Ecology and management of North Island fernbird (*Bowdleria punctata vealeae*)

Kevin Alan Parker

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Like winds and sunsets, wild things were taken for granted until progress began to do away with them. Now we face the question whether a still higher ‘standard of living’ is worth its cost in things natural, wild and free.

Aldo Leopold 1887-1948
Abstract

New Zealand fernbird (*Bowdleria punctata*) are a small cryptic passerine that exploit a variety of habitats, often characterised by a low dense understorey, with a broken emergent canopy. Fernbird were once abundant in the extensive wetlands and scrublands of pre-European New Zealand, but have undergone a decline on the mainland in the last 100 years. The current status of mainland fernbird is unclear, though they are thought to have a widespread but patchy distribution. The South Island (*B. p. punctata*) and Snares Island fernbird (*B. p. caudata*) have been studied, however little research has been conducted on North Island fernbird (*B. p. vealeae*). This study describes the breeding ecology of North Island fernbird at the Omaha Saltmarsh, and makes comparisons to previous research on the South and Snares Island fernbird. Territorial behaviour was similar between studies, however significant differences were detected in territory and clutch size and in nest location. Initial nest monitoring indicated eggs and nestlings were frequently lost to predators. Behavioural observations, monitoring of local predators, video monitoring and an artificial nest experiment were used in an attempt to identify significant predators. Strong inferential evidence implicates mustelids in all observed nest losses, however mice (*Mus musculus*) are abundant in the saltmarsh, and preyed on more than 75% of artificial nests. Natural nests are difficult to locate at the laying and incubation stage and it is hypothesised that mice may be significant egg predators. Twenty-five fernbird were translocated from an area of shrubland near Orewa, between June 2001 and July 2002, in an attempt to establish a new population on Tiritiri Matangi Island. There have been few observations of banded birds on the island since the transfers, however pairs have been heard duetting, unbanded birds were seen following the first breeding season on the Island and a pair with nestlings has been observed. Fernbird were screened for disease as part of the translocation process. The results were compared to those obtained from tui (*Prosthemadera novaeseelandiae*) and bellbird (*Anthornis melanura*) mist netted on Tiritiri Matangi Island. Virtually no disease was detected in the birds tested, aside from Coccidia in one fernbird. Whilst the collection of disease data is important, establishing normal haematological values may be of more use for long term health monitoring. It is recommended that fernbird be treated as a metapopulation, and managed using an ecosystem approach.
Preface

This study has a focus on North Island fernbird. However, each chapter can be read as an independent study, and as such, this thesis has been written as five scientific papers. Attempts have been made to avoid excessive repetition, through reference to other chapters, however some repetition is unavoidable. Chapter One describes the breeding biology of North Island fernbird at the Omaha Saltmarsh. Chapter Two describes an attempt to identify significant nest predators of fernbird at the Omaha Saltmarsh. Chapter Three outlines approaches to transferring New Zealand fernbird and describes a recent translocation to Tiritiri Matangi Island. Chapter Four details a comparative study investigating disease occurrence in mainland and island birds. Chapter Five makes recommendations for the future management of New Zealand fernbird.
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1 Breeding biology of the North Island fernbird (Bowdleria punctata vealeae)

Abstract – The breeding biology of a population of the North Island fernbird (Bowdleria punctata vealeae) in saltmarsh habitat was studied during the 2000/2001 and 2001/2002 breeding seasons. The results were compared with previous studies carried out on South Island fernbird (B. p. punctata) and Snares Island fernbird (B. p. caudata). Significant differences were found in territory size, clutch size and nest construction and placement. Fernbird nests in the current study were infested with the haematophagous mite Ornithonyssus bursa. There are no previous records of this mite associated with New Zealand fernbird. Breeding behaviour was very similar between studies. Breeding success was similar between studies, however the methods used to calculate success are unreliable and tend to overestimate true breeding success. A corrected method of calculating nesting success was applied to data obtained at Omaha, however the sample size (21 nests) was insufficient for an accurate assessment of nesting success.

1.1 Introduction

The endemic New Zealand fernbird (Bowdleria punctata) is New Zealand’s sole representative of the old world warblers (order: Passeriformes, suborder: Passeres, family: Sylviidae). Old world warblers are a large diverse group of songbirds, characterised by active foraging in vegetation for invertebrates, and loud musical calls (Heather & Robertson, 1996). The general foraging and habitat requirements of fernbird are typical of this family, however their calls are loud but simple.

Two species of fernbird are currently recognised in New Zealand. The Chatham Island fernbird (Bowdleria rufescens) is believed to have become extinct around 1900 (Heather & Robertson, 1996). There was however, an unconfirmed sighting from steep, scrub covered slopes on Mangere Island in 1971 (D.S. Horning, pers. comm., in Best, 1973). Morphological characteristics divide New Zealand fernbird into five subspecies: North Island fernbird (B. p. vealeae), South Island fernbird (B. p. punctata),
Stewart Island fernbird (B. p. stewartiana), Codfish Island fernbird (B. p. wilsoni) and Snares Island fernbird (B. p. caudata) (Turbott, 1990).

Sibley and Ahlquist (1987) recommended that Bowdleria be synonymised with the Australian genus Megalurus, on the basis of the congeneric relationship between the fernbird and the little grassbird (Megalurus gramineus). However, Olson (1990) independently concluded that anatomical differences between Bowdleria and Megalurus justify separate generic status for Bowdleria.

To early Maori, the fernbird or matata was regarded as he manu tapu, a sacred bird. Fernbird formed a link between tohunga and the gods. The bird was sacrificed when predicting the outcome of war and other important matters. Fernbird calls were regarded as good or bad omens during or preceding various activities, and the birds were used in various ceremonies (Riley, 2001).

1.2 Distribution

Buller (in Turbott, 1961) recorded fernbird in fernland, raupo (Typha orientalis) beds and low lying flats throughout the North and South Islands. He considered them to be one of New Zealand’s most common birds. Turbott (1961) stated that Maori and European land clearance might have temporarily allowed fernbird to extend their range into this modified habitat.

Fernbird disappeared from most of the lower North Island and eastern South Island in the late 1800s (Heather & Robertson, 1996). There have been no recent systematic surveys of the distribution and status of the fernbird. Knowledge of the present day distribution is primarily based on Bull (1985). The species is considered widespread but patchy (Figure 1). North Island populations are concentrated in Northland with scattered records over the Central Plateau south to the Manawatu Estuary and Porangahau. Fernbird also exist on Great Barrier, and possibly the Alderman Islands and they have recently been introduced to Tiritiri Matangi Islands (see Chapter 3; Heather & Robertson, 1996).

In the South Island, fernbird are concentrated on the West Coast, but they also occur on the eastern edge of the Fiordland Mountains, and the south east coast from Dunedin to Wakaputa Point (Heather & Robertson, 1996).
The Snares and Stewart Island populations are considered to be moderately abundant. The status of the Codfish Island population is uncertain (Heather & Robertson, 1996).

Fernbird prefer low, dense vegetation with emergent shrubs in swamps, saltmarshes, pakihi scrub, rush and tussock-covered frost flats (Heather & Robertson, 1996). They are also found in low manuka (*Leptospermum scoparium*) scrub, rata (*Metrosideros spp*.), gorse (*Ulex europaeus*) and kiekie (*Freycinetia banksii*) thickets and in bracken (*Pteridium esculentum*) and umbrella fern (*Gleichenia spp.*) (Best, 1985). On the Snares and Stewart Island offliers, fernbird live in coastal tussock meadows and in *Olearia* and *Senecio* shrublands (Best, 1985).

**Figure 1.** Distribution of New Zealand fernbird (after Bull *et al*., 1985).
1.3 Description

There is some sexual dimorphism in fernbird, however the considerable overlap means it is not possible to distinguish sexes in the hand or in the field (Best, 1973; Harris, 1987) (see Chapter 3). Fernbird have golden brown upper surfaces with broad dark brown streaks (Figure 2). The crown feathers are chestnut with a white eyebrow streak. The undersides are white with brownish black spots, that increase in size from the chin to the belly. The belly is mostly white. One of the most distinctive features of the fernbird is the long frayed tail, the ends of which are often broken and worn down, giving a spiky appearance. Fledglings tend to be darker and duller than adults, with short squared tails (Best, 1985). Fernbird increase in size with increasing latitude.

Figure 2. North Island fernbird (Photo, Geoff Moon)
1.3.1 Calling behaviour

Fernbird give a wide variety of calls, the most distinctive of which is the “utick” call. The utick call is sometimes used by the male alone and sometimes in rapid antiphonal duets with his mate (Jenkins, 1978). The territorial call of the male is usually given from a high calling post (Best, 1979) and is a monotonous repetition of one note lasting up to 15 minutes. A low clapping or chittering is often heard in border disputes (Best, 1985).

1.3.2 Foraging

Fernbird are reluctant fliers and forage by scampering and scrambling through thick vegetation like a small mammal might do, and their already frayed tails are often quite worn. Fernbird have been observed digging, lifting, burrowing through leaf litter and investigating all sites that may be hiding invertebrates (Best, 1985). Recorded prey items include Arthropods, Orthoptera, Carabids, Arachnids, Diptera, Lepidoptera and Tipulids (Best, 1985).

1.4 Previous research


1.5 Aims

The aims of this study were to examine and describe the breeding behaviour and biology of the North Island fernbird and to compare the results with studies of South
Island and Snares Island fernbird. Of particular interest is quantifying nesting success given the wide ranging and significant impacts of introduced predators on New Zealand species (Chapter 2). Fernbird are very cryptic and hence very challenging to study. Basic ecological and biological knowledge underpins any attempt to interpret the status of, manage, or form hypotheses about any species (Krebs & Davies, 1993). Baseline data are required for considering population trends. This is particularly so if it becomes apparent that a species is threatened or endangered and requires intensive management (Caughley & Gunn, 1996). Programmes to manage such species rely on a sound ecological knowledge of the species’ habits and requirements, to maximise the likelihood of success (James, 1998). Marzluff and Sallabanks (1998) state that an understanding of a species and its limiting factors must precede experimentation, so that relevant experiments can be conducted. The North Island fernbird is not considered to be a threatened species. Its current distribution is described as widespread but patchy (Heather & Robertson, 1996) (Figure 1). However, given the species’ cryptic nature, its habit of nesting low to the ground and reliance on what is often viewed as marginal and unimportant habitat (wetlands, dry scrub and fernlands) it is fundamentally important to gain some understanding of its breeding success on the mainland, if we are to ensure long term survival of the species.

1.6 Methods

1.6.1 Study site

This study was conducted in the Omaha saltmarsh (36°22' South, 174°46' East), which is located on a narrow strip of land bordered by the Mangatawhiri Spit and the Whangateau Harbour (Figure 3). The area is characterised by marine depositional landforms creating a distinctive vegetation class (Mitchell et al., 1992). One of the few remaining coastal kahikatea (Dacrycarpus dacrydiodes) forests in the North Island is located here, forming an intact ecological sequence from the Whangateau Harbour on to the Mangatawhiri Spit (Mitchell et al., 1992).

The tidal mudflats give way to scattered mangroves (Avicennia marina), before moving into an extensive saline sedgeland, characterised primarily by oioi (Leptocarpus similis), Baumea juncea and Juncus kraussii, with scattered Isolepis nodosa. There is a narrow strip of emergent vegetation, located between the saline sedgelands and coastal manuka forest. The narrow emergent band is characterised by scattered manuka, marsh
ribbon wood (*Plagianthus divaricatus*), flax (*Phormium tenax*), and New Zealand broom (*Carmichaelia* spp.) with an understorey of *Baumea juncea*, *Juncus krausii* and *Leptocarpus similis*. The manuka forest has a dense understorey of *Baumea juncea* and progresses into coastal kahikatea forest on stabilised sands. Much of the understorey is comprised of dense stands of kiekie (*Freycinetia baueriana*) with divaricating *Coprosma* spp. and scattered cabbage trees (*Cordyline australis*). All nesting behaviour was observed in the emergent band of vegetation.

The eastern side of the kahikatea forest has an open-ended predator proof fence running along its boundary. The fence is designed to prevent domestic pets dogs (*Canis familiaris*) and cats (*Felis catus*) entering the marsh from a nearby housing development. While the fence would be impassable to possums (*Trichosurus vulpecula*), it is unlikely to pose a significant barrier to any mustelid or rodent species. The threatened New Zealand dotterel (*Charadrius obscurus*) nests on the tip of the Mangatawhiri Spit, and the estuary and surrounding areas comprise important habitat for a wide range of species. The 1983-84 Protected Natural Area Survey (PNA) ranked this area as having moderate to high habitat values, however it is under intense pressure from urban and agricultural development (Mitchell *et al.*, 1992).
Figure 3. Omaha saltmarsh, Mangatawhiri Spit, North Island, New Zealand.
1.6.2 Breeding behaviour

A pilot study examining breeding success and behaviour and refining methodology was conducted from 28 November 2000 to 24 February 2001. The main part of the study involved nest monitoring from 14 November 2001 through to 26 March 2002. Over the 2000/2001 season the salt marsh was visited at least once every four days. Over the 2001/2002 season, visits were made at least once every three days. The marsh was also visited in March and April 2002 to detect any late nests.

1.6.3 Nesting territories

Nesting territories were only measured in 2001/2002. Observations and behavioural responses to playbacks were used to determine territory boundaries. Fernbird calls recorded at Omaha were played in a territory to elicit a response. When a resident bird responded to the calls it was lured to the border of a neighbouring territory. Territorial borders were marked with flagging tape at places where border disputes were initiated between neighbouring birds. Territory areas were estimated by plotting known borders with a handheld GPS and loading them onto a mapping programme (Fugawi 3, 2000).

1.6.4 Locating nests

Nesting behaviour was detected by walking the track bordering the emergent strip of vegetation between the manuka and reed beds. The locations of all birds were recorded on pieces of flagging tape tied to adjacent vegetation. Observations were numbered, along with the date and number of birds seen. For example, the second observation of two birds made on the 14 of November, would be marked as 2-14/11-2. Observations were also recorded in a field notebook.

The behaviour of the birds provided the first indication of breeding. Fernbird are difficult to observe as they very rarely fly. Most behaviour occurs under thick cover, birds only being revealed by the movement of vegetation or calls. However, whilst breeding, fernbird fly to and from the nest via a launching and landing post, usually an emergent manuka, within one to four metres of the nest. The initial walk through the marsh would flush birds with nests close to the track. These birds would usually come up from a clump of salt rushes and fly from the nest with a down-turned tail. They would often alarm call as they flew from the nest and continue to do so after landing a short distance away. Birds with chicks make frequent visits to and from nests with
invertebrates and faecal sacs. Such behaviour was often detected on the initial walk through the marsh, and later in the season.

Throughout the breeding season, any likely breeding behaviour was noted and followed up with an hour of observation. In addition those territories in which no breeding behaviour was observed, were watched for a period of one hour on at least one occasion. Observations were normally made with a pair of 8x35 binoculars. In territories where the vegetation was thick and greater than one metre high, a two-metre aluminium ladder was used for the hour-long observation period.

After breeding behaviour had been confirmed, further observation was necessary to detect the precise location of the nest. Even when it is known that a nest is in an area as small as 1m² it can still be extremely difficult to locate, and efforts to do so may result in excessive damage to the surrounding vegetation. For this reason, potential nests were observed either early in the morning or later in the evening, when there was no wind, and the swaying tops of salt rushes indicated the direction of the bird’s movement. Upon reaching the nest, the vegetation will often move in small circles as the bird settled or adjusted the nest. The 2001/2002 season was often windy making nests more difficult to locate. In some cases, it was necessary to crouch hidden in the salt rushes within two metres of the nest, in order to locate it. When searching for a nest, the parents would often reveal those with chicks, when they came in to feed them.

Once the precise location of a nest had been determined, the contents were noted. Nests were only approached in between incubation stints or between feeds, using a method similar to Harris (1987). Nests were never approached directly to minimise the risk of leading predators to them. Large steps were taken to minimise damage to the surrounding vegetation, and to avoid creating a path that led directly to the nest. The nest was approached through any adjacent standing water. A compass bearing from the closest tag was taken to facilitate future checks of nest contents. On some occasions, a sketch map of the site was also made, particularly if the nest was located late in the day. To minimise disturbance active nests were never visited close to dusk.

1.6.5 Nest Monitoring

Initial observations were made from a distance of 10 to 20 metres. If there was an active nest in the territory, nest visits were easily detected. The maximum absence
observed between nest visits was approximately 45 minutes. Fernbird are quite regular and predictable in their approach to a nest, however their behaviour could be altered if the observer is too close, other fernbird, or potential predators such as harriers (*Circus approximans*) or climatic conditions. The wind seemed to have a marked influence on their behaviour, causing them to approach nests much lower in the vegetation with shorter flights. It was sometimes necessary to observe a territory for more than one hour, as it is easy to miss visits during incubation.

Active nests were observed from a distance of 7-15 metres, depending on the behaviour of the adults. Most birds did not seem disturbed by the presence of an observer and would continue feeding and visiting the nest. If a bird seemed disturbed (alarm called, would not approach the nest) then the observation distance would be increased until normal behaviour resumed.

Nests were observed at least once every three days, more often when the chicks were close to fledging. Nests were checked at four day intervals to record contents. Nests were not approached after the chicks were 11-12 days old, as from this age they can fledge early if disturbed. Nests were generally observed for one hour. Adult visits to the nest were estimated to the nearest minute during incubation and nestling stages. When the chicks were close to fledging (12+days old) I visited the nests more frequently to determine the fledging date. When the exact fledging date was missed, fledging was determined from nest sign. Nests from which chicks had recently fledged, were generally extremely flattened and had a slight build up of faecal matter around the rim and surrounding vegetation.

Nesting success was expressed as both apparent nesting success (number of nests that successfully fledged divided by number of nests found), breeding success (number of fledglings divided by number of eggs laid) and Stanley’s estimate of nesting success (Armstrong *et al.*, 2002).

### 1.6.6 Nestling diet

An attempt was made to observe nest visits with a spotting scope when adults were feeding chicks. The intention was to accurately identify and quantify the invertebrates consumed by chicks, however the adults moved too quickly and positive identification was not possible. While a large amount of data concerning feeding visits was recorded,
positive identification of food type was only made to Order, Family or species on a few occasions.

1.6.7 Chick Banding

Chicks were metal banded (B band) when they were seven to ten days old. A unique combination of celluloid butt colour bands was also placed on each chick to aid individual recognition. Chicks were weighed and examined for condition and ectoparasites during banding.

1.6.8 Nest Parasites

A mite sample was taken from nests where young had fledged, and those that had failed due to being preyed on. A latex surgical glove was placed on the researchers hand and held in the nest for one minute. After taking the sample the glove was turned inside out and stored in a freezer. The mites were later put into a 70 percent alcohol solution and sent to Dr Allen Heath at the Wallaceville Animal Research Centre for identification.

1.6.9 Nest Structure

Nest structure and placement was measured and described after young had fledged or other nest failure. The following 11 measurements were taken to the nearest millimetre:

- Canopy height
- Distance to edge of clump
- Perimeter of clump
- Nearest other clump
- Ground to rim of nest
- Ground to base of nest
- Rim to rim external
- Rim to rim internal
- Inside depth
• Outside depth

• Landing point

The vegetation in which the nest was built and the material from which it was constructed were also recorded.

### 1.6.10 Statistical analyses

Stanley’s estimate of nesting success programme was downloaded from Ecological Archives at http://esa.sdsc.edu/Archive/E081-021 and pasted directly into the SAS editor (SAS 6.12, 1996) (Armstrong et al., 2002). Kruskal Wallace, one-way ANOVA and Mann Whitney U tests to compare territory size, clutch size and nest placement (Statistica 6.0, 2002).

### 1.7 Results

#### 1.7.1 Nesting territories

Eighteen nesting territories were identified over the 2001/2002 monitoring period (Figure 4). The average territory size was 5220± 487m$^2$ (S.E.) with a range of 2271-8244m$^2$ (n=15). Three territories were not measured, as territory boundaries were unclear. Fernbird territories at Omaha were located in a linear pattern due to the preference for the vegetation in the emergent band. Most territories only require defence on two boundaries within the emergent band. The reedbeds and manuka forest form undefended natural boundaries due to the absence of adjacent territories.

There was a significant difference in territory size between fernbird studies (Kruskal Wallance (4d.f., n=73)=54, $P<0.01$). A non-parametric multiple comparison with unequal sample sizes (Zar, 1999) showed that North Island fernbird territories at Omaha were significantly larger than those in Barlow’s (1983) study of South Island fernbird and Best’s (1973) study of Snares Island fernbird. There was no significant difference between the territory sizes in this study or those of Elliot (1978) and Harris (1987) who worked on South Island fernbird (Table 1). Barlow (1983), Best (1973) and Harris (1987) made multiple measurements of territories within and between seasons. As pairs in each study occupied territories for successive seasons, only values for the last monitored breeding season were compared to avoid pseudoreplication.
Figure 4. North Island Fernbird territories at the Omaha Saltmarsh 2001/2002 (not to scale).
Table 1. Geographic variation in territory size

<table>
<thead>
<tr>
<th>Location</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Median territory size (m²)</th>
<th>Mean territory size ± S.E.</th>
<th>n</th>
<th>Habitat type</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Omaha</td>
<td>36°22' S</td>
<td>174°46'</td>
<td>5865</td>
<td>5220±487</td>
<td>15</td>
<td>Saltmarsh</td>
<td>This study</td>
</tr>
<tr>
<td>Golden bay</td>
<td>40°44' - 40°48'</td>
<td>172°41' - 172°44'</td>
<td>8110</td>
<td>7987±498</td>
<td>6</td>
<td>Pakihi swamp</td>
<td>Elliot (1978)</td>
</tr>
<tr>
<td>Lakes Waipori (Dunedin)</td>
<td>45°59'</td>
<td>170°06'</td>
<td>13500</td>
<td>13564±1575</td>
<td>11</td>
<td>Freshwater wetland</td>
<td>Harris (1987)</td>
</tr>
<tr>
<td>Invercargill</td>
<td>46°27'</td>
<td>168°19'</td>
<td>1425</td>
<td>1376±155</td>
<td>14</td>
<td>Saltmarsh</td>
<td>Barlow (1983)</td>
</tr>
<tr>
<td>Snares Islands</td>
<td>48°07'</td>
<td>166°36'</td>
<td>2560</td>
<td>3192±318</td>
<td>27</td>
<td>Forest and maritime tussock lands</td>
<td>Best (1972)</td>
</tr>
</tbody>
</table>

1.7.2 Territorial defence

Territorial birds called most frequently in the mornings and evenings, though calls indicating territorial interactions could be heard at any time of the day. Territorial advertisements took place from the top of emergent trees and shrubs. Birds rarely called from an exposed branch, but rather just under the topmost branches.

