect that stoats caught in forested areas would be predating largely on possums and not lagomorphs. The reverse would also apply (King and Moody, 1982). By understanding the dietary requirements of the stoat and the relationship between the prey species and the habitat it survives in, it is feasible to identify these areas and expect that by locating traps in these areas there would be a greater chance that stoats would be caught.

By researching the habitat of the prey species of the stoat and comparing it against the trap catch data from existing control programmes to see if there is any correlation it is feasible that it could be used for the basis of a predictive model.

9.2.1: Stoat Stomach Contents Data

Table 9.1 shows the results of seven specimen jars containing the remains from the gut contents of stoats provided for analysis that provide an indication of stoat diet on Secretary Island. Based on this analysis it would seem logical to assume that ground weta are an important part of the stoat's diet on Secretary Island. If stoats actively search out the burrows of ground weta as opposed to randomly catching them when the weta are active at night this could provide conservation managers with an important piece of information that could be used when looking for suitable stoat tunnel locations.

Sample	Common Name	Family	Genus	Species
6	Ground Weta	Anostostomatidae	*Hemiandrus*	*fiordensis*
3	Seed material and unknown invertebrate remains			
17	Ground Weta	Anostostomatidae	*Hemiandrus*	*fiordensis*
23	Bird feathers			
	Adult moth			
	Ground Weta	Anostostomatidae	*Hemiandrus*	*fiordensis*
12	Bird feathers			
	Adult moth			
	Ground Weta	Anostostomatidae	*Hemiandrus*	*fiordensis*
19	Ground Weta	Anostostomatidae	*Hemiandrus*	*fiordensis*
	Cave Weta	Rhaphidophoridae		

Table 9.1: Summary of stoat gut samples taken from Secretary Island for analysis.

The data sets that are available for this study are very coarse in comparison to the invertebrate habitat. The ability to identify their habitat from the available datasets would be extremely difficult, if not impossible. If weta prefer a particular soil type and location for their burrows and this data was available then it would be possible to analyse this in a GIS and produce a site preference surface. However, this would not stop an operator from selecting tunnel locations that are adjacent to weta burrows if they are easily identifiable in the field.

9.3: Invertebrates

On Secretary Island there are no rats, mice or possums. Therefore the diet of the stoats is restricted to invertebrates, lizards, birds and possibly fish. When interviewed on 17 September 2007, A Cox (Department of Conservation) suggests that on Secretary Island because there are no mice any bird is susceptible to predation. Stoats will also scavenge carrion and invertebrates will become more important in their diet than in other places. Taylor and Tilley (1984) found fish bones and scales of fish less than 100 mm long in the stomach contents of 14 stoats caught on Adele Island in Tasman Bay. Taking rats, mice and possums out of the diet of stoats should theoretically make the identification of prey species habitat easier but in fact it makes it more difficult.

Invertebrates and lizards are small and have relatively small home ranges. Invertebrates found in stoat studies generally tend to be weta. There are two distinct families of weta in New Zealand: Stenopelmatidae (which includes the tree weta, tusked weta, ground weta and giant weta); and Rhapidophoridae (which includes cave or jumping weta).

9.3.1: Weta Species Descriptions

Ground weta (*Hemiadrus;* 36 species) are medium sized (12-45 mm), flightless orthopteroid insects. They are nocturnal and spend the day within a burrow beneath ground level or debris. Although Johns (2001) suggests that tunnels can be highly localised within what appears to be uniform habitat they are often overlooked but are common in forests, shrublands, grasslands and gardens. The ground weta has a mainly carnivorous diet.

Tree weta (*Hemideina;* 7 species) is the most common type of weta and usually makes its home in the holes of trees. They are found in forests and suburban gardens throughout New Zealand. The tree weta is also nocturnal and feeds on leaves, flowers, fruit and insects at night. Tree weta are characterised by the large sharp spikes on their rear hind legs.

Cave weta (60 plus species) are found in caves as their name suggests, but they can also be found in other dark places such as under houses and logs. The cave weta is characterised by the very long antennae and legs. They feed on plants, fungi and sometimes other insects.

9.4: Birds

There are a large number of different bird species on Secretary Island. These include the Fiordland crested penguin (*Eudyptes pachyrhynchus*), titi (*Puffinus griseus*), Northern Tokoeka (*Apteryx australis*), weka (*Gallirallus australis*), karearea (*Falcon novaesseelandiae*) and kakariki (*Cyanoramphus auriceps*) (Morrison and Moore, 1979; Munn, 2001; Goodman and Lettink, 2005). All of these are at risk of predation from stoats. The ones that live on the ground or have their nests on the ground or in holes in trees are more susceptible.

Gillies (1998) found that birds made up 20% of six main prey species in the gut contents of stoats. He found that small Passeriformes (perching birds) were the most commonly occurring bird prey in stoat guts. King and Moody (1982) found that apart from a being able to identify a species by a particular coloured feather, most specimens from gut samples were only labelled as "Bird". Birds made up 43% of the total gut contents that were sampled. There appears to be a variation in the percent of bird remains found in gut sample depending on the habitat and the abundance or lack of other main prey species. In a study in South Island lowland podocarp forest birds only made up 15.9% of the gut content while rats accounted for 29.5% and invertebrates 44.3% (Richard, 1996). In the Mackenzie Basin where rabbits are prolific, 69% of the gut content was from birds (Murphy et al., 1998).

If birds make up a large percentage of a stoat's diet it is beneficial to be able to identify at risk species and their habitat. These could be areas where stoats are likely to visit and are therefore ideal locations for trap tunnels.

During the second check period (7/11/2005 to 13/11/2005) five minute bird call counts were carried out on six of the tracks. A total of 67 counts were recorded at pre determined tunnel locations along the some of the tracks (Figure 9.1). Five minute bird call counts are highly variable and a crude indicator of abundance unless there are a large number of counts. Although this data was not collected prior to the trapping programme and there is only a small number of counts it may indicate why some tunnels are more successful than others.

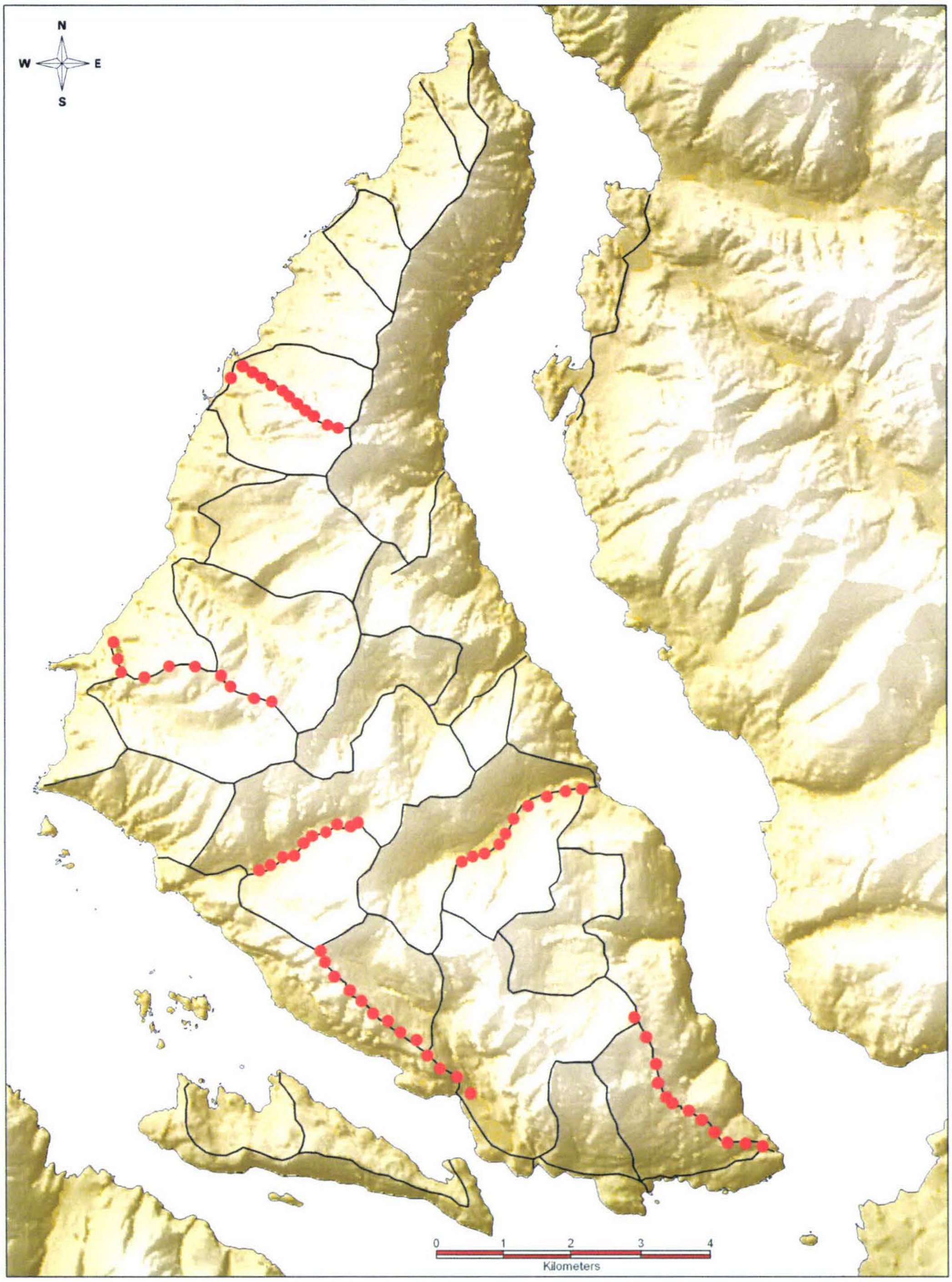

Figure 9.1: Location of five minute bird call counts on Secretary Island.

The number of stoats caught on the tracks where the bird call counts were collected are shown in Figure 9.2. All six tracks had high numbers of tomtit and grey warbler calls with the brown creeper being the next most common on four out of the six tracks.

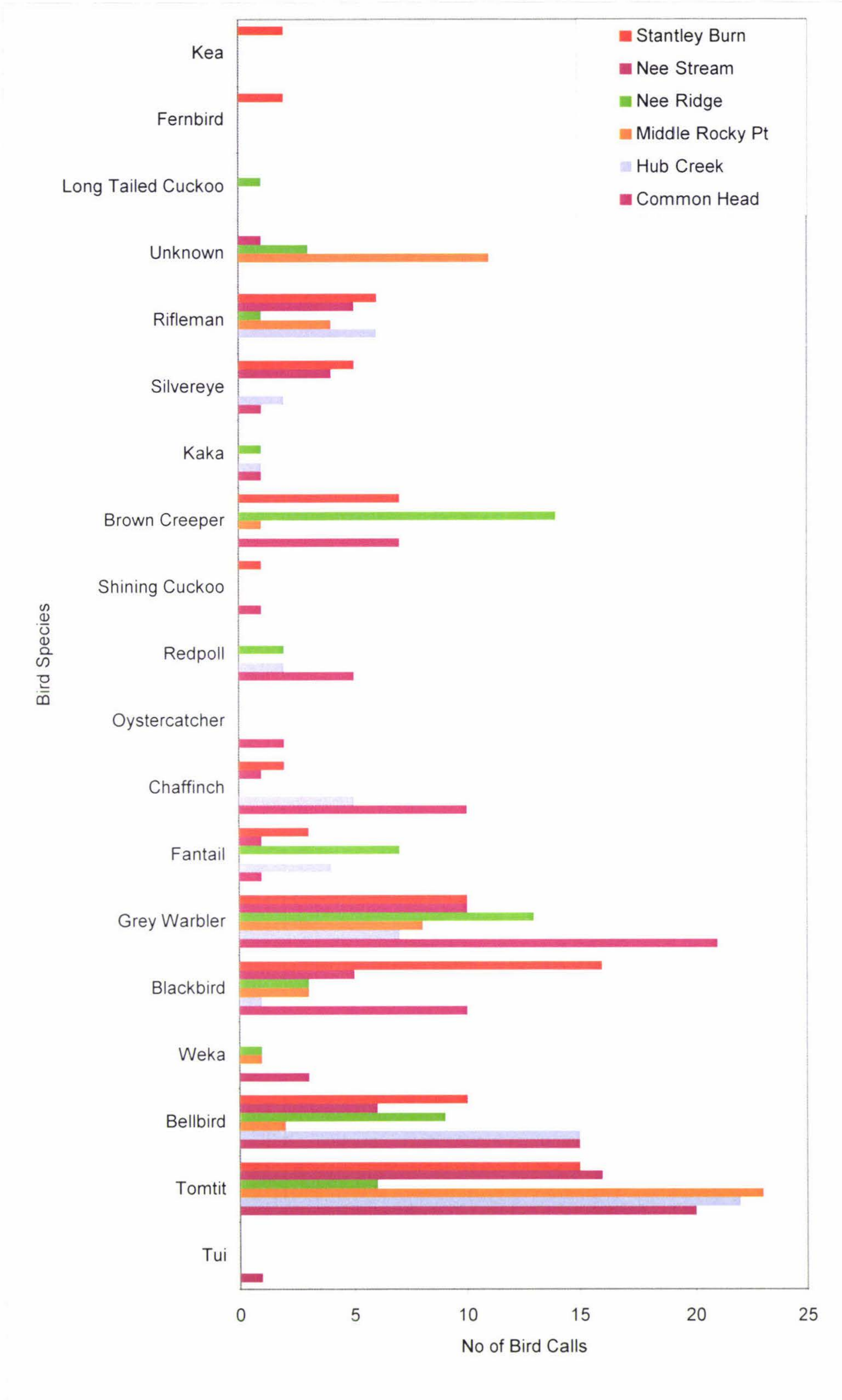

Figure 9.2: Five minute bird call counts on Secretary Island by species and track.

