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Managing populations of the Australasian harrier (*Circus approximans*) to reduce passerine bird damage in vineyards

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A thesis

submitted in partial fulfilment

of the requirements for the Degree of

Master of Applied Science

at

Lincoln University

by

Marlene Anne Leggett

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Lincoln University

2012

Abstract of a thesis submitted in partial fulfilment of the requirements for the degree of Master of Applied Science.

Managing populations of the Australasian harrier (*Circus approximans*) to reduce passerine bird damage in vineyards

By M. A. Leggett

Vineyards around the world sustain significant economic losses due to grape loss and damage caused by frugivorous passerine birds, and while bird control methods are in place, their efficacy is limited and/or short lived. With the call for more sustainable agricultural practices globally, it would be advantageous to offer an ecologically based solution to the bird problem in vineyards, while further research and development into cheaper, more effective methods of bird control that does not create noise or disturbance to communities surrounding vineyards is required.

The Australasian harrier, a native, diurnal New Zealand raptor, is the focal species of this project. With considerable numbers of harriers sited around New Zealand viticultural land, the aim of this project was to attract populations of these harriers into vineyards by providing them with an important food source – animal carcasses. The presence of harriers was expected to exploit the innate fear that pest passerine birds have towards raptors and provide an effective biological control aid that would provide an economically and environmentally sound solution to passerine bird induced grape damage as the passerines responded to the harrier rather than foraging on grapes.

The Australian harrier was attracted to raised feeding tables in Canterbury and Wairarapa vineyards with supplementary food. Results indicated it was difficult to attain regular feeding from all tables set up. Some feeding table sites saw harriers feeding off tables regularly and intermittently, while at other sites no harriers exploited the tables. When presented with a two choice food test on feeding tables, comprising one-day-old cock chicks and rabbit pieces in the springtime, chicks (86%) were the harriers' clear choice over rabbit pieces (14 %). During the summer season, there was no preference, with equal amounts of both baits taken.

Where feeding tables were present, pest bird abundance decreased by 56 %, and grape damage also decreased by 59 %; however, these results were not necessarily linked only to harrier presence. While harrier numbers increased due to feeding tables, so did the number of other predators. A further trial without feeding tables where supplementary food was placed on the ground to attract all predators, showed an increase of predators in the treatment sites compared to control sites, with harriers and cats the most frequently observed. Pest passerine bird densities in the control sites were higher than the treatment sites.

Raised feeding tables baited with animal carcasses are not necessarily a reliable method to encourage harrier feeding in vineyards. Several reasons may explain why this method may be unreliable. The best reason may be the motivation to feed off a novel object, i.e. the raised table was not sufficient because of neophobic tendencies for some harriers, and these were difficult to overcome. Alternative, easily accessible food sources were readily available in some landscapes and agonistic relationships with other species, who were frequently seen harassing harriers in study sites, may well have confounded attempts to achieve feeding off tables at all sites. Findings perhaps negate the need for any feeding tables, and supplementary feeding alone may be the key to attracting harriers and other predators into vineyards to achieve the fundamental goal of decreasing pest passerine bird numbers and consequent grape damage.

Keywords: ecosystem service, supplementary feeding, neophobia, raptors, predators, vineyards, grape damage, passerine birds, pest management

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*All photographs taken by M. A. Leggett

Chapter 1
Introduction

1.1 The problem of passerine birds in vineyards

1.1.1 Economic losses

Vineyards around the world sustain significant economic losses due to grape (*Vitis vinifera*) loss and damage caused by frugivorous passerine birds (Plesser *et al*., 1983; Somers & Morris, 2002; Berge *et al.*, 2007a; Tracey *et al.*, 2007). While it appears to be a difficult task to obtain accurate figures when assessing economic losses to the viticulture industry because of bird damage, some estimates have been made. In 1998, the estimated total loss of grape production in Marlborough, New Zealand was approximately 3%, or around $1 million NZD, despite bird control measures being in place (Boyce *et al*., 1999). The financial implications from a loss of grape production will have increased as the number of vineyards in New Zealand has grown over the past decade and the wine industry itself has shown a rapid increase. The statistical annual from "New Zealand Wine" (http://www.nzwine.com/) reported that the national vineyard in 2000 was 10,197 hectares, and had increased to 31,964 hectares by 2009.