Intruders, either real birds or recorded calls, are approached silently but directly by one of the birds (probably the male), with his or her mate 1-6 metres behind. When in close proximity to the intruder both birds will often start to “chitter”. If the intruder is within territory boundaries it will be chased from the territory. At territory boundaries birds perch above the understorey facing their opponent whilst chittering, head bobbing and holding their wings out to one side and quivering them. The feathers on the top of the head are also raised. The opposing birds were often quite close (<2 metres), and would display for up to two minutes without any chasing. After displaying, the birds appeared to return to their respective territories. Chasing and physical fighting were very rarely observed on territory boundaries. Pairs would often call to each other and duet during territory disputes.

A juvenile bird was observed calling within a breeding territory on one occasion. The call was uncharacteristic of fernbird, perhaps a developing territorial advertisement call, but drew an immediate response from the territorial birds. The juvenile was chased
from the territory. Territorial birds give alarm calls in response to humans and were observed calling and following a stoat (*Mustela erminea*) through a territory.

### 1.7.3 Nest Monitoring

Ten nests were found during 2000/2001 and nine in 2001/2002. Nests were found at both egg and chick stages. One nest found at the incubation stage in 2000/2001 was preyed on before it could be inspected. In addition, a single territory containing recently fledged chicks was detected in both 2000/2001 and 2001/2002 (Table 2). Figure five shows a nesting chronology for both monitored seasons.

**Table 2.** Summary of fernbird nests located at Omaha 2000/2001 and 2001/2002.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nest with eggs</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Nest with chicks</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Fledged chicks</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>11</td>
<td>10</td>
</tr>
</tbody>
</table>

The earliest nest fledging date observed was on the 16 November 2001. Assuming a nest-building period of three days, three days for laying (average clutch of 3 eggs), 12 days for incubation and a 16 day nestling period, the nest was probably initiated mid October 2001. Chicks fledged from the last observed nest on the 27 or 28 of February 2002. No nesting was detected after this date. Table three compares the onset and conclusion of the breeding season at Omaha with previous studies.

**Table 3.** Duration of the breeding season in fernbirds in various New Zealand locations.

<table>
<thead>
<tr>
<th>Location</th>
<th>Latitude (South)</th>
<th>Longitude (East)</th>
<th>First laying</th>
<th>Last fledging</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Omaha</td>
<td>36°22'</td>
<td>174°46'</td>
<td>Mid October</td>
<td>Late February</td>
<td>This study</td>
</tr>
<tr>
<td>Golden bay</td>
<td>40°44' - 40°48'</td>
<td>172°41' - 172°44'</td>
<td>Late August</td>
<td>Early March</td>
<td>Elliot (1978)</td>
</tr>
<tr>
<td>Lakes Waipori</td>
<td>45°59'</td>
<td>170°06'</td>
<td>Mid September</td>
<td>Early March</td>
<td>Harris (1987)</td>
</tr>
<tr>
<td>(Dunedin)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Snares Islands</td>
<td>48°07'</td>
<td>166°36'</td>
<td>Early November</td>
<td>Mid January</td>
<td>Best (1973)</td>
</tr>
</tbody>
</table>
Figure 5. North Island fernbird nesting chronology at the Omaha Saltmarsh 2000/2001 and 2001/2002.
Approximately 139 hours was spent observing active nests over both seasons. An additional 47 hours was spent observing occupied territories but no breeding behaviour was detected (Table 4).

**Table 4.** Summary of observation periods of fernbird territories at Omaha with and without nests.

<table>
<thead>
<tr>
<th>Year</th>
<th>Territories with active nests</th>
<th>Territories without active nests</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000/2001</td>
<td>69h 2m</td>
<td>12h 27m</td>
</tr>
<tr>
<td>2001/2002</td>
<td>70h 8m</td>
<td>35h 51m</td>
</tr>
<tr>
<td>Totals</td>
<td>139h 10m</td>
<td>47h 18m</td>
</tr>
</tbody>
</table>

The average clutch size over both seasons was 2.8±0.1 (S.E.) eggs, with a range of 2-4 eggs per clutch (n=18). Nests found at the chick stage were included in the average clutch size, so this represents a minimum clutch size. The mean number of chicks per nest over both seasons was 2.9±0.2 (S.E.) chicks, with a range of 2-4 chicks per clutch (n=10) (Table 5). Figure six shows the frequency distribution of clutch and brood size for both seasons.

**Table 5.** Average clutch and brood size for 2000/2001 and 2001/2002 in North Island fernbird.

<table>
<thead>
<tr>
<th>Season</th>
<th>Eggs/nest (mean ±S.E.)</th>
<th>n eggs</th>
<th>Chicks/nest (mean ±S.E.)</th>
<th>n chicks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000/2001</td>
<td>2.7±0.2</td>
<td>9</td>
<td>2.8±0.4</td>
<td>4</td>
</tr>
<tr>
<td>2001/2002</td>
<td>2.9±0.2</td>
<td>9</td>
<td>3±0.3</td>
<td>6</td>
</tr>
<tr>
<td>Combined</td>
<td>2.8±0.15</td>
<td>18</td>
<td>2.9±0.2</td>
<td>10</td>
</tr>
</tbody>
</table>
Eggs observed at Omaha were similar to those described in other studies. Fernbird eggs are ovoid, pale pink and have dark pink and purple spots and blotches, usually concentrated at the broad end of the egg (Best, 1973, 1985; Elliot, 1978; Harris, 1987). As disturbance was kept to a minimum in this study, eggs were not measured and weighed.

Average clutch size is significantly different (one way ANOVA, $F_{2, 102}=35.47, P<0.01$) between North Island, South Island and Snares Island fernbird (Table 6). Elliot’s (1978) and Harris’ (1987) studies were combined to calculate the clutch size for South Island fernbird due to the small number of clutches (n=3) found by Elliot (1978).

<table>
<thead>
<tr>
<th>Location</th>
<th>Mean clutch size ± S.E.</th>
<th>n</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Island</td>
<td>2.8±0.15</td>
<td>18</td>
<td>This study</td>
</tr>
<tr>
<td>South Island</td>
<td>3.7±0.1</td>
<td>55</td>
<td>Elliot (1978)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Harris (1987)</td>
</tr>
<tr>
<td>Snares Island</td>
<td>2.4±0.1</td>
<td>32</td>
<td>Best (1973)</td>
</tr>
</tbody>
</table>

The average length of incubation stints (n=11 nests) was 22 minutes ± 2 minutes 6 seconds (S.E.) (Figure 7). The average time between feeding visits (n=12 nests) was 6
minutes 22 seconds ± 54 seconds (S.E.) (Figure 8) or 9.4 visits per hour. A single nest in each season was followed from the egg stage to fledging (Figure 9). One nest fledged at 17 days and one at 18 days. Chicks appeared to stay within 3 metres of the nest on the day of fledging but would vacate the area within 24 hours. No observations of dependent chicks were made post-fledging at Omaha. Table seven compares incubation periods, feeding visits, and nestling periods between studies.

**Table 7.** Summary of incubation stints of North, South and Snares Island fernbird.

<table>
<thead>
<tr>
<th>Location</th>
<th>Mean incubation stint</th>
<th>Range</th>
<th>Feeding visits per hour</th>
<th>Nestling period</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Omaha</td>
<td>22 minutes (n=11)</td>
<td>1-42 minutes</td>
<td>9.4 (n=12)</td>
<td>17.5 days (n=2)</td>
<td>This study</td>
</tr>
<tr>
<td>Golden Bay</td>
<td>16 minutes (n=1)</td>
<td>10-20 minutes</td>
<td>10 (n=1)</td>
<td>16 days (n=1)</td>
<td>Elliot (1978)</td>
</tr>
<tr>
<td>Lakes Waipori</td>
<td>-</td>
<td>-</td>
<td>11.5 (n=4)</td>
<td>16 days (n=5)</td>
<td>Harris (1987)</td>
</tr>
<tr>
<td>Snares Islands</td>
<td>14 minutes 37 seconds (n=1)</td>
<td>6 seconds-35 minutes</td>
<td>11.5 (n=4)</td>
<td>21-22 days (n=?)</td>
<td>Best (1973)</td>
</tr>
</tbody>
</table>
Figure 7. Incubation stints of North Island fernbird at Omaha 2000/2001 and 2001/2002.
Figure 8. Average time between feeding visits of North Island fernbird at Omaha 2000/2001 and 2001/2002.
Figure 9. Incubation stints and time between feeding visits from eggs to fledging of North Island fernbird at Omaha 2000/2001 and 2001/2002.
1.7.4 Nestling diet

While no quantitative analysis of prey items was carried out, it was possible to identify prey items on a number of occasions. Spiders, particularly the common nursery web spider (*Dolomedes minor*) and its egg sacs, were the most frequently observed prey items. An adult fernbird was observed pecking into the side of a nursery web spider web, presumably to gain access to the adult spider or the egg sac. An adult fernbird was also observed eating marsh ribbonwood berries on one occasion. Fernbird were also observed feeding on Lepidopteran larvae and adults, Diptera, Orthoptera, Coleoptera and Blattodea.

All previous studies recorded feeding on the same orders seen at Omaha with the exception of Blattodea, which was only recorded being eaten at Omaha. Amphipods were seen been eaten in all studies except Omaha. Fernbird were recorded feeding on Odonata by Harris (1987) and Opiliones by Best (1973).

1.7.5 Chick Banding

Nine chicks from three clutches were banded over the 2001/2002 breeding season (Appendix 1). All clutches were banded when the chicks were approximately nine days old. Three nests containing chicks were not banded as the chicks were too old when the nests were located.

1.7.6 Nesting Success

Four nests successfully fledged chicks during the 2000/2001 monitoring period and seven nests failed due to predation and flooding. Six nests successfully fledged chicks during the 2001/2002 monitoring period and four nests failed due to predation and abandonment (Table 8). Most nests that were preyed on showed no sign of forced entry and the nest usually showed no sign of disturbance. The remains of an adult bird were found in one nest. The nesting material in one nest had been disturbed as a small fragment of eggshell was also found in the bottom of this nest. No predators were filmed at the fernbird nest which was video monitored however a stoat was filmed at a nearby banded rail nest.
Table 8. The outcome of monitored North Island fernbird nests at Omaha in the 2000/2001 and 2001/2002 breeding seasons.

<table>
<thead>
<tr>
<th>Breeding season</th>
<th>Total nests located</th>
<th>Successful nests</th>
<th>Eggs preyed on</th>
<th>Chicks preyed on</th>
<th>Nest flooded</th>
<th>Nest abandoned/eggs infertile</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000/2002</td>
<td>11</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>2001/2002</td>
<td>10</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Totals</td>
<td>21</td>
<td>10</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Table nine summarises the traditional method of calculating breeding success (nestlings fledged/number of eggs produced), apparent nesting success (successful nests/total nests found), and Stanley’s estimate of nesting success for the two fernbird breeding seasons at Omaha.


<table>
<thead>
<tr>
<th>Year</th>
<th>Breeding success</th>
<th>Apparent nesting success</th>
<th>Stanley’s estimate of nesting success</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000/2001</td>
<td>31%</td>
<td>36%</td>
<td>14% (95% confidence limits 2-61)</td>
</tr>
<tr>
<td>2001/2002</td>
<td>69%</td>
<td>60%</td>
<td>35% (2-92)</td>
</tr>
<tr>
<td>Combined</td>
<td>48%</td>
<td>48%</td>
<td>22% (2-78)</td>
</tr>
</tbody>
</table>

Elliot (1978) recorded two nest failures due to predation out of a total of eight monitored nests. Harris (1987) recorded nest failure due to predation, eggs not hatching, desertion at the nestling stage and flooding. More than half of all clutches observed by Best (1973) were infertile; others were broken during incubation, deserted or laid but not incubated. Nestling loss on the Snares Islands was caused by mutilation in the nest (possibly by parents), nest collapse (probably due to an incoming petrel), chilling, ruptured gut and unknown causes (Table 10).
Table 10. Causes of nest failure among fernbird studies.

<table>
<thead>
<tr>
<th>Location</th>
<th>Breeding success</th>
<th>Unsuccessful-predation</th>
<th>Unsuccessful-other</th>
<th>n</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Omaha</td>
<td>48%</td>
<td>73%</td>
<td>27%</td>
<td>11</td>
<td>This study</td>
</tr>
<tr>
<td>Lakes Waipori (Dunedin)</td>
<td>42%</td>
<td>39%</td>
<td>61%</td>
<td>46</td>
<td>Harris (1987)</td>
</tr>
<tr>
<td>Snares Islands</td>
<td>32%</td>
<td>-</td>
<td>40%</td>
<td>13</td>
<td>Best (1973)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>

1.7.7 Post Fledging Observations

Only one banded chick was observed post fledging. This bird, M-RY, has been seen approximately 800 metres from its natal territory three times, the last sighting been on the 26 of February 2002. This gives a minimum post-fledging survival time of 59 days.

1.7.8 Nest Parasites

Both adult mites and protonymphs of *Ornithonyssus bursa* were collected from six nests (Figure 10). An average of 34 adult mites (range 0-115) and 36 (0-139) protonymphs was collected from each nest. Adult and protonymph numbers peaked late December. Mite infestations did not appear to affect the outcome of nests. Of the two nests with the highest infestation one successfully fledged four chicks and the other was abandoned due to infertile eggs after at least 16 days of incubation.
1.7.9 Nest structure and construction

The nest site characteristics for 12 nests were measured (Table 11). Half of those nests measured were constructed in a discernable clump of vegetation, surrounded by other clumps within a contiguous reed bed. All other nests were located in contiguous reed beds. All nests were tightly woven into surrounding *Baumea juncea*, and cup shaped as is typical of many passerines. Nests were all well concealed with overhead cover but some became more exposed closer to fledging. Nests were constructed from reed stems, culms and sheaths from the base of reed tillers. Sixty seven percent of nests were lined with small grey, brown and white feathers. Duck (*Anas* spp.), pukeko (*Porphyrio porphyrio*) and harrier feathers were amongst those used to line nests. No fernbird feathers were detected in any nests. Four nests contained no feathers at all, six contained two or three feathers and two were heavily lined. One nest was extensively lined with *Baumea juncea* seed heads. One nest was located in *Baumea juncea* at the base of a manuka tree (approximately 2 metres high). Most of the other nests had a small (1-1.5 metre) flax, manuka or marsh ribbon wood located within 1.5 metres of the nest. In addition all nests had a small manuka located an average of 2.7± 0.45m (S.E.)
from the nest, which was used as a landing and departure point when coming to and from the nest. Second nests were recorded for two pairs. In both cases the second nests were constructed in similar locations, one 4.6 metres from the first nest, and the second four metres from the first nest.


<table>
<thead>
<tr>
<th>Measurement (mm)</th>
<th>n</th>
<th>Mean</th>
<th>Standard error</th>
<th>Coefficient of variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canopy height (from ground)</td>
<td>10</td>
<td>1231</td>
<td>45</td>
<td>11%</td>
</tr>
<tr>
<td>Rim to rim external</td>
<td>12</td>
<td>100</td>
<td>4</td>
<td>13%</td>
</tr>
<tr>
<td>Inside depth</td>
<td>12</td>
<td>65</td>
<td>3</td>
<td>14%</td>
</tr>
<tr>
<td>Rim to rim internal</td>
<td>12</td>
<td>74</td>
<td>4</td>
<td>17%</td>
</tr>
<tr>
<td>Outside depth</td>
<td>10</td>
<td>127</td>
<td>8</td>
<td>20%</td>
</tr>
<tr>
<td>Ground to rim of nest</td>
<td>10</td>
<td>285</td>
<td>23</td>
<td>25%</td>
</tr>
<tr>
<td>Perimeter of clump</td>
<td>6</td>
<td>2366</td>
<td>334</td>
<td>34%</td>
</tr>
<tr>
<td>Landing point</td>
<td>12</td>
<td>2743</td>
<td>452</td>
<td>57%</td>
</tr>
<tr>
<td>Ground to base of nest</td>
<td>12</td>
<td>145</td>
<td>27</td>
<td>65%</td>
</tr>
<tr>
<td>Distance to edge of clump</td>
<td>10</td>
<td>121</td>
<td>29</td>
<td>76%</td>
</tr>
<tr>
<td>Nearest other clump</td>
<td>7</td>
<td>737</td>
<td>218</td>
<td>78%</td>
</tr>
</tbody>
</table>

Highly significant differences in nest site characteristics are evident between fernbird studies (Table 12). A non-parametric multiple comparison with unequal sample sizes (Zar, 1999) showed significant differences in the ground to base measurements of nests at Omaha, Lakes Waipori, South Island (Harris, 1987) and Snares Islands (Best, 1973). Nests in all studies were cup shaped, and constructed from culms and leaves of available grasses, rushes and sedges and lined with varying amounts of feathers. Elliot (1978) found weka (Gallirallus australis), domestic hen (Gallus gallus), duck (Anas spp.) and goose (Anser anser) feathers from local farms and Harris (1987) found pukeko and Australasian bittern (Botaurus poiciloptilus) feathers in South Island fernbird nests. Best (1973) found sooty shearwater (Puffinus griseus), Antarctic tern (Sterna vittata) and mottled petrel feathers (Pterdroma inexpectata) in Snares Island fernbird nests. Blackburn (1967) found mottled petrel, weka and kakariki (Cyanoramphus spp.) feathers in Codfish Island fernbird nests and Guthrie-Smith (1914) found weka, harrier, pukeko, and goldfinch (Carduelis carduelis) feathers and
wool in Stewart Island fernbird nests. Elliot (1978) provides the sole record of fernbird feathers in a nest.

**Table 12.** Comparison of nest site characteristics of North, South and Snares Island fernbird.

<table>
<thead>
<tr>
<th>Nest Measurement (mm)</th>
<th>Omaha (Elliot, 1978)</th>
<th>South Island (Harris, 1987)</th>
<th>Snares Islands (Best, 1973)</th>
<th>Kruskal-Wallis (H)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canopy</td>
<td>1231±45</td>
<td>96±2</td>
<td>1284±45</td>
<td>H=13.83</td>
<td>P=0.0010</td>
</tr>
<tr>
<td>Ground to base</td>
<td>145±27</td>
<td>-</td>
<td>445±26</td>
<td>H=26.84</td>
<td>P=0.0000</td>
</tr>
<tr>
<td>Rim to rim external</td>
<td>100±4</td>
<td>114±5</td>
<td>111±0.6</td>
<td>H=14.15</td>
<td>P=0.0008</td>
</tr>
<tr>
<td>Rim to rim internal</td>
<td>75±4</td>
<td>61±2</td>
<td>67±0.5</td>
<td>H=12.95</td>
<td>P=0.0048</td>
</tr>
<tr>
<td>Ground to rim</td>
<td>285±23</td>
<td>-</td>
<td>541±26</td>
<td>H=14.71</td>
<td>P=0.0001</td>
</tr>
<tr>
<td>Inside depth</td>
<td>65±3</td>
<td>-</td>
<td>62±0.6</td>
<td>H=34.72</td>
<td>P=0.0000</td>
</tr>
<tr>
<td>Outside depth</td>
<td>127±8</td>
<td>-</td>
<td>96±0.6</td>
<td>H=8.76</td>
<td>P=0.0031</td>
</tr>
</tbody>
</table>

**1.8 Discussion**

**1.8.1 Territory size and characteristics**

Most discussions of territorial behaviour incorporate Noble’s (1939) definition of any defended area. Wittenberger (1981) stated that territorial behaviour is difficult to define, and occupies a continuum from restriction of some behaviours or activities to a certain area (such as a nest site), through to exclusive possession of an area in which all activities occur. Territorial behaviour occurs as a result of competition for resources. Individuals compete for resources such as food, mates, nest sites, increased security of parentage and protection from predation and disease, through spacing of individuals and familiarity with an area. (Krebs & Davies, 1993; Newton, 1996; Wittenberger, 1981). Krebs and Davies (1993) state that territorial behaviour will only be favoured by selection when the benefits are greater than the costs. When resources and intruders are abundant, or if risks associated with territory defence are high (such as increased predation risk), then it may not be worth defending a particular resource. Brown (1964) termed this economic defensibility. Optimal territory size varies between species in relation to the resources defended. In colonial seabirds the defended territory may comprise the nest site and a small buffer zone equating an individual birds’ reach to neighbouring nest sites. Fernbird and other species occupying exclusive multiple use territories defend larger areas. In such species, territory size tends to show a negative
correlation with food abundance. Krebs and Davies (1993) state that optimal territory size is that which maximises energy gains as shown in manipulation experiments with hummingbirds by Carpenter (1983). In some cases territory size may change in response to fluctuating food resources.

Territory size varied significantly between fernbird populations. Observed differences may be due to variation in resource availability (such as food or suitable cover/vegetation) between sites, or some other limiting factor such as predation.