The top four recorded native species were tomtit, grey warbler, bellbird and brown creeper (Figure 9.3).

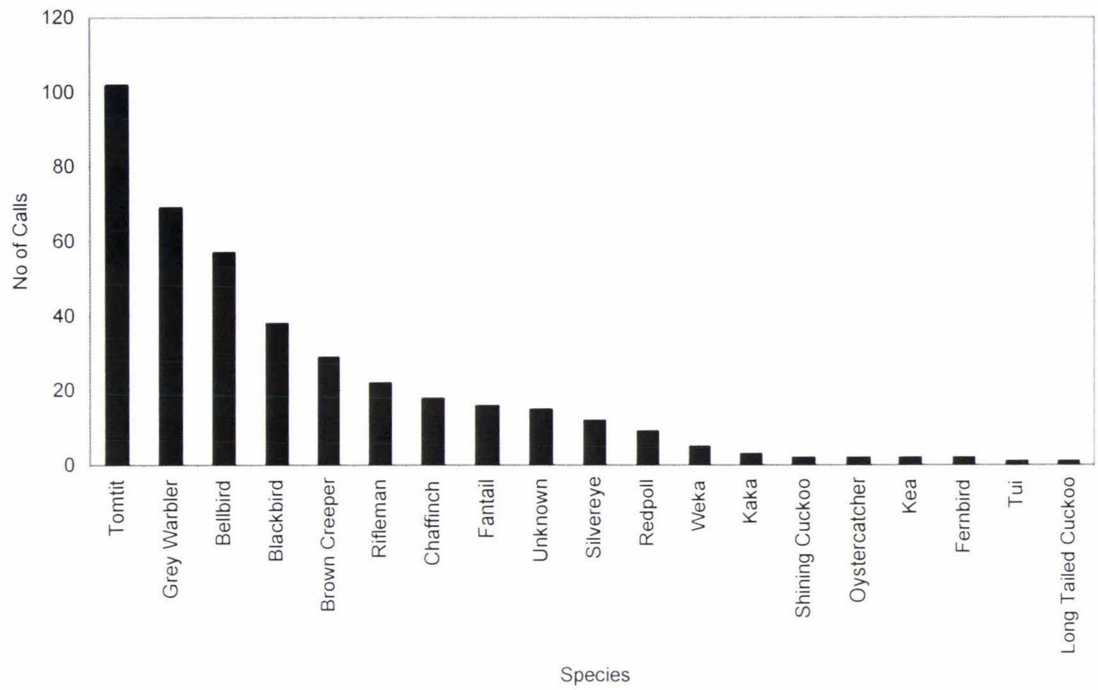

Figure 9.3: Total number of calls by species on Secretary Island.

The stoat catch data was matched with the bird call count data to see if there was any correlation between high bird call count numbers and stoat capture rates. However there were only six tunnels where bird counts were taken where stoats were caught. Of the six tracks where counts where under taken, only three had successful tunnels: Nee Stream had one, Nee Ridge had two and Stanley Burn had three (Figure 9.4). This is a very small sample and would be very difficult to make any accurate assumptions that could form the basis for a successful model.

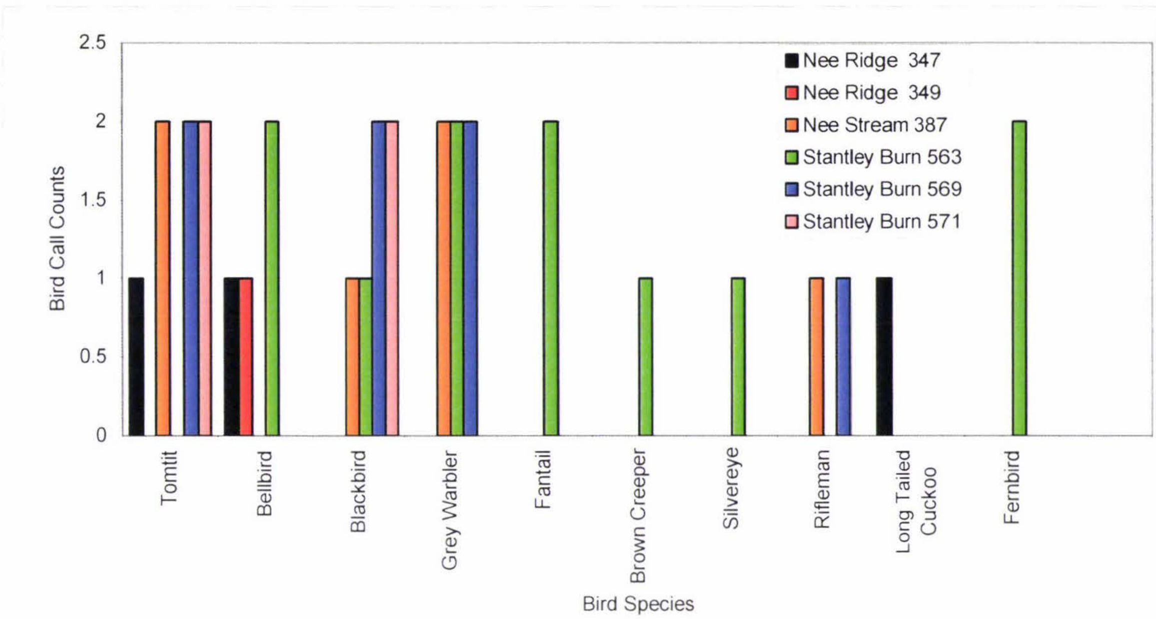

Figure 9.4: Bird call counts on Secretary Island by track and successful tunnels.

9.4.1: Bird Species Descriptions

To see if the top four species would be susceptible to stoat predation and perhaps offer some clues for further research in this area the habitat, diet, nest location and feeding habits were researched.

The South Island tomtit (*Myiomira Macrocephala*) is approximately 130 mm long and eats insects such as moths, flies, beetles, bugs and their larvae. They will also catch millipedes, spiders and earthworms. They tend to perch about 1 m or 2 m off the forest floor down and fly down and catch their prey. Tits nest in forks of branches, in knot holes or cliff ledges. They build their nests so that they are protected on several sides and sometimes from above (Reader's Digest, 1985).

The grey warbler (*Gerygone igata*) lives in a wide range of habitats from sea level to 1500 m. It needs small shrubs for nesting and is found in most types of native forests. The nest is built suspended with a small round entrance on the side. Sometimes the nest is attached at the side and the bottom. The nests are often built in manuka or gorse about 3 m off the ground. The grey warbler eats invertebrates, particularly spiders, beetles and caterpillars. Most of its food is obtained from live foliage (Reader's Digest, 1985).

The bellbird (*Anthornis melanura*) lives in native forest, forest remnants and scrub as well as exotic forest and gardens. The bellbird is more common in mixed lowland forest than beech forest. The nest is built near a flowing tree and can be anywhere from ground level to 15 m above the ground. Typically it is well hidden in or below an entanglement of vines or creepers or among the dead or growing fronds of a fern tree. They feed on nectar from many native and introduced plants. Invertebrates such as arachnids and insects are gleaned from trunks, branches and leaves (Reader's Digest, 1985).

The brown creeper (*Finschia novaeseelandiae*) lives from sea level to alpine areas in native and exotic forest. They forage through the forest canopy for insects and supplement its diet with fruit from trees within its habitat. Their nest is placed in the dense foliage of the canopy or sometimes in a dense bush or vine of the under storey (Reader's Digest, 1985).

The tomtit would be the only one of the four species that may be susceptible to predation as it feeds on the ground, although it appears that the tomtit is only on the ground for short periods as it has already targeted its prey before flying down and collecting it. They may all be susceptible to nest predation. Mohua (*Mohoua ochrocephala*) build their nests high in the canopy, usually more than 6 m above the forest floor. They are susceptible to predation by stoats but this may be because they prefer to nest in hollow trees which provide easy access for the stoat.

9.5: Discussion

Without more data that is able to identify the different bird species in the gut samples collected from stoats it would be difficult to determine which species could be used as an indicator for successful tunnel placement. At first it would appear that it would be easier to use bird data in a model compared to invertebrate data, especially if they have a preference for a particular forest habitat, but there would have to be more research carried out to determine which species should be used. This will also vary from site to site due to each species range. The other limiting factor is the current datasets that are available to model bird habitat. At best, a broad generalisation could be made that provides a starting point for further intensive study.

Chapter Ten: Discussion

10.1: Discussion

The stoat is a very adaptable mammal and can be found in most environments throughout New Zealand. It is a very effective hunter of living prey and will also forage on carrion. They have large litters of young and have the ability to respond to increases in food supplies. This makes the stoat very difficult to control. They are considered such a threat to New Zealand's biodiversity that the New Zealand government has funded research into developing new techniques to try and increase the success of control operations.

To develop successful control techniques it is imperative that the habits of the target species are known. The collection of data from stoat control operations and studies are being added to all of the time, building up a substantial data bank of information that can be used to help researchers and conservation managers. With modern technology this information can be spatially related which adds a new dimension to how research can be performed. Spatial relationships can provide indicators that would not be visible from straight statistical data. The geographical information system is an application that has a variety of analysis tools that were designed specifically to analyse spatial data. Data sets can first be analysed to extract parameters which can then be incorporated into a predictive model.

The intention of this study was to use vegetation classifications, stoat habitat, diet and home range surfaces generated from nationally available datasets to extract parameters that could be used in a model that predicted the best location for the placement of a stoat trap tunnel. It became evident early in the study that the resolution of the datasets for the two islands was not going to be detailed enough to indicate individual variables that could be used in a predictive model. Despite this the results of the spatial analysis still revealed some interesting findings that may help conservation managers.

In the coastal Fiordland environment the hotspot analysis indicated that the majority of successful tunnels were located in the warmer northwestern areas of both islands. This is also where the majority of deer have been located as well (Edge, pers. comm., 5 December 2008). These areas may have more palatable vegetation species that attract both species into them although deer tend to radically modify the structure of the forest including the lower understorey and forest floor. This in turn modifies the habitats of other forest dwellers such as birds and invertebrates. The diet analysis indicated that invertebrates made up a high percentage of the stoats diet. If this is the case then the invertebrates would require a dense forest floor litter layer to live in. It is not likely that this would be the case while deer were feeding in the area.

