The future of indigenous fauna on private land: a case study of the habitat use of the small-scaled skink (*Oligosoma microlepis*).

Rowena Teal

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"...ask the animals, and they will teach you..."
Job 12 vs 7

Abstract

The small-scaled skink (*Oligosoma microlepis*) is a small (≤67 mm SVL) endemic New Zealand lizard that is currently listed as vulnerable by the IUCN (1994). The species is diurnal and heliothermic, inhabiting rock outcrops and piles scattered throughout the central North Island. All of the ca. 17 populations are small, isolated and confined to private land. The *Oligosoma* spp. Recovery Plan (2002) outlines the need to obtain basic biological data on the species, determine threats and to conduct advocacy with landowners.

The first part of my study was to obtain an understanding of the factors affecting *O. microlepis'* habitat use. This was achieved by using the programme PRESENCE to model site occupancy of the species as a function of site covariates, as well as detection probability as a function of sampling covariates. A total of 45 sites were used, spanning 25 km^2, on three stations in the Inland Patea district. Presence-absence data and sampling and site covariates were recorded using an active search method for lizards at each site. Results showed that detection probability of small-scaled skink was most affected by rock temperature, the time of day and month surveying was carried out. Site occupancy was correlated with three site covariates. The first important site covariate was distance to the nearest stock route. Probability of site occupancy decreased as the distance to the nearest stock route increased, suggesting that grazing may maintain lizard habitat by keeping rocks clear of vegetation. The second important site covariate was the presence of a tree on the site. No *O. microlepis* were found when a tree was present on the site, probably due to shade and predation by birds. Lastly, rock piles had a significantly higher occupancy than rock outcrops. This difference could be due to a number of factors, including competitive exclusion by common gecko (*Hoplodactylus maculatus*), which were abundant on rock outcrops as well as the biophysical nature of outcrops inhibiting thermoregulation.

The second part of my study was to conduct more extensive habitat analysis using ordination plots and a classification tree, and this analysis expanded on these site

covariates affecting occupancy. Sites were more likely to be occupied if the herbaceous plant *Gingidia montana* was absent, if the site was not in a gully, if the site had a north-northwest aspect, and the site was close to a public road. This information can potentially increase the efficiency in surveying new sites for *O. microlepis*.

The third part of my study was to conduct environmental education with the farming community to create awareness of *O. microlepis* and conservation issues in the district. I did this by the sharing of knowledge, the application of skills and subsequent steps towards conservation management on their land. This study demonstrates how environmental education at a local community level is a worthwhile activity in any research on private land.

Future research is still needed on current threats to *O. microlepis* (e.g., introduced predators), the long-term impact of farming, metapopulation dynamics, and effectiveness of management techniques for conserving the species.

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I wanted to design my thesis around my love for lizards, conservation and environmental education, but I was aware that it was potentially an impossible task to incorporate all three into a Masters, particularly since the majority of rare lizards are confined to offshore islands away from the general public. After meeting a friend by chance one day, he asked me about potential thesis topics, and when I told him about my problem he informed me of the small-scaled skink which had only ever been found on private land – and that was the conception of my Masters.

Travelling to Moawhango for the first time and meeting all the genuine people there I quickly realised why the lizards choose to live in that area! The country is ruggedly beautiful, the weather is pleasantly sweltering in summer months, and the people are very welcoming. I want to thank everyone at Moawhango for allowing me to be a part of the community over the last two years and for all the good times such as countless BBQs by the river, dog trials, horse sports, and parties, but I especially want to thank those at Otupae, Kelly Land Company and Erewhon stations and all the Oruamatua Marae Trustees. I also wish to thank my beautiful (adopted) family Caroline, James, Ella and Charlotte at Erewhon who opened their home and hearts to me during the two summers of my fieldwork; I can never begin to express my love and gratitude to them.

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General Introduction

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General Introduction

1.1 New Zealand reptiles

New Zealand has the most diverse endemic reptile fauna of any temperate archipelago (Towns 1994). The New Zealand reptiles include two tuatara species (*Sphenodon* spp.) and at least 60 species of lizards from the two families Gekkonidae (geckos) and Scincidae (skinks) (Patterson 2000; Towns and Ferreira 2001; Towns *et al.* 2001; Neilson *et al.* 2004). Renowned for their colonising ability, geckos and skinks are generally considered to have arrived in New Zealand by 'rafting' after the split from Gondwanaland 80 million years ago (Whitaker 1976; Patterson 2000). All are endemic to New Zealand and the numbers of species continues to grow as new forms are discovered and known forms are re-classified (Patterson 2000).

New Zealand skinks are divided morphologically and genetically into two distinct groups (Patterson and Daugherty 1995; Towns *et al.* 2002). The species in the genus *Cyclodina* are predominately nocturnal, with heavy bodies, short limbs and toes, and a scaly lower eyelid (Whitaker 1976). The genus *Oligosoma* is made up of 28 known species (Patterson 2000; Norbury 2001), and shows great ecological diversity (Patterson and Daugherty 1995; Towns *et al.* 2002). *Oligosoma* species are predominately diurnal and terrestrial, occurring in a wide range of open habitats (Lord and Marshall 2001). They have long slender bodies, long limbs and digits, and a transparent palpebral disc in the centre of the lower eyelid (Whitaker 1976).

1.2 Human impacts

Since human arrival ca. 1000 years ago (Towns 1994), anthropocentric change has led to dramatic declines in lizard habitat and lizard abundance throughout New Zealand (Towns 1994; Patterson 2000; Towns *et al.* 2001). For example, the northern part of the North Island was once home to at least 11 species of skink, one species of tuatara and six species of gecko. Today there are only four species of gecko and four species of skink left in that region (Towns *et al.* 2001).

All tuatara and 37% of New Zealand lizard species are now confined to offshore islands (Towns *et al.* 2001), and those left on the mainland are confined to scattered, small 'islands' of remnant habitat (Towns 1994). The major driving force for these declines are what Patterson (2000) describes as the 'twin evils': introduced mammalian predators and habitat loss (Towns and Daugherty 1994; Patterson 2000; Norbury 2001).

1.2.1 Introduced predators

Introduced species are a major threat to biodiversity worldwide, posing a big threat to native species due to both predation and competition (Meffe *et al.* 1994). Successfully introduced species tend to have high reproduction rates, longevity, high genetic variability and a broad diet (Meffe *et al.* 1994), making them difficult to eradicate. Unfortunately, New Zealand has more introduced mammalian species than any other archipelago (Towns *et al.* 2001; Towns 2002).

New Zealand's terrestrial ecosystems were first radically changed with the arrival of Pacific rats (*Rattus exulans*) between 700 and 2000 years ago (Holdaway 1996; Wilmshurst and Higham 2004), and this arrival has been associated with reduced density and diversity of many indigenous species (Towns and Daugherty 1994; Towns and Ferreira 2001; Towns *et al.* 2001). These changes were accelerated with human settlement and further introductions of mammals around 1000 years later (Norbury 2001). Mammal species that were especially detrimental to skink populations include predators such as cats (*Felis catus*), mustelids (*Mustela furo*, *M. ermina*, and *M. nivalis*), mice (*Mus musculus*), and rats (*R. exulans*, *R. rattus*, and *R. norvegicus*) (Whitaker 1976; Towns and Daugherty 1994). It is estimated that a single cat may consume thousands of skinks annually (Patterson 2000). In 1983, a feral cat was killed near a rock outcrop in Otago and 14 undigested skinks were found in its stomach (Patterson 2000).

The true impact of introduced species can be seen in the positive response in lizard abundance after predator eradication on islands or intensive control on the mainland. An example of this is Pacific rats from Korapuki Island in the Mercury Islands (Towns and Ferreira 2001; Towns 2002).

Hedgehogs (*Erinaceus europaeus*) have also been documented preying on lizards and frogs (Atkinson 2001). A study by Jones *et al.* (2005) found native lizard remains in guts of 6% of *E. europaeus* sampled.

There is also evidence of non-predatory introduced mammals indirectly contributing to the decline of lizard species in New Zealand. A study by Norbury (2001) demonstrated how rabbit (*Oryctolagus cuniculus*) grazing reduces cover that lizards use for thermoregulation and protection from predators. In addition, rabbits are a primary prey for many mammalian predators in New Zealand (e.g., ferrets and cats) and sudden declines in rabbit numbers have led to a switch in prey to lizards (Norbury 2001). Although there are positive results of pest eradication on offshore islands, the impacts of introduced pests continue to threaten native lizards on the mainland (Clout and Saunders 1995), where numbers can only be controlled through ongoing management or eradications within predator-proof fences.

1.2.2 Habitat loss

Habitat loss (i.e., drained wetlands, deforestation, quarrying, damming and channelling of waterways, urbanisation) is a significant threat to herpetofauna worldwide (Ryan *et al.* 2002) and is the second major threat to skinks in New Zealand (Towns and Daugherty 1994). After human settlement in New Zealand, native forest cover was reduced from 78% of land area, to an estimated 23% by the 1980s, through fire and felling (Clout and Saunders 1995). The majority of remaining forests are now largely restricted to upland and mountainous areas, as lowlands were predominately cleared for farmland.

Most remnant patches of lowland, wetland and tussock habitat are now small and isolated, and as a result, can only sustain small populations of indigenous animals that rely on them. Compounding the situation, small populations are particularly vulnerable to the effects of intrinsic factors such as demographic stochasticity, genetic deterioration and social dysfunction (Caughley and Gunn 1996). Theory on such factors is known as the 'small population paradigm', outlining problems faced by a population whose numbers are small and capped (Caughley and Gunn 1996).

Another problem is dispersal between these habitat patches. Dispersal depends on the number and ability of dispersing individuals, and most importantly, the availability of dispersal routes between patches, such as forested corridors or waterways (Fahrig and Merriam 1994). Dispersal routes can be critical in determining regional population abundance and the long-term population persistence in patches (Fahrig and Merriam 1994).

Examples of skink species adversely affected by habitat loss in mainland New Zealand are the Otago skink (*Oligosoma otagense*) and Grand skink (*Oligosoma grande*). Both species exist on schist rock tors scattered throughout tussock in the Otago region. Agricultural development has contributed to the major decline of both species through general farming practices (e.g., burning native tussock, over sowing exotic grasses, ploughing, trampling and grazing by stock). These changes have led to the reduction of vegetative cover, and subsequently to increased predation of skinks and isolation of habitat patches (Coddington and Cree 1997).

1.3 New Zealand lizard conservation

The conservation of New Zealand lizard species relies on assessing these threats and outlining and implementing appropriate management strategies. The process of species recovery in New Zealand is organised through species recovery plans, several of which have been written for New Zealand skinks. A species recovery plan is "a statement of intentions for conservation of particular species for defined periods" (Towns *et al.* 2002). Each plan outlines long-term recovery goals and short-term objectives to restore each species to a particular level of abundance within a given timeframe (Clout and Saunders 1995). Plans also outline conservation status, threats, and past conservation efforts (Towns *et al.* 2002). The biggest limiting factor of conservation management, however, is lack of species-specific information, and recovery plans identify this and list research needs for each species.

In recent years, some New Zealand skink species have been recovering through such rigorous species-specific research and conservation management (Towns *et al.* 2001). Offshore islands and mainland sites have been the focus of intensive habitat restoration and introduced species eradication and control. Currently there are at least 60 islands around New Zealand that are rodent free (Towns and Ferreira 2001) and many mainland 'islands' that have intensive predator control (Saunders and Norton 2001). These sanctuaries are now targeted as translocation sites that provide not only direct benefits of a refuge to most remaining extant populations of New Zealand lizards, but also indirect benefits such as environmental education through community involvement and increased awareness of conservation.

1.3.1 Importance of lizard conservation

Biological diversity (or biodiversity) is defined by (Gaston 1998) as 'the structural and functional variety of life forms at genetic, population, species, community and ecosystem levels'. Gaston (1998) states that biodiversity needs to be conserved firstly because it provides sources of marketable commodities for the economy (Gaston 1998). Biodiversity is used for food, medicinal use, industrial use, recreational harvesting (fishing and hunting) and culturing (Gaston 1998). Second, biodiversity is also important because it maintains ecosystem functions essential for life, as well as providing aesthetic values. And lastly, biodiversity should be conserved because of its intrinsic value, and humans have a moral and ethical responsibility towards it (Gaston 1998).

Lizards are an important part of New Zealand's biodiversity because of their value as indicator species in environmental impact assessments (Märtens *et al.* 1996). Lizards also fill an important niche in New Zealand ecosystems, the extent of which is only just being understood. For example, New Zealand lizards are known to consume fruit and nectar as part of a broad diet (Lord and Marshall 2001) and visit many indigenous trees (e.g., Pohutukawa *Metrosideros excelsa*) and shrubs (e.g., *Coprosma* spp., *Muehlenbeckia* spp.). Recent studies show that lizards are primary seed dispersers and pollinators for many plant species (Olsson *et al.* 2000; Wotton 2002; Olesen and Valido 2003).

1.4 Environmental education in conservation

General public awareness through environmental education of the existence and importance of our native herpetofauna is a vital part of their conservation. Environmental education, as outlined by the Tbilisi Declaration (UNESCO 1978; Palmer 1998), is a principle tool at all ages in creating awareness, subject knowledge and new patterns of behaviour, all of which are essential in creating action to conserve the environment. Patterson (2000) emphasised the need to incorporate increased awareness together with other conservation initiatives specifically into the recovery of New Zealand skink species because of the lack of general knowledge by the general public compared to other indigenous species (e.g., North Island brown kiwi, *Apteryx mantelli*, kakapo, *Strigops habroptilus*, tuatara *Sphenodon* spp.). Environmental education is the means by which this awareness can be fostered.

Environmental education is especially important for species that aren't found on public conservation land, as the future of these species relies on the initiatives of landowners. A significant amount of biodiversity in New Zealand remains within the stewardship of private landowners (Ministry for the Environment 2000), and although many New Zealanders value biodiversity, many are hampered by lack of information and awareness (Ministry for the Environment 2000). An example of a vulnerable New Zealand lizard species confined entirely to private land is the small-scaled skink (*Oligosoma microlepis*).

1.5 Small-scaled skink (*Oligosoma microlepis*)

1.5.1 Species description

Oligosoma microlepis is a small, (≤67mm SVL) diurnal species known only from the central North Island (Towns *et al.* 2002). It is characterised by very small body scales, and consequently a high mid-body scale row count (38-44), and a tear drop marking below each eye. These characteristics distinguish it from all other New Zealand skinks (Whitaker 1991; Flannagan *et al.* 2001; Towns *et al.* 2002). The colour and colour pattern of *O. microlepis* is described by Whitaker (1991) as "pale greyish-brown, with a discontinuous darker mid-dorsal strip, and broad dark lateral stripe" (Plate 1.1). It contains the characteristic *Oligosoma* transparent palpebral disc in the centre of the lower eyelid, allowing the animal to see while preventing particles from entering the eye (Patterson 2000). The species has a slender body, and long limbs and digits which allow agility across the rocks. The species has flexible yet tough overlapping scales, which protect it from abrasions as well as minimising water loss through evaporation (Patterson 2000).

1.5.2 History

The first specimen of *O. microlepis* was collected from Motutaiko Island in 1971, and further animals were observed during visits to the island during the mid to late 1970s (Whitaker 1991). No further studies have been carried out due to access being denied by Ngati Tuwharetoa. Fortunately, in 1978 the species was discovered at Springvale Bridge, near the Rangitīkei River, in the Inland Patea district, 30km east of Taihape (Whitaker 1991). The species was formally named in 1990 (Patterson and Daugherty 1990; Whitaker 1991) after which the primary conservation objective for the species was to survey the wider area in an attempt to discover new populations (Whitaker 1991).

Research was conducted the following year by Whitaker (1991). Whitaker (1991) defined the habitat of *O. microlepis*, and determined the local distribution around the Springvale Bridge by questioning landowners, farm staff and other local people and conducting surveys in the general area. With increased information from the research, conservation procedures and further survey research needs could begin to be assessed. The study was successful in the discovery of seven new populations of *O. microlepis* over an area of 15,000 ha throughout the Inland Patea district, but all populations were small, very isolated and on privately owned land (Whitaker 1991). Further studies on the general habitat use and species' biology were carried out by Hutchinson (1992, 1993).

Three new populations were found in surveys in 1997 (Whitaker 1997), extending the known range to 300,000 ha, including 60 km northeast from Lake Taupo, the southern Urewera and the Inland Patea district (Whitaker 1997). These surveys increased the number of known populations to 16 as well as broadening the species' habitat definition to include pumice cliffs (Whitaker 1997). Four years later, Flannagan *et al.* (2001) conducted extensive surveys throughout the Inland Patea district during the summer 2000/2001. Surveys at the Kelly Land Company site adjacent to the Rangitīkei River were unsuccessful in finding *O. microlepis* that had previously been sighted there (Flannagan *et al.* 2001), and only small numbers of animals were located at other sites in the district. As a result, the original Springvale Bridge area was chosen as the long-term monitoring site for the species, as this site had "moderate to good populations of *O. microlepis*" (Flannagan *et al.* 2001).

Today, despite having such a large range, *O. microlepis* is still only known from a few (ca. 16) small, scattered and localised populations (average area of habitat patches between <0.25ha and 2 ha) in the central North Island (Whitaker 1991; Hutchinson 1993; Whitaker 1997). In addition, all known populations exist on privately owned land and are constantly under threat from agricultural and forestry development (Whitaker 1997) and introduced predators.

1.5.3 Current conservation status

On a positive note, the large range (300,000 ha) of *O. microlepis* spans four conservancies – Bay of Plenty, East Coast/Hawkes Bay, Tongariro/Taupo and Wanganui. This distribution, combined with their habitat use, suggests that *O. microlepis* may once have been distributed throughout the central and lower North Island, and along the axial ranges (Whitaker 1991; Towns *et al.* 2002), and could still occur in tiny localised but widely scattered populations (Whitaker 1991).

In 1992 *O. microlepis* was assigned a 'Category B' conservation priority because of its apparent rarity, restricted range and small population size and vulnerability (Whitaker 1997). The new threatened species classification list ranks *O. microlepis* as 'data poor' due to insufficient scientific information (Hitchmough 2002). The species' status is classed as in 'serious decline' (Hitchmough 2002), because populations contain ≤500 mature individuals in the largest sub-population, and the total area of occupancy is ≤ 100 ha (1 km^2) (Molloy *et al.* 2002). In addition, there is a predicted small/moderate decline of 5-30% in the total population in the next 10 years due to existing threats (Molloy *et al.* 2002). The IUCN Classification Red List for threatened species (2004) classifies *O. microlepis* as 'vulnerable', which is defined by the IUCN (1994) as 'facing a high risk of extinction in the wild'.

1.5.4 Inland Patea district

The main stronghold for *O. microlepis* is near the Springvale Bridge area (Flannagan *et al.* 2001) 30 km east of Taihape along the Napier-Taihape Road, in the geographical area known as the Inland Patea district (Figure 1.1). This area is situated in the middle of four mountain ranges (Ruahine, Kaimanawa, Otupae and Kaweka Ranges), with altitude ranging from 550 m at the Rangitīkei River to 900 m at the foothills of the Kaimanawa and Kaweka Ranges (Plate 1.2).

Current vegetation is a result of volcanic eruptions and human settlement (fires and deforestation) (Rogers 1994). Vegetation varies from pasture to tussock (e.g., red tussock, *Chionochloa rubra*) and scrub (manuka, *Leptospermum scoparium*; and kanuka, *Kunzea ericoides*), pine plantations (*Pinus radiata*) and native broadleaf/podocarp species (e.g., beech, *Nothofagus* spp.) along river valleys and throughout the nearby mountain ranges.

The geology of the area is predominately volcanic, free-draining soils, with tertiary sandstone, limestone and greywacke bedrock (Whitaker 1991). Exposed greywacke is deeply fissured and shattered, forming outcrops, scree and talus slopes and alluvial terraces along river valleys (Whitaker 1991). These formations comprise *O. microlepis* habitat.

All populations are located on sheep and beef stations ranging from rugged sites with natural vegetation to highly modified sites with intensive farming. Air temperatures throughout the year range from below 0°C to 38°C. Winds are predominately from the west and east, with annual rainfall highest in the mountains, ranging from 900-2000 mm (Whitaker 1991).