Barlow (1983) studied fernbird in very similar habitat to Omaha at an estuary near Invercargill. Territories were arranged in a similar linear pattern, however the Invercargill territories were approximately half the size. It is difficult to account for this marked difference in territory size. Pairs occupied all available habitat at Omaha and there was no apparent shortage of suitable nest sites. Barlow (1983) did not provide any details about predation, but did mention the loss of eggs and nestlings over the course of her study. In addition, South Island fernbird are larger than North Island fernbird and would be expected to hold larger, not smaller, territories (Schoener, 1968). One possible explanation could be differences in productivity between southern and northern saltmarshes. Productivity differences between north and south may be related to a general trend of increasing productivity, with longer summer days in higher latitudes. Alternatively, invasive species may be altering the ecological dynamics of the northern saltmarsh system. Support for the latter hypothesis comes from the abundance of Asian paper wasps (*Polistes chinensis antennalis*) at the Omaha saltmarsh (pers. obs.). This wasp has become widespread throughout the upper North Island since arriving in New Zealand in the late 1970s (Clapperton, 1999). In a study conducted in short shrubland habitat at Lake Ohia, Northland, Clapperton (1999) detected 210 wasp nests per hectare. Clapperton (1999) estimated that these wasps consume 478,726 prey items per hectare per season or 957.4 grams of biomass per hectare per season (February-May). Williams (1987) estimated the daily energy requirements of savannah sparrows (*Passerculas sandwichensis*) during a study examining field metabolism. Fernbird are behaviourally and morphologically similar to savannah sparrows and probably have similar energy requirements. Based on the estimates for Savannah sparrows a pair of adult fernbird would require 38.6 grams of invertebrates per day or 4632 grams over the period studied by Clapperton (1999). If
they had a brood of chicks over this period they would require an additional 349 grams of fresh invertebrates. Clapperton (1999) found that Asian paper wasps consumed Lepidoptera, Diptera, Coleoptera, Homoptera, Hymenoptera and Arachnida. Considerable prey overlap may exist with fernbird. Introduced *Vespula* wasps are known to have a significant impact on forest ecosystems in New Zealand (Beggs, 2001). It is conceivable that a new invertebrate predator could have a negative impact upon native invertebrates, and the vertebrates that depend on them and disrupt ecosystem function in shrubland and saltmarsh habitats (Clapperton, 1999). If competition with Asian paper wasps for invertebrates is occurring, North Island fernbird may require larger territories to obtain food, particularly when feeding young. Further studies are needed to verify this hypothesis.

Breeding fernbird are strongly territorial, and appear to occupy exclusive territories year round (Barlow, 1983; Harris 1987; pers. obs.). Fifty-six of 69 sightings of banded birds made by Barlow (1983) were within known territories. Best (1973) and Andrews (1995) found that territorial boundaries often followed landscape features such as ditches and tracks. There were only two territories at Omaha where this was obvious, where a small creek divided two territories. When luring a bird to the edge of a territory, individuals would often stop following at a certain point. They would continue to call and chitter in response to the recorded calls, but would not follow. Best (1973) observed a similar pattern, where birds seemed to be at the limits of their territories.

There is little consensus in the literature indicating fernbird preference for particular vegetation associations. However, fernbird show a preference for a particular habitat structure, a dense understorey with an uneven vegetation profile broken by emergent shrubs and trees (Andrews, 1995; Barlow, 1983; Best, 1979; Blackburn, 1967; Elliot, 1978; Harris, 1987). Andrews (1995) found no significant differences in vegetation height and profile, when comparing a saltmarsh and a freshwater wetland inhabited by fernbird. Most observations of fernbird, and all nests located during this study, were in the thin band of emergent vegetation between the reed beds and the manuka forest. This has a similar structure to that observed in other studies.

In contrast Best (1973) suggested somewhat more plasticity in habitat preferences and that local conditions dictate the habitat fernbird occupy. He cited the Snares Islands
and small islands off Stewart Island where fernbird inhabit low forest. This habitat plasticity may be due to vacant niches on offshore islands with depauperate passerine faunas, and an absence of introduced predators. Historical records from the North and South Island show that fernbird have always been associated with those habitats described by contemporary workers (M'Lean, 1905; Turbott, 1961).

Best (1979) suggested fernbird prefer habitats which have elevated calling posts for territorial advertisement and detection of intruders. Barlow (1983) rarely observed birds calling from elevated positions, but suggested that habitat structure may be selected for the provision of “stepping stones” or “signposts” that lead to nest sites. Harris (1987) stated that habitat selection is related to the male’s ability to see and be seen and heard, to monitor the activities of conspecifics with minimal demands on energy, and to maintain the largest areas possible, thereby reducing the chances of predation and maximising breeding output. Observations at Omaha support all these hypotheses. Birds were seen to call from elevated sites, and to monitor the activities of intruders from such points. Emergent trees and shrubs were also used as landing points for activity centred on nests.

A preference for a particular habitat type should be associated with a higher success rate in that habitat (either lower adult mortality or higher breeding success). Harris (1987) identified two distinct vegetation zones within his study area, that he considered preferred habitat due to long-term residency (2+ seasons), and the production of significantly more young than on adjacent sub-optimal habitat. This could be confounded by the age and experience of the fernbird inhabiting the respective habitats.

1.8.2 Territorial defence behaviour

The defence strategies observed at Omaha (calling, chittering, wing quivering, head bobbing, chasing, displaying and occasional physical combat) have all been observed in other studies (Andrews, 1995; Barlow, 1983; Best, 1973; Elliot, 1978; Harris, 1987). Both Elliot (1978) and Barlow (1983) observed territories where significant portions of the boundaries did not require defence, due to the absence of adjacent territories. A similar pattern exists at Omaha. Best (1973) stated that territorial defence is evenly divided between the sexes. Other studies (Barlow, 1983; Elliot, 1978; Harris, 1987) and observations at Omaha (male identified as first bird calling when duetting) suggest that the male may contribute more to defence. Elliot (1978) did not consider fernbird able
to distinguish between the calls of their mate and other birds, while Best (1973) thought that they could distinguish between mates, juveniles, foreign juveniles, intruding territorial birds and possibly intruding non-territorial birds. No support for either hypothesis was gained from observations at Omaha.

### 1.8.3 Life histories and nesting behaviour

The observed breeding season at Omaha was a minimum, and nests were very likely to have started earlier than mid-October. North Island fernbird have been observed feeding nestlings in late September on Tiritiri Matangi (Chapter 2). It is also possible that some late nests were missed. The short breeding season observed by Best (1973) on the Snares Islands may reflect the shorter season in higher latitudes.

The most frequently reported modal clutch size for 25 New Zealand passerine species (subspecies included) is three, with a range of one to six (Heather & Robertson, 1996). New Zealand fernbird fit well within this range. The factors determining variation in clutch size among fernbird studies are not immediately apparent but may be due to resource limitations or predation. Harris (1987) observed the largest average clutch size and largest average territory of all the fernbird studies and he considered that his South Island study population was near carrying capacity. Best (1973) considered density dependent factors, primarily a limited number of available territories, was a constraining factor on Snares Island fernbird, as food was abundant and predators absent. Best (1973) and Harris (1987) detected an increase in average clutch sizes of Snares and South Island fernbird as the breeding season progressed, in contrast to the usual decrease in clutch size late in the breeding season in many Northern Hemisphere species (Rowe et al., 1994).

The longer mean incubation stint recorded at Omaha is probably a reflection of larger sample size (n=11 nests). Best (1973), Elliot (1978), Harris (1987) and observations at Omaha show that incubation and feeding is shared by the sexes. Harris (1987) observed a significantly lower feeding rate in broods of 2 or 3 chicks than those with 5 chicks. All studies and observations at Omaha show an increase in feeding rate from about five days of age, an increase in the size of food items as chicks mature, and removal of faecal sacs by adults after feeding. Harris (1987) observed adults eating faecal sacs. Best (1973) recorded a decline in nest sanitation closer to fledging. Some nests at Omaha had a build up of faecal matter after chicks had fledged, while others
remained very clean. Elliot (1978) observed that single prey items were usually delivered to the nest. Similar observations were made at Omaha. Best (1973) stated that feeding rates were extremely variable, with a peak in the morning (0500-0600 hrs), a lull in the afternoon (1500-1600 hrs), and a second peak late in the evening. Fernbird are opportunistic insectivores, and observed feeding in each study probably reflects local invertebrate abundance.

No nests were found prior to laying so it is not possible to confirm M'Lean’s (1905) observation of a 12.5 day incubation period for North Island fernbird. Other observers have had similar difficulties locating nests prior to laying. Harris (1987) found three nests, from which an average incubation period of 14 days was calculated for the South Island fernbird. Best (1973) calculated a 16-day incubation period for the Snares Island fernbird from seven nests. The increasing length of the incubation period with increasing latitude may be due to the larger size of adults and eggs of southern subspecies, and the cooler environments they inhabit.

An increase in the nestling phase was expected with increasing latitude as has been observed in incubation period. This pattern is only evident when North and South Island fernbird are compared with Snares Island fernbird. There is no difference in the nestling period between North and South Island fernbird. Different nestling periods could be due to fluctuating food resources between study sites. However, the nestling times observed in this and other studies come from very small samples, and the observed differences could simply be due to natural variation.

Lack (1968) stated that observed clutch size was that which resulted in the greatest number of young surviving to fledging. Lack (1968) considered that seasonal, annual, regional and local variations in clutch size were adaptive responses to food resources. He considered that the number of broods reared each year depended primarily on the duration of abundant and suitable food resources for feeding young. Many studies cite density-dependent factors as a prime determinate of clutch size (Booth, 2000; Newton, 1996). Newton (1996) found evidence for density dependent clutch size in 8 of 20 studies. The 12 studies that found no evidence of density-dependent clutch size included studies on four species of Sylviidae. Booth (2000) found evidence for density dependent clutch size in 22 of 57 reviewed studies, and suggested that density-dependent clutch size was more frequently observed in resident species than in migrant
species. Based on this review it was suggested that migrant species might be less able to predict density later in the season however there was no significant correlation between the magnitude of the clutch size as the season progressed and population density. Booth (2000) state that density dependence is driven by competition for resources; consequently the amount of food nestlings receive is just one of the density dependent factors causing a decline in clutch size as the breeding season progresses.

Environmental factors other than food resources may affect clutch size. Patten (1999) found rainfall during egg formation to be a good predictor of clutch size in California gnatcatchers (*Polioptila californica*). Beissinger (1996) stated that a limited supply of nest sites may favour larger clutch sizes. In a study of lessor black-backed gulls (*Larus fuscus*) Monaghan *et al.* (1995) hypothesised that the capacity of female birds to produce high quality eggs may limit clutch size, as the viability of chicks from additional eggs was greatly reduced. This is probably also resource related. Many studies have found an increase in clutch size with an increase in latitude (Soler and Soler, 1992). Soler and Soler (1992) found a reduction in clutch size of jackdaws (*Corvus monedula*) with increasing latitude, but an increase in egg size. Rowe *et al.* (1994) stated that a seasonal decline in clutch size is typical of many bird populations, and may result from inexperienced birds breeding later, declining food supplies as the season progresses, or a decline in the value of late season offspring.

All the studies cited in the above discussion were conducted in the Northern Hemisphere. Average clutch sizes in both indigenous and introduced species are lower in the Southern Hemisphere, when compared with the same or similar species in the Northern Hemisphere, and southern species tend to show reduced adult mortality and extended asynchronous breeding seasons (Ghalambor *et al.*, 2001; Martin, 2000; Niethammer, 1970; Yom-Tov *et al.*, 1994). The relationship remains after controlling for phylogeny and ecology. There are a lack of data on life history strategies in Southern Hemisphere species however significant differences are emerging (Magrath *et al.*, 2000; Peach *et al.*, 2001). Armstrong and Siegfried (1991) found no significant difference in the distribution of clutch size between months of hatching in the Cape shoveler (*Anas smithii*) in South Africa. This result is a complete contrast to all Northern Hemisphere *Anas* studies they examined.
Skutch (1949) hypothesised that predation constrained clutch size in Southern Hemisphere species. Martin et al. (2000) tested this hypothesis by comparing nest visitation of Northern and Southern hemisphere species. Nest visits during incubation and nestling stages increases the risk of detection by predators. They found that nest predation constrained the rate of food delivery in both North and South American species. Martin et al. (2000) found that there was a positive correlation between clutch size and food delivery rate and a stronger negative correlation between clutch size and nest predation rate. Martin et al. (2000) found partial support for Skutch’s (1949) hypothesis. Nest predation constrained clutch size within hemispheres but did not explain variation between hemispheres.

A refinement of Skutch’s (1949) predation hypothesis can be applied to risk-taking by parents in relation to clutch size and reproductive strategies. Life history theory predicts that parents with many offspring, and a low probability of future survival, will tolerate greater risk to themselves but not their offspring. The fitness value of the current brood is high, while the probability of surviving to breed again is low (Ghalambor & Martin, 2001). Parents with less offspring, but a higher probability of future survival, will tolerate less risk to themselves. The fitness value of current offspring is low relative to the probability of surviving to breed again (Ghalambor & Martin, 2001). Ghalambor and Martin (2001) tested this theory by manipulating predation risk at the nest to parents versus offspring. Northern Hemisphere species reduced nest visits significantly more than Southern Hemisphere species, when presented with a potential nest predator. When presented with a potential adult predator, Southern Hemisphere species reduced nest visits significantly more than Northern Hemisphere species. Southern Hemisphere species had consistently lower clutch sizes and higher adult survival than Northern Hemisphere species. This relationship held when life history patterns of individual species were examined. A significant positive correlation between the magnitude of response to predators of young and clutch size, and a significant negative correlation between the magnitude of response to adult predators and clutch size, held regardless of hemisphere.

1.8.4 Methods used to compare breeding success

Various methods of reporting nesting and breeding success are used in the literature. Breeding success is often calculated by dividing the number of nestlings successfully
fledged by the number of eggs produced. Apparent nesting success is calculated by dividing the number of nests that successfully fledge young by the number of nests found. Both methods tend to overestimate success unless monitoring of nests is extremely intensive (Armstrong *et al.*, 2002). Mayfield (1961) developed an alternative method of estimating nesting success calculated from the daily survival probability of a nest. Johnson (1979) and Hensler (1981) later refined the Mayfield method. Numerous studies have shown the Mayfield method to be superior to traditional and apparent methods (Beintema, 1992). However, the Mayfield method assumes that daily survival is constant, and often requires an estimate of days to nest failure if monitoring is not intense (Armstrong *et al.*, 2002). Stanley (2000) developed an alternative method for calculating nesting success without these assumptions. Nesting success at Omaha was calculated using two traditional methods and the Stanley method, after Armstrong (2002). The Stanley method yielded an estimate of nest success (22%) that was much lower than the apparent (48%) and breeding success estimates (50%). Monitoring at Omaha was intensive and attempted to detect all nesting attempts, however it is quite likely that nests, particularly those at the laying and early incubation stages, were missed. However the 95% confidence intervals (2-78%) associated with the Stanley estimate are very large and detract from the value of the estimate. Armstrong (2002) stated that a minimum of 35 nests is required for a precise estimate of nesting success. Only 21 nests were found at Omaha. Estimation of nesting success at Omaha was also complicated by the fact that the full breeding season was not monitored. Therefore it is not possible to accurately estimate nesting success at Omaha, other than to suggest the true value lies somewhere between the high and low calculated values and that most losses are due to predation. Comparisons of nesting success at Omaha with other studies can only be made using the reported breeding success estimates of 42% (Harris, 1987) and 32% (Best, 1973). These figures can be regarded as over-estimates of nesting success. Harris (1987) also reported a Mayfield estimate of nesting success (31%).

Predation accounted for 73% of nest failures (n=11 nests) observed at Omaha. The level of predation observed prompted further investigation, including an artificial nest experiment (Chapter 2). Unlike other studies, Best (1973) was able to closely follow fledglings on the Snares Islands. Of 37 fledglings, only one died in the 40 days following fledging. The one fledgling that died was underweight and not very alert.
Best (1973) was surprised that it even fledged. The extremely high survival on the Snares was attributed to an abundance of food and shelter and a lack of predators.

1.8.5 Post fledging care and juvenile dispersal

No post fledging care was observed at Omaha, however observations of South Island and Snares Island fernbird suggest that post-fledging care is likely. In South Island fernbird Elliot (1978) observed adults feeding chicks 11 days after fledging and adults with chicks 24 days after fledging. Harris (1987) considered post-fledging care to be at least two weeks, but did not refer to any observations. Best (1973) was able to observe post fledging care on the Snares Islands, the maximum record being of a female feeding a chick 32 days after fledging. Best (1973) stated that adults tended specific young. In broods of one, parents tended the chick, in broods of two each parent took a single chick and in broods of three the male fed two chicks and the female one. No attempt to drive chicks away was observed by Best (1973) and re-nesting was not attempted until chicks ceased begging for food.

Only one of the nine banded juveniles was observed after the 2001/2002 breeding season. Both Harris (1987) and Elliot (1978) recorded few observations of juvenile birds following fledging. Barlow (1983) Elliot (1978) and Best (1973) all stated that juveniles were often ignored by adults when passing through established territories, unless they were calling. Juveniles were not readily observed at Omaha, however a young calling bird was observed being chased from a territory by the resident pair. Harris (1987) and Barlow (1983) suggested that areas of habitat adjacent to breeding territories might be important for non-territorial adults and dispersing juveniles. A similar pattern may exist at Omaha. Parts of the manuka and kahikatea forest may act as refugia for birds waiting for a territorial vacancy. Newton (1996) stated that secondary areas (such as the kahikatea forest), provide habitat for surplus individuals and a pool of potential immigrants to fill territorial vacancies. Numerous removal experiments have shown that territorial vacancies are rapidly filled (Brown, 1969). This pattern was evident at Orewa during the fernbird translocation in 2001 and 2002 (Chapter 3).
1.8.6 Nest parasites

Fernbird nests were infested to varying degrees with the mesostigmatic dermanyssid mite *Ornithonyssus bursa*. All nests sampled contained adults, protonymphs or both life stages. *O. bursa* has been detected on starlings (*Sturnus vulgaris*), domestic fowl, sparrows (*Passer domesticus*), song thrushes (*Turdus philomelos*), blackbirds (*Turdus merula*), hedge sparrows (*Prunella modularis*), mynahs (*Acidothereis tristis*), silvereyes (*Zosterops lateralis*), grey warblers (*Gerygone igata*), North Island robins (*Petroica australis longipes*), North Island saddleback (*Philesturnus carunculatus rufusater*) and people in New Zealand. It has also been found on birds and people in many other countries (Gill, 1983; Moller, 1991a; Petersen, 1979; Powlesland, 1977, 1978). *O. bursa* is a continuous ectoparasite, requiring periodic blood meals from a host species. Despite a parasite load of up to 50 000 mites per nest box Powlesland (1977) found no significant effect on growth weight, weight at 15 days, mortality, blood characteristics or lipid stores of starling nestlings, when compared with nestlings from uninfested nests. Powlesland (1977) did not consider *O. bursa* a significant mortality factor for starlings, but stated that chicks and fledglings with large mite burdens may be more vulnerable to other stresses. Moller (Moller, 1991a, b, c; 1991d, 1992, 1993, 1994, 2000) found increased reproductive costs for barn swallows (*Hirundo rustica*) as a result of *O. bursa* nest infestation, including increased preening rate of nestlings, reduced song output in second clutch swallows, reduced food provisioning of single brood breeders, a reduction in most productive clutch size and a significant effect on phenotypic characteristics (tail length in male swallows) and sexual selection. Stamp and Brunton (2002 in press) found no effects due to *O. bursa* mites on nesting success of North Island saddleback. *O. bursa* has not been associated with fernbird before, although Best (1973) recorded 1698 flea larvae (species not stated) in one nest and 129 in another. The effects of *O. bursa* on fernbird at Omaha are unknown, however bite marks were evident on chicks in one heavily infested nest when the young were banded (9 days of age). The impact of mite infestation may vary with season, weather conditions and other unknown factors. Petersen (1979) stated that *O. bursa* overwinters ectoparasitically on starlings, being present on 25% of the adult population at the beginning of the breeding season. Powlesland (1977) found 30% of nests were infested with *O. bursa* early in the breeding season, and stated that visits from non-breeding birds probably spread mites from nest to nest. No visits by non-breeding
adults or other species was observed at any fernbird nest. It is not known how mites spread between nests, or if they occur on adults between breeding seasons.

1.8.7 Nest placement and construction

Observed differences in nest placement and measurements are probably due to different vegetation associations and the increase in body size and weight of southern subspecies of fernbird. Nests at Omaha are probably significantly lower than in other studies, as they were all constructed in *Baumea juncea*. Nests could not be physically built higher in this salt rush, as structural support would be reduced and the nest would be more exposed from above. Predation at Omaha was higher than at other studies, and the low placement of nests could be a contributing factor. All described nests were well concealed in dense clumps of vegetation. Best (1973) stated that nest sites were generally chosen to provide cover and structural support. Most of the nests found by Best (1973) and at Omaha were built in single vegetation associations, while those of Elliot (1978) and Harris (1987) were built in vegetation associations. Feather lining was extremely variable in all studies and reflected local species assemblages. Best (1973) recorded the most elaborate nest construction of all fernbird studies, some nests having saucer or ring shaped bases and hoods built over the top of the nest. Harris (1987) recorded some nests with ring shaped bases. No similar observations were made by Elliot (1978) or at Omaha. Observations by Best (1973) and Harris (1987) showed nest construction took approximately three days and was carried out by both sexes.

1.9 Conclusions

The habitat characteristics and territorial defence strategies of different fernbird populations were similar throughout New Zealand. However, significant differences in territory size exist between these different fernbird populations. The largest difference in observed territory size was between Omaha, (Northland) and Invercargill, (Southland). The factors responsible for this difference in territory size are not obvious, but I hypothesis that they are related to predation and/or resource availability. In particular, I suggest that the role of Asian paper wasps on the availability of invertebrate resources be further investigated.

Average clutch size was significantly different among populations of New Zealand fernbird, the largest clutch in the South Island, and the smallest on the Snares Islands.
The factors determining fernbird clutch size were not identified in this or any other study. Egg, nestling and breeding behaviour characteristics were very similar in all the studies.

An accurate assessment of nesting success was not achieved, as monitoring did not occur over a full season, and the small number (20) of nests detected was not sufficient for accurate use of Stanley’s estimate of nest success. However the indications are that nesting success is low. Predation was responsible for most observed losses at Omaha, and appears to be greater than that observed in other studies of mainland fernbird (Elliot, 1978; Harris, 1987). Similar limitations to estimating nesting success apply to determining the impact of predators, however further study is warranted (Chapter 2).

Fernbird nests were infested with *Ornithonyssus bursa*. The effect of *O. bursa* on fernbird is not known. This is the first record of *O. bursa* been associated with New Zealand fernbird.

Fernbird generally construct cup-shaped nests, although Best (1973) recorded more elaborate nest construction in the Snares Islands. Significant differences in nest measurements between fernbird studies are probably due to different vegetation assemblages and the larger size of southern subspecies. Nests at Omaha were significantly lower to the ground than in other studies. This may be a contributing factor to the high level of predation observed at Omaha.