The northernmost hotspot area on Secretary Island is where stoat sign has been found in the snow since the last check period. This also indicates a preference for this area. There is a seal colony located on the coast in this area. This could provide another food source in the form of carrion for the stoats. There was no mention of this in the diet report, although it may be difficult to specifically identify the species from scavenged carrion. It may however be one reason why this particular area had a higher percentage of successful tunnels than other areas.

Both islands are extremely rugged and remote. To successfully carry out an eradication operation the operators have to be able to move around the islands without too much difficulty. The construction of a tracking network to facilitate this added some bias to the results of the analysis. In most areas the easiest place to locate a track was along a ridge, hence the majority of tracks and therefore stoat tunnels were located on ridges. This meant that more stoats were caught on ridges than in gullies or on faces. Both islands provided similar results because they had similar lengths of tracking on the different types of physiography. If the results from this study are going to be applied to later studies then this would need to be taken into consideration.

Stoats are known to follow along lines. Prior to the construction of the tracks on the islands these may have been deer leads, the boundaries between different vegetation types or along the ridges. It is not known if the construction of the tracks encouraged the stoats to make use of the tracks as a means of moving around their home ranges or whether they intersect the tracks while travelling from one productive area to another. If the latter is true then they will only encounter a tunnel if it is located at the intersection point. It may be that where a side ridge intersects the main ridge there is a natural path that is used by the stoats. With a high resolution DEM, these points could be identified and then uploaded into a GPS and used in the field for the location of stoat tunnels.

Although there are environmental factors that influence the success of an individual tunnel, the ability of the person setting the tunnel probably has the most impact on its success rate. An experienced operator has the ability to identify areas that are more likely to be productive than an inexperienced operator. An experienced operator will know when to place a tunnel a few metres further on than the prescribed distance to set the tunnel in a better location. A model may predict the areas that are more likely to be good sites for tunnel location but an experienced operator will be able to determine where, within these areas, is the best place for the tunnel to be located to maximize the chances of success.

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Appendix

Appendix One: June 2005 Secretary Island Tunnel Check Data

CheckDate	CheckedBy	Affiliation	Check Period	LineName	Tunnel Type	fEasting	fNorthing	TunnelRef	BaitType	Catch	Comments	WeightGms	Sex
24/07/2005	Matt Maitland	StA-DOC	1	Common Head	Wire	2038645	5529189	12b	Rabbit	Stoat		167	female
27/07/2005	Genevieve Taylor	StA-DOC	2	Common Head	Wood	2038105	5529762	19	Beef	Stoat		?	Male
25/05/2007	Genevieve Taylor	StA-DOC	1	ComH-GronoB	Wood	2036428	5528496	57	Beef	Stoat		202	Male
25/05/2007	Genevieve Taylor	StA-DOC	1	ComH-GronoB	Wood	2036379	5528492	58	Beef	Stoat		>300	Male
25/05/2007	Genevieve Taylor	StA-DOC	1	ComH-GronoB	Wood	2036315	5528418	59a	Beef	Stoat		232	female
24/07/2005	Peter McMurtrie	TAO-DOC	1	Blanket Bay Ridge	Wood	2037638	5528598	71	Beef	Stoat	white coat	209	female
24/07/2005	Sue Lake	TAO-DOC	1	Gut Hut Ridge	Wood	2036724	5528732	88	Beef	Stoat	pied white/brown	174	female
25/07/2005	Keri Antoniak	TAO-DOC	1	South Secretary Track	Wire	2037694	5530425	110	Venison	Stoat	white coat	190	female
23/07/2005	Keri Antoniak	TAO-DOC	1	East Grono Track	Wood	2037262	5531204	112	Rabbit	Stoat		290	Male
24/07/2005	Keri Antoniak	TAO-DOC	1	East Grono Track	Wire	2036516	5530937	121	Venison	Stoat		290	Male
24/07/2005	Keri Antoniak	TAO-DOC	1	North Secretary Track	Wire	2037389	5531460	139	Rabbit	Stoat		220	female
23/07/2005	Genevieve Taylor	StA-DOC	1	South Hub Ridge	Wood	2037120	5533856	167	Venison	Stoat		210	male
23/07/2005	Genevieve Taylor	StA-DOC	1	South Hub Ridge	Wood	2037034	5533602	169	Beef	Stoat		>300	female
23/07/2005	Genevieve Taylor	StA-DOC	1	South Hub Ridge	Wood	2036674	5532580	179	Rabbit	Stoat	white coat	171	female
24/07/2005	Megan Willans	DOC-contract	1	West Grono	Wire	2034637	5531609	208	Beef	Stoat		225	female
24/07/2005	Megan Willans	DOC-contract	1	West Grono	Wood	2034550	5531650	209	Venison	Stoat		280	male
24/07/2005	Megan Willans	DOC-contract	1	West Grono	Wood	2034172	5532008	214	Beef	Stoat		280	male
24/07/2005	Megan Willans	DOC-contract	1	West Grono	Wood	2034079	5532121	216	Rabbit	Stoat		200	female
25/07/2005	Megan Willans	DOC-contract	1	Harold Ridge	Wire	2034950	5531239	231	Rabbit	Stoat		200	female
23/07/2005	Hannah Edmonds	TAO-DOC	1	Hub Creek Track	Wood	2037264	5533987	247	Rabbit	Stoat	signs of whitening	260	male
23/07/2005	Megan Willans	DOC-contract	1	Hub Creek Track	Wood	2035171	5532673	272	Rabbit	Stoat		195	female
23/07/2005	Kerri-Anne Edge	TAO-DOC	1	North Hub Ridge	Wood	2036357	5534435	289	Rabbit	Stoat	white	194	female
23/07/2005	Kerri-Anne Edge	TAO-DOC	1	North Hub Ridge	Wood	2035743	5534448	294	Venison	Stoat	white, lots of fleas	196	female
24/07/2005	Peter Jackson	DOC-contract	1	North Hub Ridge	Wood	2034392	5533527	313	Rabbit	Stoat		200	female
23/07/2005	Stu Benett	StA-DOC	1	North Hub Ridge	Wood	2033983	5533030	320	Venison	Stoat		0.7lb	Unknown
25/07/2005	Hannah Edmonds	TAO-DOC	1	Nee Ridge Track	Wire	2033491	5531108	350	Beef	Stoat		190	female
25/07/2005	Hannah Edmonds	TAO-DOC	1	Nee Ridge Track	Wire	2033310	5531342	352	Beef	Stoat	white coat	200	female
24/07/2005	Stu Benett	StA-DOC	1	Nee Ridge Track	Wood	2033052	5531628	355	Venison	Stoat		?	male
24/07/2005	Stu Benett	StA-DOC	1	Nee Ridge Track	Wood	2031985	5532500	366	Venison	Stoat		0.4lb	female
25/07/2005	Stu Benett	StA-DOC	1	Nee Stream Track	Wood	2031739	5532633	380	Beef	Stoat		0.4lb	female
23/07/2005	Stu Benett	StA-DOC	1	Nee Stream Track	Wire	2032457	5532826	387	Rabbit	Stoat		0.7lb	Unknown

CheckDate	CheckedBy	Affiliation	Check Period	LineName	Tunnel Type	fEasting	fNorthing	TunnelRef	BaitType	Catch	Comments	WeightGms	Sex
23/07/2005	Stu Benett	StA-DOC	1	Nee Stream Track	Wire	2032745	5532964	390	Venison	Stoat		0.6lb	Unknown
28/07/2005	Stu Benett	StA-DOC	2	Nee Stream	Wood	2033978	5533039	408	Venison	Stoat	white coat	0.4lb	female
22/07/2005	Stu Benett	StA-DOC	1	Chocolate Ridge	Wire	2031379	5532907	410	Beef	Stoat		0.6lb	Unknown
23/07/2005	Hannah Edmonds	TAO-DOC	1	Road Track	Wire	2036155	5535823	425	Beef	Stoat		212	female
24/07/2005	Peter Jackson	DOC contract	1	Road Track	Wood	2033714	5534589	458	Rabbit	Stoat		260	Male
24/07/2005	Peter Jackson	DOC contract	1	Road Track	Wood	2033699	5534404	460	Beef	Stoat		170	female
24/07/2005	Peter Jackson	DOC contract	1	Road Track	Wire	2033638	5534212	463	Beef	Stoat		210	female
23/07/2005	Hannah Edmonds	TAO-DOC	1	Ripley Ridge	Wood	2035985	5535029	479	Beef	Stoat	Fleas	198	female
23/07/2005	Peter Kirkman	TAO-DOC contract	1	Marley Ridge	Wood	2029934	5535447	514	Beef	Stoat		200	female
23/07/2005	Peter Kirkman	TAO-DOC contract	1	Marley Ridge	Wood	2029891	5535293	517	Beef	Stoat		340	male
23/07/2005	Peter Kirkman	TAO-DOC contract	1	Marley Ridge	Wood	2030104	5535062	519	Venison	Stoat		210	female
23/07/2005	Peter Kirkman	TAO-DOC contract	1	Marley Ridge	Wood	2030246	5534755	522	Venison	Stoat	back half eaten	165	Unknown
24/07/2005	Peter Kirkman	TAO-DOC contract	1	Marley Ridge	Wood	2030985	5534392	529	Beef	Stoat		290	male
24/07/2005	Peter Kirkman	TAO-DOC contract	1	Marley Ridge	Wood	2032000	5534058	537	Venison	Stoat		305	male
23/07/2005	Peter Kirkman	TAO-DOC contract	1	Thorny Ridge	Wood	2030007	5534276	555	Venison	Stoat		200	female
27/07/2005	Peter Kirkman	TAO-DOC contract	2	Thorny Ridge	Wood	2029904	5534262	556	Beef	Stoat		210	female
23/07/2005	Peter Kirkman	TAO-DOC contract	1	Stantley Burn Track	Wood	2030147	5536085	563	Venison	Stoat		280	male
23/07/2005	Peter Kirkman	TAO-DOC contract	1	Stantley Burn Track	Wire	2030233	5535710	566	Venison	Stoat		280	male
25/07/2005	Peter Kirkman	TAO-DOC contract	1	Stantley Burn Track	Wire	2030613	5535573	569	Beef	Stoat		190	female
28/07/2005	Peter Kirkman	TAO-DOC contract	2	Stantley Burn Track	Wood	2030974	5535736	571	Venison	Stoat		195	female
25/07/2005	Peter Kirkman	TAO-DOC contract	1	Stantley Burn Track	Wire	2031824	5535523	576	Beef	Stoat		330	male
27-29/07/05	Fraser Madigan	DOC-contract	2	North All Round Pk Track	Wood	2033160	5534857	589	Rabbit	Stoat	White	255	Male
27-29/07/05	Fraser Madigan	DOC-contract	2	Leatherwood Track	Wire	2033722	5536422	604	Venison	Stoat		190	female
24/07/2005	Dave Crouchley	TAO-DOC	1	South Mahoe Track	Wire	2031628	5536023	617	Rabbit	Stoat		278	male
24/07/2005	Dave Crouchley	TAO-DOC	1	South Mahoe Track	Wood	2031108	5536595	623	Rabbit	Stoat		190	female
24/07/2005	Dave Crouchley	TAO-DOC	1	South Mahoe Track	Wood	2031148	5536876	625	Venison	Stoat		227	female
24/07/2005	Dave Crouchley	TAO-DOC	1	South Mahoe Track	Wire	2031057	5537109	627	Beef	Stoat		230	female
23/07/2005	Dave Crouchley	TAO-DOC	1	Mahoe Stream Track	Wire	2031748	5537119	634	Beef	Stoat		257	male
23/07/2005	Dave Crouchley	TAO-DOC	1	Mahoe Stream Track	Wood	2032121	5536907	637	Beef	Stoat		182	female
23/07/2005	Dave Crouchley	TAO-DOC	1	Mahoe Stream Track	Wood	2033283	5536784	647	Venison	Stoat		281	male