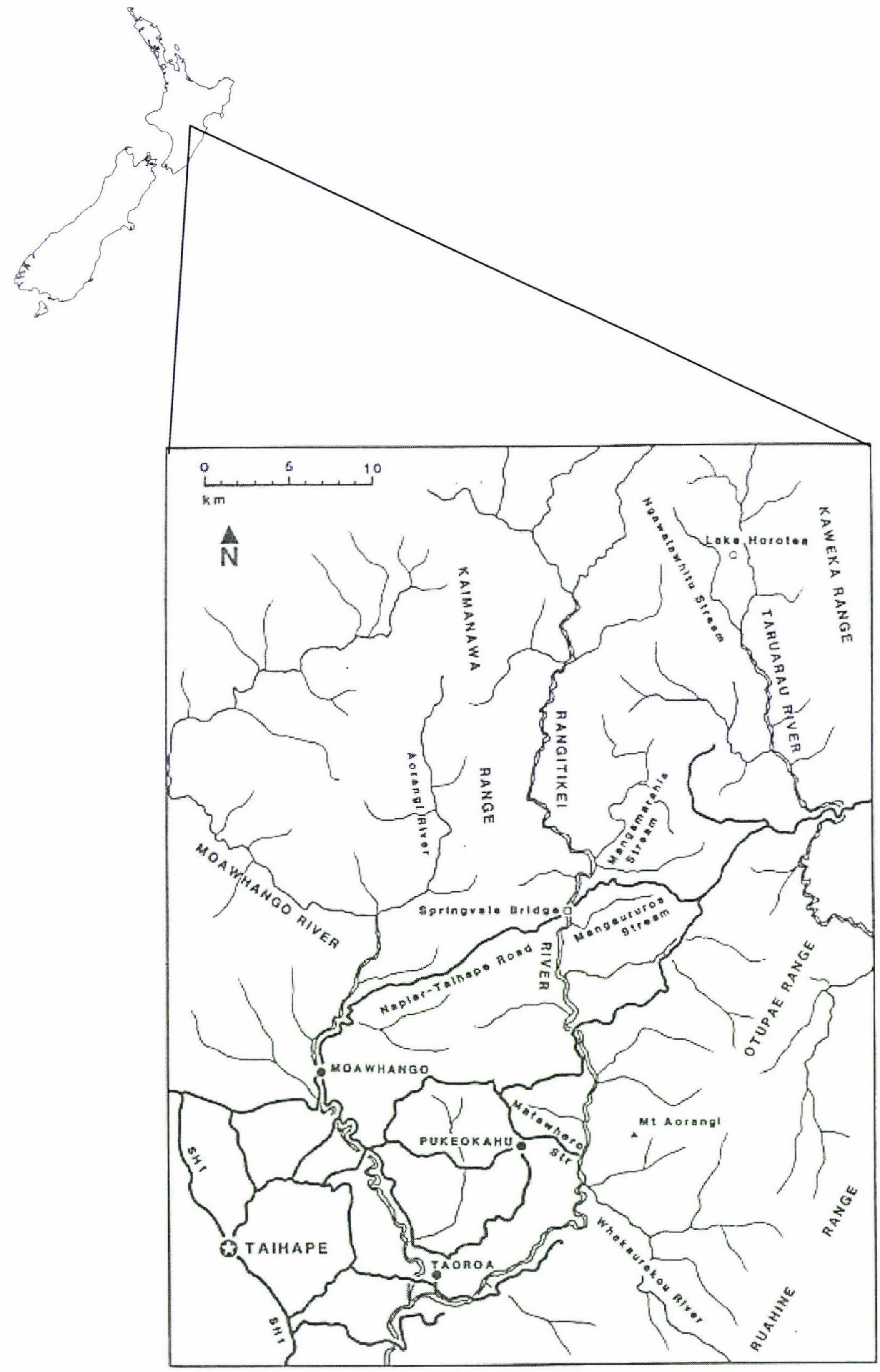

Figure 1.1 Springvale Bridge at the Rangitīkei River in the Inland Patea district, 30 km east along the Napier-Taihape Road. Source: Department of Conservation (DoC) Report (Whitaker 1991).

1.5.5 Ecology

Oligosoma microlepis is saxicolous (rock dwelling), and is found primarily at sites containing greywacke rock outcrops, rock piles of angular stones, loosely assembled with large numbers of crevices, talus slopes or riverbeds with rounded greywacke boulders (Whitaker 1991; Whitaker 1997; Flannagan *et al.* 2001). Most sites have sparse vegetation. It is thought that dense forest would have historically limited distribution of *O. microlepis* to sites naturally clear of vegetation such as river valleys and at high altitudes (Whitaker 1991). Tussock and low scrub replaced forest after the Māori fires 400-600 years ago (Whitaker 1991), probably encouraging dispersal and colonisation of new sites by the skinks.

Oligosoma microlepis is a diurnal heliotherm, actively sun-basking (Plate 1.3) at temperatures above 16°C and rock temperatures above 23.5°C (Flannagan *et al.* 2001), and shuttling and foraging during fine weather. In cool weather they shelter near or under stones, and orientate their body towards the sun (Whitaker 1997). In wet, cold or extremely hot weather they retreat to crevices within or under the rocks (Whitaker 1991; Whitaker 1997; Flannagan *et al.* 2001). Because of these thermoregulatory requirements, it has been found that the species displays a preference for north and east facing, sparsely vegetated, rocky habitat (Whitaker 1991; Flannagan *et al.* 2001).

In addition, *O. microlepis* shows a preference for rock piles and outcrops with abundant crevices and fissures, which provide more refuges and basking sites (Whitaker 1997), compared with rock piles cemented in place by volcanic ash (Hutchinson 1993) and smooth outcrops. *O. microlepis* also mark favoured sites using faecal material, which is a behaviour characteristic of relatively dense *O. microlepis* populations (Whitaker 1991).

Oligosoma microlepis coexist with common skinks (*Oligosoma nigriplantare polychroma*) and common gecko (*Hoplodactylus maculatus*) at several sites and are sympatric with speckled skinks (*O. infrapunctatum*) in the upper Rangitīkei Catchment (Whitaker 1997; Towns *et al.* 2002).

Similar to most skinks, *O. microlepis* is classed as insectivorous (Whitaker 1991; Hutchinson 1993) and faecal pellets have been found to contain invertebrate fragments (Whitaker 1991). Fruit is also an important element in the diet of many New Zealand skink species (Patterson 2000), but has not yet been observed in the diet of *O. microlepis*. They are active foragers, covering distances of up to 10 m moving through vegetation and over rocks in 20 minutes of observation (Whitaker 1997).

Similar to all but one species of New Zealand skink, *O. microlepis* are live-bearing. Young are born in late summer, between January to early March (Towns *et al.* 2002); and gravid females are frequently observed during this time (Whitaker 1991).

1.5.6 Threats

Although there is currently no record of decline for the species due to the short period of time it has been described (Hutchinson 1993) and the lack of available data, the primary threats to *O. microlepis* are thought to be the same as all other skinks throughout New Zealand, i.e., habitat degradation and introduced predators (Flannagan *et al.* 2001; Towns *et al.* 2002).

Towns *et al.* (2002) state that widespread land conversion to agriculture has potentially increased the vulnerability of *O. microlepis* populations in the upper Rangitīkei area, by separating habitat patches by distances of up to several kilometres. Pasture between sites also decreases the opportunity for dispersal of individuals and colonisation of new sites (Hutchinson 1993). Nevertheless, there is some evidence of dispersal between sites as animals have been observed travelling through pasture (Flannagan *et al.* 2001), and disused quarry sites have been colonised in recent years (Whitaker 1991). Despite these examples, even if the skinks can physically travel between sites, without sufficient cover during dispersal, the chance of predation is greatly increased. Without dispersal between sites, the long-term viability of populations within farmland is questionable.

Alternatively, studies have shown that low levels of disturbance caused by farming practice (i.e., stock grazing and trampling) can create habitat for lizards and maintain populations at sites (Hobbs and Huenneke 1992; Marty 2005). This could be the case for *O. microlepis*. For example, low levels of disturbance by grazing may prevent encroachment of vegetation onto rocks, and trampling by stock may maintain turnover of rocks (Hutchinson 1993). Disturbance on a larger scale, however, such as complete removal of rocks for roads, would be detrimental to localised populations by killing individuals and depleting habitat (Schlesinger and Shine 1994; Goode *et al.* 2005). The impacts of general farming practice on *O. microlepis*, whether positive or negative, are still largely unknown.

In addition, the agricultural landscape also supports a number of introduced predators that prey on skinks. These include cats, hedgehogs, rats and mustelids. Rabbits are also abundant, and as mentioned previously, have been linked to maintaining high levels of predators (Norbury 2001). Avian predators are also common throughout the district and include magpies (*Gymnorhina tibicen*), New Zealand bush falcon (*Falco novaeseelandiae*), rooks (*Corvus frugilegus*), and kingfishers (*Halcyon sancta*). Kingfishers especially are renowned for killing large numbers of basking lizards (Whitaker 1976).

1.6 Thesis aims and organisation

Until the conservation needs of *O. microlepis* are studied, and management set in place, the species will continue to be under constant threat of extinction. However, Whitaker (1997) and Flannagan *et al.* (2001) emphasise that before effective conservation initiatives can be carried out, information is needed on the species' range, general ecology and threats. The North Island *Oligosoma* spp. recovery plan (Towns *et al.* 2002) outlines three preferred research objectives to achieve this: 1) obtain data on distribution, habitat use, relative abundance and threats; 2) determine impacts of introduced mammalian predators on habitat patches; and 3) conduct advocacy with landowners.

This study aims to address the first and third objectives of the recovery plan for *O. microlepis*, focusing on understanding factors affecting habitat use, and conducting environmental education with farmers, local hapu and the wider community.

In Chapter 2, I model detection probabilities and site occupancy of *O. microlepis* using data I collected in a series of surveys at 45 sites that appeared to provide suitable habitat (rock piles or rock outcrops). The analysis assesses the effect of a number of environmental factors that I thought could potentially affect detection probability and/or site occupancy. I envision that this analysis will improve biological knowledge of *O. microlepis* by highlighting optimum environmental conditions for surveying the species in the future, and assisting in the selection of new sites and the protection of known ones.

In Chapter 3, I conduct a detailed habitat analysis of occupied sites of *O. microlepis* by implementing multivariate analysis of habitat variables and presence-absence data. As all populations are small and isolated, this information will provide an understanding of habitat use needed for management decisions in *O. microlepis* conservation.

Chapter 4 describes environmental education carried out during the research project with the farming community in an attempt to create awareness of the species and wider conservation issues. This will be carried out through the exchange of information by conducting talks, informal discussions and meetings with the local farming community on the research progress, as well as providing individuals the opportunity for participation in fieldwork and research planning. The success of this was evaluated at the completion of the study by comparing outcomes of environmental education outlined in the Tbilisi Declaration (1978).

Chapter 5 outlines a summary of the research and recommendations for future research and conservation management strategies of *O. microlepis*.

Plate 1.1 Picture of *O. microlepis*. Photo courtesy of: Tony Whitaker

Plate 1.2 Mt. Ruapehu and Kaimanawa Ranges, at Napier-Taihape Road intersection to Otupae. Photo courtesy of: Dr Doug Armstrong.

Plate 1.3 Picture of basking *O. microlepis*. Photo courtesy of: Tony Whitaker.

Chapter Two

Detection Probability and Site Occupancy of *O. microlepis*

Chapter Two:

Detection Probability and Site Occupancy of *O. microlepis*

2.1 Introduction

New Zealand lizard species have undergone huge declines on the mainland due to anthropogenic factors such as introduced predators, pollution and habitat loss (Towns and Ferreira 2001). Remaining populations on the mainland are small and fragmented.

The small-scaled skink (*Oligosoma microlepis*) is an endemic New Zealand lizard currently listed as vulnerable by the IUCN (1994). *O. microlepis* inhabits exposed greywacke outcrops and rock piles scattered throughout privately-owned farmland from the southern Te Urewera district, through the Kaimanawa Range to the northern Ruahine Range, as well as on Motutaiko Island in Lake Taupo (Towns *et al.* 2002). These 'habitat patches' occur naturally in this area due to freeze-thaw and erosion associated with steep slopes and high altitude. Farming practice has also accelerated this process through deforestation, grazing and extraction of substrate for roads.

Whitaker (1991, 1997) suggested that *O. microlepis* was formerly more widespread, occurring throughout the central and lower North Island along river valleys and at high altitudes where exposed rock outcrops are naturally clear of vegetation. Native vegetation in unmodified areas, such as red tussock (*Chionochloa rubra*), and manuka (*Leptospermum scoparium*), and kanuka (*Kunzea ericoides*) act as corridors allowing dispersal between these habitat patches, probably aiding in gene flow and the colonisation of new sites.

Currently, all of the ca. 16 known populations of *O. microlepis* are small, isolated and confined to privately-owned farmland (Whitaker 1991, 1997; Flannagan *et al.* 2001), which is intensively modified. Despite several surveys of the Rangitīkei district for new populations (Whitaker 1991; Hutchinson 1992; Hutchinson 1993; Whitaker 1997; Flannagan *et al.* 2001), few have been found and conservation efforts have been further confounded by the lack of biological knowledge of the species (i.e., relative abundance, population trends and habitat requirements). The North Island *Oligosoma* spp. Skink Recovery Plan outlines *O. microlepis* conservation strategies that illustrate the need to obtain more information on the species distribution, habitat, relative abundance and threats (Towns *et al.* 2002).

The preliminary step towards planning effective conservation management of a rare species like *O. microlepis* is an understanding of the relationship between the species and their habitat (Neilson *et al.* 2004; Roughton 2005). This can be achieved firstly by surveying potential sites of the species to obtain presence-absence data and develop effective monitoring techniques; and secondly by ascertaining site occupancy over the species' range to assess trends in the population.

2.1.1 Presence-absence data

Collection of presence-absence data is the most efficient method to obtain information on distribution and habitat associations when it is unrealistic to estimate abundance (MacKenzie and Barker 2004). MacKenzie and Barker (2004) state that presence-absence data have been used to assess abundance, species distributions and biodiversity (e.g., Royle and Nichols 2003; Franklin *et al.* 1996); and also to model habitat associations and metapopulation dynamics (e.g., Hanski 1992, 1994; Moilanen 1999). Because presence-absence data are used in the planning of conservation management of rare species, it's important that data collection and analysis are done properly (MacKenzie *et al.* 2002).

MacKenzie *et al.* (2002) outlines two potential sources of error when working with monitoring programs using count data. The first is spatial variation. Many habitat ranges are too large to be surveyed completely, so the selection of smaller sampling units must be made that are representative of the entire area so inference can be made to the total area of potential habitat (MacKenzie *et al.* 2002; Roughton 2005). The second and most important source of error is detectability.

2.1.2 Nondetection error

MacKenzie *et al.* (2002) state that "by not allowing for detectability and solely using count data as an index of abundance is unwise." An observed 'absence' may be the result of a true absence or simply nondetection and failure to distinguish between these possibilities can bias results (Nichols *et al.* 1986; Edwards *et al.* 1996; Nichols *et al.* 1998; Craig and Roberts 2001; Lindenmayer *et al.* 2001; MacKenzie *et al.* 2002; Moilenan 2002; Tyre *et al.* 2003; Gu and Swihart 2004). *O. microlepis* is commonly found in greywacke outcrops and piles along river valleys and streams and amongst tussock, scrub and pasture. This type of habitat makes sampling difficult because of the inability to access sites or view each site in its entirety.

Tyre *et al.* (2003) also state that "few species are so conspicuous that they are detected within an occupied site every time it is sampled, and the probability of this error is dependent upon environmental conditions, observer experience and survey methodology." These sources of variation in detection probability may make it impossible to make useful inference about the system under investigation (MacKenzie *et al.* 2002). Observer bias, survey methodology, and environmental variables (i.e., temperature, wind speed, rainfall, cloud cover, time of day, density of habitat, size of habitat) all affect detection probability.

2.1.3 Observer bias

An example of estimating nondetection error is Gardner *et al.*'s study (1999) of the geometric tortoise (*Psammobates geometricus*). The species' range is currently reduced to 31 habitat patches due to habitat destruction, competition and predation. Accurate population estimates are essential for the species' conservation. However, obtaining reliable count data has been difficult due to the tortoises' cryptic colouration and sedentary behaviour (Gardner *et al.* 1999). The purpose of the study was to determine the detection probability when searching for the geometric tortoise. The study was carried out by constructing plaster models of both juveniles and adults of the tortoise and by placing them in locations within the animal's natural habitat (Gardner *et al.* 1999). Observers surveyed predetermined transects individually as well as in groups of two and three. The average detection rate by individual observers was no more than 50%, with group detection slightly but not significantly higher. Observer experience, searching ability, density of habitat and size of models all affected the detection probability (Gardner *et al.* 1999).

Observer bias has also been tested in studies such as that by Nichols *et al.* (1986). Five observers walked 100 m transect lines individually and marked nests of White-winged dove (*Zenaida asiatica asiatica*) when they were detected. Estimated detection probabilities ranged from 0.69 and 0.93, and Nichols *et al.* (1986) concluded that observer bias can represent the largest potential source of variation in detection probability.

Lindenmayer *et al.* (2001) tested the effectiveness of field survey techniques in detecting the greater glider (*Petauroides volans*). Spotlighting is a common technique used to collect count data for many nocturnal animals. Spotlighting data were tested with the known location of radio-tracked animals. Lindenmayer *et al.* (2001) found that there was a low success rate when spotlighting for *P. volans*, suggesting that this technique substantially under-estimates the abundance of animals in the area.

Appropriate site selection and survey techniques are essential for accurate representation of a species' habitat and the sampled area. Where possible, methodology should try and minimise bias of variation through study design. MacKenzie *et al.* (2003) suggests rotating observers to different sites over several surveys if they differ in their experience and ability in detecting the target species. Observer bias can then be accounted for in the analysis.

2.1.4 Environmental variables

Detection can also be affected by environmental factors (e.g., temperature, humidity, wind speed and cloud cover) and habitat factors (e.g., vegetation cover, aspect and altitude). MacKenzie *et al.* (2002) modelled the effects of environmental conditions on detection probability and site occupancy of American toad (*Bufo americanus*) and Spring peeper (*Pseudacris crucifer*). Temperature was an important function in detection probabilities for both species. Temperature is also likely to be the most important factor when monitoring heliothermic lizards, and their detection probability will be low under any extreme conditions (low temperatures, high wind and rain) that inhibit them from emerging to bask (Roughton 2005). *O. microlepis* will not bask if the temperature is not above about 16°C (Flannagan *et al.* 2001), as they are otherwise in crevices or under rocks where they are unlikely to be detected.

For all of the above reasons, detection probabilities have to be incorporated into model design of site occupancy to make useful inference about the habitat (Nichols *et al.* 1998; Anderson 2001; MacKenzie *et al.* 2002; MacKenzie 2003; MacKenzie *et al.* 2004; Gu and Swihart 2004; Crossland *et al.* 2005). PRESENCE (MacKenzie *et* al. 2002) is a programme that incorporates both detection probabilities and habitat covariates into a model of site occupancy.

2.1.5 Modelling detection probability in PRESENCE

The programme models presence-absence data taken from repeated surveys at N sites over T sampling periods. At each visit to the site, the apparent presence (1) or absence (0) of the focal species is recorded. By visiting a site multiple times, a detection history is obtained (e.g., 1,0,0,1,1), and this detection history can then be used to estimate detection probability (p) and site occupancy (Ψ) for the species. Detection probability doesn't have to be constant throughout the season, and can be modelled as a function of factors that change even over the course of a day (e.g., temperature, humidity, wind speed, rain). In contrast, site occupancy is constant over the season, i.e., sites are assumed to be closed.

Detection histories (series of repeated surveys) can be flexible in the model. Surveys can be discrete visits on different days, multiple surveys over the same day, multiple survey plots within a larger sampling unit, or multiple observers each conducting a single survey. Sites do not need to be surveyed the same number of times. Detections can be the positive identification of the target species, or any evidence of the species (e.g., calls, tracks, territorial marking).

Before surveying, it is important to consider the potential variables affecting both detection and occupancy probability. Habitat variables such as vegetation cover may affect both probabilities, whereas variables such as abundance, current weather, observer skill and time will affect only detection probability. There are two types of variables used in PRESENCE: "season-specific" and "survey-specific". Season-specific variables are constant *within* seasons but may vary *between* seasons (e.g., habitat type, patch size, mean temperature). These may affect both occupancy and detection probability. Survey-specific variables vary between surveys and may include local environmental conditions or observer bias. These affect detection probability only.

2.1.6 Sites

Sampling units (sites) can be discrete habitat patches, such as the rock outcrops or piles in this study, or they can be transects or quadrats sampled from a large habitat range (MacKenzie *et al.* 2002). The sampling design for sites should be done on a case by case basis. For example, sites need to be large enough to have a reasonable probability of occupancy, but not so large that any measure would be meaningless. The design needs to incorporate the ecology of the species, such as territoriality, home range, scale and densities. With *O. microlepis*, the rock outcrops and piles that the skinks live on make natural sampling units.

