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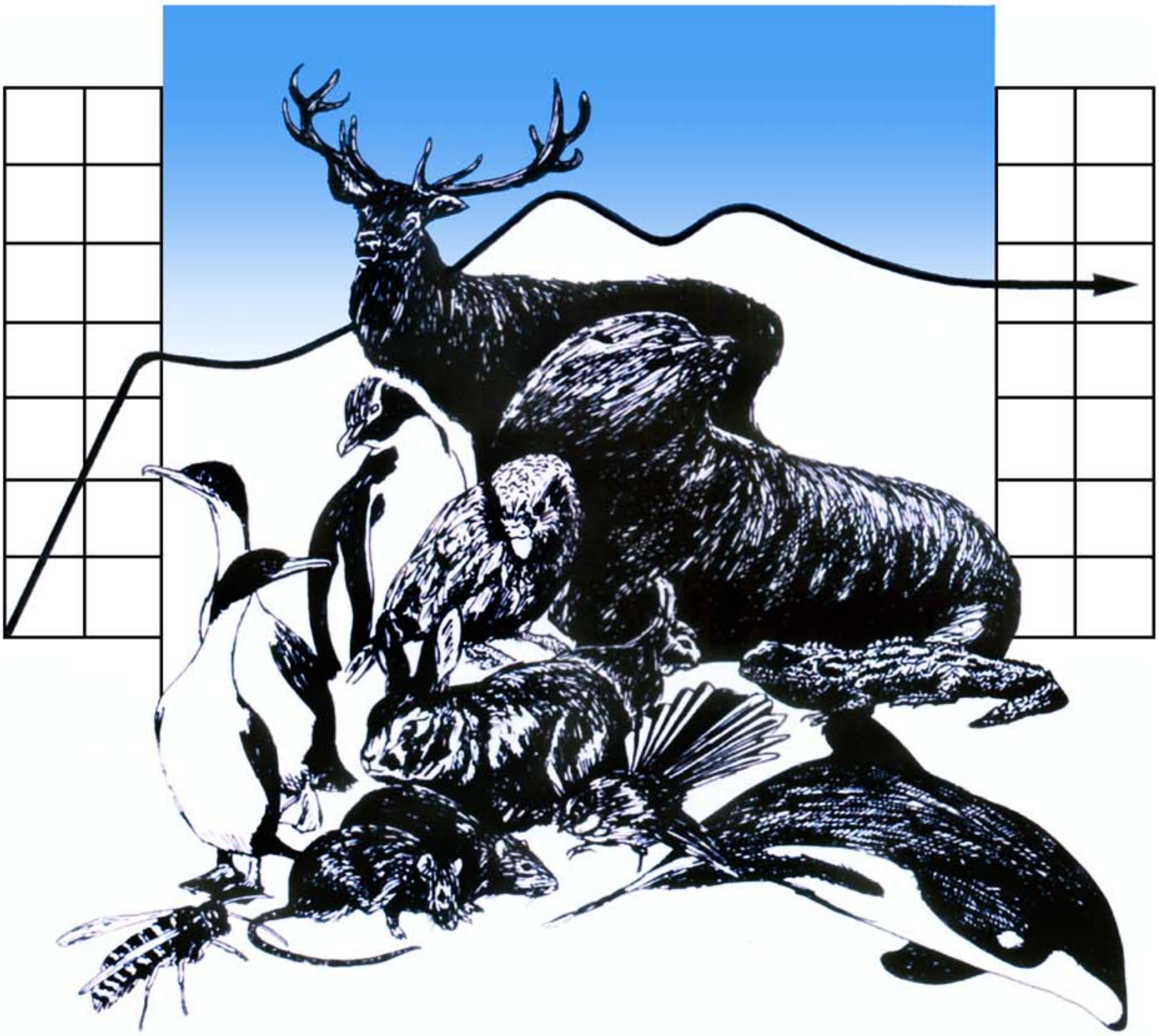

# WILDLIFE MANAGEMENT

# Assessment of habitat suitability at Orokonui Ecosanctuary, for the translocation of Maud Island frogs (*Leiopelma pakeka*) and/or **Hochstetter's frogs (***L. hochstetteri***)**

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## SUMMARY

New Zealand's native anuran fauna consists of four frog species, all belonging to the genus *Leiopelma*. Currently under consideration for translocation to Orokonui Ecosanctuary, located north of Dunedin are the Maud Island frog *L. pakeka* and Hochstetter's frog *L. hochstetteri*. Habitat quality has been one of the most important predictors of a translocation project's success. At present there are no native frogs on the South Island of New Zealand, and a successful establishment of populations here would be a major step in native frog conservation. This report assessed the habitat suitability of potential target translocation sites within Orokonui Ecosanctuary for Maud Island and Hochstetter frog species according to structural habitat, microclimate and macroclimate data.

While the results for potential *L. pakeka* translocation sites were unclear, this study has identified sites along Orokonui stream that possess habitat structurally suitable for Hochstetter frogs and has provided recommendations in identifying suitable Maud Island frog habitat within Orokonui Ecosanctuary.

Orokonui was found to be colder and to receive less sun than either the Waitakere Ranges or Maud Island but has similar relative humidity, water deficit and drainage levels. Substantial climatic deviations between the *L. pakeka* target site and Maud Island concern minimum temperature during the coldest month, annual solar radiation and winter solar radiation. Deviations of concern between the *L. Hochstetteri* target sites and the Waitakere Ranges include those for listed for *L. pakeka* as well as mean annual temperature.

More research is required into air temperature, stream water temperature and solar radiation levels before a complete risk assessment of native frog translocations to Orokonui can be undertaken.

**CONTENTS**

## 1. Introduction

New Zealand's native anuran fauna consists of four frog species, all belonging to the genus *Leiopelma* (Newman, 1996; Waldman et al., 2001). This is an ancient endemic group that has retained unique and primitive characteristics not found in more evolved species (Baber et al., 2006; Bell, 1994), which represents the most ancient elements of New Zealand's terrestrial vertebrate fauna (Bell, 1994), and as such is of high conservation value (Bell et al., 2004a). Fossil remains indicate that the family Leiopelmatidae was once distributed in both North America and New Zealand (Feller and Hedges, 1998) but it is now only represented by *Leiopelma* spp..

Prior to the arrival of humans, several other species of native frogs are known to have existed in New Zealand (Newman, 1996) which have since become extinct. The distributions of the four extant species; Archey's frog (*Leiopelma Archeyi),* Hochstetter's frog (*L. Hochstetteri*), Maud Island frog (*L. pakeka*) and Hamilton's frog (*L. Hamiltoni*), have been reduced during human occupation of the country (Bell, 1985). Their decline has been attributed to introduced fauna, habitat fragmentation (Waldman et al., 2001), disease (Bell et al., 2004b).

One of the management tools used in the conservation of native New Zealand frogs in the past is the translocation of individuals from a donor population to a new site currently uninhabited by frogs (Bell, 1994; Bell et al., 1998; Tocher & Pledger, 2005; Tocher et al., 2006; Lukis & Bell, 2007), in the hope that a new self-sustaining population will become established, expanding species ranges and minimising potential detrimental stochastic environmental threats. The majority of the native frog translocations undertaken to date have had measured success.

Objective 10.3 of the current native frog recovery plan (Bishop et al., in press) states that at least one new wild Maud Island frog population is to be established at a predator-free and/or predator-managed site by 2016. The recovery plan also highlights that translocation of Hochstetter frogs may be needed to secure highly threatened conservation management units (CMUs) (Bishop et al., in press).

One such predator-managed site currently under consideration for the translocation of Maud Island and Hochstetter's frogs is Orokonui Ecosanctuary, located north of Dunedin. The site is enclosed by a predator-proof fence (Otago Natural History Trust, *unpubl.*) and is intended to act as a completely pest-free ecological sanctuary or 'mainland island' into which a range of native fauna are currently being introduced/reintroduced.

According to Griffith et al. (1989) and Wolf et al. (1996), habitat quality has been one of the most important predictors of a translocation project's success. At present there are no native frogs on the South Island of New Zealand, and a successful establishment of new populations here would be a major step in native frog conservation.

The aim of this project is to assess the habitat suitability of potential target translocation sites within Orokonui Ecosanctuary for Maud Island and Hochstetter frog species.

## 1.1 Background to species

Both species are protected under the New Zealand Wildlife Act (1953) and amendments (1996, 2000, 2003).

### 1.1.1 *Maud Island frogs*

Maud Island frogs were first discovered in a c. 16 ha, isolated stand of native broadleaf coastal remnant forest (Stephenson, 1960). This area was subsequently protected and a stock-proof fence was erected along its perimeter in 1965 (Allen, *unpubl).* These frogs are completely terrestrial and do not rely on nearby water bodies for survival (Bell, 1978, 1985).

Until recently *L. pakeka* was restricted to Maud Island but three translocations have taken place since the publication of the original native frog recovery plan (Newman, 1996) and populations are now present on Long Island, Pelorus Sound; Motuara Island, Queen Charlotte Sound (Tocher and Newman, 1997); and Karori Wildlife Sanctuary, Wellington.

### 1.1.2 *Hochstetter's frogs*

This is the most widespread of the native frog species (Newman, 1996), ranging from the eastern Bay of Plenty to East Cape with scattered populations found throughout the northern section of the North Island from Mount Ranginui in the south to Waipu and Great Barrier Island in the north (Gemmell et al., 2003).

This species is semi-aquatic and is usually restricted to cool, rocky, stream habitats (Tessier et al., 1991), usually in native woodland habitat. It is generally found within 1st to 4th order streams (Najero Hillman E., *pers. comm.*).

# 2. Methods

## 2.1 Study sites

Although native frog habitat has been the subject of a reasonable amount of study (e.g. Newman et al., 1978; Cree, 1989; Thurley and Bell, 1994; Allen, *unpubl*; Germano, *unpubl*; and others), it was necessary to include study sites possessing native frog populations in the present study. This ensured that data were gathered uniformly at all locations and would be comparable across sites. Additional data from existing published and unpublished literature were also utilised (but excluded from statistical analyses). This study included sites at three different locations: see Figure 1 for general site locations (and position of transects within sites – discussed later).

Location 1: Maud Island, Pelorus Sound, South Island
Location 2: The Waitakere Ranges, Auckland, North Island
Location 3: Orokonui Ecosanctuary, Otago, South Island

### 2.1.1 *Maud Island*

Maud Island, covering c. 309 ha and reaching an altitude of 369 m asl, is situated in Pelorus Sound at the northern extreme of the South Island of New Zealand (41° 02' S, 173° 54' E). On the eastern portion of the island is an area of remnant coastal broadleaf forest covering c. 16 ha, in which occurs the original wild population of *L. pakeka*.

#### 2.1.2 *The Waitakere Ranges*

The Waitakere Ranges, situated west of Auckland, consist of a dissected plateau with an average elevation of about 340 m rising to 460 m in the highest region (Esler and Astridge, 1974). Much of this area is covered by the Waitakere Ranges Regional Park. Populations of Hochstetter's frogs have been observed within and adjacent to riparian habitat across much of the park (Green & Tessier 1990; Tessier et al., 1991; Green, 1994; Allen 2006 *unpubl.*; Najera Hillman, *pers. comm.*; and others).

#### 2.1.3 *Orokonui Ecosanctuary*

Orokonui Ecosanctuary, located at Waitati, c. 20 km north of Dunedin, encompasses an area of c. 307 ha and is situated in a north-facing valley comprised primarily of regenerating native forest (Otago Natural History Trust, 2005). Elevation across the site ranges from c. 30 m above sea level (asl) to c. 370 m asl. The area is dominated primarily by kanuka *Kunzea ericoides* with broadleaf and various shrub species (both native and introduced) also present throughout (Otago Natural History Trust, 2005).

### 2.2 General sampling design

All field work and data collection was carried out by the author between November 2008 and March 2009 inclusive. For each of the locations known to contain native frogs (i.e. Maud Island and the Waitakere Ranges) a transect approach was employed to collect habitat data, whereby two transects per location were investigated: one in an area considered to be optimal habitat and one in area considered to be suboptimal habitat. For the purposes of this study, which did not include detailed observations of frogs, areas that possessed relatively high frog densities were deemed to be representative of habitat to which frogs are best suited. i.e. areas known to possess frogs in high densities were classed as optimal and areas with known low densities were classed as suboptimal. The exact location of each transect was consequently based upon expert advice in the field.

Following an initial inspection of the remnant forest habitat on Maud Island, an area known to possess *L. pakeka* in high densities was chosen – it became apparent that a specific area c. 50 m x 25 m would encompass 'optimal' habitat whilst also ensuring that any suboptimal or unsuitable habitat would be excluded. Similarly, a nearby 'suboptimal' site was chosen and a 50 m x 25 m area identified. Consequently transects 50 m in length were laid along the centre of each area.

Within each transect 22 2 m x 2 m quadrats were assigned coordinates designated through restricted randomization (Greig-Smith, 1983), whereby the total transect area is divided into $N$ subareas ($N$ = number of sampling points) and one sample is taken from each (Bastow, 2007). This technique ensures that a valid estimate of error is obtained and, unlike random placement, that samples are independent (Bastow, 2007).

While the transect layout and design were almost identical for sites along streams in the Waitakere ranges and Orokonui Ecosanctuary, transect centrelines followed the streams in question rather than a straight line and, as Hochstetter's frogs are most often found close to stream edges (Bell, 1978; Green and Tessier, 1990), they were narrowed to a total width of 20 m - so as not to sample excessively unnecessary or unsuitable habitat. Also, due to the fact that additional riparian habitat data were collected (see section 2.4), which limited effort available for terrestrial study, the number of quadrats was reduced to 16 per transect.

The position of the mid point along each transect was recorded using a Global Positioning System (GPS) (Garmin® 60 CSx, Garmin Ltd., Kansas, U.S.A.) and are given in Table 1 (for choice of sites method within Orokonui Ecosanctuary see section 2.7). All target sites investigated fell within elevation ranges known to be inhabited by their respective target species.