CheckDate	CheckedBy	Affiliation	Check Period	LineName	Tunnel Type	fEasting	fNorthing	TunnelRef	BaitType	Catch	Comments	WeightGms	Sex
23/07/2005	Dave Crouchley	TAO-DOC	1	North Mahoe Track	Wire	2031763	5537804	655	Rabbit	Stoat		296	male
23/07/2005	Dave Crouchley	TAO-DOC	1	North Mahoe Track	Wood	2032063	5538321	663	Venison	Stoat		200	female
23/07/2005	Dave Crouchley	TAO-DOC	1	North Mahoe Track	Wood	2032604	5538419	667	Rabbit	Stoat		196	female
23/07/2005	Dave Crouchley	TAO-DOC	1	North Mahoe Track	Wood	2032711	5538432	668	Beef	Stoat		347	male
29/07/2005	Fraser Madigan	DOC-contract	2	Astelia Stream Track	Wood	2034735	5537427	674	Rabbit	Stoat		?	female
23/07/2005	Gerard Hill	TAO-DOC	1	South Rocky Pt Track	Wire	2032026	5538781	711	Beef	Stoat		210	female
22/07/2005	Gerard Hill	TAO-DOC	1	Middle Rocky Pt Track	Wire	2031843	5539815	725	Venison	Stoat		155	female
22/07/2005	Gerard Hill	TAO-DOC	1	Middle Rocky Pt Track	Wood	2031965	5540065	727	Beef	Stoat		205	female
23/07/2005	Gerard Hill	TAO-DOC	1	North Rocky Pt Track	Wood	2032053	5540147	750	Rabbit	Stoat		200	female
23/07/2005	Gerard Hill	TAO-DOC	1	North Rocky Pt Track	Wood	2032342	5540345	755	Venison	Stoat		360	male
23/07/2005	Gerard Hill	TAO-DOC	1	North Rocky Pt Track	Wire	2033067	5540370	763	Beef	Stoat		200	female
23/07/2005	Gerard Hill	TAO-DOC	1	North Rocky Pt Track	Wire	2033218	5540326	765	Rabbit	Stoat		285	female
23/07/2005	Gerard Hill	TAO-DOC	1	7 Kilometre Ridge	Wood	2033764	5539543	787	Rabbit	Stoat		290	male
23/07/2005	Gerard Hill	TAO-DOC	1	7 Kilometre Ridge	Wire	2033775	5539615	788	Rabbit	Stoat		260	male
22/07/2005	Michelle Gutsell	TAO-DOC	1	7 Kilometre Ridge	Wood	2034262	5541015	801	Venison	Stoat		200	female
21/07/2005	Michelle Gutsell	TAO-DOC	1	7 Kilometre Ridge	Wire	2034845	5542157	811	Beef	2 x Stoats	Female white	300/220	male/female
20 and 23/07/2005	Michelle Gutsell	TAO-DOC	1	7 Kilometre Ridge	Wire	2035435	5543092	820	Rabbit	2 x Stoats	Female white coat	250/190	male/female
23/07/2005	Michelle Gutsell	TAO-DOC	1	7 Kilometre Ridge	Wood	2035470	5543869	827	Beef	Stoat		170	female
23/07/2005	Michelle Gutsell	TAO-DOC	1	7 Kilometre Ridge	Wood	2035417	5543992	828	Venison	Stoat		300	male
23/07/2005	Michelle Gutsell	TAO-DOC	1	7 Kilometre Ridge	Wood	2035420	5544699	834	Venison	Stoat		210	female
25/07/2005	Michelle Gutsell	TAO-DOC	1	Tunzelmans Trot	Wire	2033835	5541395	841	Venison	Stoat		210	female
25/07/2005	Michelle Gutsell	TAO-DOC	1	Tunzelmans Trot	Wood	2033618	5541686	844	Venison	Stoat		210	female
25/07/2005	Michelle Gutsell	TAO-DOC	1	Tunzelmans Trot	Wood	2033283	5542084	849	Beef	Stoat		215	female
24/07/2005	Michelle Gutsell	TAO-DOC	1	The End Track	Wood	2034921	5543785	870	Rabbit	Stoat		295	male
25/07/2005	BOAT CREW	SW	1	Coastal Traps	Wood	2032991	5530540	878	Beef	Stoat		170	female
25/07/2005	BOAT CREW	SW	1	Coastal Traps	Wood	2033121	5530431	879	Venison	Stoat		196	female
25/07/2005	BOAT CREW	SW	1	Coastal Traps	Wood	2033248	5530366	880	Rabbit	Stoat		186	female
25/07/2005	BOAT CREW	SW	1	Coastal Traps	Wood	2034046	5530055	885	Rabbit	Stoat		220	female
23/07/2005	BOAT CREW	SW	1	Coastal Traps	Wood	2035591	5541232	897	Rabbit	Stoat		>300	male
23/07/2005	BOAT CREW	SW	1	Coastal Traps	Wood	2035059	5540488	902	Venison	Stoat	signs of whitening	193	female
23/07/2005	BOAT CREW	SW	1	Coastal Traps	Wood	2035018	5540092	904	Venison	Stoat		>300	male
23/07/2005	BOAT CREW	SW	1	Coastal Traps	Wood	2035965	5536614	921	Rabbit	Stoat		193	female

Appendix Two: November 2005 Secretary Island Tunnel Check Data

CheckDate	CheckedBy	Affiliation	CheckPeriod	LineName	TunnelType	fEasting	fNorthing	TunnelRef	BaitType	Catch	Comments	WeightGms	Sex
9/11/2005	ST	VOL	3	Gut hut ridge	Wood	2036625	5529912	98	Beef	Stoat			
10/11/2005	MG	DOC	3	South Secretary Track	Wood	2037336	5530172	106	Beef	Stoat			
8/11/2005	JM	DOC	3	Marley Ridge	Wire	2029993	5535190	518	Beef	Stoat			
8/11/2005	JM	DOC	3	Marley Ridge	Wire	2030194	5534887	521	Beef	Stoat			
9/01/2005	JT	DOC	3	Marley Ridge	Wood	2032119	5534118	538	Beef	Stoat			
12/11/2005	JT	DOC	3	South Mahoe Track	Wire	2031057	5537109	627	Rabbit	Stoat			
13/11/2005	JT	DOC	3	North Mahoe Track	Wood	2031446	5538049	657	Beef	Stoat			
10/11/2005	KAE	DOC	3	Middle Ridge	Wood	2034225	5542452	856	Beef	Stoat			
8/11/2005	KAE	DOC	3	The End Track	Wood	2034714	5544053	873	Beef	Stoat			

Appendix Three: February 2006 Secretary Island Tunnel Check Data

CheckDate	CheckedBy	Affiliation	Check Period	LineName	Tunnel Type	fEasting	fNorthing	TunnelRef	BaitType	Catch	Comments	WeightGms	Sex	Age
19/02/2006	Hannah Edmonds	DOC	4	BBay-Ridge	Wood	2037423	5529345	79	Rabbit	Stoat			Female	Adult
19/02/2006	Glen Coulston	DOC	4	Gut hut ridge	Wood	2036598	5529792	97	Rabbit	Stoat			Male	Juvenile
18/02/2006	Kerri-Anne Edge	DOC	4	North Hub Ridge	Wire	2036280	5534511	290	Rabbit	Stoat			Female	Juvenile
22/02/2006	Jane Tansell	DOC	4	North Hub Ridge	Wood	2035370	5534015	299	Rabbit	Stoat			Female	Adult
22/02/2006	Jane Tansell	DOC	4	North Hub Ridge	Wood	2035303	5533950	300	Rabbit	Stoat			Male	Juvenile
22/02/2006	Jane Tansell	DOC	4	North Hub Ridge	Wood	2034392	5533527	313	Rabbit	Stoat			Male	Juvenile
19/02/2006	Clea Gardiner	DOC	4	Nee Ridge Track	Wood	2033768	5530839	347	Rabbit	Stoat	Double		Female	Juvenile
19/02/2006	Clea Gardiner	DOC	4	Nee Ridge Track	Wood	2033602	5530994	349	Rabbit	Stoat			Female	Adult
19/02/2006	Clea Gardiner	DOC	4	Nee Ridge Track	Wood	2033179	5531575	354b	Rabbit	Stoat			Male	Juvenile
21/02/2006	Scott Theobald	DOC	4	Nee Stream Track	Wood	2030890	5532921	370	Rabbit	Stoat			Male	Juvenile
21/02/2006	Scott Theobald	DOC	4	Nee Stream Track	Wire	2030974	5532918	371	Rabbit	Stoat			Female	Adult
23/02/2006	Scott Theobald	DOC	4	Chocolate Ridge	Wood	2031512	5533117	413	Rabbit	Stoat			Female	Adult
23/02/2006	Scott Theobald	DOC	4	Chocolate Ridge	Wood	2031591	5533209	414	Rabbit	Stoat			Male	Juvenile
23/02/2006	Scott Theobald	DOC	4	Chocolate Ridge	Wire	2031640	5533314	415	Rabbit	Stoat			Female	Juvenile
23/02/2006	Scott Theobald	DOC	4	Chocolate Ridge	Wood	2031770	5533552	418	Rabbit	Stoat			Male	Adult
18/02/2006	Scott Theobald	DOC	4	Marley Ridge	Wood	2030186	5535579	512	Rabbit	Stoat			Female	Juvenile
18/02/2006	Scott Theobald	DOC	4	Marley Ridge	Wood	2029934	5535447	514	Rabbit	Stoat			Unknown	Juvenile
19/02/2006	Scott Theobald	DOC	4	Marley Ridge	Wood	2031114	5534354	530	Rabbit	Stoat			Female	Adult
19/02/2006	Scott Theobald	DOC	4	Marley Ridge	Wood	2032000	5534058	537	Rabbit	Stoat			Female	Juvenile
18/02/2006	Scott Theobald	DOC	4	Thorny Ridge	Wood	2029405	5534030	560	Rabbit	Stoat			Female	Juvenile
18/02/2006	Scott Theobald	DOC	4	Stantley Burn Track	Wire	2030233	5535710	566	Rabbit	Stoat			Unknown	Juvenile
19/02/2006	Scott Theobald	DOC	4	Stantley Burn Track	Wood	2030801	5535639	570	Rabbit	Stoat			Male	Juvenile
19/02/2006	Scott Theobald	DOC	4	Stantley Burn Track	Wood	2030974	5535736	571	Rabbit	Stoat			Female	Adult
19/02/2006	Scott Theobald	DOC	4	Stantley Burn Track	Wood	2031565	5535679	574	Rabbit	Stoat			Female	Adult
11/02/2006	Peter Kirkman	DOC	4	Leatherwood Track	Wood	2033673	5536549	605	Rabbit	Stoat			Female	Juvenile
15/02/2006	John Neilsen	DOC	4	South Mahoe Track	Wire	2031705	5535707	614	Rabbit	Stoat			Male	Juvenile
11/02/2006	Paul Cornille	DOC	4	North Mahoe Track	Wire	2031535	5538126	658	Rabbit	Stoat			Female	Juvenile
13/02/2006	Peter Kirkman	DOC	4	Astelia Stream Track	Wood	2034948	5538411	683	Rabbit	Stoat			Male	Adult
23/02/2006	Simon Stevenson	DOC	4	South Rocky Pt Track	Wood	2031874	5538859	710	Rabbit	Stoat			Female	Juvenile
22/02/2006	Simon Stevenson	DOC	4	Middle Rocky Pt Track	Wood	2031965	5540065	727	Beef	Stoat	Double		Female	Juvenile
22/02/2006	Simon Stevenson	DOC	4	Middle Rocky Pt Track	Wood	2032547	5539813	735	Rabbit	Stoat			Female	Juvenile
22/02/2006	Simon Stevenson	DOC	4	North Rocky Pt Track	Wire	2032914	5540408	761	Rabbit	Stoat			Female	Juvenile