Saxton (2004) reported that the common 10-15% loss in grape yield in New Zealand vineyards due to bird damage resulted in considerable economic losses. Earlier studies by Fukuda (1999) and Watkins (1999), noted that the greatest loss to New Zealand vineyards was related to grape loss/damage caused by birds, while anecdotal reports went as far as estimating a loss in wine production due to bird damage to be as much as $70 million nationally (Fox, 2008). Boyce *et al.* (1999) suggested that in some of the vineyards surveyed, more money was spent on bird control than was estimated to have been saved on crop damage. In Australia, it was reported (Tracey & Saunders, 2003) that bird damage was responsible for a total economic loss in some vineyards, while overall losses were estimated at nearly $300 million AUD annually (Tracey *et al.*, 2007).

Research into reducing bird damage currently lacks adequate information with regard to the severity and spatial distribution of damage, along with data efficacy and cost/benefit analyses related to reduction strategies (Tracey *et al*., 2007). It has also been suggested that identifying the most susceptible areas of damage in vineyards is perhaps more useful than estimating total

yield losses (Somers & Morris, 2002). Further investigation into possible causes and subsequent solutions with robust evaluation methods are required to mitigate economic losses caused by passerine birds located in vineyards.

1.1.2 Damage caused

Bird damage to grapes has two main mechanisms: removal of the whole grape and pecking of the grape, which breaks the grape skin barrier and allows the entrance of yeast, fungi, and bacteria (Boyce *et al.*, 1999; Saxton, 2004; Tracey *et al.*, 2007). *Botrytis cinerea* is an example of this; a necrotrophic fungus, it gains entry through pecked grapes and can result in heavy yield losses and tainted wine (Santos *et al.*, 2004; Elmer & Michailides, 2004; Jacometti *et al.*, 2007)

In New Zealand vineyards, the major contributors to grape damage are the introduced European starling (*Sturnus vulgaris*), European blackbird (*Turdus merula*) song thrush (*Turdus philomelos*), and the self-introduced silvereye (*Zosterops lateralis*) (Watkins, 1999; Saxton, 2004). The blackbird, starling, and song thrush take the whole grape while the silvereye, due to its smaller size, pecks the grape, producing wounds that attract wasps (*Vespula* spp.) (Porter *et al.*, 1994). Wasps may increase the size of the damaged area, and help to provide the establishment of the *Botrytis cinerea* fungus (Boyce *et al.*, 1999; Tracey & Saunders, 2003).

Reports have suggested that the introduced myna (*Acridotheres tristis*) (Saxton, 2004), and the house sparrow (*Passer domesticus*) (Tracey *et al.*, 2007; Beard, R., pers. comm. 2009), also play a part in grape damage in New Zealand vineyards. The myna is restricted by geographic location (the upper North Island) so will not affect this study's lower North/South Island's geographic location. In addition, there are conflicting opinions (Nelson, 1990; Boyce *et al.*, 1999; Saxton, 2004), on the culpability of sparrow-induced grape damage in New Zealand; therefore, these two species will not be addressed in this study.

Grape damage sustained by birds, is not consistent throughout vineyards (Somers & Morris, 2002; Tracey & Saunders, 2003), varying spatially and temporally within and between vineyards (Somers & Morris, 2002). This is supported by Saxton (2004) who observed the interior vines in a vineyard do not generally sustain much damage from bird pressure, but vines that are at the edge of the vineyard are more vulnerable to bird attack and generally sustain the most damage. In this case, smaller vineyards, with higher edge to interior area

ratios will suffer greater economic losses than larger ones (Tracey & Saunders, 2003; Saxton, 2004). Grape damage is also seasonal and most bird pressure commences in autumn, coinciding with the véraison (when the grape changes colour) and the grape-ripening period.