**Table 1.** Locations, descriptions and stream names (where applicable) of all transects included in this study.

| Transect Number | Transect Description | Location | GPS location |
|---|---|---|---|
| 1 | Optimal *L. pakeka* habitat | Maud Island | 41°01.364' S, 173° 53.674' E |
| 2 | Suboptimal *L. pakeka* habitat | Maud Island | 41°01.350' S, 173°53.710' E |
| 3 | Optimal *L. Hochstetter* habitat | Baker Stream, Waitakere Ranges | 37°01.266' S, 174°32.283' E |
| 4 | Suboptimal *L. Hochstetteri* habitat | Unnamed stream, Waitakere Ranges | 37°01.403' S, 174°32.263' E |
| 5 | Potential *L. pakeka* target site | Orokonui Ecosanctuary | 45°46.055' S, 170°35.245' E |
| 6 | Potential *L. hochstetteri* target site 1 | Orokonui Stream, Orokonui Ecosanctuary | 45° 46.444' S, 170° 35.733' E |
| 7 | Potential *L. hochstetteri* target site 2 | Orokonui Stream, Orokonui Ecosanctuary | 45° 46.450' S, 170° 35.758' E |

## 2.3 Terrestrial habitat structure

Twelve variables were recorded within each quadrat with respect to terrestrial habitat: slope, aspect, canopy height, % canopy cover, number of woody stems above 30 cm, number of woody stems above 1 m, litter depth, tree diameter at breast height (DBH), average rock size, surface soil pH, percentage ground substrate and plant species cover. Where possible, nomenclature follows Wilson (1994), otherwise it follows Dawson and Lucas (2000) for angiosperms and Crowe (1994) for pteridophytes. The choice of variables was based primarily on factors previously correlated with frog presence (Allen, *unpubl*, 2006; Bell, 1978; Bell, *unpubl*, 1995).

Slope ($^{o}$) was measured using a slope meter placed upon a 3 m straight edge laid along the steepest gradient within the quadrat. A compass was used to ascertain aspect ($^{o}$), following the direction of the steepest gradient. Canopy height (m) was measured using a clinometer (SUUNTO PM/360PC, SUUNTO, Utah, U.S.A.).

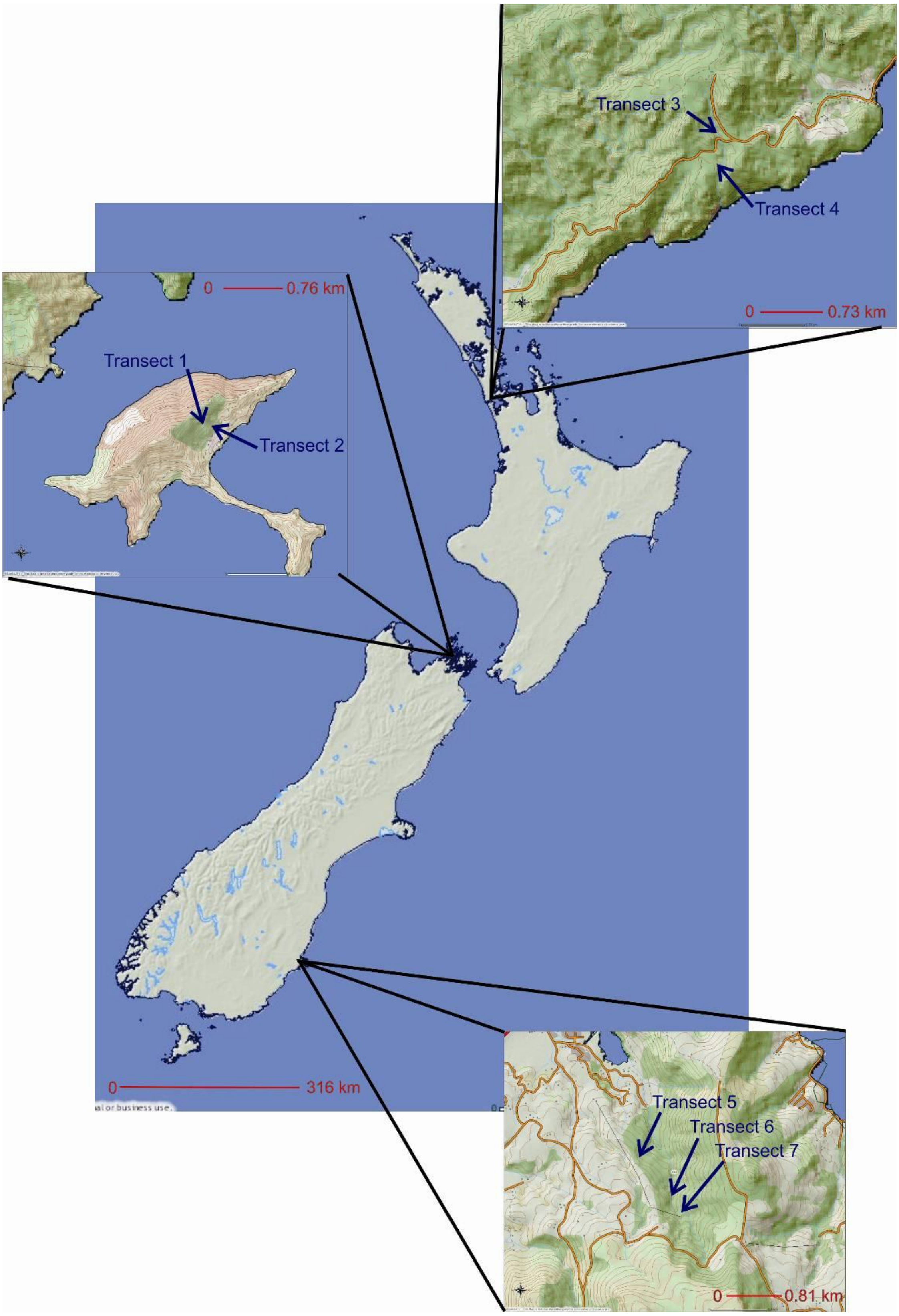


**Figure 1**. General map of locations included in this study. Also shown are approximate location of transects investigated (based on global positioning system recordings). (DoCgis Geospatial Information Platform, http://extranet.doc.govt.nz/bip/ [amended]).

Note that due to the relatively steep slopes in some areas, the height of the canopy directly above a quadrat was measured rather than tree height – tree height was often much lower. Percentage canopy cover (%) was estimated using a spherical densitometer (Model-C, Forest Densitometers, Oklahoma, U.S.A.). Estimates generated via this technique include cover formed by all vegetation above 1 m in height. Leaf litter depth (mm) was measured at 5 randomly generated points per quadrat and subsequently averaged. Where rocks were present the average rock size was approximated; rocks were divided into three size classes: small (< 30 cm diameter), medium (30 - 80 cm diameter) and large (> 80 cm diameter). pH of surface soil was measured using a portable electronic pH meter (pHep 3 Tester, Rickly Hydrological Company, OH, U.S.A.) whereby 10 g of soil was mixed with 10 ml of distilled water and a reading taken once the pH meter had stabilised (following Allen, 2006 *unpubl.*).

Percentage ground substrate was visually estimated and was divided into the following categories: rock, bare ground, ground vegetation (0 cm – 30 cm height), tiered vegetation (30 cm – 100 cm), bryophyte cover (moss), leaf litter and dead wood (twigs/logs with a diameter > 2 cm). All plants within quadrats were identified to species level and species cover was estimated visually at ground level (0 cm – 30 cm height), mid-tier level (30 cm – 100 cm) level, sub-canopy level (100 cm – canopy) and canopy level.

This approach was used to quantify terrestrial habitat at all sites included in this study.

## 2.4 Riparian habitat structure

At stream study sites 11 variables were recorded in addition to those measured for terrestrial habitat.

Water depths (mm) were recorded at 5 points per 5 m interval along each transect: centre, centre left, far left, centre right and far right.

Stream gradients (m) (height difference per 5 m stream length) were measured at 5 m intervals and bank heights (m) at every 10 m interval using a clinometer. The height of the banks above the stream water level was recorded at perpendicular distances of 1 m, 5 m and 10 m. For a greater degree of precision, bank height at 1 m from the stream edge was measured using a 1 m straight edge level and dropping a measuring tape to the water's edge.

In order to quantify stream bed substrate cover a strip transect, composed of contiguous 50 cm x 50 cm quadrats (see Plate 1, Section 7: Photographic record) was used. This was placed perpendicularly across the streams at 5 m intervals along each transect and encompassed the width of the stream to the flood water mark – as adjudged from surrounding vegetation, particularly on rocks above water but within the stream bed. Percentage substrate cover within each quadrat was visually estimated and divided into the following: mud, gravel (< 3 cm diameter), small rocks (3 – 10 cm diameter), large rocks (10 – 50 cm diameter) and boulders (> 50 cm diameter). The proportion of each variable above and below water was noted. Also recorded as percentages were leaf litter, ground vegetation and floating vegetation. For each strip transect aspect, canopy height, canopy cover, water width (cm) (width of water channel at time of study), flood width (cm) (the width of the stream from high water mark to high water mark) and water height difference (mm) (the vertical distance between the water level and the high water mark) were noted.

## 2.5 Microclimate

Microclimate measurements were taken once daily between 11 am and 2pm each day at 10 m intervals along the transect centrelines. Where possible, an additional sampling point was set up outside the forest canopy as close to the site as possible.

Relative humidity (RH) (%) was measured using a whirling hygrometer (Elcometer 116A, Elcometer Ltd., Manchester, England). Light levels ($\mu$mol $s^{-1}m^{2}$ per $\mu$A) were recorded using a quantum sensor light meter (LI-COR LI-189) - as light levels would often vary significantly over very short timescales, readings were taken every 10 seconds over a 1 minute period and then averaged. Wind speed was monitored using a wind meter (Dwyer Instruments, Inc., Michigan City, Indiana, U.S.A.).

Air temperature ($^{o}$C) was recorded at 30 minute intervals using a total of 23 temperature dataloggers (10 Hobos and 3 StowAways, Onset Computer Corporation, Pocasset MA, USA; and 10 iButtons, Maxim Integrated Products, Inc., California, U.S.A.) randomly assigned to quadrats across both transects in a given site. Where rocks or fallen logs were present, the datalogger, or at least one of the two thermistor probes available, would be placed underneath.

At stream sites daily water temperature ($^{o}$C) was monitored using a glass thermometer (Zeal, London, U.K.). Stream pH was taken in-stream using a portable pH meter.

### 2.6 Macroclimate

Geographical Information Systems (GIS) data were accessed through the University of Otago Department of Surveying. Using the New Zealand Land Cover (LENZ) database, data relating to the following variables were gathered for each of the three sites involved in the study: mean annual temperature ($^{o}$C), mean minimum temperature of the coldest month ($^{o}$C), mean annual solar radiation (MJ $m^{-2}$ per day), mean winter solar radiation (MJ $m^{-2}$ per day), annual water deficit (mm), October vapour pressure deficit (kPA) and soil drainage. Data were taken from the 25 m layer of the LENZ database.

### 2.7 Potential target release site selection

Visual survey throughout Orokonui Ecosanctuary provided the means to search for and choose a number of potential study sites. These sites were then investigated further by collecting cursory data and comparing them against data collected on Maud Island and within the Waitakere Ranges, as well as data in the existing literature, in order to assess whether variable means fell within the known ranges for the species. Two study sites along one stream running through the central valley were chosen, based on the cursory information collected, for comparison against sites known to possess Hochstetter's frogs. One study site was chosen for comparison against sites known to possess Maud Island frogs. While it may have been advantageous to select two sites or more for comparison, the paucity of habitat within Orokonui Ecosanctuary resembling that of the Maud Island forest remnant restricted this study to the one site that did seem relatively similar.

### *2.8* Analysis

The means of individual habitat structure variables were compared between relevant sites by means of Analysis of Variance (ANOVA). ANOVAs often incorporated the Games-Howell method (Games & Howell, 1976) as a number of variables were shown to have unequal variances. Tukey's B posthoc tests were performed to gain deeper insight into the precise differences between variables and sites. Alpha = 0.5 for all tests of significance in this study.

Discriminant Function Analysis (DFA) was employed to assess the differences on the composite of all variables measured. DFA is a multivariate approach to pattern recognition and interpretation, and has been used extensively in ecological investigations (Williams, 1983). Both descriptive and predictive discriminant analyses were examined. Descriptive discrimination separates groups according to linear transformations of observed variables (Williams, 1983) and is based on pre-identified groups (in this case optimal versus suboptimal habitats on Maud Island and in the Waitakere Ranges). In effect, this identifies the variables most useful in explaining the variation between sites, using a stepwise procedure (Wilk's lambda method was used in this study), and groups the samples taken within sites according to similarity. Predictive discrimination uses the produced functions to classify observations according to their probability of membership in the pre-identified groups (Rice et al., 1983). The leave-one-out classification (see Cawley and Talbot [2003] for discussion) was used to gain more reliable cross-validated results.

# 3. Results

## 3.1 Vegetation

Synopses of plant species presence and percentage cover are given in this section. For a full species list and percentage cover of each species for all study sites see Appendices. Reported are the proportions of each species as a percentage of vegetative cover present at any given tier.

### 3.1.1 *Maud Island*

A total of 18 plant species were identified across both transects studied on Maud Island. The principal canopy forming species within 'optimal habitat' were kohekohe *Dysoxylum spectabile* and mahoe *Melicytus ramiflorus*, composing 59% and 35% of canopy cover respectively. Other canopy species included tawa *Beilschmiedia tawa*, cabbage tree *Cordyline australis* and pigeonwood *Hedycara arborea*. The subcanopy vegetation was comprised of kawakawa *Macropiper excelsium* (56%), kohekohe (26%), nikau palm *Rhopalostylis sapida* (17%) and tawa (1%). Mid-tier (30 cm to 1 m in height) vegetation was dominated by nikau palm (60%) and kawakawa (20%), with supplejack *Ripogonum scandens*, inanga *Dracophyllum longifolium*, tawa and mahoe forming the remaining 20%. Ground vegetation (0 – 30 cm in height) was largely dominated by brown scale *Blechnum sp.* (54%) and nikau palm (24%).

Unlike optimal habitat, tawa was the dominant canopy species within suboptimal habitat (52%), with mahoe (23%) and kohekohe (13%) following closely behind. Kawakawa and titoki *Alectryon excelsus* comprised the remaining portion of canopy cover in approximately equal proportions. The subcanopy and mid-tier vegetation was dominated by kawakawa, with mahoe, tree fuchsia *Fuchsia excorticata* and pigeonwood also present. At ground level nikau palm accounted for c. half of the area covered by vegetation with mahoe, kawakawa, brown scale and 9 other pteridophyte and angiosperm species also recorded.