2.1.7 Assumptions

MacKenzie *et al.* (2002) outlines assumptions for model use. The first assumption is that there are no changes in occupancy within a season due to extinction or colonisation. The second assumption is that there is no unmodelled heterogeneity among sites. The third assumption is that surveys among sites are independent (i.e., observing an animal at one site will not affect the detection at another site). The fourth assumption is that species are not falsely detected when they are absent.

2.1.8 Allocation effort

MacKenzie *et al.* (2002) used simulations to evaluate how the precision of estimating Ψ as the number of sampling occasions, or the number of sites is increased. For example, if $\Psi = 0.4$, and $p = 0.3$, surveying 200 plots twice gives SE (Ψ) = 0.11, whereas surveying 80 units five times gives SE (Ψ) = 0.07. With only two surveys per site, a sample size of 500 sites was required to achieve the same level of precision, increasing the total effort by 250% (MacKenzie *et al.* 2002). There is, however, a point at which there is little gain in using 10 sampling occasions than five, so for this reason, 8 surveys (sampling occasions) were chosen for each site in this study.

2.1.9 Seasons

Appropriate seasons are species-specific, and depend on the species' mobility and ecology. PRESENCE can be used to model occupancy over a single season or multiple seasons (MacKenzie *et al.* 2002; MacKenzie *et al.* 2003). In either case, sites must be repeatedly surveyed within a season to obtain a detection history at each site. When detection probability is estimated, site occupancy can also be estimated.

This model has been applied to both short-term studies to estimate of site occupancy, and to long-term investigation into mechanisms underlying site occupancy such as colonisation and extinction rates (MacKenzie *et al.* 2003). An example of a long-term study using PRESENCE is that on Northern spotted owls (*Strix occidentalis caurina*) conducted by Franklin *et al.* (1996). Potential spotted owl territories in Northern California have been monitored since 1985 for the presence of breeding pairs and modelled to analyse the owl's site occupancy and metapopulation dynamics (MacKenzie *et al.* 2003).

In New Zealand, PRESENCE has been used to model site occupancy of Hochstetter's frog, (*Leiopelma hochstetteri*; Crossland *et al.* 2005); Mahoenui giant weta, (*Deinacrida* spp.; MacKenzie 2003); and Otago skink (*Oligosoma otagense*), and Grand skink (*O. grande*; Roughton 2005).

Roughton (2005) used this method to model site occupancy of *O. grande* and *O. otagense* on the mainland because it allowed for low densities, naturally cryptic behaviour and dense habitat, as well as allowing incorporation of environmental variables known to affect detection in reptiles. Comparisons can be made to *O. microlepis* which also occurs at low densities, is naturally cryptic, and is heliothermic, and can also be expected to be highly responsive to changes in ambient temperatures and weather conditions (Flannagan *et al.* 2001).

2.1.10 Modelling detection and probabilities of O. microlepis

The first objective of my thesis was to model detection probabilities and site occupancy of *O. microlepis* as a function of potentially important habitat variables. I anticipated that this modelling would highlight optimum environmental conditions and sampling effort required for surveying the species in the future, as well as increasing biological knowledge of *O. microlepis* to select new sites and protect known ones.

2.2 Methods

2.2.1 Study area

Survey data were collected for *O. microlepis* at 45 sites spanning 25 km^2, on three stations (Erewhon, Otupae and Kelly Land Company) (Figure 2.1). Stations are located in the Inland Patea district, in the Moawhango Ecological Region, 30 km east along the Napier-Taihape Road in the central North Island.

Each station runs sheep and beef with varying degrees of land modification and farming intensity. Vegetation on each station varies from pasture, tussock (e.g., red tussock, *C. rubra*), and scrub (e.g., manuka, *L. eptospermum scoparium*; and kanuka, *K. unzea ericoides*); pine plantations (*Pinus radiata*) and native broadleaf/podocarp species (e.g., beech, *Northofagus* spp.) along river valleys and throughout the nearby mountain ranges.

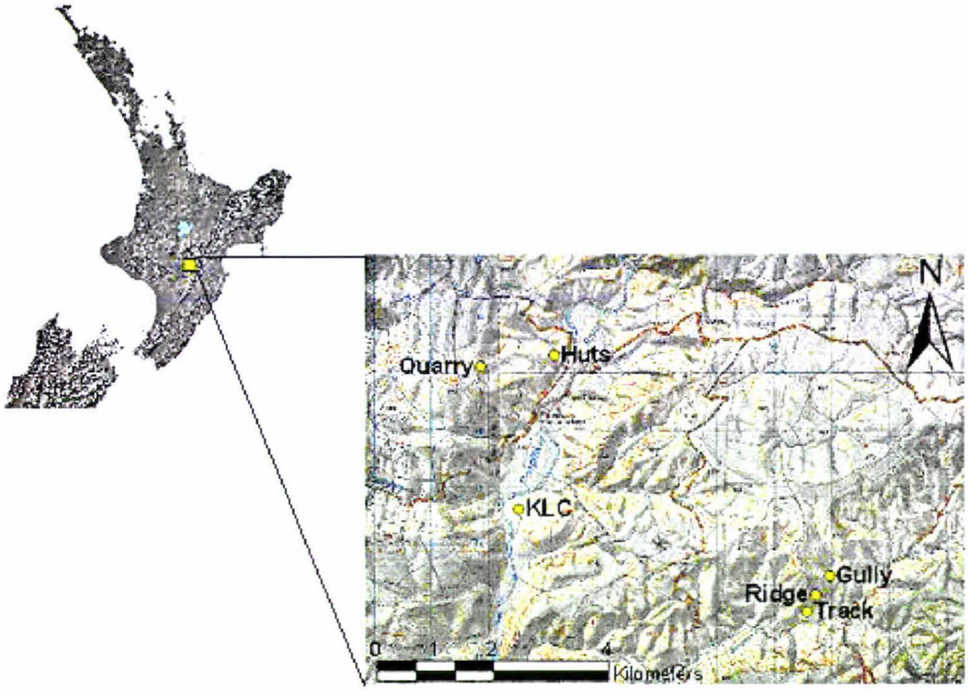

Figure 2.1 Inland Patea district, 30 km east along the Napier-Taihape Road. The yellow circles indicate the study regions Quarry and Huts at Erewhon station; KLC at Kelly Land Company station; and Gully, Ridge and Track at Otupae station.

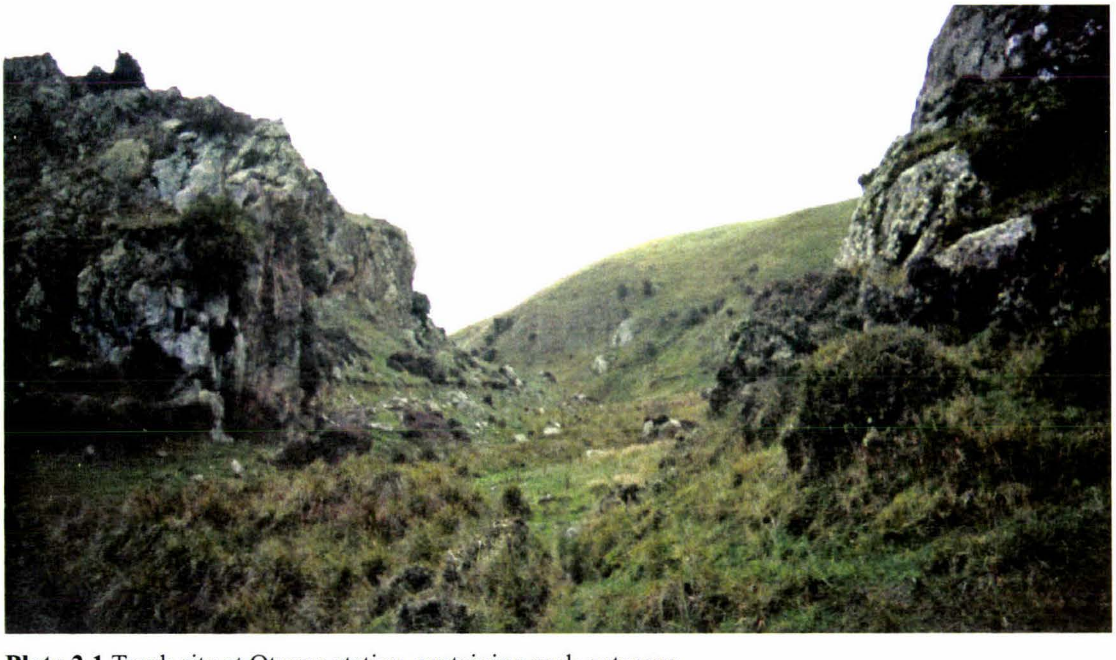

Plate 2.1 Track site at Otupae station containing rock outcrops.

Plate 2.2 Gully site at Otupae station containing two rock piles in pasture. Photo courtesy of: Dr Doug Armstrong.

2.2.2 Site selection

A total of 45 sites were chosen at 6 study regions over the three stations (Figure 2.1). This number was a compromise between the availability of sites and the time needed for the eight repeat surveys. Sites (sampling units) at each station were selected on the basis of accessibility and previous sightings of *O. microlepis* in the area from reports and discussions with landowners. Sites were then chosen non-randomly, due to accessibility, site visibility (e.g., vegetation cover) and habitat characteristics (e.g., lichen cover, size or aspect). Some sites were known *a priori* to contain skinks whereas other sites had no skink sign. Each site was a discrete habitat patch, defined as a greywacke 'rock outcrop' (defined for the purpose of this study as an exposure of bedrock that appears above the surface of the surrounding land) (Plate 2.1); or a 'rock pile' (a manmade or naturally occurring pile of loose rock) (Plate 2.2). The location of each site recorded onto a hand-held Global Positioning System (GPS 72).

REGION	GPS COORDINATE	STATION	NO. SITES
KLC	NZE2770521 N6184618	Kelly Land Co.	7
Quarry	NZE2769859 N6187124	Erewhon	10
Huts	NZE2771160 N6187324	Erewhon	10
Gully	NZE2775959 N6183437	Otupae	7
Ridge	NZE2775705 N6183102	Otupae	5
Track	NZE2775564 N6182792	Otupae	6

Table 2.1 GPS coordinates of each study region at each of the three stations.

Kelly Land Co. (KLC) station

KLC contains one study region with a total of 7 sites with an average size of 35 m^2 (±13.4), and an average ground slope of 12° (±1.8). Sites consist of rock piles of rounded greywacke river boulders, situated on exposed banks of an old river terrace of the Rangitīkei River at 555 m (±6.5) above sea level, all with a northwest aspect (283° ± 5.4). Natural vegetation was sparse throughout the pasture, with a few cabbage trees (*Cordyline australis*) and kowhai (*Sophora tetraptera*) along the river edges. On the rock piles, vegetation consists of only *Muehlenbeckia axillaries*. The slope at each site was between 11.5 and 16°, average rock number was 250 (±62.5), with an average rock size of 68 cm^2 (±4.2).

Erewhon station

Erewhon is an intensively farmed, highly modified station, running both sheep and beef. The Quarry site is the first of two Erewhon station main study regions, consisting of shattered greywacke rock piles situated at an old quarry site with an average site size of 90 m^2 (±19.5). The site is completely open, with ground slopes of 28° (±1.8) and all sites have a north-northeast exposure (124° ±46.6). The region is at an altitude of 805 m (±2.5), with no natural vegetation existing on or around the sites. Average rock number is 550 (±90), with an average size of 26 cm^2 (±4.0).

The Huts site is the second Erewhon study region, and is situated 200 m lower than the Quarry region, at the Rangitīkei River with an average altitude of 603 m (±4.9).

The site is located two kilometres north from the Springvale Bridge and public road access. Sites are northeast facing (42°±9.6), naturally occurring rock piles of shattered greywacke at the base of outcrops with an average size of 92 m^2 (±29.4). Average rock size is larger than the Quarry at 55 cm^2 (±8.4), with an average number of 400 (±122.5) rocks. All sites are located in the same gully, with an average ground slope of 26° (±0.7), which has formed naturally by a stream. Natural vegetation located on the rock piles is comprised of *Muehlenbeckia complexa*.

Otupae station

The Gully is the first of three Otupae study regions. Otupae is a sheep and beef station, which is the least modified of the three stations used in the study, containing exotic forestry plantations, as well as natural tussock, scrub areas and swamp. The Gully region is situated in a steep gully with an average ground slope of 27° (±2.2), and an average altitude of 727 m (±10.3), and contains two sites of rock piles at the base of outcrops, and five sites of greywacke outcrops with an average size of 159 m^2 (±25.5), with a range of aspects. The two rock pile sites had an average rock size of 73 cm^2 (±16.7), with an average number of 175 rocks (±107.5). Outcrops contained large crevices (fissures) with an average size of 96 cm^3 (±18.2), with an average number of 20 crevices (±5). All sites were situated in pasture, with high diversity of natural vegetation (i.e., *M. axillaries*, *Griselinia littoralis*, *Cyathodes juniperina*, *Olearia furfuracea*) occurring on the sites themselves and throughout the pasture.

The Ridge is the second region at Otupae, located on a ridge with a range of exposures at an average altitude of 710 m, and an average size of 213 m^2 (±81.9). All five sites are rock outcrops, with an average ground slope of 17° (±3.5), and natural vegetation consists of species such as *M. axillaries*, *Cyathodes juniperina*, *Hebe conlensoi var. colensoi*, *Gingidia montana*, and *Phormium cookianum*. Average crevice size was 154 cm^3 (±29.8), with an average number of 31.5 (±2.5) crevices.

The Track is the third region at Otupae, containing large, highly fissured rock outcrops, located in a gully with an average site size of 254 m^2 (±93.5). The crevices through this site are an average size of 130 cm^3 (±23.9), with an average number of 22 (±5.5) crevices. The sites contain the same range of vegetation as other Otupae sites, and a lower average altitude of 639 m (±2.6), and an average ground slope of 20° (±3.7).

2.2.3 Pilot study

The pilot study from January 2004-February 2004 provided useful information for study design. During this period, the stations Erewhon, Otupae and KLC were surveyed in areas ranging in agricultural development. The pilot study helped identify available sites and the appropriate season length over which to do the surveying for the following summer. In addition, it provided verification of lizard presence at known sites, allowed me to become familiar with the species' colouration and behaviour for accurate identification and surveying efficiency, and helped discover a new population of *O. microlepis* that has increased the total to 17 known populations.

2.2.4 Survey period

Surveying took place from November 2004 to March 2005. Travel time between Erewhon and Otupae took up to 40 minutes allowing for stock on the road and river crossings, and the KLC site took 30 minutes to walk cross-country. As a result, some sites were sampled twice in a single day. A minimum time of 1 hour had to elapse before a site was re-surveyed to allow animals to resettle.

2.2.5 Active search method

I used an active search method whereby sites were surveyed visually (Whitaker 2001). Such surveys are time efficient and easy to perform with minimal habitat destruction and disruption to animals. Permits to carry out this research were obtained from the Department of Conservation, Wanganui Conservancy (22 March 2004). Sites were accessed via stock tracks where present to minimise disturbance. I approached sites making as little noise as possible and avoided casting shadows on the site. I surveyed each site from a location at least 1.5 m away that provided a clear view of the site.

Oligosoma microlepis are heliothermic and diurnal (Whitaker 1997). Therefore sites were usually sampled on sunny days with temperatures above 16ºC (Whitaker 1997; Flannagan *et al.* 2001) and with low wind and no rain forecast. If rain started during sampling, or wind speed increased, sampling continued and these conditions were recorded. Each site was surveyed for 15 minutes using 10 X 50 6.5° wide field binoculars. The presence-absence of animals was recorded onto a spread sheet with 1 if present, and 0 if absent. The total number of animals that were seen was also recorded, along with the total number basking a one time (since animals weren't marked in any way, this was the best way to index abundance).

The presence of livestock (sheep, cattle or both), and the date and start time were also recorded. Additional notes of disturbance (e.g., traffic noise, helicopters, birds calling and circling the site), detection of other lizard species, unusual behaviour (agonistic displays) and birds near the site were also recorded during the 15 minute surveying period. After the sampling period, the site was approached, and environmental data were collected. These included a range of sampling covariates (Table 2.2) that changed over time, and could have influenced the probability of detecting skinks.

2.2.6 Sampling covariates

SAMPLING COVARIATES	
Air humidity	Month
Rock humidity	Time of day
Air temperature	Maximum basking at one time
Rock temperature	Observer downwind from site
Wind speed	Observer clothing colour
Wind direction	Rain
Cloud cover	Presence of livestock

Table 2.2 Sampling covariates measured at each site.

The first and most important sampling covariates measured were rock and air temperature. Detection has been closely correlated with these variables in *O. grande* and *O. otagense* (Coddington and Cree 1997), and *O. microlepis* (Flannagan *et al.* 2001). Rock and air temperatures were measured using digital thermometers with substrate probes at the end of 3 m wires (Slimline Electronic Dual Thermometer Y5007). Air temperatures were measured at a standard height of 1.2 m at the site, out of direct sunlight (with my back to the sun). To measure rock temperatures the probe was inserted into a crevice or under lose rubble for a minimum of 2 min for the thermometer to stabilise. Probe placement was chosen haphazardly, as crevice and rock size differed between sites.

Rock and air humidity were recorded using hygrometers, with one placed on the bare rock surface and the other held by hand at a height of 1.2 m above the site. Humidity was recorded after about 2 min when readings had stabilised. To achieve a quantitative measure of cloud cover, a 50 x 50 cm quadrat divided into 25 squares was held above the site. The percentage of cloud filling each square was recorded, and these averaged to obtain an overall measure of cloud cover. A wind meter was used to measure wind speed (km per hour), and the wind meter and a compass were used to measure wind direction.

2.2.7 Site covariates

SITE COVARIATES	
Aspect	Tree on plot
Altitude	Distance to the nearest stock track
Distance to nearest public road	Outcrop/rock pile
Size of plot	Ground Slope
Survey direction from plot	Distance to the nearest water source
Distance from the nearest farm track	Survey distance from plot
Sheep	Vegetation cover
Cattle	Lichen cover
Gully/open	Rock number
Distance to the nearest tree	Rock size
List of native plants present on the site	Crevice number
Air temperature	Crevice size
Rock temperature	

Table 2.3 Site covariates measured at each site.

Plate 2.4 A cabbage tree (*Cordyline australis*) at some of the Huts sites on Erewhon station. A tree was defined as a 'perchable' tree taller than 2 m. Photo courtesy of: Kiryn Weaver.

Aspect and survey direction from each site was recorded using a compass, and the ground slope was recorded using a clinometer. Three readings of slope (°) were taken and an average was recorded. Altitude and GPS coordinates were recorded using a handheld Global Positioning System unit (GPS 72), and distance to the nearest public road, water source, farm track and tree were also measured using the GPS if further than 50 m. If <50 m the measurement was taken using a standard 50 m measuring tape. The size of site, and distance to the nearest stock track were also measured using the tape.

A percentage of lichen and vegetation cover was visually estimated, as most sites were too large to physically measure or even sample. Native plant species present on each site that could potentially provide refuge for skinks were recorded (e.g., trees were ignored). Samples were taken for identification by Dr. Jill Rapson at Massey University.

Air and rock temperature were recorded simultaneously every 15 min for 12 days by HOBO H8 two-channel temperature data loggers at each of the 45 sites. Each logger contained an internal sensor for air temperature and an external sensor attached to a 6 foot cable (TMC6-HA) for substrate temperature. Loggers were held in white weather proof covers (with aeration vents), and attached to 120 cm plastic poles. Loggers were placed randomly beside the site to limit substrate disturbance that would occur by standing on the site itself. The substrate probes were inserted into the tightest rock crevice available or under lose rock close to the base of the logger stand.

Average rock number was recorded by averaging the total number of rocks in three 0.5 m^2 quadrats placed on each rock pile. This was randomised by dividing the rock pile into sections, labelling each one, and rolling a dice to determine the position of each quadrat. This was repeated for crevices on each rock outcrop.

Average rock and crevice size was recorded by first randomly placing each quadrat (as explained above) on the site. The quadrat was divided into 25, 10 x 10 cm squares, and assigned a number. Ten squares were chosen randomly by dice, and rocks or crevices from each square were measured; any larger than the square itself was noted as >100 cm^2. Rock size was a measurement of exposed rock surface (cm^2) available for basking, because some rocks were embedded in the soil and could not be moved. Crevice size was measured in cm^3 (length, width and depth). Depth was measured using a piece of wire inserted into the crevice. This process was repeated three times for each site.