The fact that fernbird have persisted on the mainland, despite extensive habitat loss and predation from introduced predators, suggests that they can withstand some landscape modifications. In the absence of long-term studies, particularly with regards to recruitment, adult survival and dispersal, it is not possible to make accurate predictions about population trends. Small isolated populations are generally more vulnerable to extinction, particularly when barriers to recolonisation are significant (Caughley & Gunn, 1996). There were no obvious territorial vacancies at Omaha, however fernbird may simply increase the size of territories at low population densities, effectively masking any population decline. The high level of predation observed, and the low clutch size, could be having significant long-term impacts on Omaha fernbird. This study has documented the number of breeding pairs present at Omaha and given an indication of productivity. Such data should be useful in establishing long-term trends.
The relative accessibility of the Omaha population makes it suitable for a long-term population study. The long term prospects and management of mainland fernbird are discussed in Chapter Five.

1.10 Acknowledgements

My supervisor, Dianne Brunton, provided guidance and support throughout this study. Sandra Anderson and Tim Lovegrove provided valuable advice on field techniques. Allen Heath of the Wallaceville Animal Research Centre identified the mites found in fernbird nests. The Auckland Regional Council provided much appreciated funding for this research. My good friend Rob Mouldey lives close to the Omaha saltmarsh, and provided me with a place to sleep over both breeding seasons and company on much needed fishing and surfing excursions after the long hours spent in the marsh watching the little brown birds. Tim Lovegrove and Michael Anderson provided useful comments on this chapter.

1.11 References


Skutch, A.F. (1949) Do tropical birds rear as many young as they can nourish? Ibis, 91, 430-455.


1.12 Appendices

Appendix 1. Fernbird young banded at Omaha during the 2001/2002 breeding season.

<table>
<thead>
<tr>
<th>Date</th>
<th>Band combination (K=Black)</th>
<th>Band number</th>
<th>Age (days)</th>
<th>Weight (grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>02/12/2001</td>
<td>M-KR</td>
<td>B88054</td>
<td>9 (approx.)</td>
<td>17.75</td>
</tr>
<tr>
<td>02/12/2001</td>
<td>M-KW</td>
<td>B88055</td>
<td>9 (approx.)</td>
<td>15.75</td>
</tr>
<tr>
<td>02/12/2001</td>
<td>M-KG</td>
<td>B88056</td>
<td>9 (approx.)</td>
<td>16.5</td>
</tr>
<tr>
<td>19/12/2001</td>
<td>M-RB</td>
<td>B88057</td>
<td>8</td>
<td>15.75</td>
</tr>
<tr>
<td>19/12/2001</td>
<td>M-RY</td>
<td>B88087</td>
<td>8</td>
<td>15.5</td>
</tr>
<tr>
<td>19/12/2001</td>
<td>M-RG</td>
<td>B88060</td>
<td>8</td>
<td>15.75</td>
</tr>
<tr>
<td>19/12/2001</td>
<td>M-RW</td>
<td>B88061</td>
<td>8</td>
<td>15.25</td>
</tr>
<tr>
<td>15/02/2002</td>
<td>M-WY</td>
<td>B88090</td>
<td>10 (approx.)</td>
<td>16.25</td>
</tr>
<tr>
<td>15/02/2002</td>
<td>M-WG</td>
<td>B88059</td>
<td>10 (approx.)</td>
<td>14.5</td>
</tr>
</tbody>
</table>
2 Predation of North Island fernbird (*Bowdleria punctata vealeae*): An artificial nest experiment

**Abstract** – An investigation into nest losses, and the effects of nest monitoring on North Island fernbird (*Bowdleria punctata vealeae*) was carried out in saltmarsh habitat. Predators responsible were inferred from a combination of direct observation, video monitoring of nests, monitoring of local predator assemblages, characteristic sign left in nests that were preyed on, and an artificial nest experiment. The artificial nest experiment allowed hypotheses concerning the impact of human visitation and spatial and temporal effects on nest predation to be tested. No direct predation was observed or filmed at fernbird nests, however a stoat was filmed at a banded rail (*Rallus philippensis*) nest which had been preyed on before filming began. The sign at predated nests was characteristic of that attributed to mustelids in other studies, and it is likely they are responsible for much of the predation observed. Further support for this conclusion is gained from the virtual absence of rats in the marsh, and minimal disturbance at nests that were preyed on, which excludes most avian predators. Predation at Omaha was not significantly different from other mainland studies, however the primary nest predators were. In contrast with Omaha, other mainland studies considered native avian predators to be responsible for most predation. Mice were extremely abundant in the saltmarsh and were responsible for 78% of predation at artificial nests. The artificial nest experiment detected no significant effect due to human visits, and only weak spatial and temporal patterns. A weak effect due to location was investigated, and this revealed a significant effect due to location in February. There was no significant difference between the level of predation at natural and artificial nests. It is not possible to draw definitive conclusions about the predation rate on natural nests from an artificial nest study. However, artificial nests are useful for generating new hypotheses about predation. Natural nests are difficult to detect during incubation and the results suggest that mice are potentially important predators at the laying and/or incubation stage.
2.1 Introduction

There are approximately 10 000 species of birds and nine percent of these species are nearing threatened status, seven percent are considered vulnerable to extinction and four percent are in immediate danger of extinction (Ballie & Groombridge, 1996). Only a small percentage of the world’s terrestrial and freshwater birds occur on oceanic islands, yet 93 percent of the 93 species and 83 subspecies that have become extinct since 1600 were island forms. Today more than half of all endangered birds occur on islands (King, 1985).

The endangerment and extinction of bird species is caused by a huge variety of human-induced disturbances. The many causes of endangerment and extinction rarely occur in isolation, providing additional challenges for researchers (Marzluff & Sallabanks, 1998). Habitat destruction and fragmentation has immediate impacts, through direct loss of birds as well as long term indirect impacts such as increased risk of predation, competitors, brood parasites and disease, and reduced access to resources such as food and nest sites (Marzluff & Sallabanks, 1998; Newton, 1996). Impacts due to environmental pollutants have also been well documented, and additional future impacts are likely due to the effects of ozone depletion and global warming (James, 1998). Habitat loss and deterioration has been the major cause of endangerment and extinction for island and continental species, however the impact of introduced predators, particularly rats (*Rattus spp.*) and cats (*Felis catus*), has been more profound for island species (King, 1985).

2.1.1 Predation of the New Zealand avifauna

Approximately 80 million years of oceanic isolation from all other landmasses has led to the development of a highly specialised and unique flora and fauna in New Zealand (King, 1998). The colonisation of the New Zealand landmass by humans has had a catastrophic impact on all indigenous ecosystems. All taxonomic classes have suffered huge declines. Holdaway (1989) has documented a decline of 40-50% of the avifauna, at least 50% of the frog fauna and unknown numbers of lizard and invertebrate species in the 1000 years since first human contact. Caughley (1989) provided evidence for a “…massive rearrangement of the avifauna after AD 1000”. The ultimate causes of decline are not always apparent and have doubtless varied for different species. Habitat clearance and predation by introduced mammals (including humans) has probably had
the most impact, and predation is seen as the most pervasive in effect today. Other factors such as novel diseases and competition with introduced species may also have had severe impacts (Veltman, 1996).

2.1.2 Predation of the New Zealand fernbird

Buller (in Turbott, 1961) considered fernbird to be one of New Zealand’s most widespread birds. He reported them from fernland, raupo beds and low-lying flats throughout the North and South Islands. Fernbird disappeared from most of the lower North Island and eastern South Island in the late 1800s, following extensive land clearance and swamp drainage for agricultural purposes (Heather & Robertson, 1996).

Fernbird became extinct on Herekopare Island following the introduction of cats (Fitzgerald & Veitch, 1985) and on Big South Cape Island during a ship rat (Rattus rattus) irruption in 1964 (Bell, 1976). Lovegrove and Walter (1994) cited anecdotal evidence, which suggests that fernbird have become rare, and in some cases disappeared from lowland and upland scrub sites.

Lovegrove (1992) conducted an analysis of characteristics of New Zealand birds that make them susceptible to mammalian predation. The following features were examined; feeding height, nest height, flying ability, nest site, roost site, weight, site of extant or last population and IUCN Red Data Book status.

Birds in the extinct and threatened categories were more likely to feed and nest on the ground, even when flightless species were excluded from analysis. Species less than 500 grams have had an increased risk of predation since 1700. Fernbird nest and feed on, or close to the ground, are less than 500 grams and are listed as vulnerable in the red data book (Lovegrove, 1992).

A pilot study conducted over the 2000/2001 breeding season, indicated a high level of predation within a population of fernbird occupying saltmarsh habitat on the Whangateau Harbour, New Zealand (Chapter 1). The negative impacts of introduced mammals on indigenous species have been well documented. Saddleback (Philesturnus carunculatus) and hihi (Notiomystis cincta) are among a number of species now confined to offshore islands due to their inability to persist on the mainland in the presence of mammalian predators (Heather & Robertson, 1996). Species such as kaka
(Nestor meridionalis) and kiwi (Apteryx spp.) still exist on the mainland but are in decline, again primarily because of introduced predators (Heather & Robertson, 1996). It is one objective of this study to attempt to establish the impacts and identity of predators on fernbird breeding success.

2.1.3 Identifying nest predators

A variety of methods have been applied to identify nest predators. These include:

1. Direct observation.

2. Inference based on the presence of known nest predators.

3. Inference based on remains in predated nests.

4. Inference based on artificial nest trials and experiments.

5. Video monitoring of active nests.

Direct observations of predation very rarely occur (Maier & Degraaf, 2000). Some studies have inferred predation based on local predator assemblages, characteristic remains in nests that have been preyed on, or a combination of the two (Flack & Lloyd, 1978; Major, 1991; Moors, 1983). This method is limited when a large variety of potential predators are present and can be further complicated by the behaviour of birds after their nests have been preyed on (Lariviere, 1999). Many species will instinctively remove eggshell from a nest whether it is from a hatched egg or one that has been preyed on (Brown et al., 1998).

Finding enough natural nests for a predation study can be both time consuming and difficult. Some researchers have attempted to circumvent these problems by using artificial nests as an analogue for a study species, or in some cases, a suite of species. Inferences about predation are made based on the results of such trials and experiments. Artificial nest studies have the additional advantages of providing adequate sample sizes for statistical analyses, and the ability to carry out experimental treatments that would be difficult or unethical with natural nests (Major & Kendal, 1996). The primary disadvantage is that it is impossible to fully replicate a natural nest and all its associated cues (Guyn & Clark, 1997). Rangen et al. (2000) and Major et al. (1996) recommend that artificial nests and eggs should mimic the study species as closely as possible in
order to obtain valid results. Despite the obvious limitations, artificial nests have been used in many theoretical and applied studies examining ecological theory concerning edge effect (Eriksson et al., 2001), forest fragmentation (Carlson & Hartman, 2001) and the effects of researcher visits on nest predation (Donalty & Henke, 2001).

Video monitoring equipment is becoming increasingly compact, affordable and reliable. It has been extremely useful in the management of many species both as a means of recording nesting behaviour, and predation (Brown et al., 1998; Smith, 1993). The usefulness of the technique depends on the nesting habits of the study species. Arboreal open cup nesting species, such as robins (Petroica australis) and tomtits (Petroica macrocephala) require little or no modification of the nest site to monitor the nest. Nest sites that are well concealed, such as fernbird, may require modification to monitor the nest effectively. Modification of a nest site may increase the risk of predation, thereby reducing the usefulness of this technique for some species.

2.2 Aims

The aim of this study was to identify the primary nest predators of fernbird in the Omaha saltmarsh. A combination of inference from local predator assemblages, nest sign, nest cameras and an artificial nest experiment was used. In addition to the identification of nest predators, the artificial nest experiment enabled the following hypotheses to be tested:

- That nest visitation by humans does not increase the risk of predation.

- That spatial and temporal patterns of predation, and the interaction between these factors, is constant over the breeding season.

2.3 Methods

2.3.1 Study site

This study was conducted in the Omaha saltmarsh (36°20'-36°22' South, 174°46'-174°47' East), which is located on a narrow strip of land bordered by the Mangatawhiri Spit and Whangateau Harbour. A full description of the study site is given in Chapter One (section 1.6.1).
2.3.2 Predation sign in nests

Nests that had been preyed on were closely examined for sign (footprints, hair, droppings, crushed vegetation) and remains of eggs, nestlings and adults.

2.3.3 Predator monitoring

Monitoring was conducted to identify potential predators in the Omaha saltmarsh. A 1.8 km transect with thirty-seven tracking tunnels at fifty metre spacings was established through the emergent strip in which all fernbird nests were found. The tunnels were baited with peanut butter, and were run for one night a month for three months, between December and February. Tracking tunnels provide a useful means of monitoring rodent numbers. However, they are not considered the ideal tool for monitoring mustelid numbers and only provide an indication of presence/absence (Gillies & Williams, 1998). Tracking tunnel lines targeting mustelids were not established. However their presence was frequently indicated through footprints in mud and sand areas and characteristic droppings. The presence of potential avian predators was also recorded.

2.3.4 Video monitored nests

A single fernbird nest was filmed for approximately 96 hours with a time-lapse video unit. In addition a banded rail nest (*Rallus philippensis assimilis*) which had recently been preyed on, was filmed for approximately 12 hours.

2.3.5 Artificial nest experiment

Artificial nests were exposed for a period of twelve days to replicate the natural incubation period of North Island fernbird (M'Lean, 1905). Three trials were run between December 2001 and February 2002. Commercially-available cane wicker cage bird nests were used. These nests closely resemble a natural fernbird nest in size and colour. The wicker nests were left out in the marsh for two weeks before use to weather them and reduce or remove any novel smells, which may have attracted predators. Brown and white plasticine was mixed together to create eggs that had a streaked and speckled appearance similar to fernbird eggs (Figure 16). No scent or attractant was added to the eggs. Three plasticine eggs were placed in each nest to mimic the average clutch of fernbird (Figure 11). A 1.8 kilometre transect was established through the emergent vegetation zone of the saltmarsh, between the manuka and reed beds. Nests
were stratified into groups of twenty and randomly assigned as a treatment or a control using random number tables. A starting point between one and twenty metres was selected using random number tables. Nests were spaced every twenty metres from the starting point. Treatment nests were visited every four days in the same manner as natural fernbird nests (Chapter 1). Control nests were visited only once at the end of the twelve-day exposure. Nests were placed in a clump of vegetation within the emergent layer, but not right on the edge. Suitable clumps were chosen based on the researchers experience with natural nests and selected on the basis of cover, proximity to other clumps and a nearby landing point (see Chapter 1 for a description of natural nest sites). A piece of brown twine was tied to vegetation above each nest to aid relocation, and to ensure that nests were not unnaturally exposed to aerial predators. A piece of flagging tape with the nest number and treatment was tied to vegetation four metres away from each nest. A compass bearing was taken from the flagging tape to aid relocation of nests.

A nest was considered preyed on if at least one egg had bite or scratch marks on it. All plundered nests were removed from the experiment. Samples of these nests and eggs were saved, and the skulls in the bone collection at the Auckland Museum were used to identify the predator responsible.

Ten nests were randomly selected from each trial and eleven standard measurements were taken from each of these nests (Chapter 1). Artificial nest placement was then statistically compared with that of natural nests.

2.3.6 Statistical Analysis

The artificial nest trial and comparisons of predation between fernbird studies was analysed using a categorical data modelling programme (SAS 8.0, 2002). Natural and artificial hatching success was compared with a Chi-square test. Artificial nests were compared with natural nests using multiple Mann-Whitney tests (Statistica 6.0, 2002.). To investigate any spatial patterns in predation on artificial nests, the study area was divided into three 600-metre sections along the 1.8 kilometre transect.
Figure 11. An artificial nest preyed on by mice at the Omaha Saltmarsh 2001/2002.
2.4 Results

Twenty-one fernbird nests were found and monitored during the study. The outcome of each nest was determined through observation of adult behaviour and nest sign. Predation accounted for 78% of observed losses at Omaha. Table 13 lists the outcome of all nests.


<table>
<thead>
<tr>
<th>Season</th>
<th>Fledged</th>
<th>Eggs preyed on</th>
<th>Chicks preyed on</th>
<th>Flooded</th>
<th>Infertile</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000/2001</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>2001/2002</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

2.4.1 Nest sign at nests that were preyed on

Two nests were observed either during or shortly after predation events in both the 2000/2001 and 2001/2002 breeding seasons. Predation was suspected due to an interruption in the regular visits by adult birds to the respective nests, however there was no other sign that predation had occurred. Nest loss was only confirmed after the nest site was inspected after two hours of observation. Eight nests were found that had been preyed on over the 2000/2001 and 2001/2002 seasons (five at the egg stage, three at the chick stage; (Table 13). The first nest, found in November 2000, is the only one for which the outcome is uncertain. This nest was probably preyed on late in the chick stage although it is possible the chicks fledged early. Upon discovery, it contained two chicks approximately 10-12 days old. Three days after discovery, the nest was empty. Fernbird chicks usually fledge at around 17/18 days (Chapter 1). In addition this nest was an intact tight cup, with a heavy feather lining and showing none of the typical signs of fledging with faecal matter on the rim and surrounding vegetation. For these reasons, this nest was judged to have been preyed on. The other two broods of chicks were approximately ten days old when they were preyed on. Of the eight nests that were preyed on remains were found in only two of them. One nest preyed on at the egg stage also had the remains of an adult bird in the nest bowl. In another nest preyed on at the egg stage, the nest material showed signs of disturbance and a small fragment of eggshell was found mixed with nest material. A small mouse-sized hole was found in the base of a third nest that was preyed on at the incubation stage. The hole was noted
when collecting the nest for the Auckland Museum. This hole was not recorded when the predation event was detected and may have been made after the nest was preyed on. All other nests that were preyed on were clean; i.e. were no remains left in nests, no predator sign (droppings, hair or footprints) and no sign of forced entry. All of these nests were well concealed from above following predation.

2.4.2 Predator monitoring

Constant activity by mammals was detected throughout the marsh over both monitoring periods. Frequent mustelid, i.e. Ferret (*Mustela furo*) and stoat (*Mustela erminea*) tracks and occasional rat (*Rattus spp.*) and possum tracks (*Trichosurus vulpecula*) were seen in both mud and sand areas throughout the saltmarsh (Figure 12 and 14). An average of 55% of tracking tunnels (n=37) were tracked by mice (*Mus musculus*) between December 2001 and February 2002. There was a peak in mouse activity in January when 87% of tunnels were tracked (Figure 13). Figure 20 shows the variation in tracking tunnel activity for the three locations in the saltmarsh. Potential avian predators observed in the Omaha saltmarsh are listed in Table 14.

**Table 14.** Potential avian predators of nesting fernbird observed at the study site.

<table>
<thead>
<tr>
<th>Native</th>
<th>Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>White faced heron (<em>Ardea novaehollandiae</em>)</td>
<td>Mynah (<em>Acridotheres tristis</em>)</td>
</tr>
<tr>
<td>Banded rail (<em>Rallus philippensis assimilis</em>)</td>
<td>Magpie (<em>Gymnorhina tibicen</em>)</td>
</tr>
<tr>
<td>Pukeko (<em>Porphyrio porphyrio</em>)</td>
<td>Starling (<em>Sturnus vulgaris</em>)</td>
</tr>
<tr>
<td>Australasian harrier (<em>Circus approximans</em>)</td>
<td></td>
</tr>
<tr>
<td>Australasian bittern (<em>Botaurus poiciloptilus</em>)</td>
<td></td>
</tr>
<tr>
<td>Morepork (<em>Ninox novaeseelandiae</em>)</td>
<td></td>
</tr>
<tr>
<td>Kingfisher (<em>Halcyon sancta</em>)</td>
<td></td>
</tr>
</tbody>
</table>
**Figure 12.** Predator activity in the Omaha Saltmarsh 2001/2002.

**Figure 13.** Percentage of tracking tunnels (n=37) tracked by mice (*Mus musculus*) in the Omaha Saltmarsh 2001/2002.
Figure 14. Mustelid footprints at the Omaha Saltmarsh, 2001/2002.
2.4.3 Video monitored nests

Most fernbird nests were unsuitable for video monitoring. This is because they would have required an unacceptable level of exposure and modification to film the nest, or they were located late in the nestling phase, when the disturbance associated with installing the camera could have caused early fledging. A single fernbird nest was monitored with video for approximately 96 hours late in the 2001/2002 season. The two chicks in the nest were approximately 9-10 days old when the camera was installed. They were video monitored continuously through to fledging. No predator activity was detected at this nest. Following the filming of the fernbird nest a nearby (>6m) banded rail nest that was being followed was preyed on. The nest failure was detected shortly after it had occurred; i.e. very fresh remains of eggs, that were close to hatching, were still in the nest. As with most fernbird nests, the banded rail nest site would have required too much exposure to film the active nest. However the camera was placed on the nest as soon as the predation was detected, and a stoat was filmed feeding on the remains and then sleeping in the nest for approximately 90 minutes (Figure 15).

Figure 15. Stoat filmed in a banded rail nest which had earlier been preyed on at Omaha.
2.4.4 Artificial nest experiment

A total of 33% of the artificial nests were preyed on between December 2001 and January 2002. Thirty five percent of treatment nests and 32% of control nests were preyed on (Table 15). Mice were responsible for 78% of the predation at artificial nest. Rats, birds and unknown predators accounted for the remainder (Figure 17). Considerable variation existed in the degree to which rodents preyed on nests (Figure 16). In some nests only a single bite mark would be detected on one egg. In other nests all eggs had bite marks on them, and some of them were extensively damaged. Nests preyed on by birds were quite different. The vegetation surrounding the nest was generally flattened, the nest overturned and in most cases one or two of the eggs would be gone. Remaining eggs were extensively damaged and had claw or beak marks on them (Figure 16). No mustelid predation was detected at the artificial nests.
Figure 16. Artificial eggs preyed on at the Omaha Saltmarsh 2002/2002. The top photo shows, from left to right, a real fernbird egg, an intact artificial egg, an artificial egg preyed on by mice, and an artificial egg preyed on by an unidentified bird. The bottom photo shows an artificial egg preyed on by mice with a mouse skull (Photos: Iain McDonald).
Table 15. Summary of predation of artificial nests in the Omaha Saltmarsh December 2001 to February 2002.