#### 3.1.2 *Waitakere Ranges*

A total of 38 plant species were identified across both transects in the Waitakere Ranges. Within 'optimal habitat' the principal canopy forming species included kanuka (37%), silver tree fern *Cyathea dealbata* (18%) and mahoe (13%) with 8 other tree species present. The subcanopy was dominated by silver tree fern (43%) and mahoe (30%) with 7 other tree species present. Mid-tier vegetation was primarily composed of nikau and thread fern *Blechnum filiforme*. Thirteen additional species were identified at this tier. The ground vegetation was also dominated by nikau and thread fern. A further 17 species were present here in minor proportions.

As with optimal habitat, the canopy within Transect 4 ('suboptimal habitat') was dominated by kanuka (28%) with C. rotundifolia following behind (26%). Nikau, kauri *Agathis australis*, hangehange *Geniostoma rupestre var. ligustrifolium*, manuka, pate *Schefflera digitata* and the rough tree fern *Dicksonia squarrose* also contributed to the canopy. The subcanopy prevalent species included *C. rotundifolia* (35%) and silver tree fern (34%), with nikau, hangehange, kanuka, celery pine *Phyllocladus trichomanoides*, soft tree fern *Cyathea smithii* and tawa also present. Inanga and hangehange dominated mid-tiered vegetation while nikau, inanga and *Melicytus macrophyllus* covered the greatest area at ground level.

### 3.1.3 *Orokonui Ecosanctuary*

#### *3.1.3.1 Potential L. pakeka target site*

A total of 25 plant species were identified within the potential Maud Island frog release site within Orokonui Ecosanctuary. The canopy was comprised primarily of mapau *Myrsine australis* (32%), broadleaf *Griselinia littoralis* (21%), kanuka and lemonwood *Pittosporum eugeniodes* (17%). The subcanopy was comprised of mahoe (30%), mapau (29%), lemonwood (14%), *C. rotundifolia* (9%) plus 7 other plant species. Ground vegetation was almost entirely composed of fern species here – hen and chickens fern *Asplenium bulberiferum*, crown fern *Blechnum discolor*, common shield fern *Polystichum richardii*, waterfall fern *Blechnum colensoi* and thirteen other pteridophyte species.

As with suboptimal habitat on Maud Island, mahoe was found at all levels within the forest structure. Wineberry was infrequent at both the Maud Island and Orokonui sites and supplejack, with its relatively thin growth form, composed only relatively small proportions of vegetation. While in Maud Island the hen and chicken fern was only located in 3 quadrats (across both transects) composing an average of 1.1% of ground cover, here it comprised an average of 41% of ground and tiered vegetation and covering an average of 8% of total quadrat ground cover.

#### *3.1.3.2 Potential L. Hochstetteri target sites*

A total of 33 plant species were identified across both Transects 6 and 7, the potential Hochstetter's frog target translocation sites within Orokonui Ecosanctuary. The canopy at Transect 6 was comprised primarily of kanuka (45%) and rimu (24%) with pepperwood *Psuedowintera colorata*, soft tree fern and manuka also providing significant coverage. At the subcanopy level it was the leather-leaf fern *Pyrrosia eleagnifolia* and the common shield fern that dominated with ten other species also present. Mid-tier vegetation consisted largely of the crown fern (40%) and bush flax *Astelia fragrans* (28%), as did ground vegetation in this area.

The canopy at Transect 7 was found to be almost monospecific in favour of kanuka (90%) with a subcanopy consisting of the leather-leaf fern and rimu and 8 other species noted. Crown fern composed 56% of the mid-tier level also contributed to the ground vegetation (32%), with bush flax (28%) and *Coprosma rhaminoides* also prevalent, as well as 13 other species.

Fifteen of the species present in the Waitakere Ranges were also represented in Orokonui. However, the canopy in Orokonui was obviously very different in species assemblage, being primarily formed by kanuka. While a number of the species did occur in similar proportions (e.g. marbleleaf and hairy fern) the differences between species proportions are more striking. For example, *Coprosma rotundifolia* occurred at all vegetative levels across both transects in proportions ranging from 0.8 % to 60 % in the Waitakere Ranges but was only found in Orokonui in the subcanopy at percentages of 1.7 % and 0.09 % (Transects 6 and 7 respectively) – similar results were found for mahoe and pigeonwood.

The fact that the primary canopy and subcanopy forming species of all the target sites are evergreens ensures that microclimate variables should continue to enjoy sheltered conditions during winter months.

## 3.2 Terrestrial Habitat structure

Comprehensive information including all means, standard errors and ANOVA results are presented in table format in the Appendices.

### 3.2.1 *Maud Island versus potential L. pakeka target site*

Following a one-way ANOVA only 5 of the 17 variables measured differed significantly between the target site and optimal Maud Island habitat. Furthermore, only 3 of these 5 variables possessed significantly different means from both optimal and suboptimal habitats: % canopy cover, % leaf litter and % bryophyte cover. Figure 2 shows that while the significant difference in % leaf litter is apparently justified, the mean of the target site falls neatly between that of the optimal and suboptimal habitat. Mean percentage bryophyte cover, on the other hand, falls outside of the 95 % confidence intervals for either of the Maud Island habitats, as does % canopy cover (Figure 3).

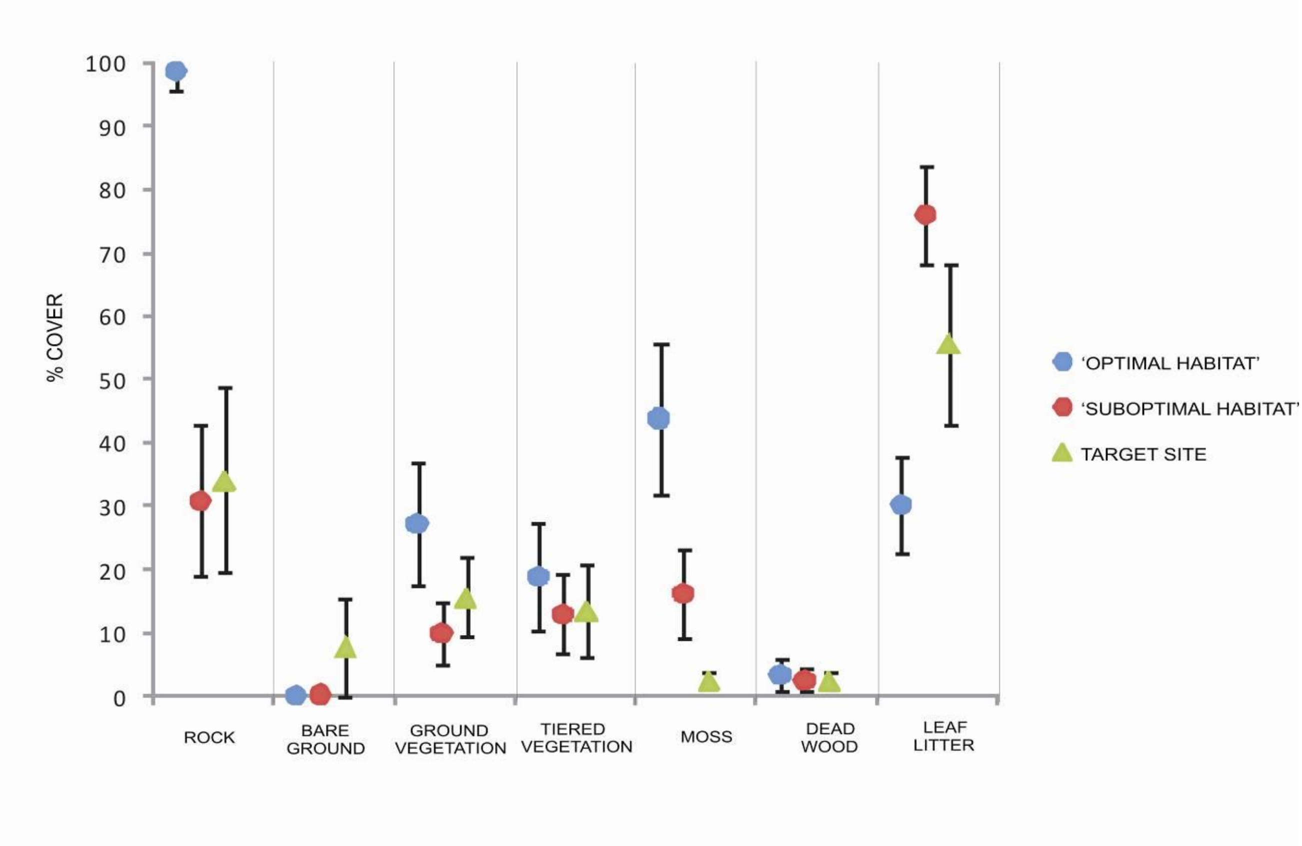


**Figure 2**. Means and 95 % confidence intervals of ground substrate variables (%) in 'optimal habitat', 'suboptimal habitat' and the Orokonui target site for *L. pakeka*.

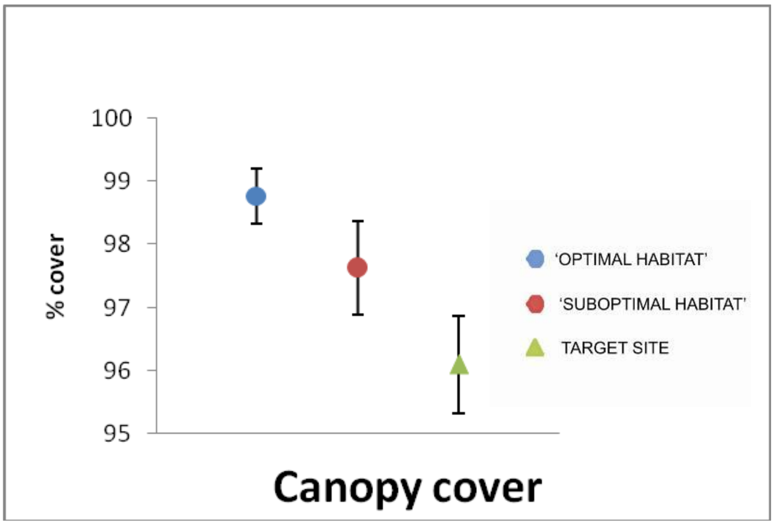


**Figure 3**. Means and 95 % confidence intervals for percentage canopy cover in 'optimal habitat', 'suboptimal habitat' and the Oroknoui target site for *L. pakeka*.

DFA identified rock cover, ground vegetation cover and canopy height as being the most useful predictors in distinguishing between sites ($p < 0.0001$ for all). Based on this, DFA classified 95.5 % of quadrats into their correct groupings (optimal or suboptimal habitat). Of the 22 quadrats sampled in Orokonui, only 4 (18.2 %) were classified as being more similar to optimal than to sub-optimal habitat. The relationships between all the sampled quadrats distinctly divided them into their respective transects (Figure 4) and, moreover, transects were well separated from each other. This indicates that the target *L. pakeka* site is substantially different to either optimal or suboptimal habitat as to be successfully classified into its own unique grouping for the majority of samples taken.

Due to the fact that rock cover was an obvious factor in the function analysis, but may possibly be a variable that could be altered in the real world via habitat enhancement, the analysis was re-run excluding rock cover from the list of variables. In this case DFA assigned 9 (40.9%) quadrats from Orokonui as being more similar to optimal habitat than to suboptimal habitat. However, it did not alter the degree of separation between transects.

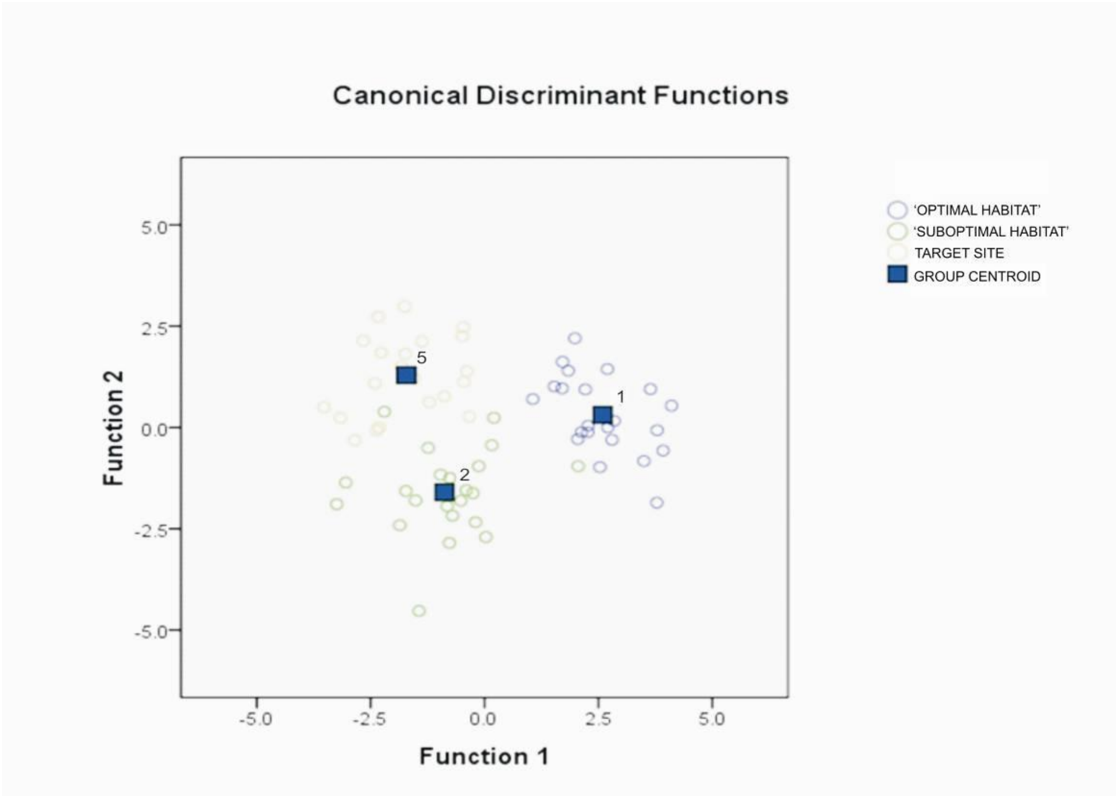


**Figure 4**. The canonical discriminant functions resulting from DFA showing the relationships between individual quadrats from 'optimal habitat', 'suboptimal habitat' and the Orokonui target site for *L. pakeka*.