2.2.8 Analysis

Data were entered into Microsoft Excel, and the detection probability and site occupancy were modelled using the program PRESENCE. Potential models were then compared using Akaike's information criterion (AIC, Akaike 1992) which indicates the most parsimonious model for the data (Burnham and Anderson 2002). Westphal *et al.* (2003) outlines the advantage of AIC over other traditional inferential statistics, stating that the AIC allows many potential models (or 'multiple working hypotheses') to be simultaneously evaluated rather than a single null vs. alternative hypothesis (Burnham and Anderson 2002). Burnham and Anderson (2002) adds that the "statistical null hypothesis testing approach is not wrong, but it is uninformative and thus, slows scientific progress and understanding."

$$AIC = -2\log(\text{likelihood}) + 2K$$

Where "likelihood" is the probability of obtaining the observed data under the model and K is the number of parameters in the model. As well as selecting the model that best describes the data, the rest of the models can be ranked using the relative difference in AIC or ΔAIC (Burnham & Anderson 2002).

$$\Delta\text{AIC} = \text{AIC} - \min(\text{AIC})$$

> *"Models with a ΔAIC_c between 0 to 2 have substantial support and can be used for making inferences. Models with ΔAIC_c between 4 to 7 have considerably less support, and models with $\Delta AIC_c \geq 10$ have essentially no support."*
>
> (Burnham and Anderson 2002).

A goodness-of-fit test can be used to determine whether any of the models were 'good in some absolute sense' (MacKenzie *et al.* 2002). It cannot be assumed that the 'true model' is contained in the set of models identified (Burnham and Anderson 2002). Lack of fit is defined by Cooch and White (2005) as the 'data not meeting the expectations determined by the assumptions underlying the model'.

PRESENCE uses a bootstrap test that simulates data based on the parameter estimates of the model. These simulated data exactly meet the assumptions of the model (Cooch and White 2005). The bootstrap test gives a p-value and a $\hat{c}$ value based on the simulations run 1000 times. The p is the probability of obtaining deviance $\geq$ that observed under the model, hence a low p (e.g., <0.05) indicates a poor fit. The $\hat{c}$ quantifies the amount of overdispersion (unmodelled variation) in the data. When $\hat{c}$ = 1.0, the model fits the data. If $\hat{c} \neq 1$ there is some degree of lack of fit. Cooch and White (2005) state comparison of models will probably be reasonable as long as $\hat{c} \leq 3$.

2.3 Results

Between 7 December 2004 and 10 March 2005, a total of 360 surveys were conducted over 45 sites (each sampled 8 times).

SAMPLING VARIABLES	DECEMBER	JANUARY	FEBRUARY	MARCH
KELLY LAND CO. STATION				
Monitoring dates	-	31 Jan	5-28 Feb	2 March
Rock temperature (°C)	-	33-47	20-47	28-43
Air temperature (°C)	-	27-37	17-36	25-34
Rock humidity (%)	-	38-50	36-54	36-43
Air humidity (%)	-	41-55	40-54	38-45
Wind speed (kph)	-	4-8	0-16	0-12
Cloud cover (%)	-	28-100	0-100	0-0
EREWHON STATION				
Monitoring dates	7-15 Dec	2-24 Jan	4-8 Feb	-
Rock temperature (°C)	24-44	15-50	18-47	-
Air temperature (°C)	19-34	18-40	19-33	-
Rock humidity (%)	35-49	35-56	33-76	-
Air humidity (%)	32-50	38-56	40-71	-
Wind speed (kph)	0-24	0-20	0-24	-
Cloud cover (%)	0-100	0-100	0-100	-
OTUPAE STATION				
Monitoring dates	-	12-25 Jan	7-27 Feb	1-10 March
Rock temperature (°C)	-	21-41	14-36	12-37
Air temperature (°C)	-	24-40	15-36	18-32
Rock humidity (%)	-	34-49	35-55	38-67
Air humidity (%)	-	37-53	38-57	41-61
Wind speed (kph)	-	0-0	0-32	0-16
Cloud cover (%)	-	0-76	0-100	0-100

Table 2.4 Environmental measurements (min-max) at each station, over each month of sampling. Kelly Land Co. station contains the site 'KLC'. Erewhon station contains the sites 'Huts' and 'Quarry'. Otupae station contains the sites 'Gully', 'Ridge', and 'Track'.

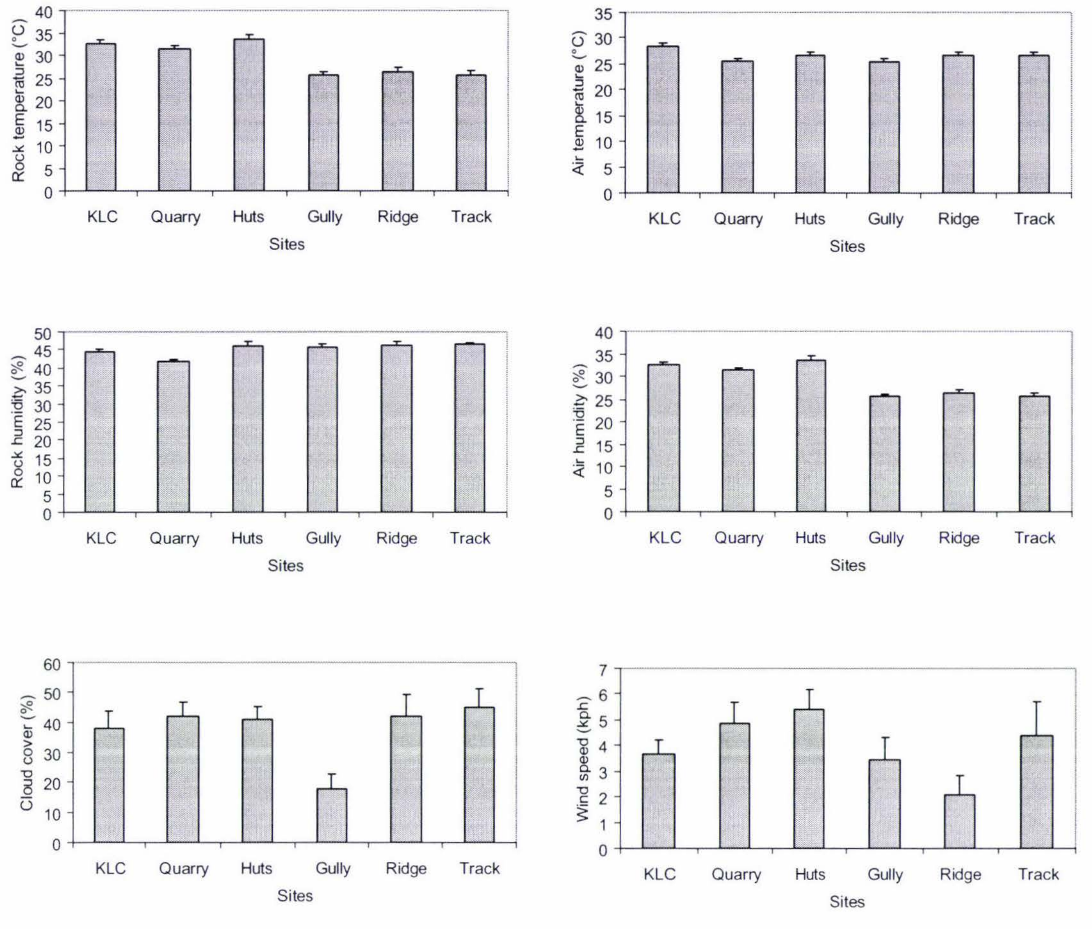

Figure 2.2 Mean measurements for air and rock temperature (°C), air and rock humidity (%), cloud cover (%) and wind speed (kph) at the six different study regions, KLC (Kelly Land Co. station), Quarry, Huts (Erewhon station), Gully, Ridge and Track (Otupae station). The vertical bars represent 1 standard error.

2.3.1 Comparison of study regions

Average air temperatures (°C) were similar at the 6 regions, KLC (28±0.6), Quarry (26±0.4), Huts (27±0.6), Gully (25± 0.6), Ridge (27±0.7) and Track (27±0.6) (Figure 2.2). Rock temperature (°C) on average was higher than air temperature at KLC (32±0.9), Quarry (31±0.7) and Huts (33±0.9) sites; and lower at all Otupae sites (26±0.2). Average rock humidity (%) was lowest at Quarry (42±0.5) and KLC (44±0.7) sites compared with the other sites, whereas air humidity was lowest at all Otupae sites (26±0.2) and highest at KLC (46±0.6), Quarry (45±0.6) and Huts (50±1.0). Cloud cover (%) was lowest at the Gully site (18±5), and wind speed (kph) was on average the lowest at Ridge (2±0.7), KLC (4 ±0.6) and Gully (3±0.9) sites.

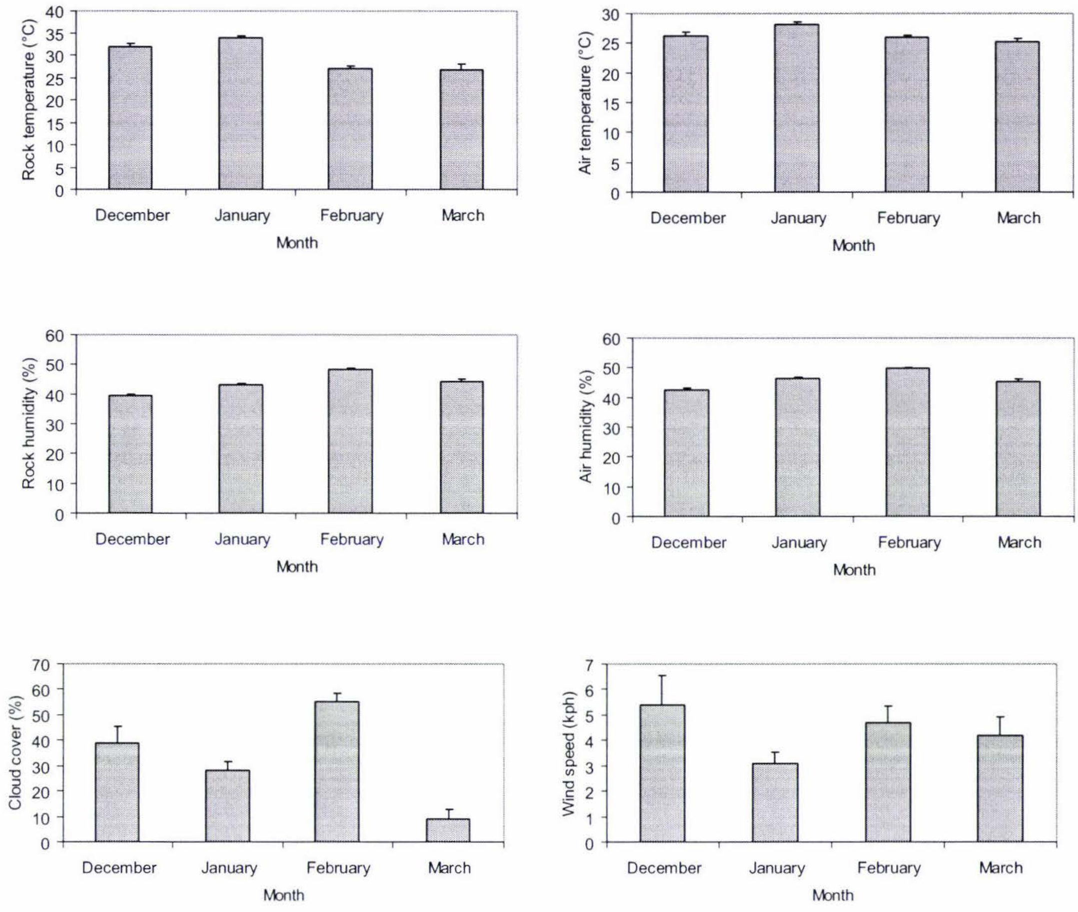

Figure 2.3 Mean measurements for air and rock temperature (°C), air and rock humidity (%), cloud cover (%) and wind speed (kph) over the four months (December – March) from a total of 360 surveys across all sites. The vertical bars represent 1 standard error.

2.3.2 Comparison of months

Recorded air temperatures ranged from 15–40°C over the entire sampling period, with an average of 26°C (±0.2). The highest average temperature was recorded in January (28±0.5). Rock temperature (°C) varied considerably among sites, and over months, ranging from 12–50°C. Highest average rock temperatures were recorded in January (34±0.7), with an overall mean of (30±0.4) across all months.

Humidity readings ranged from 32–76%, and were consistent over most months for both rock and air humidity. Maxima of both air and rock humidity were recorded in February. Cloud cover was variable over all months and all sites, ranging from 0–100%; although the lowest average was recorded in March 9.3 (±3.6), and the highest

54.7 (±3.6) in February. Maximum wind speed ranged from 24kph in December, 20kph in January, 32 kph in February and 16kph in March.

2.3.3 Detection and site occupancy probability

The model was run first using PRESENCE with no added covariates. Models were then run separately with each sampling covariate, then with each site covariate. Sampling and site covariates in models with a $\Delta AIC_c \leq 7$ had the best fit to the data, and were used in further combinations of model building, but I constrained models to have no more than 6 parameters. Data were modified in two ways after my initial analysis.

First, the 13 sampling occasions with rainfall were removed from the data set. Rainfall was shown to be an important sampling covariate (no *O. microlepis* were ever detected during rain), but models that combined rainfall with other variables often did not converge. Therefore, removal of rainfall-affected observations allowed the potential effects of these variables to be considered.

Second, the rock temperature covariate was modified. My initial analysis suggested that rock temperature was the most important covariate, but all models had poor fit ($p < 0.05$), meaning model comparisons may be unreliable. PRESENCE assumes a logistic relationship between detection (or occupancy) probability and the value of each covariate, meaning detection probability was assumed to continuously increase with rock temperature. I thought it was unlikely that this was the case, hence this assumption could potentially account for poor fit. I therefore considered two extensions of the Logistic Model, the "Optimum Model" and the "Plateau Model". Under the Optimum Model, the slope of the logistic relationship changes at some critical temperature, allowing detection probability to decrease above that value. The Plateau Model is similar but assumes a slope of zero above the critical temperature, meaning detection probability will remain constant above that value. To fit these models to the data, I first removed all sites where skinks were never detected. I then used the SOLVER function in Microsoft Excel to obtain maximum likelihood estimates for the parameters in each of the three models, and compared the models based on AIC (Table 2.5). I also calculated the proportion of skinks detected at 6 temperature ranges, and compared this observed trend to the trends predicted by the three models (Figure 2.4).

The data suggest that detection probability increased with rock temperature until the temperature reached about 20-25°C, then stayed relatively constant (Figure 2.4). The Plateau Model therefore provides the best explanation for the data, and gives an estimated critical temperature of 20.2°C (Table 2.5). The Optimum Model gives a similar relationship because the slope is estimated to be near zero above a critical temperature of 19.8°C. However, the Optimum Model is a more parsimonious explanation of the data as it has one fewer parameter, giving a lower AIC value (Table 2.5).

NAME	MODEL	α	β_1	β_2	T'	k	ΔAIC
Plateau	If $T<T'$, $\ln(p/(1-p)) = \alpha + \beta_1(T-T')$ If $T>T'$, $\ln(p/(1-p)) = \alpha$	0.231	0.904		20.2	3	0.00
Optimum	If $T<T'$, $\ln(p/(1-p)) = \alpha + \beta_1(T-T')$ If $T<T'$, $\ln(p/(1-p)) = \alpha + \beta_2(T-T')$	-0.096	0.897	0.026	19.8	4	0.82
Logistic	$\ln(p/(1-p)) = \alpha + \beta_1(T-T')$	-1.340	0.047			2	1.65

Table 2.5 Comparison of models for the relationship between detection probability and rock temperature using data from 8 surveys for *O. microlepis* at 23 sites where the species was known to occur. Notation is as follows: p, probability of detecting one or more skinks at a site during a survey; T, rock temperature during the survey; k, number of parameters in model; α, intercept parameter; β_1 and β_2, slope parameters; T', rock temperature above which the slope changes from β_1 to β_2 (Optimum Model) or to zero (Plateau Model). Maximum likelihood estimates for α, β_1, β_2 and T' were obtained using the SOLVER function in Microsoft Excel, and AIC values calculated as shown in the text. The model with the lowest AIC provides the best explanation for the data.

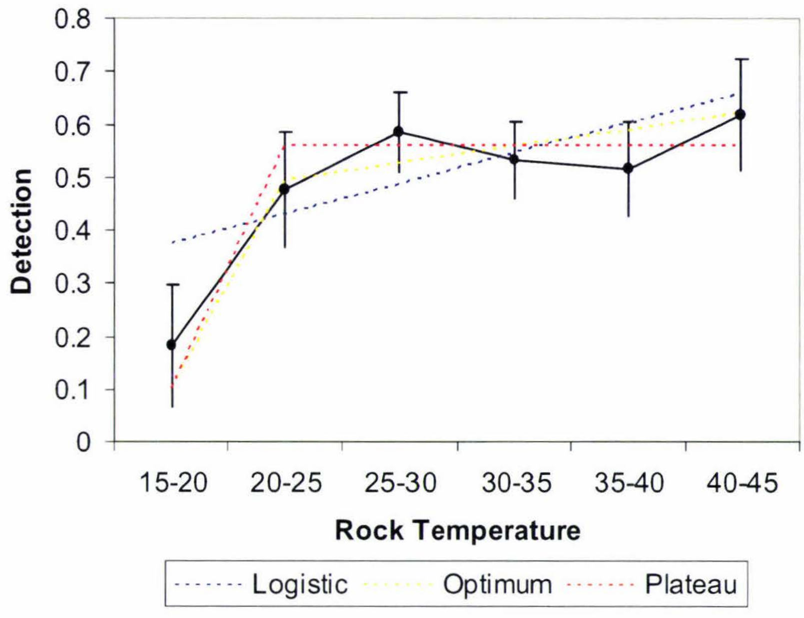

Figure 2.4 Relationship between rock temperature and probability of detecting *O. microlepis*. Solid lines and symbols show the proportion of times skinks were detected at sites where they were known to occur at each temperature range (vertical lines show one standard error, assuming a binomial distribution). Dotted lines show the predicted detection probabilities at the midpoints of each temperature range based on the three alternative models fitted to the data. The logistic model (blue) assumes a logit-linear relationship with constant slope. The optimum model (yellow) allows the slope to be different on two sides of an estimated inflection point. The plateau model (red) is similar to the optimum model, but assumes a slope of zero above the inflection point.

I therefore modified the rock temperature covariate to match the Plateau Model. That is, the new covariate gave the number of degrees below 20, and was zero for all rock temperatures ≥ 20. Models were then re-run through PRESENCE using the same process as before.

MODELS	ΔAIC	*k*	w_i
Ψ(tree, stock track) *p* (rock temperature, afternoon)	0.00	6	0.40
Ψ(tree, stock track) *p* (rock temperature, December)	1.39	6	0.20
Ψ(stock track, outcrop) *p* (rock temperature, afternoon)	1.95	6	0.15
Ψ(tree, stock track, outcrop) *p* (rock temperature)	2.31	6	0.12
Ψ(tree, stock track) *p* (rock temperature)	2.69	5	0.10

Table 2.6 Comparison of site occupancy models based on modified data collected for *O. microlepis* during 8 sampling occasions at each of the 45 sites. ΔAIC, difference in Akaike's Information Criterion (AIC) from that of the best model; w_i Akaike weight, *k* number of parameters. No skinks were recorded during sampling occasions with rainfall, and these sampling occasions are omitted from the analysis. Terms in parenthesis show variables affecting occupancy (Ψ) and detection probability (*p*) under each model: "tree", presence or absence of a tree at the site; "stock track", distance of site to nearest stock track; "outcrop", rock outcrop *vs.* rock pile; "rock temperature", number of degrees below 20 (see Plateau Model in Table 2.5); "afternoon", afternoon surveys *vs.* morning or midday surveys; excluded them from the table if they had negligible support ($w_i < 0.10$). I did not consider models with greater than 6 parameters.

Analysis of the modified data set indicated that the presence of a tree on the site, distance to the nearest stock track and the distinction between rock outcrops and rock piles were the covariates affecting site occupancy. Rock temperature, the distinction between afternoon *vs.* other surveys and the distinction between December *vs.* other surveys were the sampling covariates affecting detection probability.