CheckDate	CheckedBy	Affiliation	Check Period	LineName	Tunnel Type	fEasting	fNorthing	TunnelRef	BaitType	Catch	Comments	WeightGms	Sex	Age
18/02/2006	Simon Stevenson	DOC	4	7 Kilometre Ridge	Wire	2034845	5542157	811	Rabbit	Stoat			Male	Juvenile
18/02/2006	Simon Stevenson	DOC	4	7 Kilometre Ridge	Wood	2035239	5542607	816	Rabbit	Stoat	Double		Male & Female	Adult
18/02/2006	Simon Stevenson	DOC	4	7 Kilometre Ridge	Wood	2035555	5543296	822	Rabbit	Stoat			Female	Juvenile
18/02/2006	Simon Stevenson	DOC	4	7 Kilometre Ridge	Wire	2035555	5543775	826	Rabbit	Stoat			Female	Adult
18/02/2006	Simon Stevenson	DOC	4	7 Kilometre Ridge	Wood	2035417	5543992	828	Rabbit	Stoat	Half eaten		Unknown	Adult
19/02/2006	Simon Stevenson	DOC	4	Tunzelmans Trot	Wire	2033835	5541395	841	Rabbit	Stoat			Male	Adult
19/02/2006	Simon Stevenson	DOC	4	Middle Ridge	Wood	2033955	5542624	853	Rabbit	Stoat			Female	Juvenile
19/02/2006	Simon Stevenson	DOC	4	Middle Ridge	Wood	2034225	5542452	856	Rabbit	Stoat			Male	Juvenile
18/02/2006	Simon Stevenson	DOC	4	The End Track	Wire	2035298	5543079	863	Rabbit	Stoat			Female	Juvenile

Appendix Four: July 2006 Secretary Island Tunnel Check Data

CheckDate	CheckedBy	Affiliation	CheckPeriod	LineName	TunnelType	fEasting	fNorthing	TunnelRef	BaitType	Catch	Comments	WeightGms	Sex	Age
9/07/2006	Peter McMurtrie	DOC	5	Chocolate Ridge	Wire	2031829	5533679	420	Rabbit	Stoat				
5/07/2006	Peter McMurtrie	DOC	5	Marley Ridge	Wood	2029934	5535447	514	Rabbit	Stoat				
6/07/2006	Sanjay Thakur	DOC	5	North ARP	Wire	2033414	5535231	592	Rabbit	Stoat				
6/07/2006	Sanjay Thakur	DOC	5	Leatherwood	Wire	2033611	5536744	604	Rabbit	Stoat				
11/07/2006	Chris Whyte	DOC	5	North Mahoe	Wire	2031535	5538126	658	Rabbit	Stoat				
5/07/2006	Chris Whyte	DOC	5	7 Kilometre Ridge	Wire	2035637	5543439	823	Rabbit	Stoat				

Appendix Five: January/February 2007 Secretary Island Tunnel Check Data

CheckDate	CheckedBy	Affiliation	CheckPeriod	LineName	TunnelType	fEasting	fNorthing	TunnelRef	BaitType	Catch	Comments	WeightGms	Sex
2/02/2007	Brad Angus	DOC	7	Blanket Bay Ridge	Wooden	2037594	5528686	72	beef	Stoat	no baculum	Old	F ?
1/02/2007	Scott Theobald	DOC	7	Nee Ridge	Wooden	2032325	5532137	362	rabbit	Stoat	No Skull	Old	F ?
1/02/2007	Scott Theobald	DOC	7	Ripley Ridge	Wooden	2035935	5534619	482	beef	Stoat	Baculum	Fresh	Male
30/01/2007	Brad Angus	DOC	7	Thorny Ridge	Wooden	2030148	5534294	554	rabbit	Stoat	no baculum or pelvis	Old	F ?
17/01/2007	Paul Dawson	Contrator	7	The End track	Wooden	2035209	5543279	865	rabbit	Stoat	Baculum	Fresh	Male

Appendix Six: May 2007 Secretary Island Tunnel Check Data

Check date	Checked by	Affiliation	Check period	Line Name	fEasting	fNorthing	Tunnel type	Tunnel ref	Bait type	Catch	Comments	Condition	Sex
3/05/2007	Hannah Edmonds	DOC	8	Marley Ridge	2030608	5534512	Wood	526	Rabbit	Stoat		Old	?
3/05/2007	Hannah Edmonds	DOC	8	Marley Ridge	2032788	5534360	Wood	548	Rabbit	Stoat		Old	F?
7/05/2007	Richard Ewans	DOC	8	North All round Pk	2033474	5535583	Wood	595	Rabbit	Stoat		Freshish	M?
29/03/2007	Dave Wilson	Contractor	8	North Astelia	2033285	5538423	Wood	702	Rabbit	Stoat	3 Stoats 2 Females, 1 Male Female skull sent away	Fresh	F

Appendix Seven: January 2008 Secretary Island Tunnel Check Data

CheckDate	CheckedBy	Affiliation	CheckPeriod	LineName	TunnelType	fEasting	fNorthing	TunnelRef	BaitType	Catch	Comments	WeightGms	Sex
25/01/2008				North Hub Ridge	Wood	2035303	5533950	300		Stoat			
25/01/2008				North All Round Pk Track	Wire	2033729	5536129	616		Stoat			

Appendix Eight: July 2008 Resolution Island Tunnel Check Data

TunnelRef	sDescription	fLat	fLong	fEasting	fNorthing	fAlt	iColour	iSymbol	No. Caught
1035	Jul-08	-45.69898	166.59718	2011727	5481565	263	16711935	-146	1
1045	Jul-08	-45.695025	166.60845	2012567	5482072	465.6	16711935	-146	1
1107	Jul-08	-45.693451	166.62432	2013786	5482343	477.9	16711935	-146	1
1108	Jul-08	-45.693359	166.62576	2013897	5482362	511.1	16711935	-146	1
1111	Jul-08	-45.692734	166.62968	2014196	5482455	467.8	16711935	-146	1
1112	Jul-08	-45.691823	166.63018	2014227	5482559	414	16711680	-146	1
1306	Jul-08	-45.684298	166.66321	2016727	5483593	260.2	16711680	-146	1
1307	Jul-08	-45.685203	166.66294	2016714	5483491	236.1	16711680	-146	1
1308	Jul-08	-45.685803	166.66201	2016647	5483419	264.5	16711935	-146	1
1322	Jul-08	-45.696093	166.65197	2015956	5482218	102	16711935	-146	1
1325	Jul-08	-45.698448	166.65015	2015835	5481946	60	16711935	-146	1
1326	Jul-08	-45.69922	166.64974	2015810	5481858	68.1	16711935	-146	1
1330	Jul-08	-45.702807	166.64982	2015847	5481461	42.4	16711680	-146	1
1342	Jul-08	-45.713626	166.6493	2015900	5480259	21.3	16711680	-146	1
1343	Jul-08	-45.714461	166.64989	2015953	5480170	23.7	16711680	-146	1
1350	Jul-08	-45.720156	166.65138	2016118	5479548	18.9	16711935	-146	1
1417	Jul-08	-45.724309	166.6746	2017956	5479228	491.1	16711935	-146	1
1419	Jul-08	-45.723718	166.67701	2018138	5479308	589.6	16711935	-146	1
1432	Jul-08	-45.716024	166.68737	2018876	5480223	836.9	16711935	-146	1
1435	Jul-08	-45.713208	166.6872	2018839	5480534	732.2	16711935	-146	1
1437	Jul-08	-45.711457	166.68654	2018772	5480724	834.8	16711935	-146	1
1438	Jul-08	-45.71064	166.68578	2018706	5480810	906.4	65280	-146	2
1510	Jul-08	-45.707759	166.66118	2016772	5480981	322.2	16711935	-146	1
1511	Jul-08	-45.708229	166.66236	2016867	5480936	349.8	16711935	-146	1
1524	Jul-08	-45.707612	166.67904	2018157	5481105	843.9	16711680	-146	1
1526	Jul-08	-45.708053	166.6815	2018352	5481071	907.1	16711935	-146	1
1605	Jul-08	-45.712428	166.66721	2017280	5480500	0	16711935	-146	1
1817	Jul-08	-45.708237	166.68389	2018539	5481065	990.8	16711935	-146	1
1819	Jul-08	-45.709683	166.6856	2018684	5480915	947.3	16711680	-146	1
1905	Jul-08	-45.72969	166.65278	2016309	5478500	31.1	16711935	-146	1
1913	Jul-08	-45.736669	166.65648	2016656	5477749	35.9	16711935	-146	1
1922	Jul-08	-45.737642	166.66772	2017537	5477709	196	16711935	-146	1
1934	Jul-08	-45.737698	166.68202	2018647	5477789	430.6	16711680	-146	1

TunnelRef	sDescription	fLat	fLong	fEasting	fNorthing	fAlt	iColour	iSymbol	No. Caught
1946	Jul-08	-45.729409	166.68908	2019124	5478750	253	16711680	-146	1
1961	Jul-08	-45.721922	166.70444	2020252	5479672	231.3	16711935	-146	1
1966	Jul-08	-45.717545	166.7066	2020382	5480170	228.9	16711680	-146	1
1984	Jul-08	-45.70115	166.70998	2020504	5482007	129.4	16711680	-146	1
1986	Jul-08	-45.699249	166.70986	2020478	5482217	112.1	16711935	-146	1
2021	Jul-08	-45.69812	166.67392	2017678	5482126	413.7	16711935	-146	1
2027	Jul-08	-45.697287	166.68117	2018234	5482262	653.8	16711935	-146	1
2114	Jul-08	-45.691813	166.67244	2017509	5482816	447.1	16711935	-146	1
2116	Jul-08	-45.693738	166.67233	2017517	5482602	461.3	16711935	-146	1
2204	Jul-08	-45.699728	166.69306	2019178	5482063	754	16711935	-146	1
2303	Jul-08	-45.694562	166.71264	2020654	5482753	99.6	16711935	-146	1
2404	Jul-08	-45.690637	166.68733	2018655	5483036	937.6	16711935	-146	1
2417	Jul-08	-45.679944	166.68219	2018164	5484190	705.2	16711935	-146	1
2423	Jul-08	-45.674708	166.6795	2017910	5484754	514.9	16711935	-146	1
2531	Jul-08	-45.665894	166.69551	2019078	5485827	874.7	16711680	-146	1
2534	Jul-08	-45.663128	166.69625	2019112	5486138	799.5	16711680	-146	1
2541	Jul-08	-45.656814	166.69447	2018919	5486827	735	16711935	-146	1
2554	Jul-08	-45.646966	166.70058	2019310	5487955	673	16711935	-146	1
2627	Jul-08	-45.661026	166.71091	2020233	5486459	264.5	16711935	-146	1
2638	Jul-08	-45.670028	166.71001	2020240	5485456	498.8	16711935	-146	1
2648	Jul-08	-45.676802	166.70878	2020202	5484698	427.9	16711935	-146	1
2653	Jul-08	-45.680172	166.71103	2020406	5484338	326.7	16711680	-146	1
2657	Jul-08	-45.678944	166.71384	2020614	5484491	213.1	16711935	-146	1
2660	Jul-08	-45.676086	166.71574	2020737	5484819	101.3	16711935	-146	1
2718	Jul-08	-45.667438	166.67957	2017853	5485560	358.7	16711935	-146	1
2721	Jul-08	-45.6649	166.68168	2017995	5485854	381.3	16711935	-146	1
2731	Jul-08	-45.657375	166.68686	2018333	5486719	440.4	16711935	-146	1
2807	Jul-08	-45.677098	166.65712	2016192	5484354	326.5	16711935	-146	1
2811	Jul-08	-45.678426	166.66228	2016604	5484238		16711680		1
2902	Jul-08	-45.660405	166.64083	2014782	5486105	828.3	16711935	-146	1
2908	Jul-08	-45.665165	166.64321	2015008	5485592	626.2	16711935	-146	1
2919	Jul-08	-45.673892	166.64651	2015340	5484645	227.7	16711935	-146	1
3007	Jul-08	-45.668607	166.65433	2015902	5485278	253.4	16711935	-146	1
3024	Jul-08	-45.652912	166.6596	2016176	5487049	315.7	16711680	-146	1
3032	Jul-08	-45.65008	166.66856	2016848	5487417	484.6	16711935	-146	1
3203	Jul-08	-45.640216	166.6712	2016968	5488526	815.3	16711935	-146	1