### 3.2.2 *Waitakere Ranges sites versus potential L. Hochstetteri target sites*

Somewhat surprisingly, one-way ANOVAs confirmed that none of the means of the variables measured in the Waitakere Ranges Hochstetter frog optimal habitat differed significantly from either of the potential target translocation sites studied at Orokonui. The high proportion of ground covered by leaf litter at all sites is highlighted in Figure 5. While not statistically significantly different at the 0.05 level, the mean mid-tier vegetation cover was higher for both of the Orokonui sites in comparison to the Waitakere Ranges sites, and there appears to be relatively little overlap between the 95 % confidence intervals between the two different locations. There was little difference observed between the 'optimal' and 'suboptimal' sites suggesting that the general forest structure across both sites was suitable for frogs and that it is the stream characteristics that are affecting the presence of frogs here (see next section). According to DFA canopy cover and surface pH were found to be the most important predictors separating the groups analysed. DFA classified 81.3 % of sampled quadrats correctly. On the whole the target sites are grouped closely with the optimal

Hochstetter habitat and further from suboptimal habitat (Figure 6). This argument is strengthened by the fact that 75 % of quadrats in both of the target sites were classed as belonging to optimal rather than suboptimal habitat. From a terrestrial habitat point of view these results are encouraging and strongly indicate that the target sites in Orokonui are very similar in structure to optimal habitat.

## 3.3 Riparian habitat

### 3.3.1 *Stream bed substrate cover*

A one-way ANOVA confirmed while Transect 6 in Orokonui differed from suboptimal habitat across a wide range of variables, it significantly differed from optimal habitat with respect to only 2 variables: % boulders above water and % leaf litter below water. The only mean of any of the variables in Transect 6 that differed for BOTH optimal and suboptimal habitat was % boulders above water. Transect 7 differed from optimal Hochstetter habitat for 4 variables, and from optimal AND suboptimal habitat for 3 variables. However, 2 of these fit neatly between the overall ranges observed in the Waitkere Ranges – see % small rocks cover and % gravel cover in Figure 7.

DFA classified 96.4% of sampled quadrats correctly. 88% (66/75) and 90% of sampled quadrats from target sites (Transect 6 and 7 respectively) were classified as belonging to the optimal habitat category. Figure 8 shows a distinct separation of suboptimal habitat from either optimal habitat or from the potential translocation sites. The dense clustering of target sites along with optimal habitat, coupled with their joint distance from suboptimal habitat is encouraging. The proportions of mud below water, mud above water and ground vegetation were found by stepwise analysis to be the most useful predictors of group classification.

These results are strongly indicative that the potential target translocation sites would be suitable for Hochstetter frogs with respect to the riparian structural habitat. Of the two target sites, Transect 7 is likely to be slightly better suited to the ecological needs of the species.

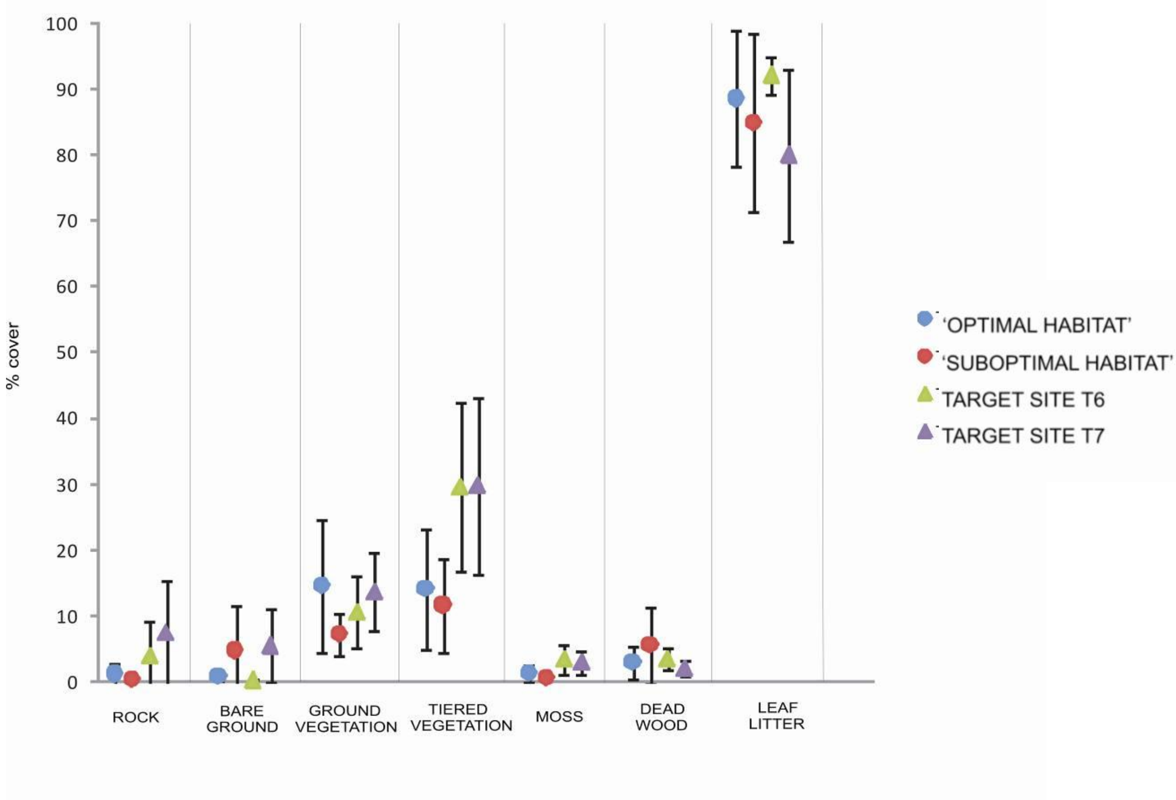


**Figure 5**. Means and 95 % confidence intervals for ground substrate variables (%) in 'optimal habitat', 'suboptimal habitat' and the target sites (T6 and T7) for *L. Hochstetteri*.

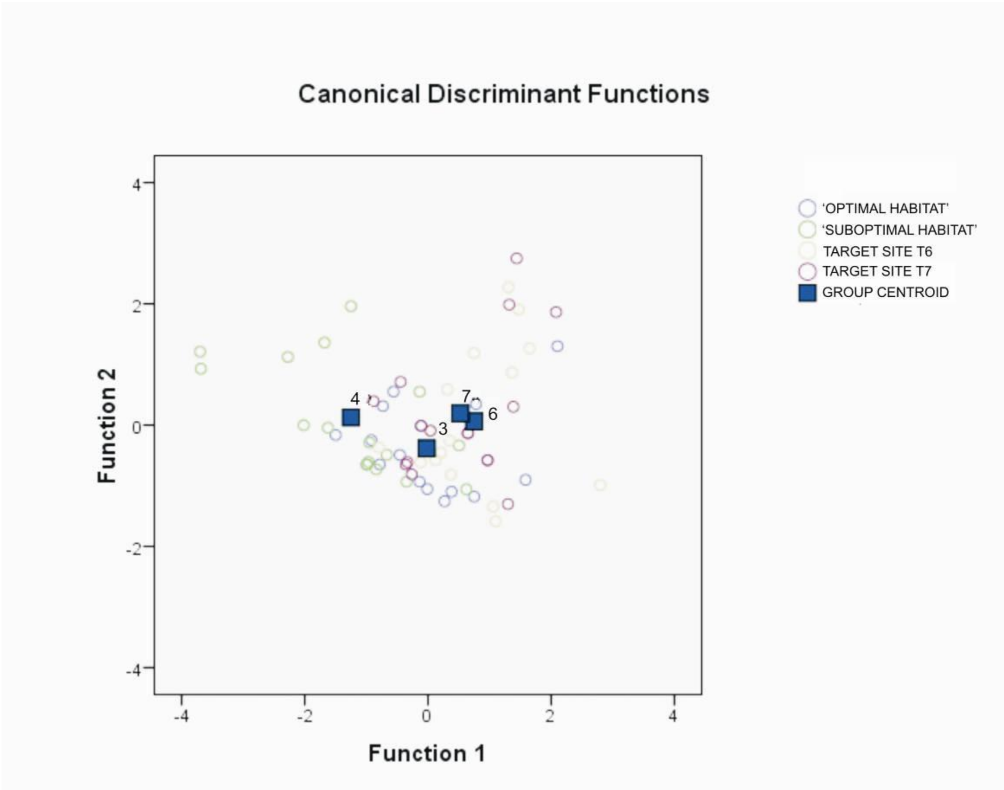


**Figure 6**. The canonical discriminant functions resulting from DFA showing the relationship between 'optimal habitat', 'suboptimal habitat' and the target sites (T6 and T7) for *L. Hochstetteri*.

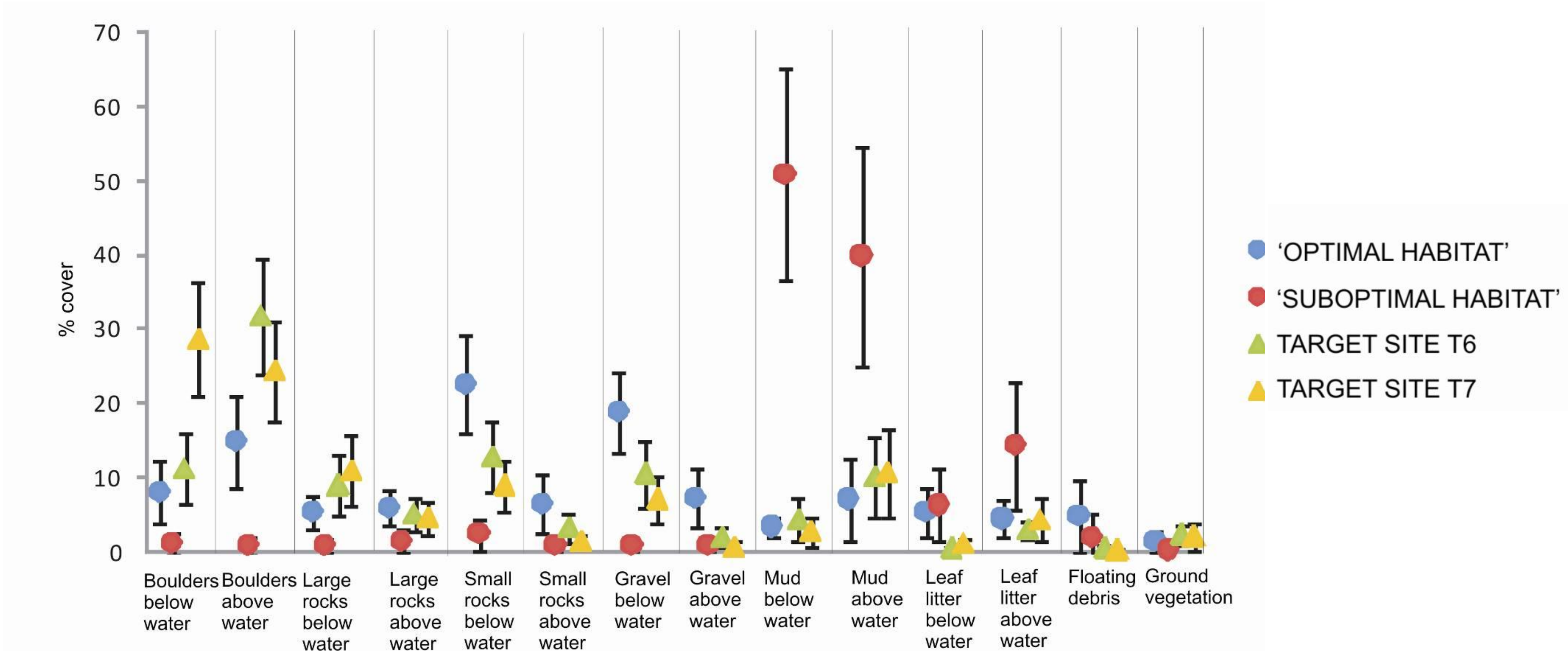


**Figure 7**. Means and 95 % confidence intervals for stream bed substrates in 'optimal', 'suboptimal' and Orokonui target sites (T6 and T7) for *L. Hochstetteri*.

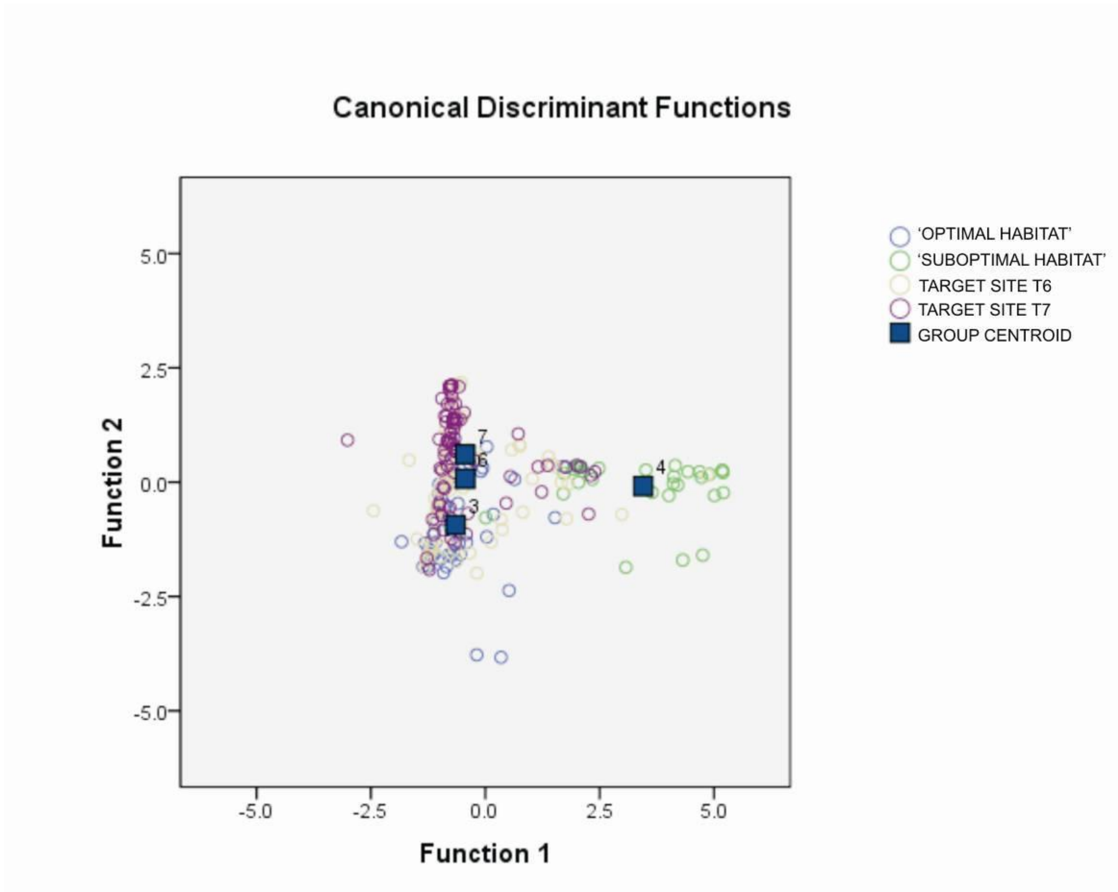


**Figure 8**. The canonical discriminant functions resulting from DFA of stream bed substrate cover proportions showing the relationship between optimal habitat, suboptimal habitat and the Orokonui target sites (T6 and T7).