ASSESSING MODEL FIT	P-VALUE	$\hat{c}$
Ψ(tree, stock track) *p* (rock temperature, afternoon)	0.371	1.03
Ψ(tree, stock track) *p* (rock temperature, December)	0.079	1.20
Ψ(stock track, outcrop) *p* (rock temperature, afternoon)	0.216	1.16
Ψ(tree, stock track, outcrop) *p* (rock temperature)	0.111	1.26
Ψ(tree, stock track) *p* (rock temperature)	0.068	1.23

Table 2.7 Parametric bootstrap test (a 'goodness of fit' test) to assess model fit

The $\hat{c}$ values for all models are between 1.03 – 1.21, indicating relatively good model fit with little overdispersion. The best model with the lowest AIC (Table 2.4) had negligible overdispersion ($\hat{c}$ = 1.03).

All models with reasonable support contained the sampling covariate rock temperature. The best three models contained a distinction between afternoons and other survey times, or between December and other months. Detection probabilities were estimated to be 0.53 for morning surveys, 0.62 for midday surveys, and 0.43 for afternoon surveys. The estimated detection probability for December (p =0.69) was higher than detection probabilities estimated for January (p = 0.54), February (p = 0.45), and March (p = 0.44).

O. microlepis populations were detected at least once in 23 of the 45 sites (Figure 2.5), producing a naïve site occupancy estimate of Ψ = 0.511.

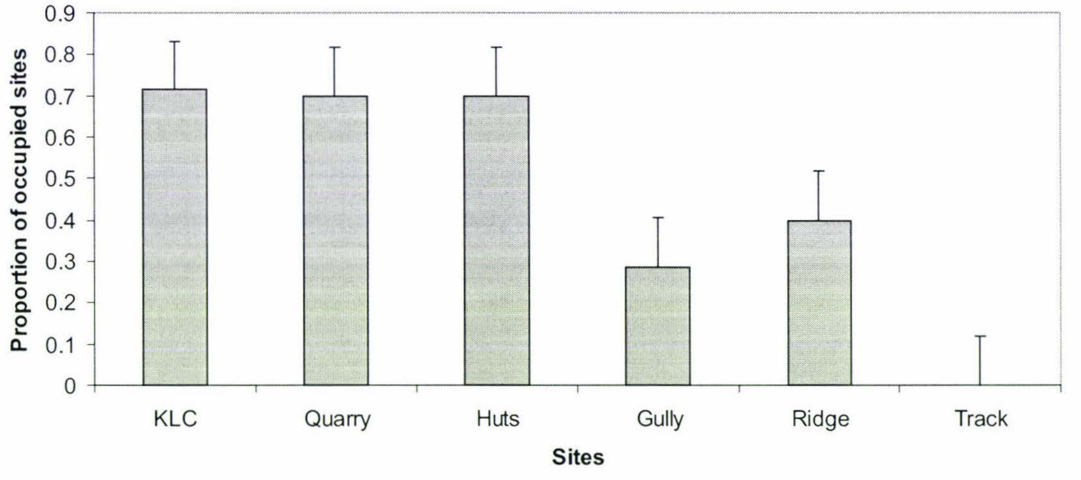

Figure 2.5 The proportion of occupied sites where *O. microlepis* were detected at least once in each of the six study regions. The vertical bars represent 1 standard error.

The top two models (Table 2.4) suggest that the key factors affecting site occupancy were the presence of a tree on the site and the distance to the nearest stock track. However, two models with reasonable support also contained the distinction between rock piles and rock outcrops.

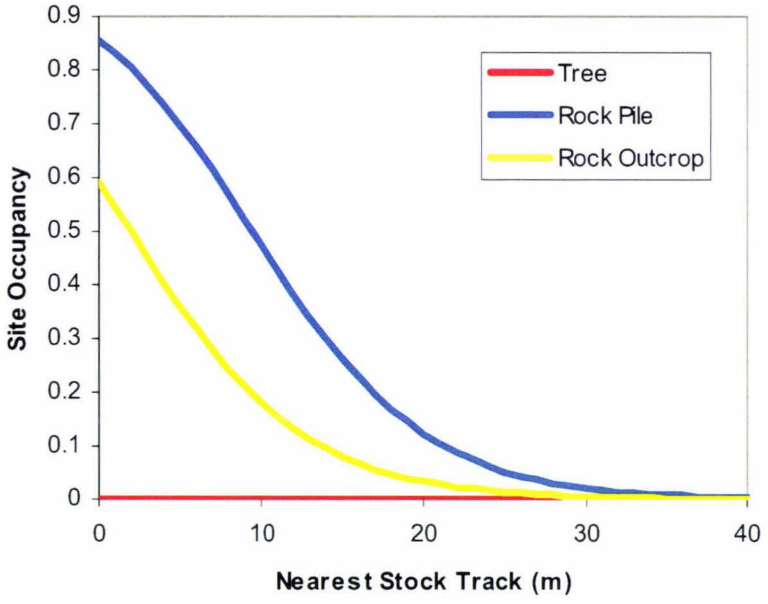

Figure 2.6 Estimated site occupancy probability for *O. microlepis* on rock piles and rock outcrops as a function of distance from nearest stock track and presence or absence of a tree on the site based on model Ψ(tree, stock track, outcrop) *p* (rock temperature) (Table 2.4).

O. microlepis were never found at any of the 8 sites with a tree present on the site, i.e., site occupancy was 0.00 for these sites (Figure 2.6). Species included cabbage tree (*Cordyline australis*); broadleaf (*Griselinia littoralis*); and macrocarpa (*Cupressaceae* spp.) trees. Site occupancy decreased with increased distance from the nearest stock track (Figure 2.6). The overall probability of occupancy was higher for rock piles (Ψ = 0.69) than for rock outcrops (Ψ = 0.19). It could be suggested that it may simply be harder to detect animals on rock outcrops than rock piles, but there was only a slight difference in the detection probabilities for rock piles (p = 0.54) compared with rock outcrops (p = 0.46).

2.4 Discussion

2.4.1 Detection probabilities

The first objective of the study was to highlight the benefits of obtaining detection probabilities as functions of sampling covariates, aiding in future surveys of *O. microlepis* at new sites. Results showed that *O. microlepis* detection was significantly affected by three variables, the first and most important of which was rock temperature.

A lizard's physiology, behaviour and ecological characteristics are governed by temperature (Huey 1982; Singh *et al.* 2002). Lizards as ectotherms, are highly dependent on heat exchange with the environment to attain and regulate optimal body temperatures within a characteristic and restricted range (Huey 1982). This regulation is achieved through the "active process" of thermoregulation (Díaz and Cabezas-Díaz 2004). Most lizards thermoregulate in two ways, by heating directly from the sun's radiation by basking (heliothermic), and through conduction by perching on previously warmed substrate (thigmothermic) (Huey 1982; Heatwole and Taylor 1987; Read and Moseby 2001; Belliure and Carascal 2002; Martín and López 2003). Most small, diurnal lizards, like *O. microlepis*, living in temperate zones, are primarily heliothermic (Martín and López 2003), but can exhibit both modes of thermoregulatory behaviour depending on environmental conditions (Heatwole and Taylor 1987; Belliure and Carascal 2002).

There are many studies documenting the importance of environmental temperatures in reptiles (Brown and Shine 2002; Martin and López 2003; Díaz and Cabezas-Díaz 2004; Fischer and Lindenmayer 2005). For example, Read and Moseby (2001) found that high temperatures were the most important environmental factor accounting for high capture rates in diurnal and nocturnal lizard species. Activity and temperature have also shown to be correlated in *Oligosoma grande* and *O. otagense*. Lizard emergence and subsequent detection was extremely weather dependent, even during summer months (Coddington and Cree 1997). Therefore it can be assumed that temperature is an important factor influencing the activity of reptiles and one of the most important variables affecting reptile detection.

It is not surprising then that rock temperature had the most weight in influencing detection of *O. microlepis*. Results showed that as rocks became warm, emergence and activity increased, significantly improving the detection probability. Basking ceased as rock temperatures increased above about 25°C. However, "shuttling" behaviour continued at high rock temperatures and skinks were also observed in shaded crevices. Shuttling is the repetitive movement of an animal between sunlight and shade and is characteristic of many lizard species (Heatwole and Taylor 1987); including *O. microlepis* (Whitaker 1997). Consequently, there was no decline in detection probability at rock temperatures up to 50°C.

The second sampling covariate affecting detection is the time of day surveying took place. Afternoon surveys had a significant lower detection probability, indicating changes in behaviour over the course of the day. Lizards typically have discrete times of day in which activity is concentrated (Heatwole and Taylor 1987), and it is not unusual for them to stop basking by mid afternoon (Cooper and Whiting 2000). This could be due to lizards modifying their behaviour according to these changes in the temperature (Belliure and Carascal 2002). However, the fact that survey time may have an effect in addition to rock temperature suggest daily activity patterns that are not explained by temperature alone. *O. microlepis* bask in the morning upon emergence, and after achieving optimal body temperature through thermoregulation, they tend to perform other daily activities such as foraging. This change in behaviour throughout the day could be the reason for the decrease in detection probability in the afternoon.

The third important sampling covariate in *O. microlepis* detection was the month that surveying took place. It has been established that thermoregulation, lizard activity and therefore detection show variation with temperature throughout the day. Activity also changes seasonally, and the higher detection probability during December surveys could be due to low energy reserves and body temperatures as animals emerge from winter dormancy. Winter dormancy has been documented in many New Zealand reptiles (Gregory 1982), and is a survival technique when environmental conditions exceed an individual's capacity for homeostasis (Zug *et al.* 2001). Patterson (2000) states that lizards are emaciated by spring as fat stores have been depleted during winter. As a result, in spring a lizard's primary need is to thermoregulate and forage.

2.4.2 Site occupancy

Important site covariates outlined by the analysis were the distance to the nearest stock track, whether a tree was present on the site, and whether the site was an outcrop or a rock pile. Results showed a negative correlation between site occupancy and the distance to the nearest stock track. The closer the stock track was to the rock pile or outcrop, the higher the probability of site occupancy. This may be due to several factors, the first of which was outlined by Hutchinson (1993) who suggested that livestock grazing may be preventing vegetation encroachment onto skink rocky habitat. This can benefit heliothermic lizards twofold: 1) by keeping rocks bare to allow basking; and 2) by inhibiting predation. Predation may be reduced due to shrubs being kept small and compact, reducing perches and cover for predator use and providing refuge for skinks.

Secondly, trampling and grazing of stock along stock tracks could be maintaining a moderate amount of disturbance at these sites. Brown (2001) noted that 'disturbance' is a primary factor in shaping any ecosystem, usually referring to physical change. Disturbance at these sites may be allowing a continual turnover of new rocks, thereby creating new habitat. There are several studies on both the negative threats (Brown 2001; Fischer *et al.* 2004), and the positive effects of livestock disturbance. Positive effects can include maintenance of diversity, structure and function in grassland ecosystems that lack natural herbivores (Hobbs and Huenneke 1992; Marty 2005). The Inland Patea district was not grassland historically, and it is assumed the saxicolous *O. microlepis* was restricted by naturally patchy habitat of rock outcrops and piles in pre-human New Zealand (Whitaker 1991). Low levels of disturbance through grazing and trampling by livestock could be maintaining *and* creating new habitat for the species.

The positive and negative effects of grazing on lizards are however species-specific (Hobbs and Huenneke 1992), so it is dangerous to make generalisations based on the affects of livestock on one species. An example emphasising this is Pukerua Bay reserve on the Kapiti coast of New Zealand. The study area had been farmed for around 100 years until a fence was completed in March 1987 (Towns and Elliot 1996). The most dramatic changes, which occurred once sheep were removed, included expansion of divaricating shrubs, increased density of young trees and the stability of stony substrates (Towns and Elliot 1996). The new habitat benefited some species of herpetofauna within the reserve, but species like *Oligosoma nigriplantare polychroma* were negatively affected by the reduction of preferred rocky, open sites by revegetation (Towns and Elliot 1996). Similarly, Read (2002) found that grazed areas have greater abundance of the agamids, *Ctenophorus nuchalis* and *C. pictus*, which are heat tolerant and naturally found in open, highly insolated habitat. Busack and Bury (1974) also found that the lizard, *Callisaurus draconoides*, was twice as abundant in grazed areas as ungrazed areas.

The positive correlation between stock disturbance and site occupancy of *O. microlepis* could aid in conservation management of the species, as stock access to sites could potentially be an important tool of habitat maintenance. It is important to add however, that reptiles may persist in areas with intermediate levels of grazing short-term, but in the long-term this may pose a significant threat to reptile habitat (Fischer *et al.* 2004). There is evidence that grazing reduces dispersal and gene flow between rock patches in Grand skinks (Berry *et al.* 2005). Research needs to be carried out to assess whether dispersal is similarly disrupted in *O. microlepis* and whether this affects the long-term viability of these populations.

Another important site covariate determining skink occupancy was the presence of a tree on the site. No lizards were ever detected at sites with trees present. This could be due to the canopy of the tree casting shade across the plot, inhibiting direct sunlight from reaching the rocks surface and decreasing rock temperature. Sites with trees were all located at Otupae station, which had lower average rock temperatures on both rock piles and outcrops (Figure 2.2). Lower air and rock temperatures at the sites with trees could be caused by the shade from the canopy. This can increase the basking time required to achieve optimal body temperature for lizards, and therefore increases risk of predation. Vitt *et al.* (1996) recorded a preference for outcrops free of tree canopy in several populations of the lizard, *Tropidurus hispidus*. Preferred habitats of the species had to have continuous sunlight during much of the day to allow basking for the species.

In addition, predation is increased by the ability of avian predators using the trees for perching to obtain better views of the rock to prey on basking lizards. Small lizards are a food source for many bird species throughout the world (Martín and López 1996; Blomberg and Shine 2000; Poulin *et al.* 2001), and there are many known diurnal avian predators of lizards in the study area, including kingfishers (*Halcyon sancta*), magpies (*Gymnorhina tibicen*), and the New Zealand bush falcon (*Falco novaeseelandiae*).

Finally, the probability of site occupancy may have been affected by rock outcrops compared to rock piles. The difference in occupancy between rock piles and outcrops could possibly be due to differences in habitat characteristics and thermal properties. Saxicolous (rock dwelling) lizards (e.g., *Tropidurus hispidus* (Vitt *et al.* 1996); *Lacerta monticola* (Martin *et al.* 1995); *Phymaturus patagonicus* (Ibargüengoytía 2005)) tend to select areas with both direct sun and with shade allowing them to thermoregulate by shuttling. Scheers and van Damme (2002) suggest that low lying rock piles provide lizards with a constant choice of sun and shade, as they are exposed to sunlight for most of the day, whereas this is not often the case with rock outcrops. For example, a south-facing rock face will have direct sun for only a short time of the day, so a lizard will have to continually move around the rock to bask effectively. In this study, rock temperature was found to be significantly lower than air temperature at all rock outcrops, thus demonstrating the difference in thermal properties of the two habitat types. Belliure and Carascal (2002) also found that rock piles have higher air temperature and decreased wind speed compared to rock outcrops. These thermal differences could be the reason for low occupancy on outcrops compared to rock piles in *O. microlepis*.

Another reason for differences in site occupancy between rock piles and outcrops could be competition for resources between common geckos (*Hoplodactylus maculatus*) and *O. microlepis*. Common geckos (*H.* maculatus) were observed in crevices on outcrops and rock piles, and could be competing for this resource. A rock pile is made up of a matrix of shattered rock, and under each of these is a potential refuge. Refuges on outcrops, however, are more limited in number. Howard and Hailey (1999) state that space (such as refuges) is the most important dimension for interspecific separation in the majority of sympatric reptiles.

Refuges are important to saxicolous lizards because they offer protection from the weather and predators such as feral cats (Kerr *et al.* 2003; Coddington and Cree 1997). Other studies of *Oligosoma* spp. have also suggested that densities were limited by the presence of the other lizards on outcrops (Coddington and Cree 1997). There needs to be further research done to test this.

2.5 Conclusion

Detectability is a major source of variation in measures of abundance in wildlife research (Bailey *et al.* 2004). If detectability is not accounted for in data collection, no analysis can make valid inferences about the species (Anderson 2001). The detection probability of a species can be affected by the observer (e.g., fatigue, inexperience, physical condition); environmental conditions (e.g., habitat type, wind speed, air temperature, precipitation); and inadequate survey methodology (Anderson 2001). When these detection probabilities are incorporated into site occupancy analysis, 'reliable information' can be obtained (Nichols *et al.* 1998; Anderson 2001; MacKenzie *et al.* 2002; MacKenzie 2003; MacKenzie *et al.* 2004). The most important sampling covariate affecting detection of *O. microlepis* is rock temperature, and detection may also have been affected by the month and time of day that surveying took place.

The probability of a site being occupied by *O. microlepis* was highest when: 1) the site was close to a stock track, possibly due to stock grazing and trampling maintaining habitat; and 2) absence of a tree on the site, possibly due to trees shading sites or providing perches for predatory birds. There was also tentative evidence that rock outcrops had a lower probability of occupancy than rock piles, possibly due to thermal properties of the rock and/or competition from common geckos.

Information on the factors affecting site occupancy will help develop effective management strategies for the conservation of this vulnerable skink on farmland.

New information on factors influencing detection can potentially aid in quantifying the effects of this management, as well as increasing the efficiency in surveying for new sites.

Chapter Three

Habitat Analysis of *O. microlepis* in the Inland Patea district

Chapter Three:

Habitat Analysis of *O. microlepis* in the Inland Patea district.

3.1 Introduction

3.1.1 Habitat selection

The term "habitat selection" is defined as the active choice of habitat by an animal in a heterogeneous environment in the absence of constraints. In reality however, habitat selection is governed by many constraints such as ecological processes and habitat characteristics (Kerr *et al.* 2003). For example, individuals may be forced to occupy less desirable habitats due to lack of habitat (e.g., fragmentation), intra- and inter-specific interactions (e.g., competition) or morphological limitations (Heatwole 1977).

3.1.2 Lizard habitat selection

Lizards, like other taxa, make habitat choices based on a variety of factors (Kerr *et al.* 2003). As ectotherms, temperature differences among habitats are particularly important because lizards regulate their body temperature through heat exchange with the environment and require appropriate sources of heat to do so (Martín and López 2003).

Habitat selection in lizards is therefore influenced by specific thermal requirements and the thermal suitability of the habitat (Belliure and Carascal 2002; Scheers and van Damme 2002; Singh *et al.* 2002). Huey (1982) states that 'there are complex interactions between reptiles and their physical environments', and these interactions involve a variety of physical and social cues (Law 1991). For example, habitat choices may reflect the morphology and behavioural characteristics of the species.

Paulissen (1988) found that small lizards occupy warmer, more open habitats than large lizards; and Vit *et al.* (1998) found that heliothermic lizards were common in tree-fall sites (with increased sun exposure) than in the surrounding forest.

In addition, habitat selection in reptiles is reliant on the structural characteristics of the environment itself (Heatwole 1977). Habitat characteristics such as vegetation and lichen cover, aspect and patch size create a thermal mosaic that will affect thermoregulation and habitat selection, and therefore, site occupancy. Because of these multiple influences on lizard habitat selection, many species have quite specific requirements (Kerr *et al.* 2003) that can lead to increased vulnerability to habitat destruction and fragmentation (Kerr *et al.* 2003).

3.1.3 Habitat selection and conservation

Habitat destruction and fragmentation due to anthropogenic activities is the major cause of species decline throughout the world (Web and Shine 2000; Goodman *et al.* 2005). Due to a species' requirement of specific habitat characteristics to survive and reproduce (Jellinek *et al.* 2004) changes in habitat can affect the size and long-term viability of populations (Walker *et al.* 2003) and thereby the conservation status of a species (Schlesinger and Shine 1994; Parris 2001). There are many studies on species habitat requirements and subsequent conservation recommendations, for example, Díaz *et al.* (2000) found that the occurrence of the lizard (*Psammodromus algirus*) was restricted to large forest fragments with a particular habitat structure. Conservation for the species therefore depends on the protection of large remnants of that habitat. Another example includes the five-lined skink (*Eumeces fasciatus*), which relies on large, moderately decayed logs and boards for refuge sites. Although the species is resilient to minor human disturbance, the skinks are severely affected by the complete removal or degradation of retreat sites. A conservation initiative for this species is to preserve these habitat features (Hecnar and M'Closkey 1998).

The sandstone velvet gecko (*Oedura lesueurii*) is another habitat specialist, relying on sandstone rocks for diurnal retreat sites, and is highly selective to the structural characteristics of these retreats. Commercial and private harvesting of these rocks has dramatically reduced the amount of retreat sites, thus increasing the vulnerability of gecko populations. Schlesinger and Shine (1994) therefore recommended creating a variety of artificial, long-lasting retreat-sites that are suitable for different sized geckos but unattractive to rock collectors (Webb and Shine 2000).

In New Zealand the threatened Grand (*Oligosoma grande*) and Otago (*O. otagense*) skinks inhabit rock tors scattered throughout farmland in Central Otago. Habitat analysis at occupied sites has found that habitat degradation from agricultural development is considered the major cause of decline for both species (Coddington and Cree 1997), and conservation management is underway to mitigate these effects.