1.1.3 Driving factors that cause damage

Saxton (2004) suggested that grape depredation by pest birds is probably reliant on many factors; including hunger, nutritional needs, mimicking behaviour of other birds, grape availability and abundance, and environmental factors. Reducing bird damage is a daunting task due to unpredictability of damage from year to year. Seasonal conditions, bird population numbers, and localisation of damage (Boyce *et al*., 1999; Tracey *et al*., 2007) are often different between years.

Grape damage by birds often correlates with the vegetation present in and around the vineyard site. Birds may nest in surrounding vegetation, i.e. shelterbelts, all year round in vineyards even when grapes are not present (Saxton, 2004) and damage is often concentrated around these features (Tracey *et al*., 2007). The close proximity of "cover" or roosting sites for passerine birds appears to enhance the damage to outer grapevine rows, allowing birds to make a swift retreat to the trees when threatened by perceived predators.

Watkins (1999) pointed out that there are both extrinsic and intrinsic factors that influence the type and level of damage that a vineyard sustains. Extrinsic includes the "structure and composition" of the surrounding habitat and intrinsic concerns the grape itself. Extrinsic factors include height and density of the vegetation, including the proximity of the vineyard to bird roosts and perching sites. Vegetative cover characteristics, an important feature in minimising predatory risk, can affect a bird's decision to remain at a foraging site (Lima, 1990; Porter *et al*., 1994; Somers & Morris, 2002; Taber, 2002; Saxton, 2004; Tracey *et al*., 2007). Intrinsic factors include maturity of the grape. Once a threshold of 13^{0}Brix (sugar level of a ripening grape) is reached, an exponential rate of damage can occur (Tobin, 1984; Watkins,1999), and factors, such as colour and size of the grape, can all affect bird foraging decisions (Boudreau, 1972; DeHaven, 1974; Watkins, 1999; Tracey & Saunders, 2003**).**

Grape vine morphology, including the height of the grape bunch, branching pattern of the plant, position of fruit on the branch and proximity to stable perches within the plant on the vine can invite different levels of damage (DeHaven, 1974; Stanley & Lill, 2001). How a fruit is presented on a plant can affect the fruit's accessibility to frugivorous bird species

(Boudreau,1972; DeHaven, 1974; Somers and Morris, 2002), while grape bunches that are closer to the ground will be more vulnerable if certain bird species, for example blackbirds and song thrushes, that are commonly ground foragers, are common in the vineyard (Watkins, 1999).

1.2   Safe and economic solutions for bird control

There is a call for more sustainable farming practices globally, including requirements for decreased uses of pesticides and other environmentally unsustainable practices. It would be advantageous to offer a more ecologically-based solution to the bird problem in vineyards. Spadoro & Gullino (2005) and Jacometti *et al.* (2007) reported the growing demand for sustainable organic agricultural practices in wine production, and Duminy (2004) suggested that there is an increased demand for organic practices with regard to wine making which includes being "ecologically accountable" to consumers. Bisson *et al*. (2002) noted that the wine industry needs to promote environmental stewardship and that consumers are beginning to expect wine production to be implemented in an environmentally sustainable manner. "Sustainable Winegrowing New Zealand" (SWNZ) is attempting to address many of these concerns today.

Aside from environmental considerations, there are economic considerations as Boyce *et al.* (1999, p.53) pointed out…"There is a case for research and development into cheaper, more effective methods of bird control. There is also good reason for the development of a cost effective and effective method that does not create a noise or nuisance".

1.3   Current control methods and evaluation

So, what has been past practice in dealing with these pest species and how effective have they been? While there has been a measure of success with some practices, they appear to remain both expensive and labour intensive. Some scaring techniques, while effective initially, are unable to sustain any significant long-term management effects. Bird control in vineyards is an ongoing problem (Taber, 2002), and control measures historically and in recent times do not always appear to be ecologically sound. Bird control practices such as gas guns and shooting can produce social issues such as noise pollution, along with adverse public reaction (Boyce *et al*., 2001). Other measures include netting of the vines, bird-scaring devices such as

hawk kites, recorded alarm and distress calls, and toxins (Dzhabbarov, 1988; Fleming, 1990; Bomford & Sinclair, 2002; Taber, 2002; Berge *et al.*, 2007a; Berge *et al.*, 2007b). Toxins such as Mesurol® have been used in the past in New Zealand as a chemical bird repelling solution in vineyards, but are no longer permitted due to unacceptable residues of the chemicals detected in wine (Saxton, 2004). Mesurol®, which has methiocarb as its active ingredient, was banned in 1992. This ingredient was found to be carcinogenic to humans (Saxton, 2004).