<table>
<thead>
<tr>
<th></th>
<th>Total nests</th>
<th>% Treatment nests preyed on</th>
<th>n</th>
<th>% Control nests preyed on</th>
<th>n</th>
<th>Combined Total</th>
<th>Total nest losses</th>
</tr>
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<tr>
<td>December</td>
<td>86</td>
<td>31%</td>
<td>13</td>
<td>30%</td>
<td>13</td>
<td>30%</td>
<td>26</td>
</tr>
<tr>
<td>January</td>
<td>87</td>
<td>40%</td>
<td>18</td>
<td>43%</td>
<td>18</td>
<td>41%</td>
<td>36</td>
</tr>
<tr>
<td>February</td>
<td>88</td>
<td>33%</td>
<td>15</td>
<td>23%</td>
<td>10</td>
<td>28%</td>
<td>25</td>
</tr>
<tr>
<td>Total</td>
<td>261</td>
<td>35%</td>
<td>46</td>
<td>32%</td>
<td>41</td>
<td>33%</td>
<td>87</td>
</tr>
</tbody>
</table>

Figure 17. Pie chart showing proportions of various predators at artificial nests (n=261) in the Omaha Saltmarsh 2001-2002.

A Chi-square test with Yates’ Correction for Continuity revealed no significant difference between natural and artificial nest predation for the 2001/2002 season ($\chi^2=0.12$, NS), nor between artificial and natural nests with the data from the 2000/2001 and 2001/2002 seasons combined ($\chi^2=2.63$, NS).

No significant effect was found due to treatment, month or location. No significant interaction was detected between location and month or treatment and month (Table 16, Figure 18). Due to the weak interaction effect between treatment and month ($P=0.074$) the data were further analysed by month. A significant difference was detected between
locations two and three in January (Figure 19; \( P=0.04 \)) and locations one and three in February (Figure 19; \( P=0.013 \)). No significant differences were detected in December (Figure 19). Figures 19 and 20 indicate an increase in predator activity, primarily mice, between December 2001 and February 2002. No pattern in mouse predation was evident in December 2001, when tracking tunnel activity indicated the relative density of mice was quite low. Tracking tunnel activity increased in January and February and appeared to be greater in locations two and three.

**Table 16.** CATMOD Maximum likelihood analysis of variance-artificial nest predation at Omaha Saltmarsh 2001/2002.

<table>
<thead>
<tr>
<th>Model</th>
<th>Source</th>
<th>d.f.</th>
<th>Chi-Square</th>
<th>Pr&gt;Chi-Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full model</td>
<td>Intercept</td>
<td>1</td>
<td>28.62</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>Treatment</td>
<td>1</td>
<td>0.92</td>
<td>0.3374</td>
</tr>
<tr>
<td></td>
<td>Location</td>
<td>2</td>
<td>3.02</td>
<td>0.2208</td>
</tr>
<tr>
<td></td>
<td>Month</td>
<td>2</td>
<td>3.42</td>
<td>0.1810</td>
</tr>
<tr>
<td></td>
<td>Location*month</td>
<td>4</td>
<td>8.53</td>
<td>0.0739</td>
</tr>
<tr>
<td></td>
<td>Treatment*month</td>
<td>2</td>
<td>0.94</td>
<td>0.6245</td>
</tr>
<tr>
<td></td>
<td>Likelihood Ratio</td>
<td>6</td>
<td>3.99</td>
<td>0.6787</td>
</tr>
<tr>
<td>By month</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>Intercept</td>
<td>1</td>
<td>11.46</td>
<td>0.0007</td>
</tr>
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<td></td>
<td>Treatment</td>
<td>1</td>
<td>0.00</td>
<td>0.9917</td>
</tr>
<tr>
<td></td>
<td>Location</td>
<td>2</td>
<td>0.96</td>
<td>0.6183</td>
</tr>
<tr>
<td></td>
<td>Likelihood Ratio</td>
<td>2</td>
<td>0.82</td>
<td>0.6626</td>
</tr>
<tr>
<td>January</td>
<td>Intercept</td>
<td>1</td>
<td>3.29</td>
<td>0.0699</td>
</tr>
<tr>
<td></td>
<td>Treatment</td>
<td>1</td>
<td>0.12</td>
<td>0.7338</td>
</tr>
<tr>
<td></td>
<td>Location</td>
<td>2</td>
<td>4.22</td>
<td>0.1214</td>
</tr>
<tr>
<td></td>
<td>Likelihood Ratio</td>
<td>2</td>
<td>0.45</td>
<td>0.7999</td>
</tr>
<tr>
<td>February</td>
<td>Intercept</td>
<td>1</td>
<td>15.51</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>Treatment</td>
<td>1</td>
<td>1.61</td>
<td>0.2042</td>
</tr>
<tr>
<td></td>
<td>Location</td>
<td>2</td>
<td>6.13</td>
<td>0.0466*</td>
</tr>
<tr>
<td></td>
<td>Likelihood Ratio</td>
<td>2</td>
<td>2.72</td>
<td>0.2573</td>
</tr>
</tbody>
</table>
Figure 18. CATMOD maximum likelihood predicted probability of predation of artificial nest at the Omaha Saltmarsh 2001/2002-full model.
Figure 19. CATMOD maximum likelihood predicted probability of predation of artificial nests at the Omaha Saltmarsh 2001/2002 by month and location (a and b were found to be significantly different).
Figure 20. Tracking tunnel activity by location at the Omaha Saltmarsh 2001/2002.
2.4.5 Natural and artificial nest comparisons

A Mann-Whitney U test revealed a significant difference \((P<0.05)\) between natural and artificial nests for the following measurements; Ground to base of nest, internal rim-to- rim, inside depth and outside depth. There were no significant differences between all other measurements (Table 17). Chapter one summarises the placement and location of natural nests located at Omaha over the 2000/2001 and 2001/2002 seasons.

**Table 17.** A comparison of natural and artificial nest measurements and placement at the Omaha Saltmarsh 2001/2002.

<table>
<thead>
<tr>
<th>Measurement (mm)</th>
<th>Median natural nests</th>
<th>Median artificial nests</th>
<th>Mann-Whitney statistic</th>
<th>(P) value</th>
<th>Mean±S.E. natural nests</th>
<th>Mean±S.E. Artificial nests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canopy height (from ground)</td>
<td>1274.5 +39</td>
<td>1313.5</td>
<td>U=108</td>
<td>(P=0.190) (NS)</td>
<td>1231±45</td>
<td>1310±28</td>
</tr>
<tr>
<td>Distance to edge of clump</td>
<td>95 +27.5</td>
<td>122.5</td>
<td>U=118</td>
<td>(P=0.317) (NS)</td>
<td>121±29</td>
<td>14±164</td>
</tr>
<tr>
<td>Perimeter of clump</td>
<td>2481 -389.5</td>
<td>2091.5</td>
<td>U=75</td>
<td>(P=0.524) (NS)</td>
<td>2366±334</td>
<td>2095±258</td>
</tr>
<tr>
<td>Nearest other clump</td>
<td>442 +12</td>
<td>430</td>
<td>U=79</td>
<td>(P=0.313) (NS)</td>
<td>737±219</td>
<td>455±82</td>
</tr>
<tr>
<td>Ground to rim of nest</td>
<td>281 +15</td>
<td>296</td>
<td>U=145</td>
<td>(P=0.888) (NS)</td>
<td>285±23</td>
<td>293±16</td>
</tr>
<tr>
<td>Ground to base of nest</td>
<td>124.5 +137.5</td>
<td>262</td>
<td>U=77</td>
<td>(P=0.004)</td>
<td>145±27</td>
<td>253±16</td>
</tr>
<tr>
<td>Rim to rim external</td>
<td>103 +0</td>
<td>103</td>
<td>U=155</td>
<td>(P=0.478) (NS)</td>
<td>100±4</td>
<td>103±1</td>
</tr>
<tr>
<td>Rim to rim internal</td>
<td>70 +18.5</td>
<td>88.5</td>
<td>U=36</td>
<td>(P&lt;0.001)</td>
<td>75±4</td>
<td>89±1</td>
</tr>
<tr>
<td>Inside depth</td>
<td>66.5 -33.5</td>
<td>33</td>
<td>U=0.00</td>
<td>(P&lt;0.001)</td>
<td>65±3</td>
<td>33±1</td>
</tr>
<tr>
<td>Outside depth</td>
<td>125.5 -84.5</td>
<td>41</td>
<td>U=0.00</td>
<td>(P&lt;0.001)</td>
<td>127±8</td>
<td>41±1</td>
</tr>
<tr>
<td>Landing point</td>
<td>2265 +235</td>
<td>2500</td>
<td>U=165</td>
<td>(P=0.676) (NS)</td>
<td>2743±452</td>
<td>2620±171</td>
</tr>
</tbody>
</table>

2.4.6 Predation losses in other fernbird studies

Predation at Omaha was compared with that observed in two South Island studies (Elliot, 1978; Harris, 1987) and one Snares Island study (Best, 1973). Significant differences in losses to predation (Table 18) are due to the inclusion of Best’s (1973) study on the Snares Islands. The Snares Islands are free of introduced mammalian
predators, and no predation due to native species was recorded. There was no significant difference in predation between mainland studies (Figure 21), however the predators responsible were significantly different (Figure 22).

**Table 18.** CATMOD Maximum likelihood analysis of variance-losses to predation in New Zealand fernbird studies. Study sites were North Island (Omaha), South Island (Golden Bay and Lakes Waihola) and Snares Islands.

<table>
<thead>
<tr>
<th>Model</th>
<th>Source</th>
<th>d.f</th>
<th>Chi-Square</th>
<th>Pr&gt;Chi-Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nest losses</td>
<td>Intercept</td>
<td>2</td>
<td>1.51</td>
<td>0.4703</td>
</tr>
<tr>
<td></td>
<td>Location</td>
<td>6</td>
<td>15.25</td>
<td>0.0184</td>
</tr>
<tr>
<td></td>
<td>Likelihood Ratio</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Egg Loss</td>
<td>Intercept</td>
<td>3</td>
<td>67.41</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Location</td>
<td>6</td>
<td>53.45</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Likelihood Ratio</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chick loss</td>
<td>Intercept</td>
<td>3</td>
<td>3.53</td>
<td>0.3163</td>
</tr>
<tr>
<td></td>
<td>Location</td>
<td>6</td>
<td>4.84</td>
<td>0.5642</td>
</tr>
<tr>
<td></td>
<td>Likelihood Ratio</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Figure 21. A comparison of losses to predation in different fernbird studies. Study sites were North Island (Omaha), South Island (Golden Bay and Lakes Waihola) and Snares Islands.
**Figure 22.** Identity of nest predators in different fernbird studies. Study sites were North Island (Omaha), South Island (Golden Bay and Lakes Waihola) and Snares Islands.
2.5 Discussion

The nesting habits of fernbird present a challenge when attempting to identify significant nest predators. The average (n=10) height of nests at Omaha from the ground to the rim of the nest was 285±23mm (S.E.). The average canopy height (from the ground) above nests at Omaha was 1231±45mm (S.E.). All nests found over the 2000/2001 and 2001/2002 breeding season were within the emergent strip in clumps or continuous beds of *Baumea juncea*. Most nests were concealed from above by the *B. juncea*, but often became progressively more exposed, as the nest came closer to fledging. The fragile nature of the vegetation at nest sites meant that simply visiting nests could cause structural damage that could expose the nest, and increase the risk of predation. Monitoring of nests had to be conducted in a manner that would minimise risk to the nesting birds. Potential bias due to the monitoring regime also had to be minimised.

2.5.1 Identification of nest predators

No direct observation of predators at fernbird nests was made over the course of this study. However, the combination of techniques used in attempting to identify nest predators of fernbird allows strong inferences to be made as to predator identity. All predation at the chick stage was most probably due to mustelids, especially stoats. This conclusion is reached due to the characteristic sign at plundered nests; i.e. a clean nest bowl, no remains, and no sign of forced entry (Flack & Lloyd, 1978). Stoats are small and agile and would be quite able to enter nests without damaging the surrounding vegetation. The stoat filmed at the banded rail nest further supports this conclusion. Although there are a number of potential avian predators in the saltmarsh, there was no evidence to suggest that they were responsible for any observed predation. Avian predators, such as harriers, tend to expose the nest to the level of the rim or alter the vegetation in some manner (Elliot, 1978), as seen in this study with the artificial nests preyed on by birds. Smaller birds such as kingfishers and mynahs are known to prey on nests and could have been responsible for some predation (Heather & Robertson, 1996). However, even small avian predators would probably alter the nest site and surrounding vegetation when visiting the nest as they are larger than a fernbird and would enter the nest from above rather than below. Rats are significant nest predators of many New Zealand species and would predate fernbird nests if they came across them. Nests
preyed on by rats are usually left in a messy state with fragments of eggs and chicks and rat droppings remaining in the bowl (Flack & Lloyd, 1978; Moors, 1983). This characteristic sign was not at Omaha. No rats were detected in tracking tunnels, very few rat prints were seen in mud and sand areas, and very few artificial nests showed sign of rat predation. The large numbers of mice at Omaha would also suggest that few rats are present, as the two species do not tend to occur together (Murphy & Pickard, 1998; Ruscoe, 2001).

Mustelids may have been responsible for observed predation at the egg stage for similar reasons to those cited above. All predation was clean and most nests showed no sign of disturbance. One of the nests preyed on at the egg stage showed signs of disturbance and contained a small fragment of eggshell. Here, rodents may have been responsible. Identifying predators at the incubation stage can be difficult due to parental behaviour, as adult birds will often instinctively remove eggshell from a nest (Brown et al., 1998). The artificial nest experiment showed that mice are potential nest predators. They are abundant in the marsh and utilise the habitat in which fernbird nest. There was no indication that they preyed on any nest at the chick stage, however mice may have been responsible for predation of at least one nest at the egg stage. Laboratory trials by Moors (1978) show that mice will feed on both nestlings and eggs. Moors (1978) also recorded predation by mice on a South Island robin nest (P. a. australis), on pipit (Anthus novaeseelandiae) nests (Moors, 1983) and storm petrel nests (M. Imber, pers. comm. in Moors (1983)). It is not known if fernbird are capable of defending a nest against a mouse or if a mouse would attempt to prey on a nest with an adult bird present. Mice and fernbird are similar in body weight (mice are slightly heavier), however there is no reference in the literature for direct predation or attack on adult birds by mice, although they have been observed killing skinks of similar or greater body weight than themselves and the remains of birds and other mice have been found in mouse stomachs (Fitzgerald & Guo, 1989; Murphy & Pickard, 1998). If the presence of an adult bird deters mice, then mouse predation may not be a frequent occurrence at the incubation stage, however it could still have some impact at the laying stage. Fernbird lay at approximately 24-hour intervals leaving the eggs unattended until incubation commences after the laying of the last egg (Best, 1973). The average clutch at Omaha is three eggs (Chapter 1), providing a window of at least 48 hours when adults are not present. Predation at the laying and incubation stage is very hard to
detect as adult birds visit the nest less frequently and are more secretive. The importance of mice as nest predators may be greater when rat densities are low, as was observed at Omaha. Mice could have been attracted to artificial nests due to the novel scent of plasticine eggs. However Bayne and Hobson (1999) found no effect due to plasticine eggs in an artificial nest trial comparing them with Japanese quail (Coturnix japonica) eggs and plasticine scented quail eggs, in an area in which deer mice (Peromyscus maniculatus) were present.

Various species of mice (some similar in size and habits to the house mouse) have been identified as nest predators in Northern Hemisphere studies (Bayne & Hobson, 2002; Bayne et al., 1997; Buler & Hamilton, 2000; Maxson & Oring, 1978; Newton & Heske, 2001). Researchers have stated that the importance of mice as nest predators has been understated due to widespread use of Japanese quail eggs in artificial nest studies. Japanese quail eggs are usually significantly larger than the passerine species they are supposed to imitate, effectively excluding small-mouthed predators such as mice (Degraaf et al., 1999; Haskell, 1995; Maier & Degraaf, 2000).

It is important to note that there are inherent weaknesses in the methods by which the above conclusions have been reached. Nest sign is often considered an unreliable indication of nest fate. Lariviere (1999) stated that patterns of predation can be both similar and remarkably different within and between predatory species, and it can vary depending on the stage of the nesting cycle at which predation occurs. In addition, detailed knowledge of potential predators occurring in an area is required to reach appropriate conclusions. Numerous studies advise caution in making inferences about predation on natural nests based on results from artificial nest studies (Weidinger, 2001; Zanette & Jenkins, 2000). However, if results and aims are carefully considered, artificial nests remain a useful tool for examining nest predation patterns, for identifying predators and generating new hypotheses regarding nest predation (Lariviere, 1999; Major & Kendal, 1996; Miller & Hobbs, 2000). Direct observation or video monitoring of active nests provides the most definitive evidence of nest predators (Brown et al., 1998; King et al., 2001). However, the nesting and behavioural characteristics of fernbird make the application of these techniques difficult. Major (1991) and Lariviere (1999) recommend a combination of techniques as has been applied in this study. While a large number of potential predators exist at
Omaha, most of these are probably novel or secondary predators in that nest predation is a rare opportunistic feeding event. Mustelids are widely documented as nest predators (Lavers & Clapperton, 1998; McDonald & Murphy, 2000). In the absence of mustelid diet studies at Omaha it is not possible to state the proportion of birds in their diets relative to other vertebrates and invertebrates, but it need not be high to have a significant impact on nesting success. Other predators, such as feral or domestic cats (*Felis catus*) may periodically visit the marsh, however all those frequenting the marsh throughout the nesting season were documented. Nest sign in New Zealand may also be more reliable than that described in Northern Hemisphere studies where a more diverse range of avian, mammalian and reptilian predators is present.

### 2.5.2 Nest predators recorded in other fernbird studies

Losses due to predation were not significantly different between this study and two other mainland studies (Elliot, 1978; Harris, 1987). While the predation rate was similar between studies, the predators responsible differed. Introduced mammals accounted for all predation at Omaha while other studies attributed more losses to native avian predators. Elliot (1978) recorded two nest failures due to predation out of a total of eight monitored nests in a study of South Island fernbird (*B. p. punctata*). Elliot (1978) only noted the presence of harriers and weka (*Gallirallus australis*) in his study area. He makes no mention of introduced predators and observed strong reactions by fernbird to weka visiting their territories. Thirty-nine percent of nest failures recorded by Harris (1987) (n=46 nests) were due to predation. Harris (1987) considered native avian predators, primarily harriers but also black-backed gulls (*Larus dominicanus*), to be responsible for most predation. Stoats, ferrets, Norway rats (*Rattus norvegicus*), possums (*Trichosurus vulpecula*) and mice were also present within his study area. Harris (1987) did not directly attribute predation to any particular mammal, but considered stoats and Norway rats the only mammals present throughout the wetland. Best (1973) recorded no losses to native predators on the Snares Islands, and these islands are also free of all introduced predators.

### 2.5.3 Identification of predators in the artificial nest experiment

A small number of nests were preyed on by unknown species of birds and rats indicating that artificial nest experiments have potential for revealing the presence of rodent and avian predators. However, no mustelid predation was detected at the
artificial nests during this study. Other artificial nest studies have revealed a large number of avian and mammalian predators including mustelids (Bayne & Hobson, 2002; Buler & Hamilton, 2000; Sloan et al., 1998). In addition to the studies cited above, Hansson (2000) studied great reed warblers (Acrocephalus arundinaceus), a member of the same family as fernbird (Sylviidae) with similar behavioural characteristics and habitat requirements. Whilst the artificial nest experiment was aimed at investigating polygyny, Hansson (2000) detected predation by marsh harriers (Circus aeruginosus), bittern (Botaurus stellaris) and water rails (Rallus aquaticus), a similar suite of predators to that at Omaha. The use of real eggs in addition to plasticine eggs was considered at Omaha so as to provide a more natural nest, and thereby increasing the likelihood of predation, particularly by mustelids. Japanese quail and domestic fowl eggs have been used in most artificial nest studies (Major & Kendal, 1996), however both would be poor models as they are significantly larger than a fernbird egg. House sparrow eggs (Passer domesticus) are of a similar size and colouration, and have been used in a number of studies, as have zebra finch (Poephila guttata) and budgerigar (Melopsittacus undulates) eggs (Maier & Degraaf, 2000; Major, 1991; Newton & Heske, 2001). However recent salmonella outbreaks in house sparrow populations and the number required regardless of species (approximately 260 eggs), precluded the use of real eggs in this study. The location of artificial nests should closely resemble that of natural nests. There was no significant difference in the locations of natural and artificial nests in this study. Both were equally available to potential predators. The observed differences in actual nest measurements should not have affected predation risk.

2.5.4 Artificial nest experiment—the effects of observer visits

When monitoring nests it is important to minimise scent, to reduce the risk of attracting predators to nest sites. When undertaking predator control the general practise is to avoid human scent as much as is practicable on traps and trap locations and to reduce novel scents that might repel predators. There was no significant difference between predation rates of nests visited once versus those visited every four days. This can be conclusively stated for mice though the situation may be different for mustelids, rats and other predators. Significant effects have been found as a result of observer visits in other studies, particularly where Corvids have been predators (Buler & Hamilton, 2000; Sloan et al., 1998). Deer mice preyed on eight percent of artificial nests within one
hour of being visited by a researcher in a study by Bayne (1997). Sloan (1998) found some statistical and photographic evidence that fishers (Martes pennanti) systematically located and preyed on artificial nests by following human scent. Esler (1993) and Major (1990) found that daily observer visits increased predation risk at artificial nests but longer intervals did not. In contrast many other studies have found no effect due to human visitation at natural or artificial nests (Olson & Rohwer., 1998; Skagen et al., 1999).