3.1.4 Habitat selection of O. microlepis

There are currently only ca. 17 known populations of the vulnerable *O. microlepis*, and all are on privately owned farmland. Sites containing populations of *O. microlepis* are discrete habitat patches of greywacke rock piles and outcrops surrounded by grassland, tussock and scrub.

An understanding of habitat selection of *O. microlepis* is essential if we are to understand the effects of general farming practice on *O. microlepis*. Read (2002) found that agricultural development (i.e., reverting native vegetation to pasture) has negatively affected Australian reptile communities through removal of vegetation cover and simplification of the vegetation structure, and disturbance from livestock.

Currently, *O. microlepis* seems to be persisting because of, or in spite of the pasture dominated landscape in which they live. Studies on habitat use are needed to determine what is maintaining populations and what management tools would be effective in *O. microlepis* conservation. For example, such information is needed to develop habitat restoration or protection on the mainland or to assess whether *O. microlepis* could persist if translocated to offshore islands.

Information on habitat use of *O. microlepis* is also important for surveying new sites. Flannagan *et al.* (2001) stated that in previous surveys for *O. microlepis* it was unclear whether environmental conditions were affecting detection or whether the site was unoccupied due to physical characteristics of the site. When detection probabilities (Chapter 2) are accounted for, useful inferences about the habitat can be made.

In this chapter I conduct a detailed habitat analysis of *O. microlepis*, by implementing multivariate analysis of habitat variables in relation to occupancy data. This information will provide an understanding of habitat use needed for management decisions in *O. microlepis* conservation, and aid in finding new sites.

3.2 Methods

3.2.1 Study sites

A total of 45 sites were chosen from three stations, Erewhon, Otupae and Kelly Land Company (KLC) (site descriptions 2.2.2). Each site was a discrete habitat patch, and defined as a greywacke rock outcrop or rock pile. Each site was surveyed for *O. microlepis* on 8 occasions from November 2004 to March 2005, and 36 habitat variables were collected at each site from April to June 2004 (described in section 2.2). Site occupancy was then assessed at each site (section 2.3) using the detection history from the 8 surveys. Detection probability was estimated to be 0.48 with an average rock temperature of 25°C so the average probability of *O. microlepis* being missed in 8 surveys is 0.005. Therefore, if *O. microlepis* hadn't been detected after 8 surveys, the site was assumed to be unoccupied for the analysis presented in this chapter. This assumption allowed multivariate habitat analyses that could not be conducted in conjunction with modelling of detection probability.

3.2.2 Habitat data collection

Average rock and air temperature at each plot were recorded with HOBO data-loggers for two weeks. Other habitat variables such as vegetation type, lichen cover, average rock size, crevice size and number and the size of plot were also measured using visual estimates, measuring tape and a 50 x 50 cm quadrat. Altitude, survey distance from plot, distance to nearest water source, public road, farm track and tree were recorded using a handheld GPS unit. For detailed descriptions refer to section 2.2.7.

3.2.3 Statistical analysis

Principle component analysis (PCA) was carried out on habitat data to combine three variables (average rock number, average rock size, crevice number and average crevice size) to obtain a general 'refuge' variable. The original 37 habitat variables (Table 2.2) were therefore reduced to 34. The 34 habitat variables and 45 sites were relativised.

A Non-metric Multidimensional Scaling (NMS) ordination was used to compare each site in relation to habitat variables, with the relative contributions of each variable displayed using Pearson Correlation coefficients. This method is suited to multivariate data that are on discontinuous scales and is defined as a 'ranking and placing of variables on *k* dimensions (axes) while minimising the stress (measure of the dissimilarity between the original distance measures and distance in ordination space) of the *k*-dimensional configuration' (McCune and Mefford 1999). A scree plot was used (Figure 3.1) to choose the dimensions used for the model. It 'adds dimensions to the model which contributes less and less to the description of the data, forming a curve' (McCune and Mefford 1999).

From the scree plot, 2 Axes were identified to best describe the data and the NMS ordination plots were then graphed and used to illustrate the position of each site in habitat space, and to identify habitat variables that corresponded to those sites occupied by *O. microlepis*. The arrows on the ordination plots show the strength of the correlation (Figure 3.2-3.5) between a set of habitat variables (Pearson correlation coefficients) and ordination axes. The angle and length of the arrow tell the direction and strength of the relationship (McCune and Mefford 1999; Goldsbrough *et al.* 2003). A Monte Carlo test was then used for the NMS to identify the dimensions that give solutions that are significantly different than those due to random chance (McCune and Mefford 1999).

A classification tree was then used (programme WEKA, Witten and Frank 2005), to explain variation of a single response variable (presence-absence of *O. microlepis*) by several explanatory variables (habitat factors) (refer to De'ath and Fabricius 2000 for details). The tree is constructed by repeatedly splitting the data, defined by a simple rule based on each single explanatory variable (De'ath and Fabricius 2000). The results presented were obtained using 10 fold cross validation, which essentially 'prunes the trees by obtaining honest estimates of true (predictive) error (Kappa statistic) for trees of a given size' (De'ath and Fabricius 2000). The Kappa statistic is defined as 'the measure of agreement between predicted (random) and observed categorisations of a dataset, while correcting for agreement that occurs by chance' (Witten and Frank 2005).

The two statistical analyses were used in different ways, the NMS ordination was used as a picture of the relationship between the sites based on the environmental variables to provide a description of the study regions. In comparison, the classification tree was used as a tool to give rates for presence-absence based on these environmental variables to use for future conservation management of the species.

3.3 Results

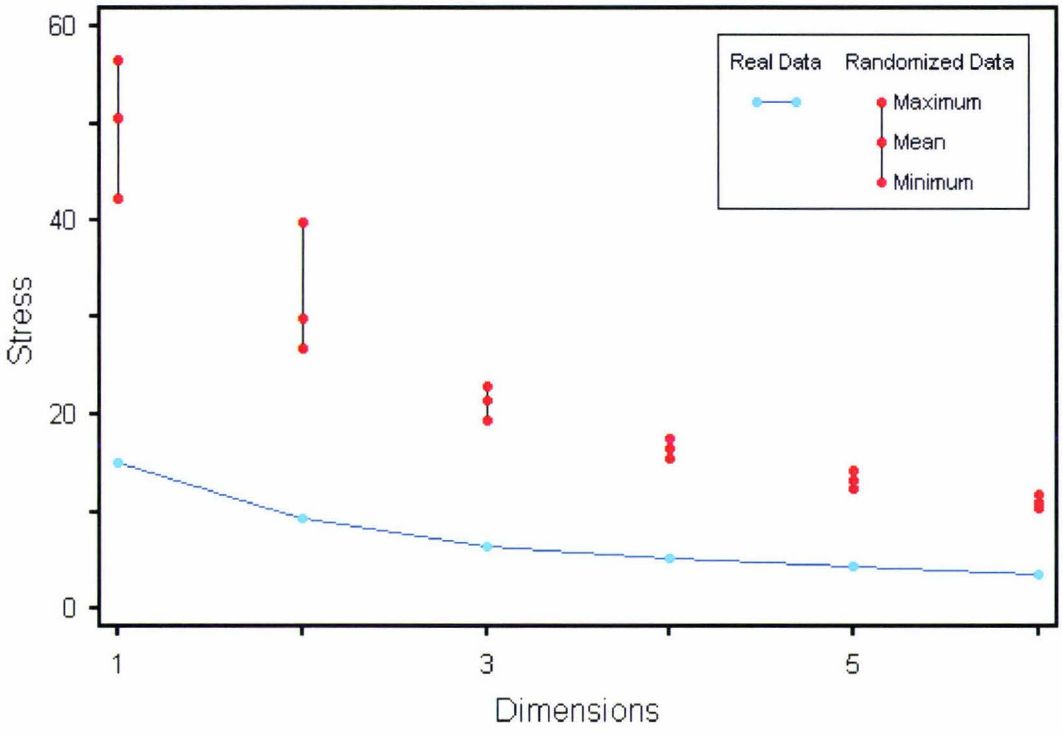

Figure 3.1 Scree plot comparing the stress of the real data (40 runs) with randomised data (50 runs) using a Monte Carlo test (P = 0.0196) P is the proportion of randomised runs with stress < or = observed stress.

The scree plot shows the structure in the ordination compared with the randomised data (i.e., mean stress for Axis 1 and 2 for randomised data = 50 and 30; compared to the real data = 17 and 9.3). The final stress value was 9.3, which gives a good approximation of the multivariate space with a low risk of drawing false inferences (McCune and Mefford 1999). For the NMS ordination the greatest reduction in stress was comprised of 2 dimensions, i.e., 2 significant axes (Monte Carlo test, $P < 0.0196$) therefore the ordination plots were graphed using two axes.

3.3.1 Ordination of sites and habitat variables

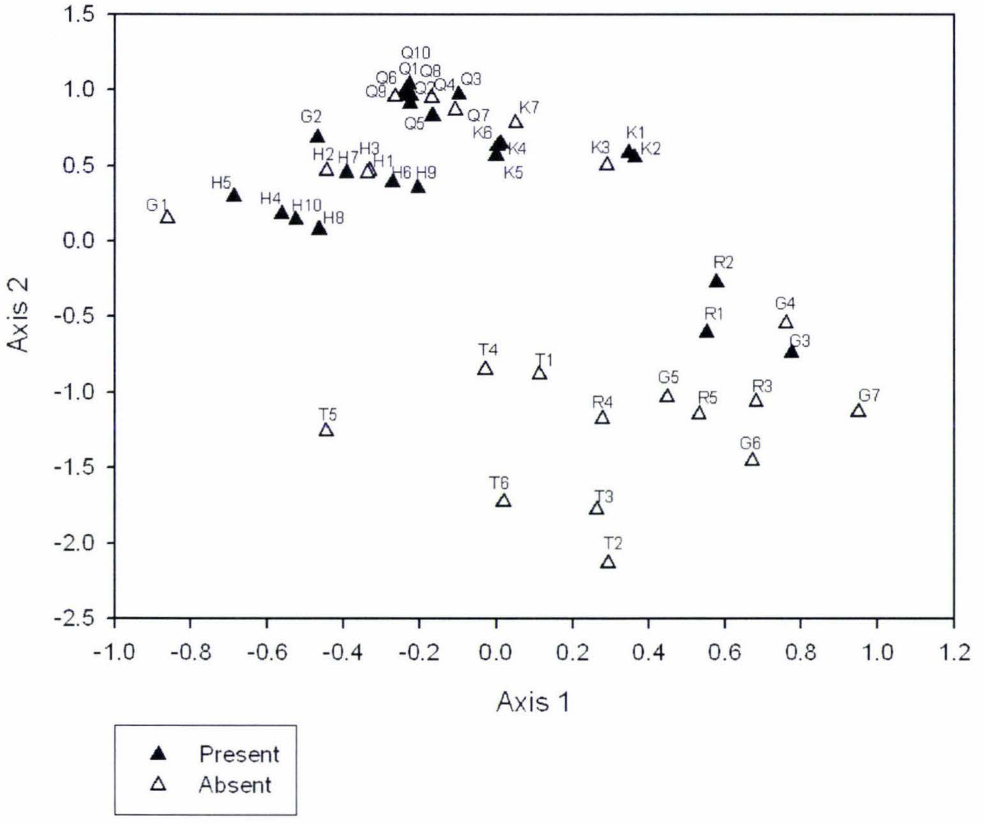

Figure 3.2 Ordination of sites based on 33 habitat variables using Non-metric Multidimensional Scaling (NMS). Black triangles represent occupied sites and white triangles represent unoccupied sites. The six main study regions are labelled as letters, K = KLC (7 total), Q = Quarry (10), H = Huts (10), G = Gully (7), R = Ridge (5), and T = Track (6). *N* = 45.

Sites were grouped based on similarities of habitat variables used in the analysis (Figure 3.2). The main grouping of sites is between rock outcrops and rock piles. The Gully, Ridge and Track study regions have only outcrops, and were clustered positively on Axis 1 and negatively correlated on Axis 2, whereas the Huts, KLC and Quarry, G1 and G2 regions consist of rock piles and were clustered positively on Axis 2 and negatively on Axis 1. The majority of rock piles sites (69%) were also occupied compared to 19% of rock outcrops (black triangles; Figure 3.2).

Table 3.1 Pearson correlation coefficients between the first two NMS ordination axes and habitat variables. The coefficients labelled (*) show a significant correlation across all 45 sites.

HABITAT VARIABLES	AXIS 1	AXIS 2
Aspect	0.45	-0.21
Altitude	0.11	0.10
Distance to road	-0.15	0.70*
Size	0.15	-0.40
Distance to farm track	0.14	-0.04
Tree	0.35	-0.73*
Distance to stock track	-0.22	-0.15
Slope	-0.33	0.14
Distance to water	-0.21	0.74*
Survey	-0.40	0.03
Vegetation cover	0.47*	-0.78*
Cattle	-0.54*	0.85*
Lichen	0.68*	-0.67*
Gully site	0.14	-0.72*
Open site	-0.14	0.72*
Rock pile	-0.70*	0.91*
Outcrop	0.70*	-0.91*
Distance to tree	-0.27	0.66*
Muehlenbeckia axillaris	0.52*	-0.04
Griselinia littoralis	0.28	-0.64*
Asplexium placcidum	0.10	-0.35
Cyathodes juniperina	0.58*	-0.56*
Melicytus alpinus	0.02	-0.60*
Olearia furfuracea	0.40	-0.63*
Gingidia montana	0.61*	-0.62*
Hebe colensoi	0.53*	-0.87*
Pyrrosia eleagnifolia	0.52*	-0.39
Phormium cookianum	0.65*	-0.48*
Coriaria arborea	-0.11	-0.36
Muehlenbeckia complexa	-0.41	0.06
Pteridium esculentum	0.31	-0.35
Average air temperature	0.09	0.23
Average rock temperature	0.08	0.27
Refuge	-0.65*	0.88*

The NMS ordination analysis provided descriptions of sites used in the study by grouping them based on correlations between habitat variables and sites (Table 3.1). Axis 1 (Table 3.1) described a gradient that was positively correlated with the habitat variables vegetation cover (0.47), lichen (0.68), outcrop (0.70), *M. axillaries* (0.52), *C. juniperina* (0.58), *G. montana* (0.61), *H. colensoi* (0.53), *P. eleagnifolia* (0.52), *P. cookianum* (0.65); and negatively correlated with cattle (-0.54), rock pile (-0.70), and refuge (-0.65), thus sites that were outcrops with high vegetation and lichen cover, and contained several native plant species were grouped together at the upper end of the NMS Axis 1. Sites that were rock piles had cattle present and were abundant in refuges with low vegetation and lichen cover and were grouped at the lower end of the NMS Axis 1.

In comparison, Axis 2 was most positively correlated with distance to road (0.70), distance to water (0.74), cattle (0.85), open sites (0.72), rock piles (0.91), distance to tree (0.66) and refuge (0.88); and negatively correlated with tree (-0.73), vegetation cover (-0.78), lichen (-0.67), gully site (-0.72), outcrop (-0.91), *G. littoralis* (-0.64), *C. juniperina* (-0.56), *M. alpinus* (-0.60), *O. furfuracea* (-0.63), *G. montana* (-0.62), *H. colensoi* (-0.87), *P. cookianum* (-0.48). These relationships are shown visually in Figures 3.3-3.4.

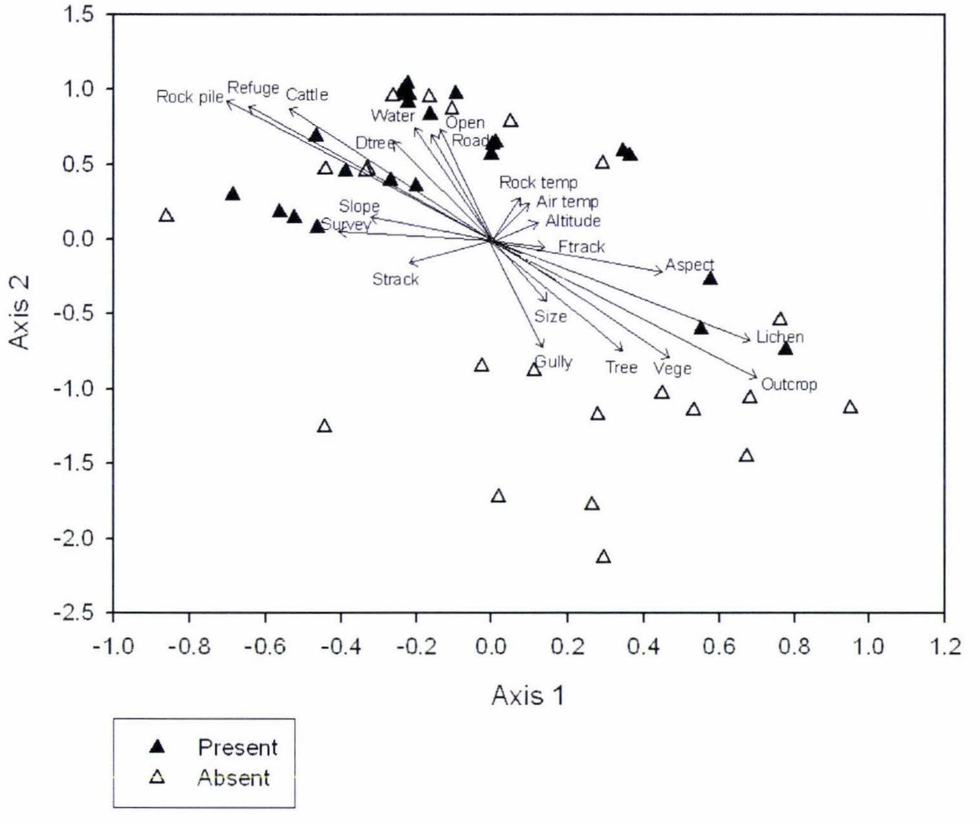

Figure 3.3 Ordination plot of correlations between rock habitat variables and ordination axes scores. The sites are represented by triangles and habitat variables are labelled arrows. Abbreviations are as follows: Road, distance to nearest road; Ftrack, distance to nearest farm track; Tree, presence of a tree on the site; Strack, distance to the nearest stock track; Survey, survey distance from the site; Vege, vegetation cover; Dtree, distance to the nearest tree; Air temp, average air temperature; Rock temp, average rock temperature.

The distribution of the sites and habitat variables on the ordination plot (Figure 3.3) shows that rock piles, refuge, cattle (r = >0.8), and lichen, outcrop (r = <-0.67) were the factors that contributed most to grouping of sites based on correlations with habitat variables (Table 3.1). Huts, Quarry, KLC, G1 and G2 sites were grouped in the top part of Axis 2, which is positively correlated with rock piles, refuges and the presence of cattle at the sites. The remaining 16 sites at Otupae were grouped on the left side of Axis 1, and were positively correlated with vegetation cover, lichen and outcrops. Thus the sites at Otupae were predominately outcrops and were densely vegetated, with more lichen compared to the rock pile sites that were clear of vegetation, with cattle and abundant refuges.