TunnelRef	sDescription	fLat	fLong	fEasting	fNorthing	fAlt	iColour	iSymbol	No. Caught
3301	Jul-08	-45.649212	166.68029	2017752	5487584	626.2	16711680	-146	1
3307	Jul-08	-45.648188	166.68619	2018202	5487733	639.6	16711935	-146	1
3408	Jul-08	-45.635769	166.70079	2019230	5489197	492.1	16711935	-146	1
3601	Jul-08	-45.61064	166.67213	2016786	5491809	46.7	16711935	-146	1
3609	Jul-08	-45.617218	166.67626	2017164	5491105	224.4	16711935	-146	1
3610	Jul-08	-45.617602	166.67752	2017265	5491070	280.6	16711935	-146	1
3613	Jul-08	-45.619453	166.68067	2017526	5490884	445.9	16711935	-146	1
3710	Jul-08	-45.633426	166.68223	2017767	5489345	889.6	16711935	-146	1
3718	Jul-08	-45.629027	166.6893	2018279	5489875	642.8	16711935	-146	1
3803	Jul-08	-45.628897	166.66404	2016314	5489737	789.8	16711935	-146	1
3809	Jul-08	-45.633265	166.66819	2016674	5489278	824.2	16711935	-146	1
3905	Jul-08	-45.619364	166.66151	2016035	5490778	563.9	16711935	-146	1
3907	Jul-08	-45.621064	166.66222	2016105	5490594	737.9	16711935	-146	1
3908	Jul-08	-45.622007	166.66214	2016107	5490489	749.5	16711935	-146	1
3909	Jul-08	-45.622941	166.66173	2016083	5490383	787	16711935	-146	1
3910	Jul-08	-45.623859	166.66151	2016074	5490280	817.7	16711935	-146	1
4003	Jul-08	-45.614439	166.66618	2016356	5491352	202.2	16711680	-146	1
4101	Jul-08	-45.628267	166.63471	2014028	5489629	570.7	16711935	-146	1
4111	Jul-08	-45.621387	166.63678	2014130	5490404	439	16711935	-146	1
4112	Jul-08	-45.620444	166.63688	2014129	5490509	410.8	16711935	-146	1
4125	Jul-08	-45.613987	166.64882	2015002	5491297	483.2	16711935	-146	1
4134	Jul-08	-45.611599	166.6596	2015820	5491627	356.3	16711935	-146	1
4202	Jul-08	-45.631047	166.63669	2014206	5489333	589.6	16711935	-146	1
4305	Jul-08	-45.614663	166.61442	2012333	5491013	329.1	16711680	-146	1
4309	Jul-08	-45.61212	166.61757	2012556	5491314	163.8	16711935	-146	1
4312	Jul-08	-45.613444	166.62081	2012819	5491187	72.2	16711680	-146	1
4313	Jul-08	-45.614053	166.62171	2012894	5491125	113.6	16711935	-146	1
4315	Jul-08	-45.614565	166.6243	2013100	5491084	203.9	16711935	-146	1
4323	Jul-08	-45.620305	166.62874	2013495	5490475	445.7	16711935	-146	1
4333	Jul-08	-45.628362	166.63364	2013946	5489612	569.5	16711935	-146	1
4405	Jul-08	-45.623908	166.61497	2012456	5489992	428.1	16711935	-146	1
4407	Jul-08	-45.624749	166.61714	2012632	5489912	414.7	16711935	-146	1
450	Jul-08	-45.734622	166.60854	2012919	5477685	20.1	16711935	-146	1
4504	Jul-08	-45.637406	166.62264	2013169	5488543	175.1	16711680	-146	1
4508	Jul-08	-45.637197	166.6277	2013561	5488597	207.5	16711935	-146	1
4601	Jul-08	-45.639926	166.62037	2013015	5488250	0	16711680	-146	1

TunnelRef	sDescription	fLat	fLong	fEasting	fNorthing	fAlt	iColour	iSymbol	No. Caught
4604	Jul-08	-45.6399	166.62417	2013310	5488276	320	16711935	-146	1
4614	Jul-08	-45.645817	166.63251	2014009	5487671	656.2	16711680	-146	1
4618	Jul-08	-45.646904	166.63752	2014408	5487581	700.2	16711935	-146	1
4622	Jul-08	-45.648167	166.64229	2014790	5487470	-0.1	16711680	-146	1
4806	Jul-08	-45.641312	166.61195	2012372	5488045	391.4	16711680	-146	1
4808	Jul-08	-45.639444	166.6121	2012368	5488253	347.2	16711935	-146	1
4812	Jul-08	-45.635943	166.61376	2012466	5488651	235.6	16711680	-146	1
4820	Jul-08	-45.630809	166.61805	2012755	5489246	352.7	16711935	-146	1
4903	Jul-08	-45.625967	166.59568	2010974	5489646	317.1	16711935	-146	1
4904	Jul-08	-45.625226	166.59648	2011030	5489733	291.6	16711935	-146	1
4905	Jul-08	-45.624304	166.59678	2011045	5489837	219.3	16711680	-146	1
4911	Jul-08	-45.619308	166.597	2011019	5490392	8.5	16711935	-146	1
4919	Jul-08	-45.614158	166.60116	2011297	5490988	226.8	16711935	-146	1
4920	Jul-08	-45.613389	166.60194	2011351	5491078	249.6	16711935	-146	1
4924	Jul-08	-45.612813	166.60672	2011718	5491171	332.5	16711935	-146	1
4929	Jul-08	-45.616743	166.60991	2012000	5490755	389	16711935	-146	1
4931	Jul-08	-45.618361	166.61127	2012120	5490584	404.6	16711680	-146	1
4932	Jul-08	-45.618857	166.61241	2012213	5490536	410.4	16711935	-146	1
5009	Jul-08	-45.632392	166.59567	2011029	5488934	462.8	16711935	-146	1
5018	Jul-08	-45.638586	166.60177	2011557	5488285	418.1	16711935	-146	1
5019	Jul-08	-45.638995	166.60297	2011654	5488247	444	16711935	-146	1
5026	Jul-08	-45.644755	166.60563	2011911	5487625	538.5	16711935	-146	1
5028	Jul-08	-45.646566	166.60607	2011961	5487427	526.2	16711935	-146	1
5033	Jul-08	-45.650311	166.60999	2012298	5487036	529.1	16711680	-146	1
5042	Jul-08	-45.658448	166.61272	2012581	5486151	699.2	16711935	-146	1
5046	Jul-08	-45.661695	166.61466	2012760	5485803	655.5	16711935	-146	1
505	Jul-08	-45.730746	166.61175	2013134	5478134	197.2	16711935	-146	1
5102	Jul-08	-45.641256	166.58899	2010587	5487911	541.8	16711935	-146	1
5110	Jul-08	-45.636067	166.59618	2011101	5488530	497.8	16711680	-146	1
5206	Jul-08	-45.635995	166.56534	2008703	5488349	264.2	65280	-146	2
5211	Jul-08	-45.636205	166.5719	2009215	5488366	330.3	16711680	-146	1
5218	Jul-08	-45.630758	166.57622	2009503	5488996	244.3	16711680	-146	1
5219	Jul-08	-45.629813	166.57626	2009498	5489101	257.3	16711935	-146	1
5220	Jul-08	-45.628899	166.57655	2009512	5489204	242.6	16711935	-146	1
5222	Jul-08	-45.627252	166.57532	2009402	5489379	147	16711935	-146	1
5223	Jul-08	-45.626441	166.576	2009448	5489473	113.8	16711680	-146	1

TunnelRef	sDescription	fLat	fLong	fEasting	fNorthing	fAlt	iColour	iSymbol	No. Caught
5228	Jul-08	-45.623518	166.58107	2009817	5489828	296.2	16711935	-146	1
5229	Jul-08	-45.623172	166.58233	2009912	5489874	306.1	16711680	-146	1
5234	Jul-08	-45.625416	166.58782	2010358	5489659	352.9	16711935	-146	1
524	Jul-08	-45.727385	166.63357	2014798	5478639	573.5	16711935	-146	1
5304	Jul-08	-45.640842	166.56421	2008658	5487805	224.4	16711935	-146	1
5308	Jul-08	-45.642536	166.56889	2009036	5487646	317.8	16711935	-146	1
5309	Jul-08	-45.643042	166.57003	2009129	5487597	324.1	16711935	-146	1
532	Jul-08	-45.727479	166.64336	2015559	5478688	232	16711935	-146	1
5406	Jul-08	-45.654363	166.55853	2008335	5486272	213.3	16711680	-146	1
5410	Jul-08	-45.655018	166.56384	2008753	5486232	278.2	16711935	-146	1
5422	Jul-08	-45.657145	166.57845	2009907	5486086	360.6	16711935	-146	1
5426	Jul-08	-45.654801	166.58259	2010208	5486371	364.2	16711680	-146	1
5507	Jul-08	-45.6658	166.58189	2010250	5485148	149.4	16711935	-146	1
5511	Jul-08	-45.662757	166.58464	2010437	5485502	107.6	16711680	-146	1
5514	Jul-08	-45.661339	166.58789	2010677	5485679	228.7	16711935	-146	1
5523	Jul-08	-45.656528	166.59735	2011370	5486270	404.8	16711935	-146	1
5525	Jul-08	-45.654827	166.59728	2011350	5486458	443.3	16711935	-146	1
5532	Jul-08	-45.651619	166.60539	2011952	5486863	487.8	16711935	-146	1
5611	Jul-08	-45.669754	166.59105	2010996	5484766	422.1	16711935	-146	1
5619	Jul-08	-45.67161	166.60114	2011796	5484622	554.1	16711935	-146	1
5710	Jul-08	-45.666984	166.62913	2013930	5485305	787.9	16711935	-146	1
5804	Jul-08	-45.685747	166.57164	2009628	5482875	215.7	16711935	-146	1
5806	Jul-08	-45.685336	166.57431	2009832	5482937	322.9	16711935	-146	1
5807	Jul-08	-45.684722	166.57545	2009915	5483012	311.8	16711680	-146	1
5821	Jul-08	-45.682938	166.59463	2011389	5483327	692.3	16711935	-146	1
5824	Jul-08	-45.680233	166.59631	2011496	5483637	617.3	16711935	-146	1
5828	Jul-08	-45.678268	166.60029	2011788	5483879	539.7	16711935	-146	1
5834	Jul-08	-45.68017	166.60762	2012374	5483713	478.6	16711680	-146	1
5837	Jul-08	-45.679881	166.61156	2012677	5483769	455.3	16711935	-146	1
5846	Jul-08	-45.674825	166.61857	2013178	5484372	580.3	16711935	-146	1
5910	Jul-08	-45.675475	166.56704	2009181	5483985	76.1	16711680	-146	1
5924	Jul-08	-45.679483	166.55451	2008243	5483464	47	16711935	-146	1
601	Jul-08	-45.722299	166.59241	2011560	5478952	19.8	16711935	-146	1
602	Jul-08	-45.721839	166.59356	2011645	5479010	45.5	16711935	-146	1
6028	Jul-08	-45.641259	166.5592	2008272	5487728	86.2	16711935	-146	1
6029	Jul-08	-45.640297	166.55927	2008269	5487835	107.1	16711680	-146	1