2.5.5 Artificial nest experiment-Spatial and temporal patterns of predation

Tracking tunnel activity increased as the breeding season progressed. The probability of artificial nest predation also showed an increase as the season progressed, particularly at the southern end of the saltmarsh. This could be occurring as the resident mouse population increases through the season either in response to local food resources or migration. Mouse population densities may fluctuate widely between habitats. The density of mice at Omaha is unknown. Ruscoe (2001) stated that mouse populations increase through the summer, peaking in autumn/winter. Miller (1999) recorded densities of 12-14 mice per hectare in summer and 22-24 in autumn/winter in sand dune areas. Ruscoe (2001) recorded 27-50 mice per hectare in August and November following beech mast seeding. Fitzgerald (1996) suggested that increases in mouse numbers following heavy seeding from hard beech (Nothofagus truncata) may be the result of increased invertebrates rather than simply a response to seed. A similar pattern could be evident at Omaha, the resident mouse population responding to seeding by rushes such as Leptocarpus similis, Baumea juncea and Juncus krausii, increased invertebrates as a result of seeding or a combination of both factors. If this scenario is correct, mice may be competing with fernbird for invertebrate food. Migration could be occurring from the urban area to the north, the rough farmland to the south, or from the east, an area comprised of sand dunes and a new housing development. If mice are migrating into the marsh, the tracking tunnel and experimental nest results suggest that they are coming in from the rough farmland to the south, due to the increased mouse activity recorded at the southern end of the saltmarsh during this study.
2.6 Conclusions

Conclusive identification of nest predators at Omaha was not possible, however strong inferences can be made based on observations, nest monitoring, predator monitoring and artificial nest losses. A variety of potential nest predators is present at Omaha. The role of mustelids is likely to be important (Figure 15). However, this study shows that there is a need for research into the impacts of mice as predators and competitors (see also Moors, 1983). The importance of mice as invertebrate and reptile predators has been confirmed (Ruscoe, 2001), but there does not appear to have been any research into their role as nest predators. The results of the artificial nest experiment suggest that mice are at least potential nest predators and may have a significant impact on fernbird particularly at the laying and incubation stage. This impact may be more apparent when rat numbers are low. Mice may also be significant competitors for invertebrate foods.

Nest predation at Omaha is primarily due to introduced predators, and the level seems to be higher than that observed in other studies conducted on South Island fernbird and Snares Island fernbird. Prior studies have identified native avian predators as being more significant than introduced mammalian predators.

There was no significant difference in predation between artificial and natural nests. Placement and general measurements of artificial and natural nests were also similar. However, no conclusions about the rate of predation on natural nests can be drawn from this study, given the lack of mustelid predation on artificial nests, the small number of natural nests and the lack of long-term replication (the data on artificial nests were from only one breeding season).

The artificial nest experiment generated a new hypothesis by identifying mice as potential nest predators. The experiment also revealed limited predation by birds and rats. Mustelids were not identified as predators at artificial nests. The future use of suitably sized-natural eggs in addition to plasticine eggs, may better detect mustelid and rodent predation because there would be no confounding parental behaviour (e.g. removal of eggshells).

In this study the frequency of observer nest visits did not significantly affect the level of mouse predation, although visits may have affected the level of predation by mustelids,
rats and other predators in different ways. Regardless of any real or perceived effect due to visitation, where possible, disturbance should always be minimised for breeding birds.

The observed change in probability of predation for artificial nests as the study progressed may be due to the natural increase of the resident mouse population at Omaha or migration from adjacent areas. If migration into the saltmarsh was occurring, then it is probably from the rough farmland to the south.

2.7 Acknowledgements

My supervisor Dianne Brunton provided helpful feedback in the design of this study and assistance with statistical analyses. Tim Lovegrove provided helpful comments this chapter at very short notice as did Darryl Jeffries. Brian Gill, Auckland Museum, kindly provided skulls for comparative purposes and Iain McDonald, School of Biological Sciences, took the photos of artificial eggs and mouse skulls. The Auckland Regional Council provided funding for this study. Various friends at Robbie’s cottage joined in the onerous task of making several hundred plasticine eggs (and many other interesting plasticine creations!).

2.8 References


3 The establishment of fernbird (*Bowdleria punctata*) populations via translocation: Methods and techniques

Abstract –Twenty-five North Island fernbird (*Bowdleria punctata vealeae*) were translocated from an area of lowland shrublands near Orewa to Tiritiri Matangi Island in two transfers in 2001 and 2002. Fifty four percent of birds were caught between sunrise and 10:00 h. Low mist nets were set in thick vegetation with overhead cover in known territories. Lure tapes of locally collected calls (particularly of target birds or close neighbours) elicited territorial responses from target birds. Captured fernbird were successfully held in individual transfer boxes heavily lined with vegetation for up to 24 hours. In captivity, birds showed a preference for active invertebrate food. Post-release monitoring has been difficult due to the cryptic behaviour of fernbird, the small number transferred, and the abundance of dense scrubby habitat on Tiritiri Matangi Island. Although relatively few re-sightings have been made, fernbird have been seen and heard in many parts of the island, often some distance from the three release sites. Unbanded birds were seen after the 2001/2002 breeding season, and a nest with chicks was located in September 2002. One of the nesting birds was unbanded. Other fernbird translocations are reviewed and recommendations are provided to guide managers undertaking future translocations of this species.

3.1 Introduction

Translocation refers to a release of animals with the intention of establishing, re-establishing or augmenting an existing population (IUCN *in Griffith et al.*, 1989). Griffith *et al.* (1989) state that translocations may consist of more than one release, and may be conducted on both native and non-native species, often to establish or augment game species for hunting, but also to re-establish rare or threatened species. Griffith *et al.* (1989) estimated between 1973 and 1986, approximately 700 translocations occurred per annum, of at least 93 species of birds and mammals, occurred in Australia, Canada, Hawaii, New Zealand and the United States. The number of translocations implemented, particularly of rare and threatened species, is likely to increase in the near
The outcome of a translocation tends to vary among projects and success rates are not high, particularly for rare and threatened species (Griffith et al., 1989; Lindenmayer, 1994; Wolf et al., 1996). Factors contributing to success have been identified for many translocations (Armstrong & McLean, 1995; Griffith et al., 1989; Lovegrove & Veitch, 1994; Veltman, 1996; Wolf et al., 1998; Wolf et al., 1996) and the technique is not only a practical conservation tool but also a potential testing ground for hypotheses regarding conservation biology and ecological theory (Armstrong et al., 1994; Sarrazin & Barbault, 1996; Soderquist, 1994).

3.6.1 Translocations in New Zealand

Richard Henry pioneered translocations in New Zealand in the late nineteenth-century in a failed attempt to establish kakapo (*Strigops habroptilus*) and kiwi (*Apteryx spp.*) on Resolution Island, Fiordland (Hill & Hill, 1987). Lovegrove (1994) stated that although many early transfers failed, techniques were progressively refined, and translocations have become a key component of many highly successful recovery programmes for species such as kakapo, black robin (*Petroica traversi*) and South Island saddleback (*Philesturnus carunculatus carunculatus*) (Butler & Merton, 1992; Elliott et al., 2001; Pierre, 1999). More than 400 translocations, primarily of birds but also reptiles and invertebrates, have been carried out in New Zealand (Armstrong & McLean, 1995; Saunders, 1994).

3.1.2 Fernbird translocations

Previous translocations of fernbird occurred in the late 1970s and the mid 1990s. In 1979 an attempt was made to translocate North Island fernbird from Omaha to Tahuna-Torea reserve in Auckland to establish a new population. Codfish Island fernbird (*B. p. wilsoni*) were identified as being at risk from a poisoning programme to clear Codfish Island of kiore (*Rattus exulans*). To safeguard this subspecies, it was decided to establish a second population before the poisoning programme (McClelland, 1997). Stewart Island fernbird (*B. p. stewartiana*) were reintroduced to Kundy Island from Big Island following successful eradication of weka (*Gallirallus australis*) on Kundy Island (P. McClelland, pers. com. 2002).
North Island fernbird were identified as a species suitable for reintroduction to Tiritiri Matangi Island (Tiritiri Matangi) as part of ongoing ecological restoration (Hawley, 1997; Lands and Survey, 1982). The initial proposal was submitted in 1994, but was rejected due to Department of Conservation (DOC) concerns about the impacts on source populations and other species on Tiritiri Matangi. A small population in shrublands in Recommended Area for Protection 21 (RAP21) (Mitchell et al., 1992), Orewa, were considered suitable as a source population due to the similar habitat, close proximity to Tiritiri Matangi and construction of the Orewa to Puhoi motorway extension. The motorway designation traverses the eastern side of RAP21 and will destroy the territories on the motorway footprint. Translocation of birds such as those at Orewa, which are threatened by development, will prevent disrupting otherwise undisturbed populations. The status of the population at Orewa was not well known and fernbird are difficult to survey accurately, beyond mapping territorial adults (Harris, 1987) (Chapter 5). However Anderson (1992) conducted five-minute point counts at Orewa and considered fernbird to be “occasionally” present in wetlands and emergent broadleaf forest and “common” in the shrublands.

3.7 Aims

This study aimed to determine suitable methods for capturing and transferring North Island fernbird and to establish a viable breeding population on Tiritiri Matangi. Information on previous transfers of Codfish Island, Stewart Island and North Island fernbird are also summarised and analysed and recommendations are provided to guide managers undertaking future translocations of this species.

3.8 Methods

3.8.1 First translocation from Orewa to Tiritiri Matangi in 2001

Fernbird were captured for the transfer to Tiritiri Matangi from RAP21, Orewa, between 25 June and 8 August 2001 (Figure 23). The proposed Orewa to Puhoi motorway route traverses this area. Approximately six fernbird territories on the footprint of the motorway were identified.
Figure 23. Map showing the locations of the source population for the fernbird translocation in RAP21 near Orewa and the nearby release site on Tiritiri Matangi Island.

The 2001 transfer commenced with very little warning due to habitat clearance that was underway within RAP21. A casual survey in 2000 and 2001 had revealed that fernbird occurred in areas to be cleared. These birds were targeted for capture first. Birds in areas not under immediate threat of losing their habitat were caught as they were located. Birds were detected with recorded calls. Upon detection, a mist net was erected in the immediate area. The vegetation in RAP21 consists of a thick understorey of *Gleichenia dicarpa* and prickly hakea (*Hakea sericea*). When setting mist nets, a strip of vegetation approximately one metre wide and six metres in length was cleared to bare ground. The nets were loosely pegged to the ground along the cleared strip, and the top of the net was raised to approximately 1.8m high. Sites with thick vegetation on either side were chosen, to provide cover for approaching birds, particularly in the middle section of the net (Figure 24). At some sites the vegetation cleared whilst establishing the site was used to provide additional screening of the net to make it less visible to the birds. A speaker connected to a two-way switch was placed on either side of the net. The birds were lured into the vicinity of the net using a hand held speaker on which short sequences of calls were played. When a bird approached, the lure calls were shifted to the speakers on either side of the net. The volume of the calls was reduced and very short (<5 second) sequences were played on the side of the net nearest
the bird. When a bird was close to the net, the calls were switched to the speaker on the opposite side to lure the bird through the net towards the other speaker. The locations and times of capture were recorded for all birds, as were the total number of nets set and the number of days spent catching for the transfer.

Captured birds were held in black cotton bags. Each bird was weighed using a 100-gram Pesola spring balance. The culmen was measured from the tip of the bill to the point at which it disappeared into the feathers on the head. The folded wing was measured with vernier callipers in the style of a wing ruler, from the carpal joint to the tip of the longest primary. The tail was measured from the point at which it emerged from the body to the tip of the longest feather. All birds were banded on the tarsus with a metal B band and a unique combination of celluloid colour butt bands. One of the conditions of the permit granted by DOC to translocate the birds was that blood, cloacal and faecal samples be taken from a minimum of three birds to ascertain the risks of fernbird transferring diseases to Tiritiri Matangi. The DOC request was expanded into a comparative study investigating disease on mainland and Tiritiri Matangi birds (Chapter 4). The transfer, banding and disease screening was carried out under permits issued by DOC and the University of Auckland Animal Ethics Committee (Approval notice N960).

Individual birds were held in modified cardboard pet carry boxes. Each box contained a single perch and was lined with plenty of vegetation to provide the bird with cover (Figure 25). Known numbers of live mealworms (*Tenebrio molitor*), wax moth larvae (*Galleria mellonella*), crickets (*Teleogryllus commodus*) or locust (*Locusta migratoria*) nymphs and water were provided.

Where possible the birds were transferred on the same day by helicopter or boat. However when birds were captured late in the evening it was necessary to hold them overnight. They were then transferred to Tiritiri Matangi the following day either by helicopter or boat.

All 13 birds from the 2001 transfer were released at the top of Lighthouse gully (Figure 29). Post release monitoring was carried out with recorded calls. Calls were played in release areas and all other habitat including areas where fernbird would not normally be expected.
Figure 24. Typical fernbird mist net site in low shrubland vegetation in RAP21 near Orewa (Photo: Darryl Jeffries).

Figure 25. Cardboard pet boxes showing lining of vegetation to provide cover and insulation for captured fernbird (Photo: Tim Lovegrove).
3.8.2 Second translocation from Orewa to Tiritiri Matangi Island in 2002

The second transfer of fernbird to Tiritiri Matangi from RAP21, Orewa, took place during May-July 2002. Due to a delay in the construction of the Orewa to Puhoi motorway extension, there was no habitat clearance underway during the 2002 transfer. This allowed a more measured and planned approach to be taken. The same methods for setting up nets and finding birds used the previous year were repeated in 2002. However, in contrast to 2001, birds were located on as many territories as possible before the transfer. Mist net sites were then established simultaneously in all of the territories. On the first two days of catching three mist net teams worked simultaneously, in an attempt to catch as many birds as possible at one time. A single catching team then worked the area for an additional three days to catch any birds that had been missed. It was then intended to leave the RAP21 capture area for a period of two weeks to allow displaced birds and any floating birds to settle back into territorial vacancies. A long period of inclement weather prevented any catching for a period of six weeks, after which three catching teams worked for two days. Despite perfect conditions (still and overcast) and active birds on territories no birds were caught during the second catching period. It was suspected that this was because the birds were becoming habituated to lure calls. A further week of catching was carried out by a single team using newly recorded calls from target territories. This proved to be more effective.

Two birds were released in an area of flax (*Phormium tenax*) and bracken (*Pteridium esculentum*) above Northeast Bay approximately 800 metres from where three fernbird from the 2001 transfer have been regularly sighted (Figure 29). Ten birds were released on the top western end of Lighthouse Gully. Post release monitoring was carried out in the same manner as in 2001 (Figure 29).

3.9 Results

3.9.1 Transfers from RAP21 Orewa to Tiritiri Matangi Island in 2001 and 2002

In total 26 fernbird were caught and 25 transferred to Tiritiri Matangi during the period June 2001-July 2002 (Table 21). Eighteen days were spent catching (morning and/or evening) in 2001 and 11 days in 2002. Twenty-six net sites were used in 2001 and 20
in 2002. Fifty four percent of the birds were caught between sunrise and 10:00 h, 11% between 10:00-13:00 h and 35% between 15:30 h and sunset (Figure 26). Most captures after 15:30 h were of single birds, a pair only being captured once. On three occasions pairs were seen together prior to capture within minutes of each other at the same net. It is quite probable that these birds were pairs, however this could not be confirmed in the hand. Two pairs were caught from two other nets at the same time, however in both cases there appeared to be a third bird on the territory. Territorial defence was occurring and it was unclear which birds were caught. Multiple captures were made from some territories, one in particular accounting for 33% of all birds caught 2001 and 2002. Birds were caught on the same territory within 24 hours of each other on two occasions, but it is impossible to say if these were the mates of the birds already caught or birds that had filled a vacancy. A bird caught in 2001 that escaped during processing, was recaptured in 2002 within 50m of the site of initial capture and transferred. The recapture occurred on the territory from which 33% of all birds were caught.

![Figure 26. Summary of the time of day of fernbird captures at RAP21 Orewa.](image_url)
3.9.1.1 Adult measurements and weights

The average measurements (±standard error) were:

1. weight 18 grams (±0.31)
2. culmen 12.00 mm (±0.21)
3. wing 55 mm (±0.70)
4. tail 92.3 mm (±2.00)

A statistically significant correlation was found between wing and tail, weight and culmen, and culmen and wing (Table 19, Figure 27). All other correlations were weak (Table 19). There is no clear discrimination between any mensural characteristics and no evidence of a bimodal distribution. Three birds, two males and a female, were sexed from blood samples collected for disease screening purposes (Figure 27). Four birds had short square tails, indicating they were either first year birds or adults that had recently moulted. Measurements and banding information for individual birds are listed in Appendix One.

Table 19. Mensural correlations for 26 North Island fernbird captured during the translocation from RAP21 near Orewa to Tiritiri Matangi Island 2001-2002.

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Product moment correlation coefficient</th>
<th>F Statistic</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wing/tail</td>
<td>r=0.59</td>
<td>F=12.03</td>
<td>P=0.00*</td>
</tr>
<tr>
<td>Weight/culmen</td>
<td>r=0.52</td>
<td>F=8.69</td>
<td>P=0.01*</td>
</tr>
<tr>
<td>Culmen/wing</td>
<td>r=0.42</td>
<td>F=4.9</td>
<td>P=0.04*</td>
</tr>
<tr>
<td>Culmen/tail</td>
<td>r=0.20</td>
<td>F=0.94</td>
<td>P=0.34</td>
</tr>
<tr>
<td>Weight/wing</td>
<td>r=0.19</td>
<td>F=0.87</td>
<td>P=0.36</td>
</tr>
<tr>
<td>Weight/tail</td>
<td>r=0.17</td>
<td>F=0.68</td>
<td>P=0.42</td>
</tr>
</tbody>
</table>
Figure 27. Significant ($P<0.05$) mensural correlations for 26 North Island fernbird captured during the translocation from RAP21 near Orewa to Tiritiri Matangi Island 2001-2002
3.9.1.2 Disease screening

Blood and faecal samples were taken from seven fernbird. The results are discussed in Chapter four.

3.9.1.3 Holding birds

More wax moth larvae and crickets were consumed than locusts or mealworms (Figure 28). All birds survived the transfer though some appeared stressed on release (fluffed up, slow). Areas where stressed birds were released were checked, but no bodies were detected after release (1-2 days). Six birds were held overnight in 2001 and three in 2002.

![Figure 28. Summary of live food consumption by captive North Island fernbird during translocations from RAP21 near Orewa to Tiritiri Matangi Island in 2001 and 2002.](image)

3.9.1.4 Monitoring

Sixty hours of post-release monitoring was carried out between July 2001 and September 2002 (Table 20). An additional 15 records from reliable observers were also collected over this period. Figure 29 shows the locations and dates of all observations over this period. Unconfirmed observations have been reported from all areas of the island, particularly Northeast Bay, Pohutukawa Bay and Fishermans Bay. Most observations have been of birds heard calling. Band recoveries have been rare. The
nests were not in the same location as the three birds detected in March 2002.

**Table 20.** Summary of post release monitoring of translocated North Island fernbird on Tiritiri Matangi Island.

<table>
<thead>
<tr>
<th>Date</th>
<th>Sightings</th>
<th>Location</th>
<th>Bands</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 July 2001</td>
<td>2 birds</td>
<td>Near Bush 22</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>2 birds</td>
<td>Near Bush 23</td>
<td>-</td>
</tr>
<tr>
<td>26 July 2001</td>
<td>1 bird</td>
<td>Wharf Road</td>
<td>-</td>
</tr>
<tr>
<td>6 September 2001</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>24-25 November 2001</td>
<td>1 bird</td>
<td>Little Wattle Valley</td>
<td>M-R</td>
</tr>
<tr>
<td>20-21 March 2002</td>
<td>3 birds</td>
<td>Northeast Bay</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>1 bird</td>
<td>Lighthouse Gully</td>
<td>-</td>
</tr>
<tr>
<td>19-21 September 2002</td>
<td>3 birds</td>
<td>Northeast Bay</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(a single bird and a nesting pair with chicks)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 29. Locations of fernbird sightings on Tiritiri Matangi Island July 2001-September 2002.
3.9.2 Previous fernbird translocations

Previous translocations of fernbird (Table 21) have used similar techniques, although all have actively driven birds into nets as well as passively calling them in with lure calls (M. Taylor, pers. com. 2001; McClelland, 1997). The fernbird captured on Codfish Island were not held any longer than four hours (McClelland, 1997).

Brood patches were evident on some captured birds transferred to Putauhinu Island. One bird died during the transfer and one was extremely stressed on release (panting, shivering, could not stand) (McClelland, 1998). G. Moon (pers. com., 2001) stated that birds captured at Omaha were in a stressed state on release as a result of handling. The measurements and banding details of the six birds caught in 1979 at Omaha for the transfer to Tahuna-Torea are listed in Appendix Two.


<table>
<thead>
<tr>
<th>Source</th>
<th>Release site</th>
<th>No of birds</th>
<th>Date</th>
<th>Post release monitoring</th>
<th>Deaths</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Codfish Island</td>
<td>Kaimohu Island</td>
<td>19</td>
<td>January 1997</td>
<td>20 hours</td>
<td>Unknown</td>
<td>Failed for unknown reasons</td>
</tr>
<tr>
<td>Codfish Island</td>
<td>Putauhinu Island</td>
<td>22</td>
<td>November to December 1997</td>
<td>Yes</td>
<td>One bird</td>
<td>Successful</td>
</tr>
<tr>
<td>Big Island</td>
<td>Kundy Island</td>
<td>24</td>
<td>1995</td>
<td>Yes</td>
<td>Unknown</td>
<td>Successful</td>
</tr>
<tr>
<td>Omaha</td>
<td>Tahuna-Torea</td>
<td>6</td>
<td>May-June 1979</td>
<td>Yes</td>
<td>Unknown</td>
<td>Failed for unknown reasons</td>
</tr>
</tbody>
</table>

3.10 Discussion

3.10.1 Translocations from Orewa to Tiritiri Matangi, 2001-2002

Twenty-five birds were moved in two translocations approximately one year apart. Griffith et al. (1989), Wolf et al. (1996) and Wolf et al. (1998) suggest that the numbers of animals released is an important component of success, as small populations are more susceptible to stochastic events. However large numbers (80-120 for birds, 20-40 for large mammals) do not increase the chances of success. Lovegrove and Veitch
(1994) stated that transfers of New Zealand birds have normally consisted of 15-40 birds, with successful releases of as few as five robins (*Petroica spp.*) on three occasions (see also Armstrong & Ewen, 2001; Butler & Merton, 1992).