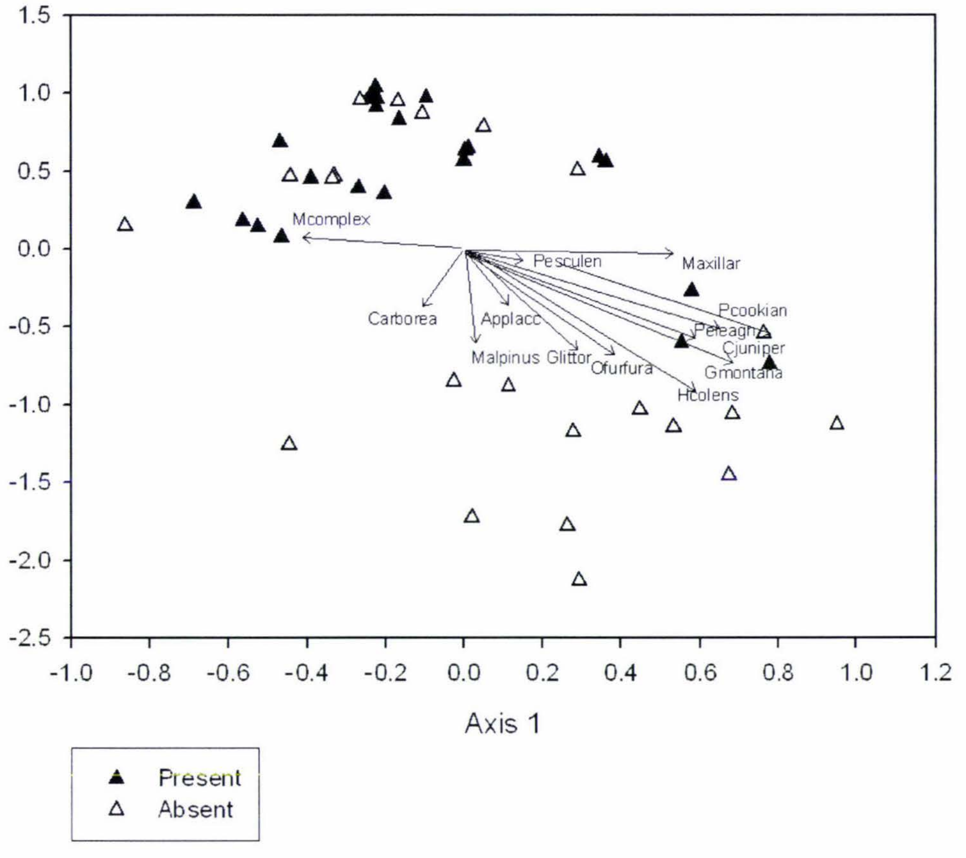

Figure 3.4 Ordination plot of correlations between plant species habitat variables and ordination axes scores. Abbreviations are as follows: Maxillar, *Muehlenbeckia axillaris*; Glittor, *Griselinia littoralis*; Applacc, *Asplexium placcidum*; Cjuniper, *Cyathodes juniperina*; Malpinus, *Melicytus alpinus*; Ofurfura, *Olearia furfuracea*; Gmontana, *Gingidia montana*; Hcolens, *Hebe colensoi*; Peleagn, *Pyrrosia eleagnifolia*; Pcookian, *Phormium cookianum*; Carborea, *Coriaria arborea*; Mcomplexa, *Muehlenbeckia complexa*; Pesculen, *Pteridium esculentum*.

The distribution of the sites and plant habitat variables (Figure 3.4) shows that *M. complexa* was the only plant that was negatively correlated with Axis 1 (r = -0.41) and this species contributed to the grouping of the Huts, Quarry, KLC, G1 and G2 sites in the bottom part of Axis 1. The remaining 16 sites at Otupae were grouped on the left side of Axis 1, and were positively correlated with the native plant species *C. juniperina*; *G. montana*, *H. colensoi*, *P. eleagnifolia*, *P. cookianum* and *Muehlenbeckia axillaries* (r = >0.52).

3.3.2 Classification tree

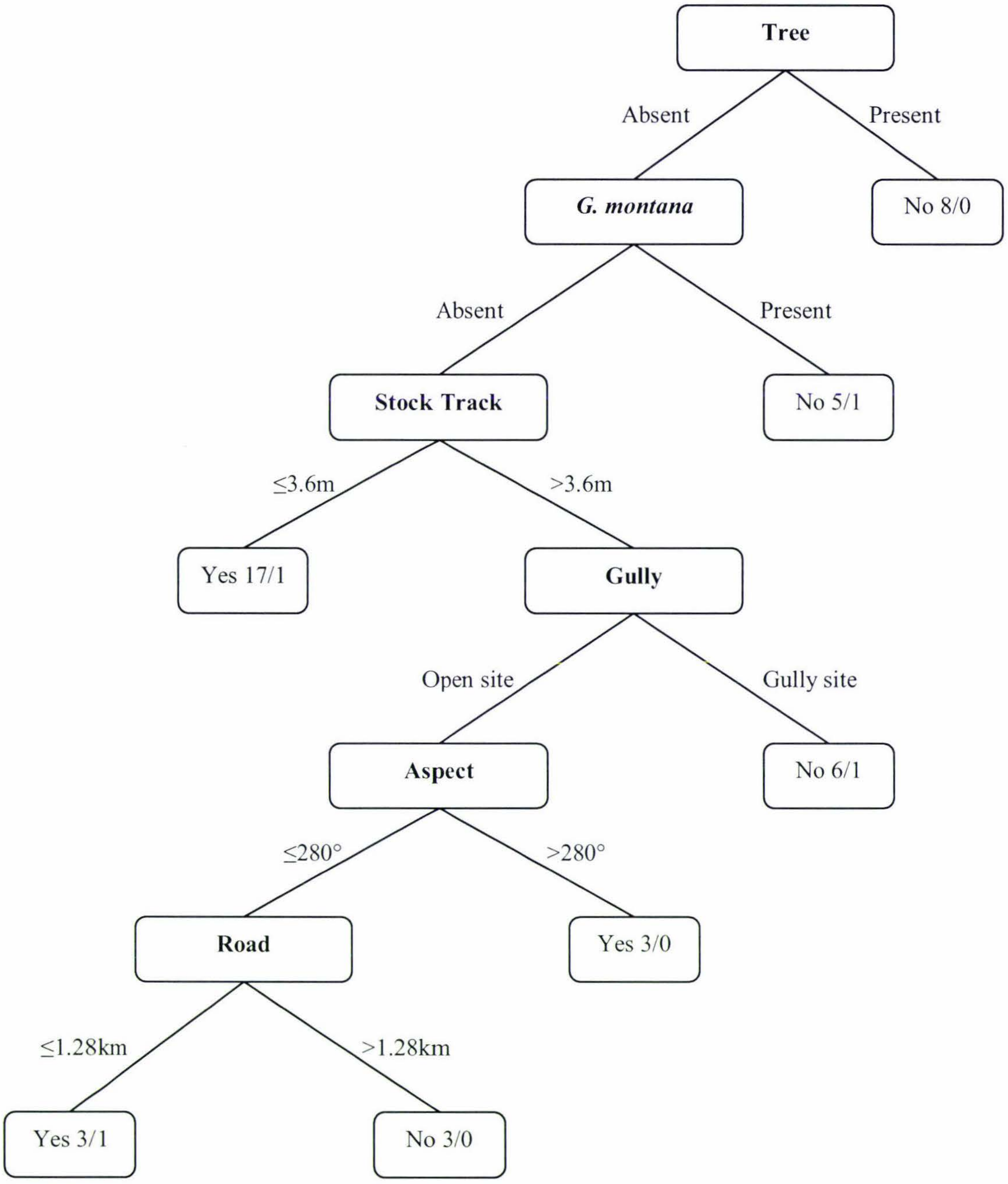

Figure 3.5 Classification tree revealing environmental variables relating to the presence-absence of *O. microlepis*. Each leaf is classified according to the presence (yes) or absence (no) of *O. microlepis* in each instance (6/1). For example, when a tree was present at a site, the site was unoccupied (no) in 8 cases and occupied in 0 cases (8/0). Important explanatory variables classified are tree, *Gingidia montana*, stock track, gully, aspect and distance to the nearest road. The tree correctly classified 69% of the instances, with a misclassification rate of 31% (Kappa statistic = 0.3762).

The classification tree analysis revealed that the presence of a tree was the most important environmental variable (Figure 3.5). The splits are based on the proportions of presences and absences in the groups. The leaves of the tree are characterised by their dominant category (present or absent), and the proportion of sites in each category. The classification tree shows that the presence-absence of *O. microlepis* at sites was determined by a narrow set of habitat variables. The first explanatory variable was tree, where *O. microlepis* was absent at 100% of the sites containing trees (n = 8), and *O. microlepis* was also absent at 80% of the sites containing *G. montana* (n = 5). The next explanatory variable was stock track, *O. microlepis* was present at 95% of sites within ≤3.6 m of a stock track (n = 17). *O. microlepis* was absent from 83% of sites situated in a gully (n = 6), and present at 100% of sites with an aspect >280° (n = 3), and 66% of sites if a public road was within 1.28 km (n = 3).

3.4 Discussion

3.4.1 Habitat selection

Classification trees determine habitat variables affecting site occupancy by finding a set of rules from the data to enable to the prediction of the probability of encountering *O. microlepis*. NMS ordination plots were also used to provide a descriptive analysis of study sites based on habitat variables. For *O. microlepis* there were six habitat variables identified as important for site occupancy. These include whether a tree was present on the site, the presence of the native plant *Gingidia montana*, distance to the nearest stock track, whether the sites were located in a gully or out in the open (exposed), the aspect (orientation) of the site and the distance to the nearest public road. Classification trees are invaluable tools in increasing the efficacy of surveying for rare species by avoiding sites with habitat variables that produce low rates of site occupancy, and can also be useful for the management of known sites and selection of new sites for translocation.

3.4.2 Explanatory variables – tree, Gingidia montana, *aspect, gully*

Most of the habitat variables identified by the classification tree analysis as affecting occupancy of *O. microlepis* were associated with temperature. This is because habitat use depends on the specific ecological processes of each species, and lizards as ectotherms select habitat based on the thermal suitability of a site. The presence of a tree was outlined as the most important explanatory variable in determining site occupancy of *O. microlepis*. As discussed earlier (section 2.4.2), I propose that absence of *O. microlepis* at sites with trees could be due to the decrease in temperature of the rock caused by the shade of the canopy. Goldsbrough *et al.* (2003) found that canopy cover altered the heating and cooling rates of rocks and retreat sites, and other *Oligosoma* spp. such as the spotted skink (*Oligosoma lineoocellatum*) on Stephens Island have been found to select habitat restricted to cliffs and steep slopes without trees (East *et al.* 1995). Trees could also increase predation by providing perches for birds to scan the site for basking lizards. Birds are known as important predators of diurnal lizards (Blomberg and Shine 2000), and the predation risk is increased further by the longer basking time required by the cooler rocks under the shade of the tree.

The classification tree analysis identified the native plant species *Gingidia montana* as an important explanatory variable for *O. microlepis* after the presence of a tree at a site. Analysis showed that *O. microlepis* selects against sites containing *G. montana* (Figure 3.5). *G. montana* is a small herbaceous plant that is regionally rare. It grows in grassland and on rocky habitats where browsing animals (cattle or deer) have restricted access (i.e., rock outcrops and cliffs) (Lund 2003). Occupied sites were also negatively correlated with most other native plant species (Figure 3.4) and this relationship again (like the presence of a tree) could be due to temperature. This is because vegetation can be used by lizards in different ways, and has been found to play an important role in structuring reptile communities (Jellinek *et al.* 2004). For example, many species of lizards use vegetation for thermoregulatory behaviour for "shuttling" between sun and shade for thermoregulation, and is also used as refuges from predators (Bauwens *et al.* 1999; Cooper and Whiting 2000; Kerr *et al.* 2003; Vanhooydonck and van Damme 2003).

In contrast, heliothermic *O. microlepis* appears to select habitat that is relatively clear of vegetation (including trees) to maximise exposure to solar radiation at the sites. Other studies have also found that higher light in gaps positively influence heliothermic reptile abundance (Greenberg 2001). For example, the Amazonian lizard (*Tropidurus hispidus*) selects isolated rock outcrops that have continuous sunlight during much of the day due to lack forest vegetation (Vitt *et al.* 1996).

North and northwest facing sites (280-360°) were also outlined by the classification tree as an important habitat variable, and all sites contained *O. microlepis*. This could also be due to temperature because these sites have highest exposure to direct sunlight during the day. This confirms findings by Flannagan *et al.* (2001) who found *O. microlepis* populations selected north facing sites.

Lastly, the situation of a site in a gully was an important variable negatively correlated with the presence of *O. microlepis* at a site. Sites situated in a gully were mostly outcrops (Figure 3.3) and had less exposure to sunlight than open sites. These sites received less sunlight throughout the day and therefore had lower average temperatures (section 2.3.1). In addition, gully sites also contained more vegetation (Figure 3.4). All of these factors of gully sites affect the temperature at the site, and decrease a lizard's chances of effective thermoregulation (section 3.3.2). A study by Langkilde *et al.* (2005) demonstrated this type of relationship with habitat selection in five montane scincid lizards in south-eastern Australia. These species preferred sites that were more open than those generally available, with less vegetation and moss cover on the substrate. Occupancy was said to be a function of higher exposure to solar radiation at these sites with these specific habitat characteristics. Sun-exposed sites are likely to reflect fitness benefits to lizards that utilise these areas compared to cooler and moister habitats (Langkilde *et al.* 2005).

3.4.3 Explanatory variables – distance to the nearest stock track and public road

The last two explanatory variables identified by the classification tree as affecting *O. microlepis* presence at a site were distance to the nearest stock track and public road. If a site was within 3.6 m of a stock track or 1.28 km of a road, sites had higher rates of occupancy, showing that *O. microlepis* may be selecting sites that have higher disturbance than others. Death (1996) stated that 'biological and physical disturbances are a natural feature of many environments' Hutchinson (1993) hypothesised that stock disturbance (e.g., grazing) could be maintaining preferred habitat of *O. microlepis* by preventing vegetation encroachment on the site (Figure 3.4), as well as trampling (Figure 3.3) creating a continual turnover of rocks for new habitat (refer to section 2.4.2).

Studies show that reptiles are affected by agricultural practices (Hecnar and M'Closkey 1998); but whether this has positive or negative affects on a species is species-specific. Evidence suggests that *O. microlepis* seems to persist in areas with moderate levels of disturbance because habitat is being maintained by general farming practice. However, high stocking rates could lead to land degradation (Sawadogo *et al.* 2005) and the death of individuals. This is supported by Hobbs and Huenneke (1992) who state that intermediate levels of livestock access at sites would be most effective at maintaining diversity and structural complexity of the habitat. In addition Goode *et al.* (2005) found that the relative abundance of lizards was increased at lightly disturbed sites.

Anthropogenic disturbance measured by the distance to the nearest road was also an important explanatory variable for *O. microlepis* presence at a site. Many studies have measured the remoteness of habitat by the distance to the nearest road. The Huts study region at Erewhon station for example, contained fishing huts and had the easiest access compared to other sites used in the study (Figure 3.3). Interestingly, the closer the road was to a site, the greater the likelihood of occupancy of *O. microlepis*. For example, sites within 1.28 km distance of the nearest public road had a 66% chance of occupancy compared to 0% if further away.

3.5 Conclusion

Agricultural development of the Inland Patea district by deforestation and the increase in pasture may have led to an increase in the range of *O. microlepis* due to creation of new habitat (reduced vegetation) and the maintenance of old sites (stock disturbance). Unfortunately this patchy habitat is on private land, and the development of effective conservation strategies of *O. microlepis* have been hindered by limited biological knowledge of the species and the effects of general farming practice.

Analysing habitat selection of *O. microlepis* is a preliminary step in assessing the survival chances of the species and making effective management decisions. The species seems to select relatively open, sun-exposed sites that contain specific thermal characteristics, and farming appears to be maintaining these habitats through low vegetation cover and disturbance by stock and human activities. Now habitat selection information of *O. microlepis* has been obtained, management strategies can begin to be carried out accordingly. For example, based on information from this study, fencing sites containing populations of *O. microlepis* could be detrimental to the survival of the species because of the encroachment of vegetation. Alternatives such as pest control around sites would be more beneficial. In addition, the classification tree can act as a good management tool for guidelines in future surveying of new sites of *O. microlepis* by outlining habitat characteristics such as aspect, the absence of trees and vegetation, and the presence of cattle and stock routes near or on the site which were good predictors of site occupancy.

However, the long-term viability of populations at these sites is still unknown. Although lack of natural vegetative cover may be preferential for thermoregulation, the lack of vegetation cover within the pasture may be preventing dispersal or significantly increasing the risk of predation during dispersal. Howard and Hailey (1999) found that specialised rock-dwelling lizards (like *O. microlepis*) fail to disperse to other sites through other habitat types. Therefore the physical capability of animals dispersing between sites needs to be examined, as well as the genetic implications of this dispersal.

Chapter Four

Environmental Education on Private Land

Chapter Four:

Environmental Education on Private Land

4.1 Introduction

Biological diversity (or biodiversity) is defined as diversity at genetic, population, species, community and ecosystem levels (Gaston 1998), contributing to the life-supporting capacities of the environment (Davis and Cocklin 2001). High levels of New Zealand indigenous biodiversity have economic, cultural, intrinsic and aesthetic importance (Clough 2000). Unfortunately, New Zealand landscapes are severely modified (Davis and Cocklin 2001). As a result, habitat loss and degradation and introduced predators have led to dramatic declines in biodiversity.

The New Zealand Biodiversity Strategy (Department of Conservation and Ministry for the Environment 2000) focuses specifically on halting the decline of indigenous biodiversity across all land tenure types. The strategy states in Goal Three the intention to:

> *Maintain and restore a full range of remaining natural habitats and ecosystems to a healthy functioning state, enhance critically scarce habitats and sustain the more modified ecosystems in production and urban environments; and do what else is necessary to maintain and restore viable populations of all indigenous species and subspecies across their natural range and maintain their genetic diversity.*
>
> Department of Conservation and Ministry for the Environment (2000)

The Strategy challenges every New Zealander to understand, maintain, conserve and share in the benefits of this biodiversity.

4.1.1 Biodiversity on private land

Both in New Zealand and worldwide, private land contains many threatened species and natural habitats not found in protected areas. In North America for example, 2.1 million farmers manage ca. 400 million ha and thus control 43% of the country's natural habitat (Messmer *et al.* 1996). Unfortunately, many governments, including that in New Zealand, lack the resources to fund much of the conservation management of this biodiversity and it therefore depends on the initiatives of landowners (Oldfield *et al.* 2003).

Research and environmentally sound farming practice initiated by landowners have had immense benefits to the conservation of biodiversity worldwide (Jacobson 2002). Jacobson (2002) reports a diverse range of approaches including the maintenance of existing habitats, the halt of habitat degradation through better management, and the restoration of lost habitat (e.g., wetlands, lowland forest). The focus of such management can be at a diverse range of levels.

Management can focus on ecosystems, such as the long leaf pine (*Pinus palustris*) ecosystems in North America which are managed to support hundreds of plants and animals (Alavalapati *et al.* 2002). Management may focus on particular sets of species. For example, approximately 60% of Europe's threatened bird species are associated with lowland farmland, and 'Environmentally Sensitive Areas' schemes protect many rare bird species through the ecological enhancement of agricultural landscapes on private land (Ausden and Hirons 2002). Management may also focus on single species such as the English cirl bunting (*Emberiza cirlus*) which had declined to 118 pairs by 1989 (Ovenden *et al.* 1998). Research indicated that agricultural development was largely responsible for the decline of this species through the reduction of winter food and habitat loss (Ovenden *et al.* 1998). The Countryside Stewardship Scheme launched in 1991 offered farmers payments to enhance and conserve landscapes for wildlife. Since that time the cirl bunting increased to an estimated 360-380 occupied territories by 1997 (Ovenden *et al.* 1998).

Single species management on private land can be beneficial in several ways; firstly by the direct improvement of the conservation status of the species; and secondly, by acting as an umbrella species for other native species that require the same habitat. Single species management can also create awareness of conservation issues at a larger scale.

Most protected natural areas in New Zealand are restricted to mountainous and upland areas that are unrepresentative of the natural range of New Zealand's indigenous biodiversity (Department of Conservation and Ministry for the Environment 2000). Thus, there are currently many species and entire ecosystems that exist solely on private land, and the skill and commitment of landowners is the key to conserving this biodiversity. Unfortunately, not all landowners are aware of this responsibility or are always prepared to shoulder it (Davis and Cocklin 2001). Conservation management strategies (e.g., pest control, fencing forest remnants, species monitoring) and focus (e.g., single species, multiple species or ecosystems) depend on a variety of factors and constraints affecting individual landowners. These include personal motivation, knowledge, cultural commitments, resources, farm structural characteristics, ecological variables and support of each individual landowner (Davis and Cocklin 2001; Raedeke *et al.* 2001). In addition, because there is often limited information on the ecological condition of this biodiversity (e.g., effects of agriculture, introduced species), and because what is studied is classified and assessed in many different ways (Ministry for the Environment 2000), biodiversity is often difficult to manage effectively (Hilty and Merenlender 2003) even when farmers are committed to doing so. Conservation on private land is therefore dependent not only on an understanding of the ecology, but also the socio-economic processes involved (Ovenden *et al.* 1998).

The majority of landowners in rural New Zealand have a strong desire for conservation, but find major barriers such as lack of finance and time to undertake environmental projects on their land (Davis and Cocklin 2001). Norton and Miller (2000) concluded that it is possible to sustain both productivity and protect native biodiversity and Craig *et al.* (2000) state that there are numerous possibilities for integrating production and conservation. A variety of economic incentives exist for landowners and these often allow biological features to be viewed as assets rather than liabilities (Clough 2000), encouraging cooperation and interest in conservation management.

Clough (2000) lists some of these incentives as cost sharing and management agreements, agricultural land retirement schemes, covenants and conservation easements, public or grant-aided land purchase, wild species management and enhancement schemes.