### 3.3.2 *Other stream variables*

A number of other variables were measured at 5 m, and 10 m intervals along the transects and as such could not be included in the above DFA due to the different scale at which they were sampled. Homoscedasticity was confirmed via the Levene statistic for all variables. For the majority of the 15 variables no significant difference was observed between any of the 4 transects. Only aspect, water width and exposed substrate width (flood width – water width) showed significantly different means. A breakdown of individual variables means according to transect, associated standard errors and ANOVA results are given in Appendix.

Only Transect 6 differed from both optimal and suboptimal habitat with respect to stream width. Transect 7 did not. Both potential target translocation sites had significantly higher mean water widths. However, Hochstetter frogs are known to inhabit streams several metres wide (Green and Tessier, 1990) so this is not viewed as a negative result.

While the streams surveyed in the Waitakere Ranges had aspects ranging from northeast ($4^o$) to southeast directions ($165^o$) (facing downstream), the sites in Orokonui faced southwest ($230^o$) to northwest ($308^o$). This was a necessary compromise when choosing the potential target sites as Orokonui is situated in a valley primarily facing in a northwesterly direction. All streams included in this study were 1st order streams.

Overall both target sites appear to be very structurally similar to optimal *L. hochstetteri* habitat, with perhaps Transect 7 being more suitable than Transect 6, but only narrowly so.

### 3.4 Microclimate

Due to the fact that microclimate measurements could not be taken at different study locations simultaneously, the results of this section are not strictly statistically comparable between sites. However, they do provide a snapshot of microclimate at each site. Unfortunately due to the distance from the edge of the canopy to the *L. Hochstetteri* potential target sites it was not possible to take measurements outside the canopy within a time period short enough to be considered simultaneous.

The relative humidity at all sites was reasonably high under the canopy (Table 2). The average % difference in RH between samples under the canopy and those outside the canopy appears to be higher in the potential *L. pakeka* target site than for both the Maud island sites. Most likely, this would be of benefit rather than detriment to frogs. High relative humidity is important to frogs as it prevents evaporative stress through desiccation via water evaporation (Pough et al., 2001). It also appears that the Maud Island sites allowed more light through the canopy than the *L. pakeka* target site. Mean air temperatures above ground were consistently higher than those below ground across all sites. Air temperatures were lower in Orokonui but this is undoubtedly affected by the different sampling period. Stream water temperatures can vary seasonally and, although the Waitakere Ranges streams and Orokonui Stream were measured during different seasons, the difference in temperatures between the

Hochstetter habitat streams and the potential target sites appear to be substantial. Temporal changes in biological activity can result in seasonal variations in surface water acidity (Fitzhugh et al., 1999) but this would not be likely to strongly affect small ground-fed, canopy-covered streams such as Orokonui Stream and this suggests that the acidity of Orokonui Stream is likely to similar to those in the Waitakere Ranges all year round.

It should be noted that while wind speeds of up to 5 knots were noted outside the Maud Island canopy no detectable wind was observed within the canopy – this was similar for the Waitakere Ranges sites with wind speeds of up to 4 knots. The most striking difference was at the Orokonui *L. pakeka* target site where, although wind speed was not strong enough to be detected by the wind meter under the canopy it reached speeds of 14 knots immediately outside the canopy during the same time period. Although it was not possible to directly compare wind speeds at the *L. hochstetteri* target sites with those outside the canopy, no wind was observed under the canopy during the entire study period, including on days known to have had relatively strong winds outside of the canopy. All the sites studied appear to provide substantial shelter.

## 3.5 Macroclimate

All classifications of mean values into categories are based on the LENZ Technical Guide (Leathwick et al., 2003). Over the period covered by LENZ mean minimum temperature of the coldest month, the mean annual temperature, mean annual solar radiation and mean winter solar radiation were all higher in both the Waitakere Ranges and on Maud Island than they were for Orokonui (Table 3). Also, the mean annual RH was higher in the sites known to possess frogs than for either target sites, although all sites are classed as 'Moderate'. Soil drainage was given as 'well-drained' for Maud Island and moderately to well-drained for all other sites.

On the whole, the only deviations of particular concern between the *L. pakeka* target site and Maud Island are with respect to the minimum temperature during the coldest month, annual solar radiation and winter solar radiation, with the other variables all falling into the same categories for each site.

Deviations of concern between the *L. Hochstetteri* target sites and the Waitakere Ranges include those for listed for *L. pakeka* above as well as mean annual temperature.

In general, Orokonui is colder and receives less sun than either the Waitakere Ranges or Maud Island but has similar RH, water deficit and drainage

**Table 2**. Microclimate data recorded between 12:00 and 15:00 each day at all study sites. Means and standard deviations (SD) are presented. RH = relative humidity. RH difference = % positive difference in RH compared to outside canopy.

| Transect | Air T (°C) | SD | Under object T (°C) | SD | Light level (μmol $s^{-1}$ $m^{-2}$) | SD | Light reaching forest floor (%) | RH (%) | SD | RH Difference (%) | Water T (°C) | SD | Water pH | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 16.08 | 1.44 | 13.98 | 0.712 | 13.27 | 27.1 | 1 | 84.19 | 8.61 | 9.5 | NA | NA | NA | NA |
| 2 | 16.25 | 1.15 | 13.98 | 0.758 | 14.99 | 41.45 | 1 | 84.36 | 8.91 | 9.7 | NA | NA | NA | NA |
| 3 | 16.06 | 1.322 | 15.42 | 2.116 | 41.72 | 98.26 | 2.5 | 85.1 | 7.38 | 10.3 | 15.13 | 0.56 | 6.57 | 0.87 |
| 4 | 16.34 | 1.57 | 15.6 | 1.56 | 25.19 | 41.36 | 1.5 | 85.44 | 8.06 | 10.8 | 15.25 | 0.57 | 6.65 | 0.14 |
| 5 | 10.29 | 2.346 | 10.2 | 1.681 | 3.59 | 5.58 | 0.5 | 88.17 | 5.29 | 19.1 | NA | NA | NA | NA |
| 6 | 11.87 | 1.271 | 10.95 | 1.105 | 13.68 | 5.01 | NA | 98.5 | 2.65 | NA | 10.5 | 0.51 | 6.73 | 0.38 |
| 7 | 10.79 | 1.313 | 10.637 | 1.001 | 12.9 | 8.71 | NA | 98.5 | 2.65 | NA | 10.5 | 0.51 | 6.68 | 0.38 |

**Table 3**. Means and categorical classifications of macroclimate variables examined using the Land Environment New Zealand database for sites included in present study.

| Site | Minimum June T (°C) | Annual T (°C) | Annual solar radiation ($MJ/m^2/day$) | Annual RH (%) | Annual water deficit (mm) | Winter solar radiation ($MJ/m^2/day$) |
|---|---|---|---|---|---|---|
| Maud Island | 5 | 11.7<br>Mild | 14.7<br>High | 67<br>Moderate | 0<br>Nil | 4.6 |
| Waitakere ranges | 5.3 | 13.4<br>Warm | 15.1<br>High | 69<br>Moderate | 34<br>Low | 5.8 |
| Orokonui *L.pakeka site* | 2.6 | 10<br>Mild | 12.4<br>Low | 60<br>Moderate | 41<br>Low | 3.8 |
| Orokonui *L. hochstetteri sites* | 2.5 | 9.8<br>Mild | 12.4<br>Low | 61<br>Moderate | 20<br>Low | 3.8 |

## 4. Discussion

### 4.1 Habitat structure

The vegetation of all the sites studied, while differing in species assemblage, was found to be primarily of indigenous forest species. Most New Zealand native frog populations are found in this habitat type, although at some locations native frogs have been observed in areas of exotic plantation forestry (Crossland et al., 2005). *L. pakeka* has even been observed in open grassland habitat adjacent to its forest remnant stronghold (Bell, 1995, *unpubl*; *pers. obs.*), but this is likely due to competition resulting from the thriving but resource-limited population here. The only apparent difference in vegetation structure is the almost ubiquitous presence and dominance of kanuka within Orokonui Ecosanctuary. However, as this is an evergreen species there is no especial known reason why this would affect frogs translocated to the sanctuary and overall the vegetation appears suitable for either frog species under consideration.

The results of the comparison between the *L. pakeka* target site and Maud Island terrestrial habitat are not clear. Initial inspection deems only canopy cover and moss cover be to significantly different and fall outside the ranges of both Maud Island habitats studied. A habitat model for *L. pakeka* (Allen, *unpubl.*) estimates canopy cover to have a mean of 92.8 % (SE = 0.87) - the target site exceeds this – and moss cover may not be a component of the habitat affecting frog survival. This leads one to believe that the habitat may be suitable for frogs, particularly given that with rock removed from the DFA 40 % of quadrats appear to resemble optimal habitat.

Nevertheless, the resulting statistical distance of the target site from either of the Maud Island habitats is unsettling. It may be a question of homogeneity: 1) Not all variables measured possessed homogenous ranges among samples, a necessary assumption of DFA (Williams, 1983) – this may have given unreliable results; 2) The habitat within the transect was not homogenous – note was made of this during field study. Of the total transect area (1250 $m^2$), a specific block (situated in the southeast of the transect) c. 200 $m^2$ visually resembled optimal *L. pakeka* habitat, with the remaining transect appearing more similar to suboptimal habitat. This may have led to the separated grouping resulting from the DFA due to the high variance between samples, as in effect 2 different habitats were being sampled. Ideally, sampling should aim to obtain the minimum variance (Kenkel et al., 1989) and this was not the case here.

The comparison between the Waitakere Ranges and Orokonui *L. hochstetteri* sites is much more clearly cut than that for *L. pakeka*. Terrestrial and riparian habitat structures in both potential target sites were shown by ANOVAs and DFA to resemble optimal Hochstetter habitat, and while minor differences in stream bed substrate cover were observed, these would not be expected to negatively impact a translocated population. Also, Orokonui stream was noted to contain an abundance of freshwater crayfish which have been shown to be negatively correlated with suspended solid concentrations and current velocity and most studies associate crayfish with sheltered sites (Usio and Townsend, 2000). These are characteristics also favoured by Hochstetter's frogs (Green and Tessier, 1990).

As frog populations often have high densities per unit area - *L. hochstetteri*: up to 59.8 frogs per 100 m stream lengths (Baber et al., 2006); *L. pakeka*: 220 per 100 $m^2$ (Tocher et al., 2006), any suitable stream sections on the scale of a few hundred meters long (in the case of Hochstetter frogs) or any suitable terrestrial habitat c. 50 x 50 m (in the case of Maud island frogs) would likely be substantial for a translocated population.

In conclusion, the sites investigated along Orokonui Stream are likely to be suitable for target translocation sites for *L. Hochstetteri*, with regard to habitat structure – both terrestrial and riparian.

### 4.2 Climate

All sites in this study had relatively high RH levels at a microclimate scale, even within the dry periods that occurred during the survey period. As wind can affect RH it is also encouraging that the target translocation sites appear to be in very sheltered situations. RH, annual water deficit and drainage within Orokonui Ecosanctuary appear to be suitable for native frog species.

The primary lack of information resisting the commencement of a translocation of native frogs to Orokonui lies with annual mean temperature, minimum mean temperature of the coldest month and annual solar radiation. While lower mean air temperatures are expected in Orokonui due to its latitudinal position, the question remains as to whether native frogs can survive these temperatures.

Subfossil distributions of *L. Hochstetteri* and *L. Hamiltoni* show that until the late Holocene these species ranged from Punakaiki, on the west coast of the South Island, to Waitomo in the North Island (Newman, 1996). No subfossil material has been positively identified *L. pakeka*, but there is no method for distinguishing between the skeletons of Hamilton's frog and the Maud Island frog (Newman, 1996) and these have similar habitat requirements and may even be the same species (Holyoake et al., 2001). So although the mean annual temperatures for Orokonui were below those for either Maud Island or the Wiatakere Ranges, fossil ranges of the *L. pakeka* and *L. Hochstetteri* include areas where present day mean annual temperatures are 10.6 – 10.8 $^{o}$C (based on LENZ database) (Allen, *unpubl.*) – similar to those of Orokonui. In the past 1,000 years New Zealand's temperatures have fluctuated ± 2 $^{o}$C, with a 0.5 $^{o}$C increase in the past one hundred years (Salinger, 1991). This may be evidence that these species could withstand the colder temperatures in Orokonui. In the same vein, fossil distributions include areas that receive 13 - 14 MJ/m$^2$/day mean annual solar radiation (Allen, *unpubl.*), lower than sites within their current range. This is still higher than that of Orokonui, but does suggest these species can tolerate lower radiation levels than those found within their current range. Correlations between UV-B increase and amphibian declines in Central America have been identified (Middleton et al., 2001) but there is also some evidence that frogs may require certain levels of solar radiation to aid their immune response. Fossil sites also have low annual water deficits, like those in Orokonui.

Although Orokonui Stream may be colder than either of the Hochstetter frog habitats included in this study, the species is known to inhabit, and may even prefer, cold streams (Najero-Hillman E., *pers.comm.*). The temperature of Orokonui stream, although cold for the summer period during which it was recorded, would not be expected to vary greatly as it is fed directly by a spring, which is located near to the study sites.