TunnelRef	sDescription	fLat	fLong	fEasting	fNorthing	fAlt	iColour	iSymbol	No. Caught
6107	Jul-08	-45.647549	166.54327	2007089	5486933	256.8	16711935	-146	1
6202	Jul-08	-45.640034	166.54462	2007128	5487774	267.9	16711680	-146	1
6206	Jul-08	-45.636223	166.54572	2007180	5488203	269.8	16711935	-146	1
6210	Jul-08	-45.632548	166.54584	2007157	5488611	239.5	16711680	-146	1
6211	Jul-08	-45.631619	166.54619	2007176	5488716	231.1	16711935	-146	1
6213	Jul-08	-45.630221	166.54457	2007038	5488861	195.5	16711935	-146	1
630	Jul-08	-45.716143	166.62357	2013925	5479824	740.3	16711935	-146	1
6306	Jul-08	-45.652187	166.53061	2006146	5486341	0	16711935	-146	1
6307	Jul-08	-45.651383	166.53139	2006200	5486435	250.8	16711935	-146	1
6311	Jul-08	-45.648268	166.53428	2006397	5486798	238.8	16711935	-146	1
6316	Jul-08	-45.643426	166.53712	2006575	5487352	282.5	16711680	-146	1
6319	Jul-08	-45.642425	166.54088	2006858	5487486	274.1	16711680	-146	1
637	Jul-08	-45.710658	166.62839	2014251	5480461	627.1	16711935	-146	1
6404	Jul-08	-45.645097	166.53278	2006252	5487140	241.4	16711935	-146	1
645	Jul-08	-45.704015	166.6315	2014435	5481216	684.8	16711935	-146	1
6609	Jul-08	-45.663133	166.52392	2005723	5485087	95.3	16711935	-146	1
6701	Jul-08	-45.680152	166.53036	2006373	5483241	272.7	16711935	-146	1
6710	Jul-08	-45.6751	166.53899	2006999	5483854	240	16711935	-146	1
6715	Jul-08	-45.670857	166.54156	2007161	5484340	269.8	16711935	-146	1
6717	Jul-08	-45.668974	166.54194	2007174	5484551	279.1	16711935	-146	1
6721	Jul-08	-45.665357	166.54216	2007159	5484953	289.5	16711935	-146	1
6803	Jul-08	-45.67188	166.52427	2005827	5484120	238.1	16711935	-146	1
6903	Jul-08	-45.686223	166.51929	2005567	5482500	234.4	16711680	-146	1
6913	Jul-08	-45.680647	166.5292	2006287	5483179	280.6	16711680	-146	1
7002	Jul-08	-45.677173	166.50948	2004725	5483442	187.6	16711680	-146	1
7008	Jul-08	-45.672414	166.51396	2005031	5483997	202	16711935	-146	1
7010	Jul-08	-45.670849	166.5155	2005137	5484180	222.4	16711935	-146	1
7109	Jul-08	-45.684977	166.51314	2005078	5482600	260.4	16711935	-146	1
721	Jul-08	-45.706958	166.60537	2012432	5480731	742.5	16711680	-146	1
7213	Jul-08	-45.681669	166.5045	2004378	5482913	202	16711935	-146	1
7217	Jul-08	-45.678211	166.50593	2004458	5483305	142.2	16711935	-146	1
7401	Jul-08	-45.691421	166.49651	2003844	5481783	167.9	16711680	-146	1
7501	Jul-08	-45.702124	166.47942	2002612	5480491	132.1	16711680	-146	1
7502	Jul-08	-45.702092	166.48078	2002717	5480503	136.9	16711935	-146	1
7507	Jul-08	-45.697919	166.48248	2002812	5480976	134.2	16711935	-146	1
7509	Jul-08	-45.696388	166.48383	2002903	5481154	131.6	16711680	-146	1

TunnelRef	sDescription	fLat	fLong	fEasting	fNorthing	fAlt	iColour	iSymbol	No. Caught
7519	Jul-08	-45.691241	166.49232	2003517	5481777	142.9	16711935	-146	1
7521	Jul-08	-45.691127	166.49496	2003721	5481806	163.8	16711935	-146	1
7609	Jul-08	-45.707702	166.49245	2003673	5479954	152.3	16711680	-146	1
7621	Jul-08	-45.700004	166.50295	2004420	5480872	244.8	16711935	-146	1
7704	Jul-08	-45.704608	166.48121	2002773	5480227	153.9	16711935	-146	1
7706	Jul-08	-45.706261	166.48269	2002902	5480053	200.1	16711935	-146	1
7707	Jul-08	-45.70722	166.48258	2002902	5479946	183.3	16711935	-146	1
7803	Jul-08	-45.729915	166.4568	2001103	5477271	145.3	16711680	-146	1
7804	Jul-08	-45.729248	166.45584	2001023	5477339	145.5	16711935	-146	1
7810	Jul-08	-45.724202	166.45359	2000803	5477884	116.4	16711935	-146	1
7814	Jul-08	-45.720949	166.45576	2000943	5478258	90.7	16711680	-146	1
7818	Jul-08	-45.718556	166.4596	2001219	5478547	69.3	16711680	-146	1
7830	Jul-08	-45.709983	166.46845	2001830	5479552	114.8	16711935	-146	1
7840	Jul-08	-45.703525	166.47785	2002502	5480326	122.9	16711935	-146	1
7915	Jul-08	-45.721723	166.47387	2002355	5478285	189	16711680	-146	1
8004	Jul-08	-45.733601	166.45685	2001140	5476863	169.1	16711680	-146	1
8008	Jul-08	-45.730437	166.45965	2001329	5477231	173.6	16711935	-146	1
801	Jul-08	-45.712476	166.60199	2012218	5480099	640.6	16711935	-146	1
802	Jul-08	-45.711671	166.60279	2012273	5480193	642.3	16711935	-146	1
804	Jul-08	-45.709909	166.60374	2012331	5480394	648.3	16711935	-146	1
904	Jul-08	-45.698784	166.61757	2013308	5481711	623.3	16711935	-146	1
AP1	Jul-08	-45.654166	166.71505	2020496	5487244	7.3	65280	-146	2
AP5	Jul-08	-45.676122	166.71941	2021022	5484837	8.5	16711935	-146	1
C10	Jul-08	-45.671658	166.55338	2008086	5484324	12.4	16711935	-146	1
C2	Jul-08	-45.661592	166.55593	2008196	5485455	1.3	16711935	-146	1
C56	Jul-08	-45.727453	166.7116	2020855	5479102	7.6	16711935	-146	1
C65	Jul-08	-45.71755	166.71839	2021297	5480240	0.8	16711935	-146	1
C72	Jul-08	-45.705319	166.72116	2021408	5481612	-2.5	16711935	-146	1
C81	Jul-08	-45.692602	166.71961	2021179	5483012	-2.5	16711680	-146	1
C95	Jul-08	-45.627061	166.71644	2020372	5490256	9.5	16711935	-146	1
DIS4	Jul-08	-45.609603	166.67182	2016753	5491922	16.5	0	-146	1
DIS6	Jul-08	-45.610069	166.6701	2016623	5491860	15.7	16711935	-146	1
FH3	Jul-08	-45.695515	166.57739	2010160	5481828	9.7	16711680	-146	1
L15	Jul-08	-45.762667	166.67519	2018332	5474980.9	13.3	16711935	-146	1
L19	Jul-08	-45.759058	166.68135	2018779	5475418	9.5	65280	-146	2
L21	Jul-08	-45.757477	166.68531	2019072	5475617	9.3	16711680	-146	1

TunnelRef	sDescription	fLat	fLong	fEasting	fNorthing	fAlt	iColour	iSymbol	No. Caught
L29	Jul-08	-45.753092	166.69714	2019952	5476174	6.1	16711680	-146	1
L31	Jul-08	-45.751986	166.70088	2020233	5476319	7.1	16711680	-146	1
L33	Jul-08	-45.750837	166.70417	2020478	5476466	10.7	16711935	-146	1
M10	Jul-08	-45.630999	166.73037	2021489	5489903	6.4	16711680	-146	1
M22	Jul-08	-45.68226	166.73823	2022536.8	5484269.3	0.1	16711935	-146	1
M24	Jul-08	-45.686794	166.73874	2022615	5483770	5.9	16711935	-146	1
M26	Jul-08	-45.689997	166.7374	2022538	5483407	7.8	16711680	-146	1
M3	Jul-08	-45.613499	166.72982	2021297	5491839	14.3	16711680	-146	1
M5	Jul-08	-45.618065	166.73116	2021440	5491341	12.6	16711680	-146	1
M52	Jul-08	-45.725364	166.73248	2022457.7	5479458.3	18.6	16711935	-146	1
M53	Jul-08	-45.725304	166.73306	2022501.7	5479468.4	68.1	16711680	-146	1
M57	Jul-08	-45.719681	166.73486	2022593.7	5480102.3	194.8	16711935	-146	1
M65	Jul-08	-45.710136	166.7349	2022515.7	5481160.3	249.6	16711935	-146	1
M75	Jul-08	-45.697786	166.73815	2022662.7	5482548.3	169.3	16711935	-146	1
M8	Jul-08	-45.628398	166.72967	2021412	5490187	6.6	16711680	-146	1
M9	Jul-08	-45.629578	166.73029	2021471	5490060	7.6	16711680	-146	1
R04	Jul-08	-45.708515	166.5765	2010204	5480382	8.3	16711680	-59	1
R10	Jul-08	-45.712029	166.57312	2009973	5479972	7.1	16711680	-59	1
SC1	Jul-08	-45.601973	166.6739	2016849	5492780	17.4	16711680	-146	1

Appendix Nine: August 2008 Resolution Island Tunnel Check Data

TunnelRef	sDescription	fLat	fLong	fEasting	fNorthing	fAlt	iColour	iSymbol	No. Caught
1109	Aug-08	-45.693606	166.62714	2014006	5482343	504.1	16711935	-146	1
1408	Aug-08	-45.724572	166.66286	2017047	5479128	202.5	16711935	-146	1
1419	Aug-08	-45.723718	166.67701	2018138	5479308	589.6	16711935	-146	1
1426	Aug-08	-45.720812	166.68464	2018705	5479676	870.1	16711935	-146	1
1971	Aug-08	-45.712908	166.70746	2020409	5480689	218.3	16711935	-146	1
1979	Aug-08	-45.705756	166.70989	2020536	5481496	191.9	16711935	-146	1
2018	Aug-08	-45.69754	166.67006	2017373	5482167	384.4	16711935	-146	1
2022	Aug-08	-45.698094	166.67526	2017782	5482137	431.5	16711935	-146	1
2109	Aug-08	-45.68842	166.66831	2017159	5483167	419	16711935	-146	1
2205	Aug-08	-45.699615	166.69413	2019260	5482082	712	16711935	-146	1
2402	Aug-08	-45.692652	166.68738	2018676	5482813	859.3	16711935	-146	1
2412	Aug-08	-45.683932	166.6855	2018455	5483768	905.7	16711935	-146	1
2515	Aug-08	-45.680169	166.69914	2019482	5484267	805	16711935	-146	1
2526	Aug-08	-45.670401	166.69707	2019238	5485337	868.4	16711935	-146	1
2601	Aug-08	-45.646634	166.70195	2019413	5488000	629.5	16711935	-146	1
2735	Aug-08	-45.653683	166.68534	2018183	5487119	463.7	16711935	-146	1
3309	Aug-08	-45.646843	166.68818	2018345	5487894	634.4	16711935	-146	1
3904	Aug-08	-45.61845	166.66194	2016061	5490882	501.2	16711935	-146	1
4134	Aug-08	-45.611599	166.6596	2015820	5491627	356.3	16711935	-146	1
4635	Aug-08	-45.643361	166.65639	2015844	5488088	758.1	16711935	-146	1
4913	Aug-08	-45.617639	166.59686	2010993	5490576	67.4	16711935	-146	1
5406	Aug-08	-45.654363	166.55853	2008335	5486272	213.3	16711935	-146	1
5422	Aug-08	-45.657145	166.57845	2009907	5486086	360.6	16711935	-146	1
5433	Aug-08	-45.648954	166.58572	2010400	5487038	386.8	16711935	-146	1
5808	Aug-08	-45.684305	166.57672	2010010	5483066	329.1	16711935	-146	1
5820	Aug-08	-45.68284	166.5927	2011238	5483326	638.7	16711935	-146	1
6203	Aug-08	-45.639082	166.54487	2007139	5487881	262.6	16711935	-146	1
6212	Aug-08	-45.630719	166.5459	2007146	5488814	221.2	16711935	-146	1
6711	Aug-08	-45.674206	166.53946	2007027	5483956	234.7	16711935	-146	1
7827	Aug-08	-45.712519	166.467	2001740	5479262	111.4	16711935	-146	1
7918	Aug-08	-45.720338	166.47748	2002623	5478461	202.2	16711935	-146	1
M3	Aug-08	-45.613499	166.72982	2021297	5491839	14.3	16711935	-146	1
M40	Aug-08	-45.710826	166.72907	2022069	5481049	18.9	16711935	-146	1
RA11	Aug-08	-45.745168	166.5917	2011703.7	5476413.6	0.6	16711935	-146	1