Although New Zealanders often have a strong desire and emotional support for the environment, they generally lack the depth of understanding in environmental issues, skills and information to make a difference (Treeby 2001). While all the other issues remain important, it seems that this final point is a critical barrier to the enhancement of biodiversity on private land. The need for more effective environmental education with landowners through consultation, practical involvement and the sharing of information is an obvious response to this issue.

4.1.2 Conservation on private land, through environmental education

Environmental education is a way to empower people with knowledge and create new patterns of behaviour. The Tbilisi Declaration (1978) described education as having a leading role to play in creating awareness and a better understanding of the environment, providing people with the knowledge, values, commitment and skills needed to protect and improve the environment, thereby creating new patterns of behaviour (UNESCO 1978; Palmer 1998).

In New Zealand, the discussion document, 'Learning to Care for our Environment' (Ministry for the Environment 1998) was published in conjunction with the Ministry of Education and followed on from Tbilisi Declaration in describing education as the key component in providing knowledge, awareness, attitudes and values that would motivate people in sustaining the environment throughout their lives at all ages, and at all levels of society (Treeby 2001).

Environmental education is also regarded as a critical aspect of wildlife conservation and resource management (Jacobson and McDuff 1998), especially on private land. Increasing environmental awareness on the part of landowners and the farming community is frequently cited as critical to the success of conservation programmes and schemes (Messmer *et al.* 1996; Craig *et al.* 2000). Craig *et al.* (2000) state that through environmental education the whole community can be involved in the sustainability and protection of indigenous biodiversity.

Environmental education can occur in a variety of ways. For example, Messmer *et al.* (1996) gave landowners a calendar with information on 46 conservation practices beneficial to wildlife. To determine whether the calendar motivated landowners to implement any of the practices, they undertook follow-up research. Most respondents (98%) adopted at least one of the wildlife conservation practices as a result of the calendar information they received (Messmer *et al.* 1996).

As outlined by the Tbilisi Declaration (UNESCO 1978), environmental education is also an approach in developing an environmental ethic, where people view themselves as an active part of the environment. For example, landowners can recognise that their management decisions dramatically impact on ecosystem structures and functions on their land (Raedeke *et al.* 2001). To achieve this, the community and landowners need to first be aware of these impacts, acknowledge that they contribute to solving these problems (Raedeke *et al.* 2001) and be aware of the benefits of the integration of ecologically and economically sustainable practice before conservation management can take place (Treeby 2001).

The aim of this chapter is to describe the environmental education conducted with the farming community during my research in an attempt to create awareness of *O. microlepis* and wider conservation issues. This education was carried out through the exchange of information by conducting talks, informal discussions and meetings with the local farming community on the research progress, as well as providing individuals the opportunity for participation in fieldwork and research planning. I evaluated my success at the completion of the study by comparing outcomes of environmental education with those outlined in the Tbilisi Declaration (1978).

4.2 Case study: *Oligosoma microlepis* on private land

Moawhango is a farming settlement nestled in the Inland Patea district 30 km east of Taihape in the central North Island. Scattered throughout this area are ca. 17 populations of the vulnerable *Oligosoma microlepis*. All known populations are small, isolated and on private land (Flannagan *et al.* 2001; Towns *et al.* 2002). The survival of *O. microlepis* is therefore entirely dependent on landowner initiatives and goodwill for site access, species monitoring and management. The *Oligosoma* spp. Recovery Plan (2002) emphasises this need, stating in its conservation objectives for *O. microlepis* the need to conduct advocacy with landowners (Towns *et al.* 2002). Education can be a powerful tool in achieving this objective by creating awareness and species protection (Miles 1994).

Many rare New Zealand reptiles such as *O. microlepis* have conservation education and public awareness goals outlined in their Recovery Plans. For example, Objective three in the Tuatara Recovery Plan (Gaze 2001) states that public awareness of tuatara (*Sphenodon* spp.) and related conservation issues will be promoted through accessibility to captive animals and certain wild populations of tuatara. The draft Recovery Plan for grand (*O. grande*) and Otago Skink (*O. otagense*; Norbury *et al.* 2006) also outlines the need for public awareness of the conservation status and threats faced by grand and Otago skinks in the long term, because like *O. microlepis* a significant number of populations remain on private land. Actions for increasing awareness of grand and Otago skinks, include building better relationships with landowners, inviting local schools to be involved in fieldwork, and sharing information and engaging the whole community through community led skink conservation initiatives (Norbury *et al.* 2006). In addition, the Central Otago Ecological Trust has been established, and this trust is focused on grand and Otago skink conservation through education (Norbury *et al.* 2006).

The goals for environmental education (UNESCO 1978) signal clearly that education should be a participatory process and not one that is imposed on people. With this in mind, and informed by the literature referred to above, my project was conceived and developed as a conjoint science research and educational endeavour, achieved by conducting environmental education through interactions within the farming community. Hilty and Merenlender (2003) emphasises that this relationship between landowner and researcher, developed through the sharing of progress reports and information can strengthen collaboration and communication. In my study, the research became a community project where information was shared between the researcher and the local community, not just with the landowners. No quantitative data were collected on these interactions, but a diary was kept to record how relationships and behaviours changed during my time in the Inland Patea district.

The future of *O. microlepis* on private land depends largely on the goodwill of and initiatives taken by landowners. By encouraging community involvement in the project, knowledge was shared and conservation management initiated and maintained long after the completion of the research. Zint (1998) supports this type of integrative research by insisting that scientists should support the development of conditions in which individuals can obtain information and skills in order to carry out their own inquiries into environmental issues in their own communities.

4.2.1 Farmers

Hilty and Merenlender (2003) consider that the way that landowners are contacted greatly influences whether or not they choose to support research on their land. It was important for me in making my initial visits to each farm manager and his/her family before commencing my research to emphasise that their involvement in the project was welcomed, appreciated and needed. Discussions about the project gave them the opportunity to offer their views, ideas and relevant information applicable to the project, and each farmer was given a proposed outline of the research, and invited to contact me if they had further questions or ideas. The majority of farmers and landowners were willing to allow access to sites containing *O. microlepis*, and appreciated the invitation to be involved. The regularity of the subsequent offers of help and information confirmed the value of this approach. All the landowners/managers were helpful and obliging in every possible way.

This input was invaluable, and I was granted access to three stations; Otupae, Erewhon and Kelly Land Company. Farmers also suggested sites on each station that I could visit, provided maps and field equipment including Radio Transmitters (RTs), accommodation, detailed histories of each station, as well as providing assistance during my fieldwork. My initial contacts at each station introduced me to other local people who I also discussed my research with, and as I was a talking point in the community, a deeper and wider interest was created.

My involvement within the community didn't stop at the initial visits. During the two summers that I spent living in the Inland Patea district, I was made part of the community. As had been anticipated in conceiving the project, every interaction had an educational component for both myself and community members. As most farmers require a considerable knowledge base to manage diverse agricultural systems (Young 2002), they had a lot to contribute towards the research. Interactions with farmers ranged from informal gatherings (BBQ, horse sports, morning tea), specific meetings regarding the research, and telephone conversations. On an early visit to the area, for example, I was introduced to a worker at Otupae who took me around the whole station, sharing with me information about the station including the lithology of the area, soils, general farming practice, indigenous and introduced species, history of human settlement and climate. This experience demonstrates the comprehensive local knowledge that scientists can potentially use to learn background information of a study area, saving considerable time and enriching the project.

There was always the opportunity to meet new people and talk about the research at social occasions. The majority of people had never heard of *O. microlepis*, and were intrigued to find out more and become involved. For example, a BBQ was held at Erewhon at the beginning of summer 2004/05, and everyone from the district attended. There was great interest and many questions regarding preliminary results from the previous summer's pilot study, including the state of the lizard populations and the effects farming might be having on them. Many people who I had not previously met showed an interest in my work, having heard of the project in the previous months. This was a powerful demonstration of the way in which environmental education can be shared easily across lines of communication throughout small farming communities.

The research on *O. microlepis* generated a collective pride and interest, and as local people learnt about the research they informed new families and visitors to the district about the research and their role in it. The research became a conversation piece, and those that had grown up in the district most of their lives had stories about lizards, although few had heard about or seen *O. microlepis*. One farm manager had lived in the district for over 18 years and had significant interest in the natural ecology of the area, but had never seen *O. microlepis* despite several surveys being undertaken for the species over the years. He monitored my project closely and with enthusiasm, regularly visiting the sites (sometimes with his family) and informing visitors of the species, and his interest has continued since the completion of the research.

Interest in the research was ongoing and there were many fieldwork volunteers and frequent phones calls from locals regarding skink sightings and related questions, instigating many discussions. New Zealand lizards are good catalysts for discussion on ecosystem health and wider conservation issues in New Zealand because everyone has seen the effects of introduced predators first hand (e.g., the majority of people that I talked with could recall a time their cat had brought a lizard into the house), and most have seen a dramatic decline in numbers in recent years. Consequently, many farmers intensified their killing of feral cats on their land once they were made aware of the threat they pose to native fauna.

People were more than willing to share experiences involving lizards. For example, I was rung by a local worker at Erewhon who reported that he and his father were cutting away an old tree stump and disturbed several skinks. He was interested in what species they were and how the animals could inhabit an old stump.

Rural communities like Moawhango are very conscious of environmental change and dependent on the weather and the natural landscape for their livelihoods. While most had a desire to conserve natural areas on their land, they were cautious of researchers because of concerns of the finance, time and knowledge requirements of conservation management. With open lines of communication, problems concerning my research were discussed, and biological information and potential management schemes were shared and all the feedback was positive.

4.2.2 School children

Children are an important target audience for environmental education because it is during childhood that life goals and environmental information are acquired that shape decisions made as an adult (Young 2002). So it was imperative that children were a focal group for sharing research information. A formal talk on environmental education and herpetofauna was conducted at the local Moawhango school. This talk covered the broad topic of lizards, defining a lizard, unique New Zealand species, and focused on *O. microlepis* and the work I was doing with the species. The children prepared for my talk by organising questions for homework. This was a good opportunity to discuss my research with their parents, most of which lived on stations outside the study area. As a result, many parents attended the talk as well as children and this was extremely valuable and heartening.

The talk created environmental awareness by informing the children about New Zealand lizards, and helped change the children's views of the area they live in. Prior to the talk, many children and adults in the area were unaware that lizards even existed in the area, and after the talk I received phone calls of sightings. During discussions that followed the talk, some children commented that they had seen grey lizards on rocks at the back of their farm, and on visiting the farm this site was found to contain a new population of *O. microlepis*. This was an invaluable outcome because it increased the number of occupied sites available to survey, and was a striking confirmation of value of the approach taken in that the children could introduce a new site to the scientific community.

In addition to the discussions after the talk at the school, I received several phone calls asking questions, providing information regarding sightings of lizards and offers of access to other stations. The children had essentially 'educated' their parents by talking about the information they learnt at school.

Throughout the research the children who helped with fieldwork displayed a constant thirst for knowledge. On a lizard hunt one evening only invertebrates were found, but the children asked about the habitats where lizards live, what they eat, and why they might be found on the farmland. In addition, they asked questions relating to the conservation status of the species, and why they are as rare as they are. While I was surveying at Otupae, the farm manager's son was helping me and noticed a skink travelling through the grass between sites. This was the first time that this had been observed during the research and because of his experience with *O. microlepis* he was able to identify the animal. This information contributed significantly to the biological knowledge of *O. microlepis*. During surveying of *O. microlepis* he also noticed a common gecko (*Hoplodactylus maculatus*) basking on a rock outcrop, another behaviour that had not been observed during the study.

4.2.3 Local Māori

Environmental education has to be adaptable in application, not only across ages but across cultural boundaries. In New Zealand, 50% of the remaining indigenous forest on private land is Māori owned (Davis and Cocklin 2001). Under the Treaty of Waitangi, Article 2, Māori are guaranteed 'the full and exclusive and undisturbed possession of...their forests' (Wright *et al.* 1995). Māori tend to have a holistic view of the environment, valuing all components of the ecosystems, all of which possess a mauri (lifeforce), mana (integrity), wairua (spirit) and are tapu (sacred) (Ministry for the Environment 2000).

Māori are also generally keen to collaborate with government agencies (e.g., Department of Conservation) and other parties in regards to active management of conservation on their lands, as tangata whenua and kaitiaki (guardians) of these ecosystems.

The Biodiversity Strategy (2000) states that development of effective conservation management is constrained by factors such as 'insufficient capacity and resources within iwi and hapu', the 'variability in experiences in building and maintaining working relationships', and 'a need for greater sharing of experiences between local and central government, with iwi and hapu'. All of these sets of issues can be solved to some extent by environmental education (section 4.3).

Therefore, it was important to include the local hapu, Ngati Whitikaupeka of Mokai Patea in the research. Extensive tracts of farmland and forest in the district are owned by Māori. To introduce the research to the hapu representatives, a meeting was organised through a friend who was also a member of the hapu at Moawhango. The meeting was invaluable. There was significant interest in my research, because lizards are a significant part of Māori legend of the area. Information such as historical records of lizard sightings and stories were shared. I was also privileged to be allowed to visit and photograph the wharenui at the Oruamatua marae (Plate 4.1) that contained whakairo (carvings) of the giant lizard called Pohokura that features in the legends pertaining to the area (Plate 4.2).

From the meetings with hapu representatives, I was granted access to Māori land in the Moawhango area, and although this came too late for use in my project, it has opened up lines of communication for future research. Awareness for the species has also been created, and this awareness could improve the prospect of populations on private land under the guardianship of local Māori.

4.3 Outcomes

The outcomes of environmental education in the Inland Patea district address all the major intentions of the Tbilisi Declaration (1978) (Table 4.1).

ENVIRONMENTAL EDUCATION OBJECTIVES (TBILISI DECLARATION 1978)	STUDY OUTCOMES
1. to create awareness and a better understanding of the environment;	1. Created awareness of *O. microlepis* and other conservation issues in the Inland Patea district.
2. to provide every person with opportunities to acquire the knowledge, values, commitment and skills needed to protect and improve the environment;	2. The study has provided biological knowledge about *O. microlepis*, enhancing the value of these animals, thereby increasing the local community's commitment towards them. The participation in fieldwork has also provided new skills.
3. to create new patterns of behaviour of individuals, groups and society as a whole towards the environment.	3. Through the study outcomes above, new patterns of behaviour have been created (i.e., knowledge of local biodiversity has led to changes in land development processes).

Table 4.1 Study objectives and outcomes based on the intentions of environmental education in the Tbilisi Declaration (1978).

First, environmental education in the farming community has created awareness and a better understanding of the *O. microlepis* as well as other conservation issues in the Inland Patea district.

Second, it has provided people with the *knowledge* that developed throughout the research period. This was observed in the progression of discussions from basic questions regarding the skinks, to more in-depth conversations about conservation in New Zealand. Environmental education has also enhanced the *value* of these animals in the local community and increased the level of *commitment* to protect them. A collective sense of pride has grown from the research; the local community discuss the research, the lizards and experiences. One station is in the process of establishing a covenant over an area of tussock land. The idea of doing this already existed, but action appears to have been catalysed by the educational process.

Environmental education has also provided people with the *skills* needed to protect and improve the prospects of this species, which have risen in response to participation in fieldwork. For example, after participating in fieldwork individuals developed competencies in surveying techniques, and could identify ideal surveying conditions and potential skink habitat. These skills are essential in finding potential new populations on their land, and monitoring known ones.

Third, environmental education has created *new patterns of behaviour*. Farmers are regularly visiting sites of *O. microlepis* on their farms, taking their children, and informing visitors about these animals. They are considering native biodiversity before modifying landscapes on their farms, especially paddocks containing populations of *O. microlepis*, and seeking additional information.

Environmental education is now a long-term, if not *life-long process* for these people. Even people moving away from the area have taken knowledge, skills and values with them that have been instilled through environmental education from the work with *O. microlepis* into other parts of the country. These families still keep in contact and during conversations, ask questions regarding the progress of the skinks, but also ask questions regarding conservation projects in their new areas and how they can become involved. Environmental education in the Inland Patea farming community has created awareness and empowered people with the knowledge and skills to actively get involved with environmental schemes both in the district and beyond for many years to come.

4.4 Summary

Much of New Zealand's indigenous biodiversity is found solely on private land and there is potential for local communities to play an active role in the protection of these rare species and ecosystems. The case study in Moawhango, Inland Patea district has demonstrated how environmental education can provide a better outlook for a rare species, such as *O. microlepis* by creating greater understanding by residents of the indigenous biodiversity and conservation issues in their region. This, coupled with a community based approach, developing a sense of pride in the protection of local flora and fauna has led to the sharing of knowledge, application of skills and the subsequent steps towards conservation management on their land as a feature of local community life.

Future conservation work on private land would benefit significantly by incorporating environmental education into the research methods; (i.e., providing opportunities for practical involvement in fieldwork; or simply regular consultation and sharing of information with landowners and other interested groups on the progress of the research). This study demonstrates the numerous benefits of environmental education at a local community level, and how it is a crucial activity in protecting indigenous species on private land.

Plate 4.1 Wharenui at Oruamatua marae. Photo courtesy of: Oruamatua Marae Trust

Plate 4.2 Whakairo (carving) of giant lizard, Pohokura. Photo courtesy of: Oruamatua Marae Trust

Chapter Five

Conservation of *O. microlepis*: Summary and Recommendations

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5.1 Summary

Centuries of human-induced habitat loss and degradation, as well as introduced mammalian predators, have led to dramatic declines in the distribution and abundance of New Zealand lizards. The conservation of New Zealand lizard species therefore relies on assessing these threats and implementing appropriate management strategies. However, effectiveness of these strategies is limited by lack of species-specific information because of lizards having low densities over large ranges and naturally cryptic behaviour.

Oligosoma microlepis is a vulnerable, endemic lizard located in small, isolated habitat fragments on private land in the Moawhango, Inland Patea district, in the central North Island. Biological knowledge and current threats to *O. microlepis* are predominantly unknown, and the *Oligosoma* spp. Recovery Plan outlines the need for focused research as well as advocacy with landowners to improve the management and long-term survival of the species.

My research was divided into three parts. The first was an analysis of detection probability and site occupancy of *O. microlepis* to improve surveying techniques for the species. Detection probability was modelled as a function of sampling covariates, and site occupancy as a function of site covariates (using the program PRSENCE). The most important sampling covariate affecting detection of *O. microlepis* was rock temperature, and detection may also have been affected by the month and time of day that surveying took place. Therefore future surveying should be restricted to early summer months and days with high temperatures to obtain the highest probability of detection. The probability of site occupancy was highest when the sites were rock piles, close to stock tracks and in the absence of trees.

The second part of the research was a detailed habitat analysis based on site occupancy data. A classification tree illustrated important explanatory variables of *O. microlepis*, and confirmed and expanded on those variables outlined in the previous analysis. Important habitat variables included the presence of a tree and *Gingidia montana* on the site, aspect, the distance to the nearest stock track and public road, and the location of the site in a gully. This information can be used as an effective tool in quantifying the effects of future conservation management and in developing methodology for searching for new sites.

In the last part of the thesis I conducted advocacy and environmental education with landowners and the farming community in the Inland Patea district through shared knowledge, skills and fieldwork experiences. Environmental education improved the prospect for *O. microlepis* on private land by creating awareness of the species and wider conservation issues within the district for landowners and farmers to make informed decisions for future conservation management.

5.2 Recommendations

The increased understanding of *O. microlepis* biology through this research can contribute to the establishment of effective conservation management strategies for the species, and environmental education with landowners and the farming community has created awareness, thereby dramatically improving the long-term prospects for the species on private land. Further recommendations include:

1. Further surveys in the central North Island should be conducted. These should encompass Lake Taupo, Bay of Plenty and the Wairarapa, focusing specifically on areas managed by the Department of Conservation. Also surveys should incorporate the new habitat information.

2. Comparative study of dispersal between modified (agricultural) and natural (tussock and scrub) sites should be carried out to determine the effects of agricultural development on connectivity and viability of populations by using genetic and demographic data.

3. Regular monitoring of Erewhon station sites at Springvale (Quarry and Huts) should continue to collect habitat, genetic, demographic and population viability data.

4. It is imperative that advocacy and liaison with landowners should continue for the long-term protection and survival of *O. microlepis* at sites on private land.

5. There should be further work to identify the key threats to *O. microlepis* (i.e., introduced predators, habitat degradation, agricultural development and disease) and develop appropriate management options.

6. A captive population needs to be established to provide a subsidiary in the event of disaster (i.e., fire, flood, disease) and also to source animals for translocations.

7. The establishment of protected mainland sites (e.g., monitored, unfenced, effective predator control) should be a long-term goal for *O. microlepis*.

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