Armstrong (2001) questioned the rationale behind follow up translocations, such as that conducted in this study with Tiritiri Matangi fernbird. Armstrong (2001) analysis was based on a closely monitored population of North Island robins (*Petroica australis longipes*) for which population parameters were available. Armstrong and Ewen (2001) suggested doing a cost benefit analysis before conducting any follow up translocations. Given the small number (13) of fernbird transferred in 2001, the absence of population parameters and threats to the source population due to further land clearance, a follow up translocation was considered expedient.

The importance of high quality habitat has been acknowledged in many studies (Griffith *et al.*, 1989; Lindenmayer, 1994; Wolf *et al.*, 1998; Wolf *et al.*, 1996), while others suggest it has been overstated, particularly for New Zealand birds (Craig, 1997). Andrews (1995) found no significant differences when comparing vegetation structure and density in Lighthouse Gully, Tiritiri Matangi, with two mainland sites occupied by fernbird. Historical records suggest fernbird had a wide mainland distribution in scrub and wetland habitats, particularly the extensive brackenlands, a result of Maori and European land clearance (Turbott, 1961). Fernbird have also been recorded in forested areas on some predator free offshore islands (Best, 1973). Such evidence suggests that fernbird exhibit habitat plasticity analogous to species such as North Island saddleback (*P. c. rufusater*) (Craig, 1994). Predation by introduced mammals probably causes most losses of breeding North Island fernbird and their nests (Chapters 1 and 2). Abundant suitable habitat and a lack of mammalian predators on Tiritiri Matangi should help to ensure that the translocation is successful.

Translocations in New Zealand have been widely criticised as *ad hoc* trials from which little has been learnt (Armstrong & McLean, 1995; Armstrong *et al.*, 1994). Unfortunately the circumstances under which the Orewa to Tiritiri Matangi transfer occurred, left little time to introduce an experimental component, though a natural experiment emerged with regards to the rapid replacement of birds on territories. In a review of territorial behaviour Newton (1992) stated that numerous removal experiments have revealed the presence of non-territorial birds, which rapidly take up
vacancies following removal of territory holders. Such experiments have also shown that some territories are favoured over others (Lovegrove & O'Callaghan, 1982), replacement being rapid on high quality territories and rare or non-existent on poor quality territories. The pattern observed at Orewa supports the latter finding. Replacement was rapid on one territory compared with all others from which birds were removed. The bird recaptured in 2002 was caught on the favoured territory. It was initially captured in 2001 on an adjacent territory, with the capture sites only about 50m apart.

Despite a lack of experimental manipulation, methods and techniques for capturing and transferring fernbird have been developed and refined, thereby facilitating future work with this species. Fernbird are very challenging to work with due to their secretive cryptic behaviour in very dense habitats. They are however very territorial, a feature easily exploited for capture. Except for a single pair caught in the afternoon, all multiple captures and suspected pairs were caught between sunrise and 10:00 h. Fernbird are most responsive to lure calls in the first two hours after dawn. The two birds captured in the middle of the day were targeted as they were actively calling on territory, and they rapidly responded to lure calls. Attempts to draw silent birds to nets on known territories in the middle of the day were unsuccessful, and are probably counterproductive because the birds become habituated to the lure calls. All afternoon captures, except one, were of single birds, presumably members of a pair on territory. The second bird would continue to respond to calls, however would not approach the net. Late in the day some even appeared to have gone to roost. Again, continued playback is probably counterproductive. When fernbird became habituated to lure calls, new calls were recorded on the target territories. Playback of an individual’s own call, or those of their mate or a close neighbour, usually gave a rapid response.

Mist net sites should ideally be located within known territories. If the net is close to a territorial boundary, the birds will respond to lure calls but may not approach. Moving a net only a few metres would often result in the capture of such birds. Birds were only caught in net sites with overhead cover. As arboreal insectivores which feed in dense vegetation, fernbird probably have keen eyesight. The birds often approached nets in open areas, but would not cross them. They would either fly over them or go around
them. Moving a net to a nearby site with overhead cover would often result in a capture.

The thick shrubland vegetation at Orewa meant that the capture methods used by McClelland (1997; 1998) and at Omaha (M. Taylor, pers. com., 2001) could not easily be used. Flushing birds into nets may add to an already stressful situation for some birds. In open sites with very low vegetation, such as Codfish Island and Omaha, it may be the only effective method of capture, however if other methods are available they should be used.

In captivity fernbird showed a preference for active live food such as crickets and wax moth larvae over slower moving mealworms. Provision of active invertebrates may encourage feeding by captive birds. Fernbird were successfully held for up to 24 hours. There have not been enough band recoveries to determine survivorship of same day transfers verses those held overnight. One bird (M-R), which was held overnight and from which blood and cloacal samples were taken, has been recorded on four occasions up to 12 months after release. While few conclusions can be based on one bird, it is at least an indication that individual birds can survive the stress of translocation.

Best (1973) found wing and tail length to be the best predictors of sex for Snares Island fernbird (*B. p. caudata*) when conducting a discriminant function analysis, however some overlap still occurred. Harris (1987) found a combination of tail length and culmen length provided the best discrimination of sex for South Island fernbird (*B. p. punctata*). Despite a statistically significant correlation, no biologically significant discrimination was evident when mensural characteristics were compared for the North Island fernbird transferred to Tiritiri Matangi. This might be due to an over-representation of young birds, or one sex, in this small sample. Behavioural observations, DNA analysis and unbanded birds and nesting activity on Tiritiri Matangi confirm that both sexes were caught. First year birds may also have been caught as indicated by the short square tails, as opposed to the characteristic worn frayed tails of adult fernbird.

Post release monitoring has been acknowledged as a crucial yet often neglected aspect of many studies (Armstrong & McLean, 1995; Lovegrove & Veitch, 1994; Pierre, 1999). Despite a large amount of post release monitoring on Tiritiri Matangi, very few
observations have been made. For many species this would indicate a failed introduction. However, the behavioural characteristics of fernbird make them a difficult species to monitor, particularly as a small population in a large area of potential habitat (Tiritiri Matangi is 220 hectares). All observations between July 2001 and March 2002 were of single birds, and only one band recovery was made. Since March 2002, there have been observations of two or three birds together (up to four separate observations on one day) but again no band recoveries. Despite extensive time and effort, and birds that were often within one metre of an observer, band recoveries have been very difficult to obtain, as the birds will not leave dense cover. Future transfers could include birds with radio transmitters to facilitate post-release monitoring. The use of transmitters would have to be carefully considered because fernbird live in tight, dense vegetation. Transmitters would probably have to be glued to the base of the tail as any harness attachment would probably get caught in vegetation. Clipping of feathers to glue transmitters to the birds back would probably also be unsuitable because fernbird are quite loosely feathered (pers. obs.), and the birds seem to get quite wet pushing through dense vegetation. The removal of feathers may have a negative effect on the thermoregulatory abilities of a small passerine. Radio transmitters would have to be tested on territory-holding birds prior to being placed on transferred birds, to test the effect of transmitters on survival. In the absence of a trial, mortality effects would be confounded by the transfer process (capture, handling, measuring, transport etc).

Fernbird have bred on Tiritiri Matangi. Unbanded birds were seen after the first breeding season on the island, and pairs have been observed duetting in three separate parts of the island. A pair with nestlings was observed in September 2002. At least one member of the nesting pair was unbanded, confirming breeding of first year birds on the island. There were no records of fernbird on the island before the transfer and it is unlikely any fernbird would have been overlooked, given the large number of experienced researchers, conservation workers and enthusiastic bird watchers that have visited the island on a regular basis for more than 20 years.

The goal of a self-sustaining fernbird population on Tiritiri Matangi is still unconfirmed. There is some debate as to what defines a successful introduction. Sarrazin and Barboult (1996) cite a measure of a three-year breeding population with
recruitment higher than the death rate of adults a measure of success and Beck (1994), who cites a translocated population of 500 individuals. Sarrazin and Barboult (1996) then suggest that a short-term measure would be the first wild born generation following translocation. Under this criterion the transfer to Tiritiri Matangi has been successful in the short term.

3.10.2 Comparisons with previous fernbird translocations

The Codfish Island to Kaimohu Island translocation failed while the Putauhinu Island and the Big to Kundy Island transfers were successful. McClelland (1997) suggested the Kaimohu translocation might have failed due to habitat differences between the two islands, predation from resident banded rail (*Rallus philippensis*), water shortage or stress during the transfer. McClelland (1997) thought it unlikely that the translocation failed due to stress as the birds were held for very short periods (4 hours or less), and a previous translocation of Stewart Island fernbird using similar techniques was successful.

McClelland (1998) stated that the death of one bird and doubtful condition of another on release at Putahinu Island was probably due to stress from being held in a double-ended transfer box with a bird in the opposite end. McClelland (1998) suggested birds in double-ended boxes might be more susceptible to stress, as they can hear the other bird, but cannot fight or escape from the perceived opponent. McClelland (1998) also stated that stressed birds could be provided with a glucose/saline solution on release to aid recovery.

It was difficult to find information about previous translocations of fernbird. The Department of Conservation does not appear to have any current accessible central translocation database for accessing information on prior translocations. Such a database would prove invaluable for staff within DOC and groups outside the Department conducting translocations. Information needs to be collated on both successful and unsuccessful translocations to provide guidance for managers conducting future translocations.

The Omaha to Tahuna-Torea translocation failed for unknown reasons. The very small number of birds shifted probably contributed to the failure.
3.11 Conclusions

3.11.1 Comparisons with other studies

The Codfish Island to Kaimohu Island translocation failed for unknown reasons, but may have been related to different habitat, predation, water shortage or stress. The Codfish Island to Putauhinu Island transfer was successful.

The Big Island to Kundy Island translocation was successful. Very little information was available on this transfer. The Department of Conservation should establish an accessible national database containing details of all translocations conducted regardless of the outcome.

The Omaha to Tahuna-Torea transfer failed for unknown reasons.

3.11.2 Recommendations for future transfers

3.11.2.1 Procedure

- Fernbird are most responsive to recorded calls early in the day, particularly in the two hours after daybreak.

- Multiple captures, including pairs, are most likely in the morning. In this study, captures later in the day comprised mainly single birds.

- The use of recorded calls should be minimised at all times to prevent habituation amongst the target population.

- In this study local calls, particularly those of targeted individuals or their close neighbours, resulted in successful captures of birds.

- Mist net sites will be determined by the local vegetation and terrain, however in this study low nets with overhead cover were found to be most effective, especially when set in known territories.

- Fernbird can be successfully held in individual transfer boxes for up to 24 hours, although holding and transport times should always be minimised if possible.

- Captive birds should be provided with a known number of active invertebrates, so that food intake can be monitored.
• McClelland (1998) stated that individual birds should be kept in separate boxes and saline/glucose solution could be administered to stressed birds on release.

3.11.2.2 Data collection

• North Island fernbird could not be sexed in the hand. No useful discrimination was detected from the mensural characteristics recorded (weight, wing, tail and culmen). Mensural characteristics are quickly and easily collected when processing birds. Future transfers should collect the characteristics obtained in this and other studies (Best, 1973; Harris, 1987). Larger samples may reveal greater discrimination, particularly if combined with DNA sexing techniques.

• DNA sexing may be the most reliable determinant of sex.

• Disease and baseline health data should be collected during every translocation (Chapter 4) especially when birds are being introduced to locations which may be free of some diseases and pathogens.

• A record of catch effort (number of nets set, days in the field, time of capture etc) should be kept for each translocation.

3.11.2.3 Post release monitoring

• Post release monitoring has proven to be difficult on Tiritiri Matangi due to the large area of potential habitat, the small number of birds and their cryptic behaviour. Despite a large number of observations, very few band recoveries have been made. However pairs have been recorded duetting, unbanded birds have been seen, and a pair with nestlings has been observed. This confirms short-term success. North Island fernbird can survive the transfer process and are able to breed on Tiritiri Matangi. It remains to be seen if a permanent population will establish on the island, however the abundant suitable habitat and no mammalian predators should provide a favourable environment for the new population to become established.

• Post-release monitoring is an essential component of any transfer. In this study, recordings of calling birds and some anecdotal sightings did assist with the post-release monitoring.
• The outcome of translocations, especially of cryptic species such as fernbird, may not be immediately apparent.

• Radio transmitters may be useful monitoring tools for future fernbird translocations. However field trials should be conducted on resident territorial fernbird to assess the effects of transmitters on survival.

3.12 Acknowledgements

A large number of people have contributed their time and effort to establishing fernbird on Tiritiri Matangi Island. Sandra Anderson and Tim Lovegrove provided invaluable advice, support and instruction in the field. I could not have conducted this transfer without their help. My supervisor, Dianne Brunton, also helped in the field and provided useful comments on this chapter. The Supporters of Tiritiri Matangi provided funding and many volunteers willing to brave the Orewa mud to help catch fernbird. Carl Hayson of the Supporters was particularly instrumental in making this transfer happen. Rosalie Stamp of DOC performed a sterling effort in pushing through the transfer permit as the bulldozer and chainsaws were warming up to do their wicked work. Numerous volunteers from the University of Auckland Ecology Lab came out and helped (thanks to my angels!), as did volunteers from DOC and the Royal Forest and Bird Protection Society. Ben Barr provided able assistance for the last week of catching. Tim Lovegrove and Michael Anderson provided helpful comments on this chapter. Lastly, thanks to all the little brown birds, whose lives were rudely interrupted for a quick trip to an island paradise.

3.13 References


Soderquist, T.R. (1994). The importance of hypothesis testing in reintroduction biology: examples from the reintroduction of the carnivorous marsupial *Phascogale*


### 3.14 Appendices

#### 3.14.1 Appendix One: Details of fernbird captured for transfer, Orewa to Tiritiri Matangi Island 2001-2002.

<table>
<thead>
<tr>
<th>Band number</th>
<th>Colour bands</th>
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<th>Tail (mm)</th>
<th>Culmen (mm)</th>
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### 3.14.2 Appendix Two: Details of North Island fernbird captured for translocation from Omaha to Tahuna-Torea, 1979.

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<td>15/5/79</td>
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4 Wildlife disease and implications for New Zealand Conservation

Abstract – Blood, cloacal and faecal samples were taken from North Island fernbird (Bowdleria punctata vealeae) during a translocation from Orewa to Tiritiri Matangi Island. Samples were taken from tui (Prosthemadera novaseelandiae), bellbird (Anthornis melanura) and one starling (Sturnus vulgaris) on Tiritiri Matangi Island. All birds were examined for avian pox in the hand. Samples were tested for avian malaria, atoxoplasma, yersinia, salmonella and coccidia. Coccidia was detected in one fernbird. No other disease was detected in any of the birds sampled. Despite the largely negative result in this study, disease screening, baseline haematology and biochemistry normal values should be collected at all opportunities, particularly when translocating birds. The importance and significance of disease to the conservation of New Zealand’s biodiversity is discussed.

4.1 Introduction

Disease can be broadly defined to include viral, bacterial, fungal, protozoan and metazoan parasites (Cunningham, 1996). Scott (1988) stated that disease might lead to death, increased susceptibility to predation or further disease, lowered reproductive capacity, or a combination of these factors. Infection with a parasite does not necessarily result in the death of the infected organism, and in some cases there may be little or no negative impacts (Cunningham, 1996). Haldane (1949 cited in May (1988) stated that disease has been the dominant selective force in human populations for at least 10 000 years. However, it is only relatively recently that interest in the effects of disease on wildlife populations has extended beyond those that impact upon human health, economic or recreational interests (Dasak et al., 2000; Deem et al., 2001; May, 1988). Leopold (1933) stated that the “the role of disease in wildlife conservation has been radically underestimated”. In contrast to this statement, almost all contemporary writers emphasise that disease has been virtually ignored in ecological research (Cunningham, 1996; Friend et al., 2001; May, 1988). Friend et al. (2001) state that the writings of notable ecologists such as Elton (1927) and Lack (1954) suppressed serious
discussion of the role of disease for decades. Current research dealing with disease has primarily consisted of opportunistic observations of individuals or large mortality events such as botulism in waterfowl, rinderpest in African ungulate species and avian malaria (*Plasmodium spp.*) in Hawaiian passerines (Deem *et al.*, 2001; Spalding & Forrester, 1993). Spectacular mortality events aside, it has been acknowledged that disease is difficult to detect and study in wild populations (Friend *et al.*, 2001; McCallum & Dobson, 1995). Despite the difficulties there are increasing efforts to document the impacts of disease on wild populations (May, 1988). Anthropogenic influences such as global habitat fragmentation, climate change and the increasing movement of exotic organisms, both intentional (exotic pet trade) and unintentional (mosquitoes) are all likely to contribute to an increasing emergence of diseases in wild populations (Friend *et al.*, 2001; Homberger & Beissinger, 2002; May, 1988; Scott, 1988). Deem *et al.* (2001) state global changes in habitat, wildlife populations and disease ecology make an understanding of the role of disease imperative, particularly with regards to conservation biology. Spalding (1993) states the role of disease as a component of endangered species research and translocation projects has been vastly underestimated. Dasak *et al.* (2000) warned that emerging infectious diseases threaten not only global biodiversity, but human and domestic animal health as well.

### 4.2 Wildlife Disease in New Zealand

There has been very little documentation of wildlife disease in New Zealand. However given the long history of introduced species with each successive human colonisation event, drastic landscape change and the frequent use of translocation as a conservation tool, disease may have had, and could be continuing to have, a profound impact on indigenous ecosystems. The study of wildlife disease in New Zealand has been similar to that in other parts of the world; the focus has been on those diseases that pose a threat to human concerns, particularly the transmission of tuberculosis to livestock (Cowan & Rhodes, 1992). Disease is cited by Heather and Robertson (1996) as a possible factor of decline in five New Zealand bird species. Bellbird (*Anthornis melanura*) provide a particularly compelling argument for the role of disease in New Zealand, given that they disappeared from the upper North Island in the 1860s but have persisted throughout the remainder of the country in the face of drastic landscape change and introduced predators (Craig, 1997). However, there is no conclusive evidence linking disease to the endangerment or extinction of any New Zealand species. Most accounts
are anecdotal reports of individual birds, either free-living or under intensive threatened species management, afflicted with a particular disease. The Department of Conservation (DOC) has recognised the potential threat of disease, particularly with regards to species translocations, and has prepared guidelines for disease screening and data collection (Jakob-Hoff, 1999). A national database called Huia is being established for the collation of disease information in New Zealand wildlife.

4.3 Aims

The Department of Conservation requested that a minimum of three and a maximum of six North Island fernbird (*Bowdleria punctata vealeae*) be screened for disease as part of the 2001/2002 fernbird translocation to Tiritiri Matangi Island (Tiritiri Matangi) (Chapter 3). Results were to be discussed with veterinary advisors and “...in the light of known information about disease risks present at the transfer site, a decision on any implications for the transfer progressing will be made” (S.Taylor, pers. com., 2001).

Due to limited information about avian disease on Tiritiri Matangi, DOC’s disease screening request was expanded to form a comparative study aimed at determining the presence or absence of six avian diseases in:

1. An isolated fernbird population.

2. A sedentary bellbird population on Tiritiri Matangi.

3. Tui (*Prosthemadera novaeseelandiae*) and starlings (*Sturnus vulgaris*) that move freely between Tiritiri Matangi and the mainland.

It was hypothesised that any disease detected in fernbird would already be present on Tiritiri Matangi, due to the long history of translocations and the daily movement of large numbers of birds between the island and the mainland.

4.4 Methods

Cloacal smears, blood and faecal samples were collected from fernbird from Orewa and from bellbird, tui and one starling on Tiritiri Matangi. The Orewa samples were collected from fernbird captured for transfer to Tiritiri Matangi in June-August 2001 and May 2002 (Chapter 3). Tui and bellbird samples were collected on Tiritiri Matangi August-September 2001. The starling sample was taken from a single bird shot by
DOC staff on Tiritiri Matangi in September 2002. Tui and bellbird were captured in mist nets set in front of flowering karo (*Pittosporum crassifolium*) and kowhai (*Sophora microphylla*).

Blood samples were collected from the brachial wing vein (Jakob-Hoff, 1999) (Figure 30). The vein was pricked with a 27-gauge needle. Blood from bellbird and tui was collected with a small capillary tube and then blown on to slides with a small dropper. The uptake of blood was too slow when taking samples with capillary tubes from fernbird so the slides were placed directly on the wing. While a blood smear was made with a cover slip, the assistant holding the bird applied pressure with a sterile swab against the wing until bleeding ceased. Cloacal smears were taken with a lubricated paediatric swab that was inserted into the bird’s cloaca (Figure 31). Fresh faecal matter was collected if birds defecated while being handled, or collected from the black cotton holding bags. All samples were labelled with the date, species identification and location. All birds were physically examined for signs of avian pox.

Blood smears were tested for avian malaria and atoxoplasma (*Atoxoplasma spp.*). A full blood count was also taken from each smear. Cloacal smears were tested for yersinia (*Yersinia spp.*) and salmonella (*Salmonella spp.*). Faecal samples were tested for coccidian parasites. All samples were sent to the Auckland Animal Health Laboratory. Disease samples were collected under permit from DOC and the University of Auckland Animal Ethics Committee (Approval notice N960).
Figure 30. Blood collection from a tui (Photo: Steve Hart).

Figure 31. Taking a cloacal swab from a tui (Photo: Steve Hart).
4.5 Results

Coccidia was detected in a single fernbird transferred to Tiritiri Matangi in 2001. Avian pox was not detected in any of the 43 birds physically examined over the course of this study (Table 22). Concerns about the effects of taking cloacal swabs, particularly from fernbird (body weight 16-22 grams), resulted in smaller sample sizes for those diseases requiring this sampling method (yersinia and salmonella). It was not possible to test bellbird or tui for coccidia. Both species were feeding on nectar at the time of capture and all faecal matter was in a liquid state.

Table 22. Incidence of disease in four species of passerine birds on Tiritiri Matangi.