While many aspects of the climate within the Orokonui site seem suitable for native frogs, more data are required regarding air temperature, water temperature and solar radiation to ensure these variables will not negatively affect frog survival were a translocation(s) to proceed.

### 4.3 Other considerations

It must be stressed that this report considers habitat structure and climate solely. No consideration is given here to the host of other factors which need to be carefully considered prior to carrying out a species translocation such as predator-prey interactions, disease etc.

## 5. Recommendations

- Extensive data should be gathered on the range of solar radiation, air and stream temperatures in areas known to be currently inhabited by Hochstetter's frogs. This could include the use of the LENZ database but should also incorporate weather station and field data, such as that currently being compiled by Eduardo Najero Hillman (AUT).
- Data should be gathered for fossil sites of *L. pakeka* and *L. hochstetteri* pertaining to minimum mean temperatures during the coldest month and winter solar radiation – these were not available in the existing literature.
- Extensive data on the temperatures within Orokonui Ecosanctuary should be gathered for comparison to results from the above recommendations. These should be based on weather station and field data. Temperature data collected at Orokonui such as that collected by the Zoology Department, University of Otago, in relation to tuatara may also be useful here.
- The temperature fluctuations of Orokonui stream should be monitored over a period of 1 or more years so as to be compared to results from the above recommendations.
- It may be possible to alter the structural habitat analyses by using hypothetical spreads of data in order to examine where the primary differences between the

target site and optimal *L. pakeka* habitat lie. This might include replacing observed rock cover percentages with those closer to 'optimal' to investigate whether the resulting hypothetical habitat becomes more closely grouped with optimal habitat. Successful analyses may be the key to understanding the difference between the sites investigated and may provide suitable recommendations for habitat enhancement of the area identified in this study.

- While much of Orokonui Ecosanctuary was searched for potential *L. pakeka* translocation sites, it was not possible to cover the entire sanctuary within the timeframe provided, and survey was largely restricted to the portion of the site where elevation and aspect values fell within the known range for this species (primarily the western side of the main Orokonui Stream Valley). Other sites may exist on the eastern side of the valley which could be suitable for this species and further search would be advantageous.

## 6. Conclusions

This study has identified sites along Orokonui stream that possess habitat structurally suitable for Hochstetter frogs and has provided recommendations in identifying suitable Maud Island frog habitat within Orokonui Ecosanctuary. It has also indicated that while a number of climatic variables appear suitable for either species, more research is required into air temperature, stream water temperature and solar radiation levels before a complete risk assessment of native frog translocations to Orokonui can be undertaken.

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# 9. Appendices

## 9.1 Maud Island vegetation

Plant species present and percentage cover of each species at each tier within Maud Island Transects.

| | OPTIMAL HABITAT | | | | SUBOPTIMAL HABITAT | | | |
|---|---|---|---|---|---|---|---|---|
| **SCIENTIFIC NAME** | **%GROUND VEG** | **%TIERED VEG** | **%UPPER VEG** | **% CANOPY VEG** | **%GROUND VEG** | **%TIERED VEG** | **%UPPER VEG** | **% CANOPY VEG** |
| *Alectryon excelsus* | 0.0038 | | | | 0.0853 | | | 0.0558 |
| *Aristotelia serrata* | 0.0019 | | | | 0.0190 | | | |
| *Ascarina lucida* | | | | | 0.0142 | | | |
| *Asplenium bulberiferum* | 0.0019 | | | | 0.0095 | | | |
| *Asplenium obtusatum* | 0.0094 | | | | 0.0047 | | | |
| *Beilschmiedia tawa* | | 0.0339 | 0.0120 | 0.0364 | | | | 0.5186 |
| *Blechnum nigrum* | 0.0188 | | | | 0.0379 | | | |
| *Blechnum sp.* | 0.5386 | | | | 0.0616 | | | |
| *Cordyline australis* | | | | 0.0227 | | | | |
| *Dracophyllum longifolium* | 0.0094 | 0.0508 | | | | | | |
| *Dysoxylum spectabile* | | | 0.2638 | 0.5864 | 0.0047 | 0.0144 | | 0.1279 |
| *Fuchsia excorticata* | | | | | | | 0.0414 | |
| *Hedycara arborea* | 0.0377 | | | 0.0005 | 0.0047 | | 0.0193 | |
| *Macropiper excelsium* | 0.0188 | 0.2000 | 0.5564 | | 0.1327 | 0.5891 | 0.8703 | 0.0698 |
| *Melicytus ramiflorus* | | 0.0407 | | 0.3541 | 0.1327 | 0.2902 | 0.0690 | 0.2279 |
| *Phymatosorus diversifolius* | 0.1186 | | | | | | | |
| *Rhopalostylis sapida* | 0.2392 | 0.6034 | 0.1679 | | 0.4929 | 0.1063 | | |
| *Ripogonum scandens* | 0.0019 | 0.0712 | | | | | | |

## 9.2 Orokonui vegetation

Plant species present and percentage cover of each species at each tier within Orokonui Transects.

| SCIENTIFIC NAME | ***L. Hochstetteri* TARGET SITE T6** | | | | ***L. Hochstetteri* TARGET SITE T7** | | | | ***L. pakeka* TARGET SITE** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **%GROUND VEG** | **%TIERED VEG** | **%UPPER VEG** | **% CANOPY VEG** | **%GROUND VEG** | **%TIERED VEG** | **%UPPER VEG** | **% CANOPY VEG** | **%GROUND VEG** | **%TIERED VEG** | **%UPPER VEG** | **% CANOPY VEG** |
| *Adiantum aethiopicum* | | | | | | | | | 0.0056 | | | |
| *Archeria traversii* | | | | | | 0.0024 | | | | | | |
| *Aristotelia fruticosa* | | | | | | | 0.0019 | | | | | |
| *Aristotelia serrata* | | | | | | | | | 0.0028 | | | |
| *Asplenium bulberiferum* | 0.1204 | 0.0425 | | | 0.0383 | 0.0024 | 0.0039 | | 0.5621 | 0.2576 | | |
| *Asplenium terrestre* | | | | | | | | | 0.0085 | | | |
| *Astelia fragrans* | 0.2042 | 0.2781 | | | 0.2775 | 0.0612 | | | 0.0311 | 0.2068 | | |
| *Blechnum colensoi* | | | | | | | | | 0.0819 | 0.0508 | | |
| *Blechnum discolor* | 0.3455 | 0.4013 | | | 0.3158 | 0.5576 | | | 0.1102 | 0.1356 | | |
| *Blechnum filiforme* | | | | | | | 0.0097 | | | | | |
| *Blechnum procerum* | | | | | | | | | 0.0028 | | | |
| *Blechnum sp.* | 0.0628 | | | | 0.0287 | | | | | | | |
| *Carpodetus serratus* | | | | | | 0.0047 | | 0.0133 | | | 0.0266 | 0.0093 |
| *Coprosma colensoi* | | | 0.0468 | | | | 0.0951 | | | | 0.0681 | 0.0465 |
| *Coprosma linariifolia* | | | | | | | | | | | 0.0032 | 0.0009 |
| *Coprosma rhaminoides* | | | | | 0.1244 | 0.0635 | | | | | | |
| *Coprosma rotundifolia* | | | 0.0173 | | | | 0.0097 | | 0.0113 | 0.0712 | 0.0915 | |
| *Cordyline australis* | | | 0.1179 | | | | | | | | | |
| *Cyathea smithii* | 0.1204 | 0.1401 | | 0.0803 | 0.0383 | 0.2635 | | | | | | |
| *Dacrydium cupressinum* | | | 0.0173 | 0.2409 | | | 0.2777 | | | | | |
| *Dicksonia squarrosa* | | 0.0637 | | | | | | | | | | |
| *Dracophyllum longifolium* | | | 0.0867 | | | | 0.0388 | | | | | |
| *Griselinia littoralis* | | | | 0.0146 | 0.0096 | 0.0141 | | | | 0.0847 | 0.0519 | 0.2138 |
| *Hedycara arborea* | | | 0.0087 | | | | 0.0194 | | | | | |
| *Kunzea ericoides* | | | | 0.4526 | 0.0239 | | | 0.9067 | | | 0.0065 | 0.2045 |
| *Lastreopsis hispida* | | | 0.0520 | | | | | | | | | |
| *Leptopteris hymenophylloides* | 0.0576 | 0.0318 | | | 0.0096 | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Leptospermum scoparium* | | | | 0.0730 | | | | | | | | |
| *Melicytus ramiflorus* | | | | 0.0365 | 0.0048 | | | 0.0133 | | 0.0203 | 0.2998 | 0.0418 |
| *Myrsine australis* | | | 0.0572 | | | | 0.0350 | | 0.0198 | 0.1458 | 0.2927 | 0.3160 |
| *Pellaea rotundifolia* | | | | | | | | | 0.0198 | | | |
| *Phymatosorus diversifolius* | 0.0419 | | | | 0.0096 | | | | | | | |
| *Pittosporum eugeniodes* | | | | | 0.0048 | 0.0071 | | 0.0667 | | | 0.1395 | 0.1673 |
| *Polystichum richardii* | | | 0.2652 | | | | 0.1515 | | 0.1045 | 0.0271 | | |
| *Pseudopanax crassifolius* | 0.0052 | | | | 0.0048 | 0.0071 | | | 0.0169 | | | |
| *Psuedowintera colorata* | 0.0366 | 0.0425 | 0.0017 | 0.1022 | 0.0431 | 0.0047 | 0.0078 | | | | 0.0065 | |
| *Pyrrosia eleagnifolia* | | | 0.3154 | | | | 0.3359 | | 0.0028 | | | |
| *Ripogonum scandens* | | | | | | | | | 0.0028 | | 0.0013 | |
| *Rubus australis* | | | 0.0121 | | | | | | 0.0028 | | 0.0123 | |
| *Schefflera digitata* | 0.0052 | | | | 0.0048 | | | | 0.0141 | | | |
| *Ulex europaeus* | | | 0.0017 | | 0.0622 | 0.0118 | 0.0136 | | | | | |

## 9.3 Waitakere Ranges vegetation

Plant species present and percentage cover of each species at each tier within Waitakere Ranges Transects.

| | OPTIMAL HABITAT | | | | SUBOPTIMAL HABITAT | | | |
|---|---|---|---|---|---|---|---|---|
| SCIENTIFIC NAME | %GROUND VEG | %TIERED VEG | %UPPER VEG | % CANOPY VEG | %GROUND VEG | %TIERED VEG | %UPPER VEG | % CANOPY VEG |
| *Agathis australis* | | | | | 0.0259 | | | 0.0738 |
| *Aristotelia fruticosa* | | | | | 0.0172 | | | |
| *Beilschmiedia tawa* | | | | | | | 0.0313 | |
| *Blechnum filiforme* | 0.1699 | 0.2344 | | | | | | |
| *Blechnum fraseri* | 0.0039 | | | | | | | |
| *Blechnum penna-marina* | 0.0039 | | | | | | | |
| *Blechnum sp.* | | 0.0469 | | | 0.0172 | | | |
| *Carex gaudichaudiana* | | | | | 0.0172 | | | |
| *Carpodetus serratus* | 0.0039 | | | | 0.0345 | 0.0157 | | |
| *Coprosma foetidissima* | | | | | 0.0431 | | | |
| *Coprosma macrocarpa* | 0.0193 | 0.1172 | 0.1568 | | 0.0086 | | | |
| *Coprosma rotundifolia* | 0.0154 | 0.0078 | 0.0165 | 0.0596 | 0.0172 | 0.0105 | 0.3448 | 0.2583 |
| *Cordyline australis* | | | | 0.0066 | | | | |
| *Cyathea cunninghamii* | 0.0039 | 0.1016 | 0.0198 | | | | | |
| *Cyathea dealbata* | | 0.0781 | 0.4274 | 0.1755 | 0.0862 | 0.1780 | 0.3396 | |
| *Cyathea smithii* | | | | | 0.0086 | 0.0052 | 0.0522 | |
| *Dacrydium cupressinum* | | | | 0.0662 | | | | |
| *Dicksonia squarrosa* | | 0.0156 | | | | | | 0.0295 |
| *Dracophyllum longifolium* | 0.0232 | 0.0625 | | | 0.1552 | 0.3089 | | |
| *Dysoxylum spectabile* | 0.0077 | 0.0117 | | 0.0331 | | | | |
| *Elatostema rugosum* | 0.0193 | | | | | | | |
| *Geniostoma rupestre var. ligustrifolium* | | | | | 0.0690 | 0.2827 | 0.0993 | 0.0738 |
| *Hedycara arborea* | 0.0463 | 0.0273 | 0.0083 | 0.0199 | 0.0259 | | | |
| *Histiopteris incisa* | 0.0039 | | | | | | | |
| *Hoheria populnea var. populnea* | 0.0270 | | 0.0330 | 0.0033 | | | | |
| *Knightia excelsa* | 0.0116 | | | | 0.0259 | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Kunzea ericoides* | 0.0039 | | 0.0330 | 0.3709 | 0.0862 | 0.0524 | 0.0104 | 0.2841 |
| *Lastreopsis hispida* | 0.0502 | | | | 0.0776 | | | |
| *Leptospermum scoparium* | | | | 0.0662 | | | | 0.0738 |
| *Macropiper excelsium* | | 0.0117 | | | | | | |
| *Melicytus macrophyllus* | | | | | 0.1207 | 0.0628 | | |
| *Melicytus ramiflorus* | 0.0541 | 0.0391 | 0.2970 | 0.1325 | | | | |
| *Nestegis cunninghamii* | | | | | 0.0086 | | | |
| *Phyllocladus trichomanoides* | | | | | | | 0.0209 | |
| *Rhopalostylis sapida* | 0.4903 | 0.2266 | | | 0.1552 | 0.0838 | 0.1014 | 0.1476 |
| *Ripogonum scandens* | | 0.0078 | | | | | | |
| *Schefflera digitata* | | | | | | | | 0.0590 |
| *Vitex lucens* | 0.0425 | 0.0117 | 0.0083 | 0.0662 | | | | |