Appendix Ten: Wardle Vegetation Classes

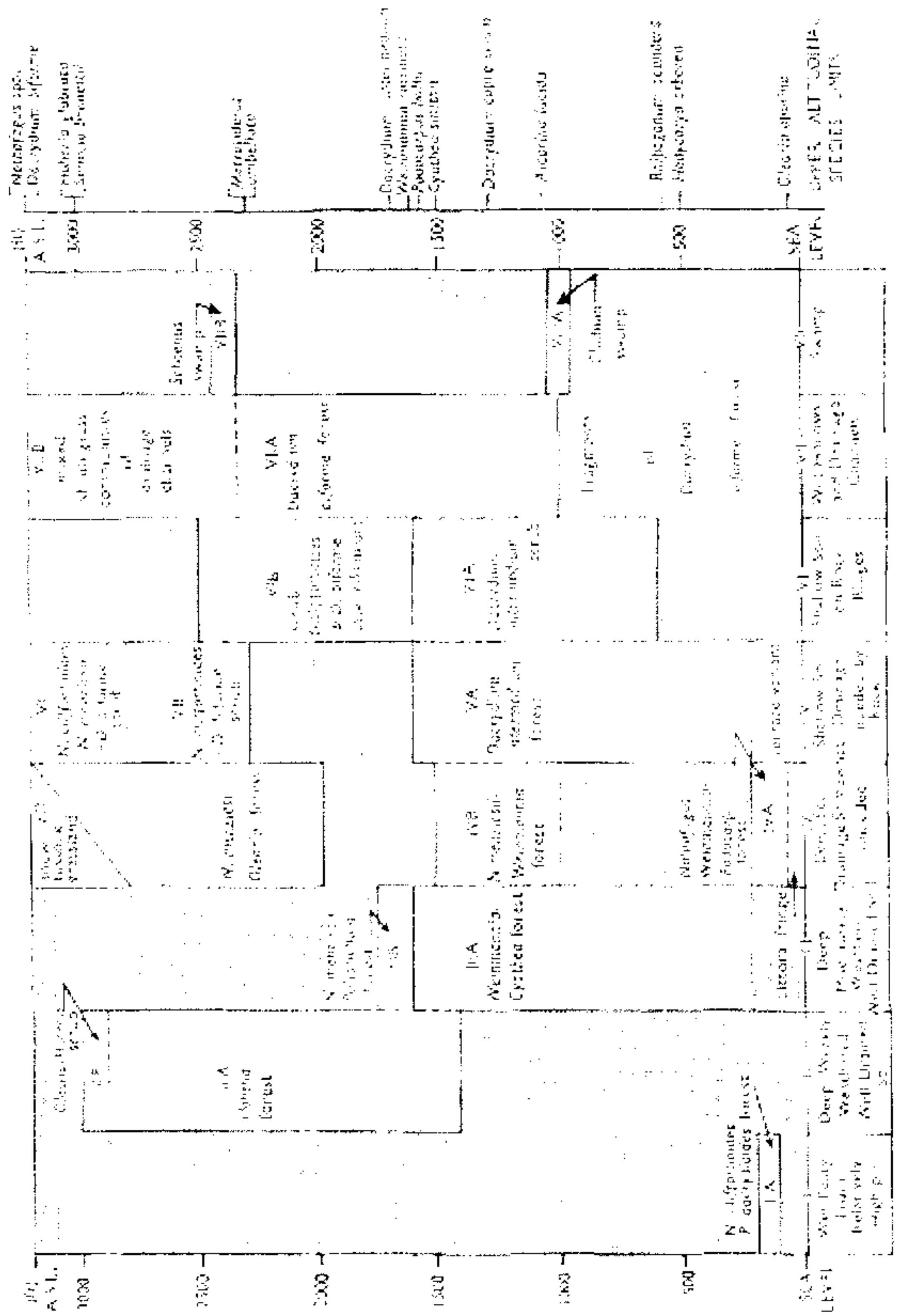
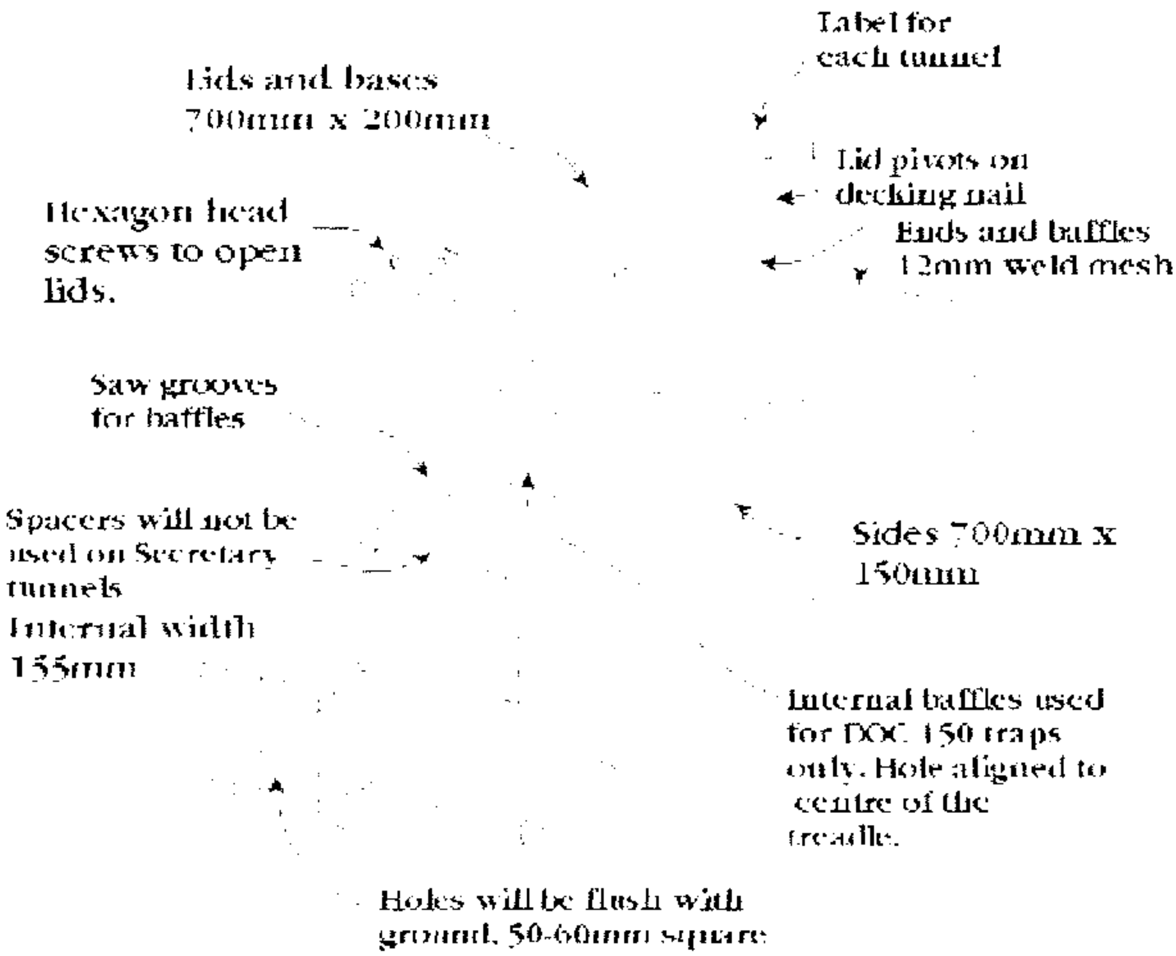


FIG. 1—Tabular representation of distribution of plant communities in relation to soil and altitude. Shaded areas indicate gaps in field observations. Broken lines between communities indicate where transitions were noted in the field. Transitions also occur between communities IA and IVA, between IIIA and IVA, and between communities of classes V and VII.

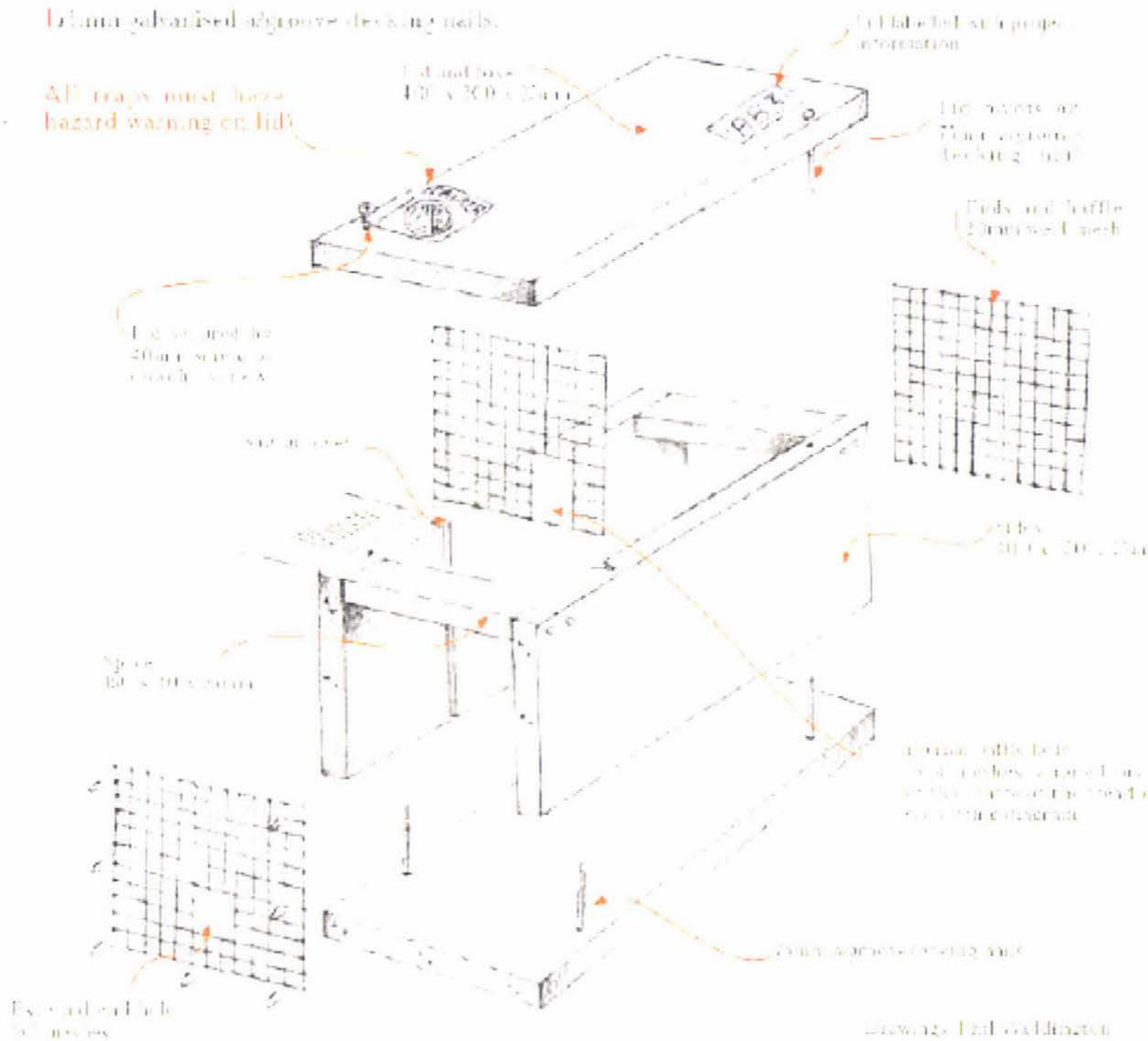
Appendix Eleven: Tunnel Design – Secretary Island

Wooden Tunnel Design – Drawing P. Waddington



Appendix Twelve: Tunnel Design – Resolution Island

Wooden Tunnel Design – Drawing P. Waddington



Appendix Thirteen: Wire Tunnel Design – Resolution Island