<table>
<thead>
<tr>
<th></th>
<th>Orewa Fernbird</th>
<th>Tiritiri Matangi Bellbird</th>
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</table>

Haematology profiles are listed in Appendix One. As these are the first haematology profiles collected for these species, only very limited inferences can be made. In commenting on the results, veterinarian R. Jakob-Hoff (pers. com., 2002), stated the low heterophil count in fernbird is of interest, but uninterruptible due to small sample size. The high basophils (20%) in one fernbird, suggest an early inflammatory response due to minor infection or injury. Small numbers of toxic heterophils in one bellbird suggested low level infection or toxaemia. The high number of polychromasisis and presence of young cells in one bellbird indicates regeneration of red blood cells due to recent or current anaemia.

4.6 Discussion

Coccidia was the only disease identified in any of the birds screened in this study. A positive result was gained for a single fernbird that was transferred to Tiritiri Matangi from Orewa in 2001. R. Jakob-Hoff (pers. com., 2002) stated that this is most likely normal, and of no consequence, as most passerines carry their own species of coccidia.
The presence of coccidia lends some support to the hypothesis posed, as coccidia has been detected in North Island saddleback (*Philesturnus carunculatus rufusater*) and hihi (*Notiomystis cincta*) on Tiritiri Matangi (Huia database). Coccidia has also been detected in North Island brown kiwi (*Apteryx australis mantelli*) (R. Jakob-Hoff, pers. com., 2002).

None of the other diseases were detected in any of the birds sampled. This is not an indication that these diseases do not exist within the species sampled, nor that they are not susceptible to these diseases (Cunningham, 1996). Laboratory testing is the most reliable method of checking for the presence of disease or parasites, as symptoms are often quite general and shared by a variety of pathogens (Scott, 1988). Scott (1988) stated that a negative result may indicate a recent infection or parasites that are not producing eggs or larvae. A negative serology result may indicate an individual has never been infected, infection is so recent that no antibodies have yet developed, the host has been infected but only had short term immunity and no antibodies are present, or that the host is or was infected but was unable to produce antibodies (Scott, 1988). A positive result for macroparasites such as coccidian, is a clear indication that the host is infected (Scott, 1988). Scott (1988) states that a positive result for a serological test can indicate an infection is present, a previous infection to which the host is now immune, cross-reaction with shared antibodies from another infection or the presence of antibodies passed from mother to offspring.

No reference to the diseases tested for, or any other disease, was located for fernbird, starlings or bellbird. Bergguist (1986) reported avian spirochaetosis caused by *Borrelia spp.* in eight tui from the Auckland region. Anecdotal reports of tui deaths and characteristic symptoms (disoriented, weak, unable to fly, mucus discharge) were reported from around Auckland, including two birds on Little Barrier Island at the same time as Bergguist’s (1986) observations.

The haematology profiles collected are the first for these species in New Zealand. Haematology profiles vary considerably between species (Jakob-Hoff, 1999). The small samples collected in this study, and the absence of comparative data, preclude comment on the normality of the profiles. However, minor infection of unknown origin was detected in one fernbird and one bellbird and anaemia was detected in one bellbird (R. Jakob-Hoff, pers. com., 2002).
The investigation of disease in New Zealand is hindered by a paucity of information. It is unclear what type of disease should be investigated for most species. The disease screening protocol requested by DOC was based on those diseases that have been detected in other New Zealand species (R. Jakob-Hoff, *pers. com.*, 2002) (Table 23).

**Table 23.** Observed occurrences of six diseases in New Zealand birds.

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<tr>
<th>Disease</th>
<th>Species</th>
<th>Reference</th>
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<td></td>
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<td>Butler (1992)</td>
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<td></td>
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</tr>
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<td></td>
<td>Dunnock (<em>Prunella modularis</em>)</td>
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<td>D. Nelson (<em>pers. com.</em>, 2001)</td>
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<td></td>
<td>kereru (<em>Hemiphaga novaeseelandiae</em>)</td>
<td>Williams (1955)</td>
</tr>
<tr>
<td></td>
<td>gulls (<em>Larus spp.</em>)</td>
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<td></td>
<td>yellow-eyed penguin (<em>Megadyptes antipodes</em>)</td>
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<td>hihi</td>
<td>Jakob-Hoff (1999)</td>
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<tr>
<td>Atoxoplasma</td>
<td>hihi</td>
<td>Jakob-Hoff (1999)</td>
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<tr>
<td></td>
<td>North Island saddleback</td>
<td>R. Empson (<em>pers. com.</em>, 2002)</td>
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Despite the extremely limited results gained, the expense and time involved and the stress imposed on individual birds, the collection of disease data is important as it enables the identification of new diseases and the spatial and temporal tracking of existing diseases. The collection of baseline health surveillance data, such as blood haematology and biochemistry, may prove to be even more valuable in establishing “normal values” for a particular species, as indicators of health (Jakob-Hoff, 1999) (Appendix 1). Deem *et al.* (2001) emphasise the importance of baseline monitoring to
prevent new health problems emerging rather than dealing with crisis situations. Such information can often be collected from the same samples used for disease screening. Jakob-Hoff (1999) recommended a minimum of 40 healthy individuals be sampled in order to establish a significant range of normal values. While such data are more likely to be collected for threatened species, efforts should be made to collect information from a range of species. All opportunities to collect baseline data should be exploited (Deem et al., 2001; Spalding & Forrester, 1993). Vigilant field workers can also contribute by noting and collecting dead or dying individuals (Jakob-Hoff, 1999; Wobeser, 1994). Proper training and practice is essential to prevent wasted effort and undue stress to study animals. Accurate haematology profiles could not be obtained from some of the first samples taken in this study, as avian blood cells are extremely fragile and the cells were damaged whilst preparing blood smears. Practice and discussion with an experienced veterinarian, allayed early concerns about the effect of taking cloacal smears from small passerines.

Given the restricted distribution and small population size of many threatened species such as kakapo (*Strigops habroptilus*) and takahe (*Porphyrio mantelli*), detection of disease may be even more difficult. However Deem et al. (2001) emphasised that the potential for disease to spread on the small, often densely populated islands that many threatened species inhabit is much higher. Disease may first emerge in a common species, as has been recently observed in sparrows and silvereyes (D. Nelson, *pers. com.*, 2001). These species may act as vectors for transmitting disease to island populations of threatened species.

Avian diseases have emerged unpredictably across the globe, the magnitude of impacts varying greatly among species (Friend et al., 2001). New diseases may emerge, undergo geographic expansion, re-emerge or make novel appearances in areas from which they were previously unknown. The West Nile virus has emerged in more than 60 species of wild bird and several mammals, including humans, since first detection in North America in 1999 (Friend et al., 2001). Massive mortality due to an unidentified pathogen has devastated vulture populations in India, Pakistan and Nepal in the last decade (Friend et al., 2001; Risebrough, 2002). A recent outbreak of avian conjunctivitis has swept through a naïve population of house finches (*Carpodacus mexicanus*) on the east coast of the United States (Dhondt & Hochachka, 2002; Friend
et al., 2001). Avian malaria and avian pox has been a significant agent of decline in Hawaiian passerines (Atkinson et al., 1995; Kuehler et al., 1996; Ralph & Fancy, 1995). New Zealand’s isolation may afford little protection against emerging infectious diseases; for example antibodies to a domestic chicken pathogen, infectious bursal disease virus, have been detected in penguin populations in Antarctica (Dasak et al., 2000).

The ecological importance of disease is becoming much more recognised both as an influence on historical and contemporary extinctions and declines (Dasak et al., 2000). Conservation management strategies frequently employed in New Zealand, particularly translocations, could be seriously affected by disease. Despite largely negative results such as those gained in this study, the investigation of diseases, and the accumulation of an extensive database, is of profound importance for the maintenance of New Zealand’s biodiversity.

4.7 Conclusions

Coccidia was detected in a single fernbird, lending some support to the hypothesis posed, that disease present on the mainland would also be on Tiritiri Matangi. Coccidia has been detected in hihi and saddleback on Tiritiri Matangi.

None of the other diseases screened for were detected in any species tested. Despite a negative result, various diseases may still be present. Detection of disease in New Zealand wildlife is particularly difficult, as so little is known about what to look for. The collection of baseline haematology profiles whilst screening for disease may prove to be more valuable for general wildlife health monitoring by providing normal values for various species. Disease samples and baseline haematology profiles should be collected at every opportunity.

The restricted distribution of many threatened species on small-densely populated islands could make them vulnerable to disease, particularly if common species act as vectors between the mainland and the islands. Disease has emerged as a serious conservation problem in many species around the world. Whilst disease has not been proven to have contributed to the decline or extinction of any New Zealand species, there is no reason to think that New Zealand species are immune to future disease
emergence. Disease screening and wildlife health monitoring should be an important component in the maintenance of New Zealand’s biodiversity.

4.8 Acknowledgements

My supervisor Dianne Brunton provided advice and support throughout this study. Sandra Anderson’s assistance and guidance in the collection of all disease samples was invaluable. Talya Oron, Ron Moorhouse and Ji Weihong assisted in the mist netting and collection of samples on Tiritiri Matangi. The Supporters of Tiritiri Matangi Incorporated provided funding for laboratory disease screening. Richard Jakob-Hoff, the Auckland Zoo veterinarian, provided guidance in collection techniques and helpful comments on results, as did Lyn Happy and Karen Cooper of Gribbles Veterinary Pathology (formally Auckland Animal Health Laboratory). Tim Lovegrove, Jonathan Boow and Michael Anderson provided helpful comments on this chapter.

4.9 References


### 4.10 Appendices

#### 4.10.1 Appendix one. Baseline haematological values collected from birds on Tiritiri Matangi Island and at Orewa 2001-2002.

<table>
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5 Management of North Island fernbird
(*Bowdleria punctata vealeae*): An ecosystem approach

**Abstract** – Fernbird (*Bowdleria punctata vealeae*) have undergone a significant decline in distribution since the arrival of Europeans. The current distribution is described as widespread but patchy, however the species is not considered to be threatened. Many populations are small and isolated and dispersal patterns are unclear. Fernbird should be managed using a metapopulation approach aimed at protecting the ecosystems in which they persist, rather than a focus on the individual species. Such a focus will benefit a wider range of species and may facilitate the future reintroduction of rare species into protected and restored habitats. Recommendations are made for research and management of North Island fernbird.

5.1 Introduction
Conservation in New Zealand has been characterised by heroic rescues of endangered wildlife by skilled and dedicated workers. The Chatham Island black robin (*Petroica traversi*) is perhaps the most extreme example of this. An intensive management effort involving habitat repair, cross-fostering, and island translocations brought a population of just five individuals (one breeding pair) back from the brink of extinction (Butler & Merton, 1992). Several other species have recovered from near extinction due to an intensive management effort (Armstrong & McLean, 1995; Elliott *et al.*, 2001; Lovegrove & Veitch, 1994). Research and management techniques are constantly being refined. Advances in pest control, particularly poisoning techniques and predator proof fencing, have facilitated removal of rodents from progressively larger islands and have led to the creation of mainland islands. The focus of conservation management has typically been on protecting threatened species in secure locations, generally offshore islands (Craig, 1997). However, the last decade has seen increasing efforts to transfer species back from offshore islands to secure mainland locations undergoing restoration (T. Lovegrove, *pers. com.* 2002; R. Empson, *pers. com.* 2002). It has been argued that single species management is only a partial solution, and that efforts should
increasingly include a landscape approach to preserving biodiversity (Hobbs, 1994; Simberloff, 1997). There can be little argument that intensive management is still necessary to prevent an irreversible decline of some New Zealand species, such as kakapo (*Strigops habroptilus*) (Elliott *et al.*, 2001). There are however, a number of species, such as fernbird (*Bowdleria punctata*), pipit (*Anthus novaeseelandiae*) and variable oystercatcher (*Haematopus unicolor*), whose status on the mainland is uncertain. While these species are not generally considered threatened they have all undergone significant declines as a result of human activities (Heather & Robertson, 1996). Conservation research and management should focus on identifying species that are potentially at risk. These species may significantly benefit from management and research actions that are considerably less intensive than those focused on threatened species. A wider ecosystem approach enables multiple goals to be achieved. Hobbs (1994) stated that the species making up the biodiversity of a region depend on functioning landscapes. Species conservation can only occur if these landscapes are protected (Hobbs, 1994). Methods of protection such as predator control benefit communities of species and in the long-term facilitate the reintroduction of rarer species to protected and restored habitats.

### 5.2 Recommendations

#### 5.2.1 The mainland distribution and status of New Zealand fernbird

Fernbird have persisted on the mainland longer than many other native species, despite habitat fragmentation and the introduction of mammalian predators. This suggests that fernbird have behavioural adaptations to significant environmental change and new predation pressures. However there has been no widespread survey of fernbird since the Ornithological Society of New Zealand and the New Zealand Wildlife Service compiled the New Zealand Atlas of Bird Distribution in the late 1970s and early 1980s (Bull *et al.*, 1985). A decline in fernbird populations would most likely go undetected due to their cryptic behaviour and preference for habitats rarely visited by people. Harris (1987) stated that while the 1985 Atlas indicated a relatively widespread distribution, more than half of all populations recorded were probably small (<10 pairs) and in isolated remnants of habitat. Observations at Omaha during the present study, strongly suggest that introduced predators account for most losses of fernbird eggs and nestlings (Chapter 2). An adult bird was also killed on the nest during this study.
Predation and habitat changes may therefore be having a significant impact on mainland fernbird populations. The Atlas survey is being repeated and may indicate current fernbird population trends. The following recommendations are made:

- If a decline is detected further research establishing the causal factors responsible should be conducted, particularly regarding the role of introduced predators, competitors and habitat degradation.

- Point counts and distance sampling techniques are probably poor indicators of fernbird abundance due to the unpredictable and cryptic habits of fernbird (*pers. obs.;* Harris, 1987).

- Individual fernbird populations should be surveyed by mapping breeding territories with recorded calls early in the breeding season (June-August).

### 5.2.2 Fernbird dispersal

Nests at Omaha were observed through to fledging, however only one bird was observed post-fledging. Only a small number of fernbird were banded (n=9) and this study was only conducted over two breeding seasons. Very little is known about the dispersal abilities of fernbird. However fernbird, probably juveniles, have been observed >20km from the nearest breeding population following the breeding season (Heather & Robertson, 1996). A combination of banding and genetic analysis may reveal the degree of relatedness among separate populations of fernbird, and provide valuable information on dispersal and mortality. The Omaha population would be suitable for such a study as the saltmarsh is relatively easy to access and there are a number of wetlands of varying sizes in the surrounding area to which fernbird might disperse.

- An extensive long term banding study, ideally on a population with a range of dispersal options (*i.e.* suitable habitat within a range of distances, e.g. 1km, 5km, 10km, 20km, from the banded population), should be conducted to determine dispersal ability and adult and fledgling mortality.

- Genetic analysis of separate populations within a region may also provide useful information regarding relatedness and dispersal patterns.
5.2.3 Potential predators and competitors at Omaha

Mice (*Mus musculus*) and Asian paper wasps (*Polistes chinsis antennalis*) are common in the Omaha saltmarsh (Chapter 1, Chapter 2). Both species have been identified as potential predators or competitors in New Zealand ecosystems (Clapperton, 1999; Moors, 1978, 1983) however very little research has been conducted on either species. Mice may be egg predators of laying or incubating fernbird and might also compete for invertebrate resources. Mice and Asian paper wasps may both compete with fernbird for invertebrate resources.

- A mark recapture study and dietary analysis of mice would contribute to an understanding of their abundance and impact on the saltmarsh ecosystem and confirm if they are significant predators of nesting fernbird.

- The role of Asian paper wasps as potential competitors for invertebrate resources should be quantified. Asian paper wasps may be having significant impacts on the entire ecosystem, much like *Vespula* wasps in forested areas (Beggs, 2001).

5.2.4 Regional differences in territory size

Barlow (1983) detected significantly smaller territories (Chapter 1) than those observed at Omaha in a study of South Island fernbird (*B. p. punctata*) in saltmarsh habitat near Invercargill. This is surprising as South Island fernbird are larger, therefore might be expected to have larger territories, and a greater ability to defend them. The factors determining territory size are not apparent, however Asian paper wasps are not present in the South Island, which may contribute to observed differences (Clapperton, 1999).

- A comparative study, particularly of a northern and southern saltmarsh, may reveal the role of introduced predators and competitors and different resource availability relative to latitude.

5.2.5 An ecosystem approach to the management of the Omaha saltmarsh

An additional 46 species of birds were recorded in the Omaha saltmarsh over the course of this study, including uncommon and threatened species such as Australasian bittern (*Botaurus poiciloptilus*) and New Zealand dotterel (*Charadrius obscurus*) (Appendix
Skinks (probably shore skinks, *Oligosoma smithi*) were seen in the marsh on several occasions and sloughed gecko skin (*Naultinus spp.*) was found in vegetation in the marsh. Apart from pampas grass (*Cortaderia selloana*) and gorse (*Ulex europaeus*) at the southern boundary the saltmarsh is relatively weed free. An open-ended predator proof fence designed to exclude domestic pets and possums (*Trichosurus vulpecula*) has been constructed along the eastern boundary of the kahikatea (*Dacrycarpus dacrydiodes*) forest. This provides an opportunity to further protect the saltmarsh. The short-term study conducted did not reveal any fernbird population trends, however as mentioned, introduced predators account for most losses of eggs and chicks (Chapter 1). Fernbird are not considered a threatened species. However their cryptic behaviour and low nesting habits make them difficult to monitor and susceptible to predation. The Omaha fernbird population and the ecosystem that they inhabit would benefit from control of the introduced predators and competitors in the marsh. An ecosystem approach would essentially create a wetland mainland island, a project that has yet to be attempted in New Zealand.

- Establishment of a poison bait station to control rodents and possums. Control need not be year round, but could be pulsed at intervals leading up to and during the breeding season.

- A perimeter line of predator traps (Fenn and cat cage traps) will control cats (*Felis catus*) and mustelids (*Mustela spp.*).

- The predator proof fence could be extended and modified to exclude mustelids and rodents. Reinvasion is likely as it is not possible to fence the entire saltmarsh. However introduced mammals could be kept at lower densities than might otherwise be observed in the absence of a fence.

- Protection could be funded and maintained by Department of Conservation or through a local Landcare group, such as the New Zealand Royal Forest and Bird Protection Society.

- Monitoring and research on invertebrates, vertebrates and plant communities should accompany protection measures, in order to document their effectiveness.
Due to its small size, relative ease of access and diverse avian community the Omaha saltmarsh is an ideal location for ecosystem studies.

5.2.6 Management of mainland fernbird populations

Fernbird populations are described as widespread but patchy (Heather & Robertson, 1996). Given the lack of information on dispersal and population trends, fernbird should be managed as a metapopulation.

Isolated populations of fernbird and the ecosystems they inhabit can be protected and enhanced with the same techniques recommended for the Omaha saltmarsh (predator and competitor control, habitat enhancement such as predator proof fencing and weed control).

5.2.7 Fernbird translocations

It has been shown that it is possible to successfully transfer fernbird, though the long-term outcome of the transfer to Tiritiri Matangi is still uncertain (Chapter 3). The translocation of fernbird to Tiritiri Matangi will provide an opportunity to investigate the effects of introduced predators on breeding success, and fernbird habitat plasticity in an environment free of introduced predators. A radio telemetry study on the post-release behaviour of fernbird may contribute to the success of future translocations. Concerns regarding transmitter use are outlined in Chapter Three.

Fernbird are a suitable species for early release in many restoration projects due to their preference for early successional vegetation and their ability to withstand some predation.

Transfers must be followed up with post release monitoring.

Transfers to mainland sites may be complicated by post-release dispersal behaviour.

A pilot study on the effects of radio transmitters on territorial fernbird should be conducted prior to transfer in order to ascertain any negative effects of transmitter attachment on fernbird survival.
• Disease samples (blood and faecal samples) and baseline haematology values should be collected during any translocation of fernbird (Chapter 4).

5.3 Acknowledgements

Emma Marks, Paul Barnett and Michael Anderson provided useful comments on this chapter

5.4 References


5.5 Appendices


Black shag (Phalacrocorax carbo)

Pied shag (Phalacrocorax varius)

Little shag (Phalacrocorax melanoleucos)

White-faced heron (Ardea novaehollandiae)

Australasian bittern (Botaurus poiciloptilus)

Paradise shelduck (Tardorna variegata)

Mallard (Anas platyrhynchos)

Grey duck (Anas superciliosa)
Australasian harrier (*Circus approximans*)

Pheasant (*Parvo cristatus*)

Banded rail (*Rallus philippensis*)

Spotless crake (*Porzana tabuensis*)

Pukeko (*Porphyrio porphyrio*)

South Island pied oystercatcher (*Haematopus ostralegus*)

Variable oystercatcher (*Haematopus unicolor*)

Spur-winged plover (*Vanellus miles*)

Pied stilt (*Himantopus himantopus*)

Banded dotterel (*Charadrius bicinctus*)

New Zealand dotterel (*Charadrius obscurus*)

Bar-tailed godwit (*Limosa lapponica*)

Black-backed gull (*Larus dominicanus*)

Red-billed gull (*Larus novahollandiae*)

Caspian tern (*Sterna caspia*)

White-fronted tern (*Sterna striata*)

Kereru (*Hemiphaga novaeseelandiae*)

Kaka (*Nestor meridionalis*)

Eastern Rosella (*Platycercus eximius*)

Shining cuckoo (*Chrysococcyx lucidus*)

Morepork (*Ninox novaeseelandiae*)
Kingfisher (*Halcyon sancta*)

Welcome swallow (*Hirundo tahitica*)

Silvereye (*Zosterops lateralis*)

Grey warbler (*Gerygone igata*)

Blackbird (*Turdus merula*)

Song thrush (*Turdus philomelos*)

Skylark (*Alauda arvensis*)

North Island fernbird (*Bowdleria punctata vealeae*)

Fantail (*Rhipidura fulginosa*)

Tui (*Prosthemadera novaeseelandiae*)

House sparrow (*Passer domesticus*)

Chaffinch (*Fringella coelebs*)

Redpoll (*Carduelis flammea*)

Goldfinch (*Carduelis carduelis*)

Yellowhammer (*Emberiza citrinella*)

Starling (*Sturnus vulgaris*)

Myna (*Acridotheres tristis*)

Australian magpie (*Gymnorhina tibicen*)