## 9.4 Maud Island sites versus Target sites ANOVA results

| Variable | Transect | mean | SE | Transect A | Transect B | Significance |
|---|---|---|---|---|---|---|
| SLOPE | 1 | 30.68 | 2.180 | 1 | 2 | .000[a] |
| | 2 | 18.64 | 1.462 | 1 | 5 | .636 |
| | 3 | 33.41 | 2.049 | 2 | 5 | .000[b] |
| ASPECT | 1 | 67.27 | 4.745 | 1 | 2 | .122 |
| | 2 | 95.59 | 13.036 | 1 | 5 | .914 |
| | 3 | 58.95 | 20.037 | 2 | 5 | .288 |
| CANOPY HEIGHT | 1 | 13.9659 | .55018 | 1 | 2 | .006[a] |
| | 2 | 10.3550 | .94001 | 1 | 5 | .003[b] |
| | 3 | 10.5723 | .78819 | 2 | 5 | .983 |
| % CANOPY COVER | 1 | 98.7709 | .20964 | 1 | 2 | .024[a] |
| | 2 | 97.6245 | .35732 | 1 | 5 | .000[c] |
| | 3 | 96.1000 | .36968 | 2 | 5 | .014[c] |
| % ROCK | 1 | 98.64 | 1.364 | 1 | 2 | .000[a] |
| | 2 | 30.91 | 5.747 | 1 | 5 | .000[b] |
| | 3 | 34.23 | 7.043 | 2 | 5 | .929 |
| % BAREGROUND | 1 | .05 | .045 | 1 | 2 | .187 |
| | 2 | .27 | .117 | 1 | 5 | .122 |
| | 3 | 7.73 | 3.722 | 2 | 5 | .136 |
| % GROUNDVEG | 1 | 27.32 | 4.688 | 1 | 2 | .007[a] |
| | 2 | 9.91 | 2.407 | 1 | 5 | .106 |
| | 3 | 15.64 | 3.046 | 2 | 5 | .313 |
| % TIEREDVEG | 1 | 18.82 | 4.148 | 1 | 2 | .496 |
| | 2 | 12.95 | 3.051 | 1 | 5 | .588 |
| | 3 | 13.45 | 3.491 | 2 | 5 | .994 |
| % MOSS | 1 | 43.82 | 5.693 | 1 | 2 | .001[a] |
| | 2 | 16.18 | 3.326 | 1 | 5 | .000[c] |
| | 3 | 2.55 | .549 | 2 | 5 | .001[c] |
| % DEAD WOOD | 1 | 3.27 | 1.235 | 1 | 2 | .880 |
| | 2 | 2.55 | .865 | 1 | 5 | .807 |
| | 3 | 2.41 | .616 | 2 | 5 | .991 |
| % LEAF LITTER | 1 | 30.27 | 3.653 | 1 | 2 | .000[a] |
| | 2 | 76.05 | 3.667 | 1 | 5 | .003[c] |
| | 3 | 55.59 | 6.107 | 2 | 5 | .019[c] |
| LITTER DEPTH | 1 | 37.523 | 3.9953 | 1 | 2 | .867 |
| | 2 | 39.832 | 2.1194 | 1 | 5 | .557 |
| | 3 | 43.291 | 3.8557 | 2 | 5 | .714 |
| STEMS ABOVE 30 CM | 1 | 6.00 | 1.374 | 1 | 2 | .651 |
| | 2 | 7.55 | 1.066 | 1 | 5 | .093 |
| | 3 | 2.73 | .614 | 2 | 5 | .001[b] |
| STEMS ABOVE 1 M | 1 | .86 | .249 | 1 | 2 | .021[a] |
| | 2 | 2.14 | .380 | 1 | 5 | .069 |
| | 3 | 1.68 | .258 | 2 | 5 | .588 |
| ROCKSIZE | 1 | 2.59 | .107 | 1 | 2 | .124 |
| | 2 | 2.23 | .146 | 1 | 5 | .284 |
| | 3 | 2.27 | .176 | 2 | 5 | .979 |
| SURFACE pH | 1 | 6.036 | .1159 | 1 | 2 | .027[a] |
| | 2 | 5.323 | .2331 | 1 | 5 | .109 |
| | 3 | 5.668 | .1351 | 2 | 5 | .415 |

[a] Mean of optimal habitat and suboptimal habitat site significantly different.
[b] Mean of potential target site significantly different to either optimal or suboptimal site.
[c] Mean of potential target site significantly different to BOTH optimal AND suboptimal site.

## 9.5 Waitakere versus target sites terrestrial ANOVA results

| Variable | Transect | Mean | SE | Comparison TRANSECT | TRANSECT | Sig. |
|---|---|---|---|---|---|---|
| SLOPE | 1 | 25.00 | 3.672 | 3 | 4 | .883 |
| | 2 | 21.00 | 4.028 | 3 | 6 | .976 |
| | 3 | 27.13 | 3.618 | 3 | 7 | .500 |
| | 4 | 31.94 | 3.245 | 4 | 6 | .674 |
| | | | | 4 | 7 | .173 |
| | | | | 6 | 7 | .756 |
| ASPECT | 1 | 170.56 | 24.417 | 3 | 4 | .613 |
| | 2 | 214.50 | 26.054 | 3 | 6 | .995 |
| | 3 | 161.44 | 29.901 | 3 | 7 | .938 |
| | 4 | 192.88 | 30.009 | 4 | 6 | .547 |
| | | | | 4 | 7 | .947 |
| | | | | 6 | 7 | .879 |
| CANOPYHEIGHT | 1 | 12.9194 | .95641 | 3 | 4 | .983 |
| | 2 | 13.5044 | 1.30204 | 3 | 6 | .127 |
| | 3 | 18.0419 | 2.00288 | 3 | 7 | .250 |
| | 4 | 15.3988 | .88756 | 4 | 6 | .253 |
| | | | | 4 | 7 | .631 |
| | | | | 6 | 7 | .630 |
| CANOPYCOVER | 1 | 97.2375 | .36142 | 3 | 4 | .007[a] |
| | 2 | 95.3200 | .39998 | 3 | 6 | .137 |
| | 3 | 95.9700 | .43571 | 3 | 7 | .555 |
| | 4 | 96.3113 | .59678 | 4 | 6 | .693 |
| | | | | 4 | 7 | .523 |
| | | | | 6 | 7 | .967 |
| STEMSABOVE30CM | 1 | 4.13 | 1.625 | 3 | 4 | .814 |
| | 2 | 2.56 | .701 | 3 | 6 | .658 |
| | 3 | 2.19 | .379 | 3 | 7 | 1.000 |
| | 4 | 4.13 | .576 | 4 | 6 | .965 |
| | | | | 4 | 7 | .331 |
| | | | | 6 | 7 | .043[a] |
| STEMSABOVE1M | 1 | 1.06 | .347 | 3 | 4 | .873 |
| | 2 | 1.44 | .353 | 3 | 6 | .992 |
| | 3 | 1.19 | .262 | 3 | 7 | .246 |
| | 4 | 2.06 | .392 | 4 | 6 | .941 |
| | | | | 4 | 7 | .641 |
| | | | | 6 | 7 | .271 |
| DBH | 1 | 35.75 | 14.631 | 3 | 4 | .236 |
| | 2 | 85.69 | 21.173 | 3 | 6 | .330 |
| | 3 | 99.19 | 33.436 | 3 | 7 | .530 |
| | 4 | 64.00 | 14.611 | 4 | 6 | .986 |
| | | | | 4 | 7 | .833 |
| | | | | 6 | 7 | .771 |
| LITTERDEPTH | 1 | 62.025 | 6.7512 | 3 | 4 | .933 |
| | 2 | 56.619 | 6.0820 | 3 | 6 | .570 |
| | 3 | 50.656 | 5.5599 | 3 | 7 | .979 |
| | 4 | 57.538 | 9.2430 | 4 | 6 | .887 |
| | | | | 4 | 7 | 1.000 |
| | | | | 6 | 7 | .919 |
| ROCKSIZE | 1 | .50 | .329 | 3 | 4 | .987 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 2 | .38 | .180 | 3 | 6 | 1.000 |
| | 3 | .50 | .242 | 3 | 7 | .191 |
| | 4 | 1.44 | .316 | 4 | 6 | .975 |
| | | | | 4 | 7 | .035[b] |
| | | | | 6 | 7 | .109 |
| SURFACEPh | 1 | 4.569 | .1231 | 3 | 4 | .021[a] |
| | 2 | 3.819 | .2048 | 3 | 6 | .623 |
| | 3 | 4.781 | .1246 | 3 | 7 | .980 |
| | 4 | 4.631 | .1060 | 4 | 6 | .003[b] |
| | | | | 4 | 7 | .009[b] |
| | | | | 6 | 7 | .796 |
| ROCK | 1 | 1.13 | .769 | 3 | 4 | .779 |
| | 2 | .38 | .180 | 3 | 6 | .725 |
| | 3 | 3.88 | 2.511 | 3 | 7 | .387 |
| | 4 | 7.38 | 3.743 | 4 | 6 | .524 |
| | | | | 4 | 7 | .282 |
| | | | | 6 | 7 | .864 |
| BAREGROUND | 1 | .81 | .344 | 3 | 4 | .650 |
| | 2 | 4.69 | 3.275 | 3 | 6 | .356 |
| | 3 | .19 | .136 | 3 | 7 | .331 |
| | 4 | 5.44 | 2.614 | 4 | 6 | .534 |
| | | | | 4 | 7 | .998 |
| | | | | 6 | 7 | .229 |
| GROUNDVEG | 1 | 14.63 | 4.742 | 3 | 4 | .461 |
| | 2 | 7.19 | 1.517 | 3 | 6 | .875 |
| | 3 | 10.56 | 2.585 | 3 | 7 | .998 |
| | 4 | 13.69 | 2.827 | 4 | 6 | .677 |
| | | | | 4 | 7 | .208 |
| | | | | 6 | 7 | .847 |
| TIEREDVEG | 1 | 14.13 | 4.267 | 3 | 4 | .967 |
| | 2 | 11.63 | 3.364 | 3 | 6 | .182 |
| | 3 | 29.56 | 6.029 | 3 | 7 | .191 |
| | 4 | 29.81 | 6.285 | 4 | 6 | .070 |
| | | | | 4 | 7 | .078 |
| | | | | 6 | 7 | 1.000 |
| MOSS | 1 | 1.25 | .602 | 3 | 4 | .697 |
| | 2 | .50 | .329 | 3 | 6 | .287 |
| | 3 | 3.44 | 1.037 | 3 | 7 | .408 |
| | 4 | 2.88 | .836 | 4 | 6 | .064 |
| | | | | 4 | 7 | .069 |
| | | | | 6 | 7 | .974 |
| DEADWOOD | 1 | 2.88 | 1.147 | 3 | 4 | .818 |
| | 2 | 5.50 | 2.775 | 3 | 6 | .977 |
| | 3 | 3.44 | .780 | 3 | 7 | .922 |
| | 4 | 2.06 | .602 | 4 | 6 | .890 |
| | | | | 4 | 7 | .629 |
| | | | | 6 | 7 | .512 |
| LEAFLITTER | 1 | 88.63 | 4.822 | 3 | 4 | .965 |
| | 2 | 84.88 | 6.357 | 3 | 6 | .896 |
| | 3 | 92.13 | 1.329 | 3 | 7 | .687 |
| | 4 | 80.00 | 6.096 | 4 | 6 | .685 |
| | | | | 4 | 7 | .945 |
| | | | | 6 | 7 | .249 |

[a] Mean of optimal habitat and suboptimal habitat site significantly different.
[b] Mean of potential target site significantly different to either optimal or suboptimal site.
[c] Mean of potential target site significantly different to BOTH optimal AND suboptimal site.

## 9.6 Waitakere versus target sites stream bed ANOVA results

| Variable | Transect | mean | SE | Comparison Transect | Comparison Transect | Significance |
|---|---|---|---|---|---|---|
| BOULDERSBW | 1 | 8.09 | 2.062 | 3 | 4 | .011[a] |
| | 2 | 1.10 | .717 | 3 | 6 | .765 |
| | 3 | 11.18 | 2.405 | 3 | 7 | .000[c] |
| | 4 | 28.67 | 3.823 | 4 | 6 | .001[b] |
| | | | | 4 | 7 | .000[c] |
| | | | | 6 | 7 | .001[a] |
| BOULDERSAW | 1 | 14.89 | 3.110 | 3 | 4 | .000[a] |
| | 2 | .84 | .553 | 3 | 6 | .006[c] |
| | 3 | 31.74 | 3.951 | 3 | 7 | .172 |
| | 4 | 24.37 | 3.398 | 4 | 6 | .000[c] |
| | | | | 4 | 7 | .000[b] |
| | | | | 6 | 7 | .492 |
| LARGEROCKSBW | 1 | 5.43 | 1.119 | 3 | 4 | .002[a] |
| | 2 | .87 | .470 | 3 | 6 | .445 |
| | 3 | 8.96 | 2.079 | 3 | 7 | .163 |
| | 4 | 10.92 | 2.376 | 4 | 6 | .001[b] |
| | | | | 4 | 7 | .000[b] |
| | | | | 6 | 7 | .925 |
| LARGEROCKSAW | 1 | 5.92 | 1.198 | 3 | 4 | .011[a] |
| | 2 | 1.39 | .769 | 3 | 6 | .959 |
| | 3 | 5.11 | 1.109 | 3 | 7 | .833 |
| | 4 | 4.56 | 1.082 | 4 | 6 | .034[b] |
| | | | | 4 | 7 | .085 |
| | | | | 6 | 7 | .985 |
| SMALLROCKSBW | 1 | 22.53 | 3.293 | 3 | 4 | .000[a] |
| | 2 | 2.39 | 1.036 | 3 | 6 | .085 |
| | 3 | 12.83 | 2.357 | 3 | 7 | .002[c] |
| | 4 | 8.93 | 1.709 | 4 | 6 | .001[b] |
| | | | | 4 | 7 | .008[c] |
| | | | | 6 | 7 | .539 |
| SMALLROCKSAW | 1 | 6.51 | 1.969 | 3 | 4 | .037[a] |
| | 2 | .94 | .409 | 3 | 6 | .454 |
| | 3 | 3.22 | 1.025 | 3 | 7 | .063 |
| | 4 | 1.35 | .485 | 4 | 6 | .169 |
| | | | | 4 | 7 | .916 |
| | | | | 6 | 7 | .353 |
| GRAVELBW | 1 | 18.87 | 2.678 | 3 | 4 | .000[a] |
| | 2 | .90 | .295 | 3 | 6 | .082 |
| | 3 | 10.51 | 2.216 | 3 | 7 | .002[c] |
| | 4 | 7.07 | 1.596 | 4 | 6 | .000[b] |
| | | | | 4 | 7 | .002[c] |
| | | | | 6 | 7 | .589 |
| GRAVELAW | 1 | 7.30 | 1.976 | 3 | 4 | .011[a] |
| | 2 | .84 | .275 | 3 | 6 | .061 |
| | 3 | 1.99 | .645 | 3 | 7 | .009[b] |
| | 4 | .65 | .425 | 4 | 6 | .360 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | 4 | 7 | .983 |
| | | | | 6 | 7 | .312 |
| MUDBW | 1 | 3.40 | .689 | 3 | 4 | .000[a] |
| | 2 | 50.90 | 6.988 | 3 | 6 | .924 |
| | 3 | 4.39 | 1.430 | 3 | 7 | .951 |
| | 4 | 2.76 | .978 | 4 | 6 | .000[b] |
| | | | | 4 | 7 | .000[b] |
| | | | | 6 | 7 | .783 |
| MUDAW | 1 | 7.06 | 2.747 | 3 | 4 | .001[a] |
| | 2 | 39.84 | 7.211 | 3 | 6 | .861 |
| | 3 | 10.07 | 2.673 | 3 | 7 | .804 |
| | 4 | 10.72 | 2.995 | 4 | 6 | .002[b] |
| | | | | 4 | 7 | .003[b] |
| | | | | 6 | 7 | .998 |
| LEAFLITTERBW | 1 | 5.40 | 1.659 | 3 | 4 | .989 |
| | 2 | 6.32 | 2.388 | 3 | 6 | .024[b] |
| | 3 | .50 | .153 | 3 | 7 | .071 |
| | 4 | 1.17 | .312 | 4 | 6 | .092 |
| | | | | 4 | 7 | .164 |
| | | | | 6 | 7 | .218 |
| LEAFLITTERAW | 1 | 4.47 | 1.271 | 3 | 4 | .133 |
| | 2 | 14.35 | 4.232 | 3 | 6 | .734 |
| | 3 | 3.01 | .636 | 3 | 7 | 1.000 |
| | 4 | 4.40 | 1.414 | 4 | 6 | .057 |
| | | | | 4 | 7 | .134 |
| | | | | 6 | 7 | .807 |
| FLOATINGDEBRIS | 1 | 4.81 | 2.491 | 3 | 4 | .755 |
| | 2 | 1.87 | 1.609 | 3 | 6 | .314 |
| | 3 | .46 | .254 | 3 | 7 | .275 |
| | 4 | .27 | .142 | 4 | 6 | .821 |
| | | | | 4 | 7 | .754 |
| | | | | 6 | 7 | .916 |
| VEGETATION | 1 | 1.43 | .724 | 3 | 4 | .333 |
| | 2 | .19 | .086 | 3 | 6 | .828 |
| | 3 | 2.30 | .709 | 3 | 7 | .953 |
| | 4 | 2.05 | .937 | 4 | 6 | .021[b] |
| | | | | 4 | 7 | .206 |
| | | | | 6 | 7 | .997 |

[a] Mean of optimal habitat and suboptimal habitat site significantly different.
[b] Mean of potential target site significantly different to either optimal or suboptimal site.
[c] Mean of potential target site significantly different to BOTH optimal AND suboptimal site.

## 9.7 Waitakere versus target sites other variables ANOVA results

| | | | | Comparison | | |
|---|---|---|---|---|---|---|
| | **Transect** | **Mean** | **Std. Error** | **Transect** | **Transect** | **Significance** |
| WATERWIDTH | 1 | 161.00 | 22.639 | 1 | 2 | .043[a] |
| | 2 | 79.27 | 16.832 | 1 | 3 | .006[c] |
| | 3 | 326.36 | 36.339 | 1 | 4 | .087 |
| | 4 | 272.50 | 36.845 | 2 | 3 | .000[c] |
| | | | | 2 | 4 | .002[b] |
| | | | | 3 | 4 | .728 |
| HIGHWATER – lowwater WIDTH | 1 | 54.68 | 5.373 | 1 | 2 | 0.835 |
| | 2 | 61.13 | 5.476 | 1 | 3 | 0.001[c] |
| | 3 | 106.67 | 11.998 | 1 | 4 | 0.57 |
| | 4 | 63.28 | 3.927 | 2 | 3 | 0.004[c] |
| | | | | 2 | 4 | 0.989 |
| | | | | 3 | 4 | 0.005[a] |
| HIGHWATERHWATERH | 1 | 220.91 | 29.270 | 1 | 2 | .976 |
| | 2 | 234.55 | 16.313 | 1 | 3 | .508 |
| | 3 | 292.09 | 41.046 | 1 | 4 | .592 |
| | 4 | 278.00 | 34.117 | 2 | 3 | .577 |
| | | | | 2 | 4 | .667 |
| | | | | 3 | 4 | .993 |
| CANOPYCOVER | 1 | 110.5745 | 14.94723 | 1 | 2 | .780 |
| | 2 | 96.3836 | .36510 | 1 | 3 | .740 |
| | 3 | 95.2755 | .35928 | 1 | 4 | .760 |
| | 4 | 95.8120 | .53957 | 2 | 3 | .168 |
| | | | | 2 | 4 | .816 |
| | | | | 3 | 4 | .841 |
| CANOPYHEIGHT | 1 | 19.5770 | 8.71760 | 1 | 2 | .890 |
| | 2 | 13.2955 | 1.38718 | 1 | 3 | .683 |
| | 3 | 9.7391 | .50114 | 1 | 4 | .687 |
| | 4 | 9.7900 | .55547 | 2 | 3 | .125 |
| | | | | 2 | 4 | .138 |
| | | | | 3 | 4 | 1.000 |
| ASPECT | 1 | 137.5591 | 13.03111 | 1 | 2 | .005[a] |
| | 2 | 70.1818 | 11.63366 | 1 | 3 | .000[c] |
| | 3 | 273.1818 | 3.25246 | 1 | 4 | .000[c] |
| | 4 | 283.8000 | 9.13212 | 2 | 3 | .000[c] |
| | | | | 2 | 4 | .000[c] |
| | | | | 3 | 4 | .699 |

[a] Mean of optimal habitat and suboptimal habitat site significantly different.
[b] Mean of potential target site significantly different to either optimal or suboptimal site.
[c] Mean of potential target site significantly different to BOTH optimal AND suboptimal site.

## 9.8 Maud Island landing permit

52155

Department of Conservation
*Te Papa Atawhai*

***MAUD ISLAND***
***Landing Permit***
***Tom Shand Scientific Reserve***

Pursuant to S57 Reserves Act 1977, and subject
To the conditions contained in this permit

| | | |
|---|---|---|
| Sophie Penniket<br>P O Box 300,<br>Wanaka.<br><br>027 324 6553<br>03 443 1211 | [*Permit Holder*]<br>[*Address*]<br><br><br>[*Phone No*] | Permit No: 57/08<br>Date: 6/11/08<br>is authorised to enter<br>Tom Shand Scientific Reserve<br><br>**For the following purpose;**<br>**Frog Work – Scientific.** |

| | |
|---|---|
| **Period of Permit 18/11/08 to 8/12/08** | **Names of Other Party Members:**<br>**Bastian Egeter. (Field staff for Jen Germano)** |
| **Approved landing site (s)** | |
| **Vessel/Plane Name/Type/Description**<br>**DOCF approved vessel** | |
| **Special Conditions** | |

***Conditions of Permit***

1. This permit is not transferable, must be carried and produced on demand.
2. You enter the island at your own risk. The permit holder will be liable for all costs incurred by the Department for search & rescue, pollution, introduction of pests, damage, fire fighting, or other loss as a result of the use of this permit.
3. The permit holder shall ensure that;
   a. Access and landings occur only as agreed with the resident officer.
   b. They report to the resident officer immediately on arrival and shall adhere to all instructions given by that officer with respect to conduct on the island. No wildlife shall be handled other than as may be approved by that officer.
   c. All clothing and stores are clean and free of seeds or other plant material; footwear must be thoroughly clean and dry
   d. All stores are sealed on packing or are repacked on day of departure. All stores shall be unpacked only in a designated (rodent-proof) area.
   e. No fires are lit, cooking is confined to the accommodation buildings and smoking occurs only in the immediate house environs – and in dry weather not at all.
   f. No animals or firearms are brought onto the island.
   g. No plants, wildlife, soil or rocks, historic sites are damaged, removed or disturbed.
   h. All rubbish accumulated during the visit is removed.
4. Committing any offence or breach of these conditions will cancel this permit
5. This permit may be altered or revoked at any time.

Signature of Commissioner
Name: Roy Grose

Signature of Permit Holder

**Maud Island is special, being home to endangered species and historic sites.**
**Help protect the island from animal/plant pests and from fire.**
***DIAL 111 TO REPORT FIRES & OTHER EMERGENCIES***

## 9.9 Waitakere Ranges research permit

Auckland Regional Council
TE RAUHITANGA TAIAO

Bastian Egeter
Wildlife Management, Zoology Department,
University of Otago,
P.O. Box 52, Dunedin.
bastianegeter@yahoo.ie
021-02240188

21 Pitt Street
Private Bag 92 012, Auckland
New Zealand
DX CP 28 008 Pitt St
Telephone +64 9 366 2000
Facsimile +64 9 366 2155
www.arc.govt.nz

10 December 2008

Dear Bastian Egeter,

**Consent to undertake research in the Waitakere Ranges Regional Park between 1 and 31 December 2008.**

Thank you for the details about your proposed research on assessing the habitat suitability at Orokonui Ecosanctuary (Otago Region), for the translocation of Maud Island frogs and/or Hochstetter's frogs. Your proposal outlines the assessment of environmental variables including annual temperature, annual solar radiation, annual water deficit, vapour pressure deficit, soil drainage and monthly water balance ratio to be undertaken at a range of sites to better understand the habitat requirements of Hochstetter's frogs. One of these sites is the Waitakere Ranges parkland.

The Auckland Regional Council will grant permission for you to undertake the research at the Waitakere Ranges Regional Park, subject to the conditions outlined below:

**Waitakere Ranges Regional Park (referred to as the Park) Use Conditions:**

**1. Collection of Samples, Disturbance to or Handling of Flora and Fauna Permitted**

1.1 Collection of climatic and soil variables as outlined in the research proposal is permitted.
1.2 The collection of soil samples to a total of 1kg in weight for research purposes as detailed in the application is permitted.

**2. Protection of site values**

2.1 Damage or endangerment of natural features, animals, plants or historic resources on the Park, or bringing any plant or animal pest onto the site(s) is not permitted
2.2 Collection, permanent marking, interference with or taking of trees, shrubs or plants (including seedlings) from the Park is not permitted unless allowed by this consent.
2.3 No animals on the Park are to be handled or taken unless allowed by this consent. Where protected wildlife under the Wildlife Act is to be handled a permit is also required from the Department of Conservation.
2.4 All field equipment must be uncontaminated by dirt, animal or plant material prior to entering the Park and if it has come into contact with wildlife, sterilised with anti viral solutions. Boots and clothes must be completely free of mud and seeds. The attached



procedures on Kauri dieback disease must be adhered to. This will also minimise the risk of the spread of the chytrid fungus.
2.5 Samples must not be collected in such quantities from the Park that the taking would unduly deplete the population or ecological associations, or damage biologically sensitive areas or values.
2.6 Samples are to be collected away from tracks, huts, picnic areas or areas of high public use on the Park and as far as practicable, out of sight of the public.
2.7 Access in the Park is by foot only or on approved vehicle access tracks.
2.8 Wherever practicable, access routes to the collection areas on the Park should avoid damage to natural features or values.
2.9 Obtaining permission to cross private land to reach the Park is the responsibility of the consent holder.
2.10 Contamination of any body of water within the Park is not permitted.
2.11 All waste and rubbish must be removed from the Park and disposed of it in an environmentally sound manner.

**3. Facilities, Equipment and Tools**

3.1 Structures or facilities shall not be erected or brought onto the Park without the prior written consent of the Auckland Regional Council.
3.2 The use of Auckland Regional Council Parks operational, equipment, offices and buildings are only by prior arrangement with the ranger staff at the relevant Park Depot within the Park.
3.3 Tools or equipment left on the Park overnight are at the consent holder's own risk. During the day tools and equipment not in use are to be placed well out of view from public walking tracks and recreation areas.
3.4 All tools and equipment, including markers, flagging tape etc., must be removed from the Park by the expiry date of the consent.

**4. Reporting**

4.1 Upon completion of the research, the consent holder shall forward a copy of the research findings, reports and publications to the Auckland Regional Council (Address – Alison Davis, Arataki Visitor Centre, PO Box 60-228, Titirangi, Waitakere City). An electronic copy is acceptable.
4.2 If requested, the consent holder shall keep the Auckland Regional Council and Iwi informed on the progress of this research.
4.3 The consent holder accepts that the Auckland Regional Council may provide copies of these findings to Iwi and stakeholders.

**5. Health and Safety**

5.1 The consent holder must supply a health and safety plan for approval prior to working at the site to the Senior Ranger - Conservation (Western Sector – contact Alison Davis 098170084). The Auckland Regional Council Park staff will notify site hazards prior to the research commencing.
5.2 The consent holder shall conduct the activity in a safe and reliable manner, and shall comply with all statutes, bylaws and regulations, and all notices and requisitions of any competent authority relating to the conduct of the collecting activity.

**Applicant**

Signed [signature]

Name: BASTIAN EGETER

Date: 15/01/09

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

Signed [signature]

Name: Alison Davis, Acting Principal Ranger

Date: 29/12/08

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- 5 -

6.5 This consent does not confer on the consent holder any interest in any sites on the Park, nor does it derogate in any way from the rights of the public to use and enjoy the whole or any part of the Park.

**7. Requirements:**

7.1 Please sign two copies of this document indicating agreement to the above conditions and forward one copy, to this office, before starting research on the Park. The second copy is for your records.

Return Address:
Arataki Visitor Centre
PO Box 60-228,
Titirangi, Waitakere City

Yours sincerely

[signature]

Alison Davis
Senior Ranger, Conservation
Western Sector
Auckland Regional Council
Ph. 098170084

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- 4 -

### 9.10 Plate 1

Strip transect used to quantify stream bed habitat.