Bomford & Sinclair (2002) reported that most of the ecological research on bird damage control has been on habitat manipulation e.g. removing vegetation, which provides shelter for birds, or planting decoy crops to attract birds away from the target crop. However, they noted that for reasons such as effort and resources required to implement these ideas and a general lack of awareness of the benefit of these practices, there has been a failure in growers adopting these practices.

1.3.1 Shooting

Shooting is the most widely used form of bird control but according to some studies, the least effective (Fleming, 1990; Bomford, 1992; Tracey & Saunders, 2003). Its aim is to reduce populations of pest birds, thereby decreasing damage to target crops (Bomford, 1992). It is a costly and time-consuming method of bird control and Fleming (1990) and Boyce *et al.* (1999) reported that some wine growers found this practice inefficient as many pest birds learn to avoid shooting. While it may have its place in bird control, it may be only effective as a reinforcement of other forms of control, such as gas guns (Tracey & Saunders, 2003).

1.3.2 Exclusion

Exclusion netting, although expensive, is effective, because it directly prevents pest birds from contact with the ripening grape (Yim & Kang, 1982; Jarvis, 1985; Boyce *et al*., 1999; Sinclair, 2002; Taber, 2002; Komeda *et al.*, 2005; Berge *et al*., 2007a). However, netting has its drawbacks; nets increase humidity, leading to an increase of pathogens, and they can inhibit photosynthesis reducing the quality of the grape (Saxton, 2004). Application and retrieval of nets is labour intensive and time consuming. In New Zealand, questions have been raised about the bio-degradability of materials used in netting practice with the discarding of single-use nets after grape harvest (Beard, R. pers. comm., 2009). Hanni & Eccli (2006) support this by noting that netting practices are ecologically undesirable, however, the

disposal of old nets is now a controlled activity under the SWNZ and is offered by netting companies when new nets are being purchased.

1.3.3 Visual and acoustic deterrents

Bird scaring techniques, like the "Peaceful Pyramid" which "reflects light into the air at the reverse angle of the bird's approach and the intensity of the reflection confuses the bird by overloading its visual sensory receptors and so removing the impulse to land and feed" (Fukuda *et al*., 2008), and the eye-spot balloon (mimics predators eyes) trialled by Fukuda *et al.* (2008), are of little value. The authors noted that these techniques would not provide any economic advantage to winegrowers. In an earlier study Hickling (1995), supported these observations noting that bird-scaring methods, such as eye-spot balloons, while demonstrating a measure of success initially, are often short-lived as the pest birds begin to habituate to the balloons after one to two weeks.

Gas guns are used frequently but wine growers have anecdotally reported that these devices can act as an attraction to ripening grapes rather than as a fear-producing deterrent. They note that gas guns appear to signal to birds that ripening grapes are associated with the sound the gun produces. Tracey & Saunders (2003) reported gas guns to be more effective than shooting. However, while birds would immediately respond to the sound of this device, flying upwards, they return to forage on grapes within minutes of the gas gun sounding (pers. obs.). Daugovish *et al.* (2006) and Tracey *et al.* (2007) noted that other visual devices such as hawk-kites, raptor models and acoustic devices such as gas guns rapidly lose effectiveness as pest birds become accustomed to them**.** Another method observed included vineyard staff driving up and down the vine rows and sounding their quad bike horns within the vineyard. However, there is no research to support whether this method is effective.

1.4 Bird control and the fear factor

Passerine birds that perceive an increased risk from predators may alter habitat use, including foraging behaviour, with flow on effects for reproductive success and future population dynamics (Dunn *et al*., 2010). Fearful (e.g. from predator presence), frugivorous passerine birds, such as those found in vineyards, will often modify foraging behaviour with regard to amount of food taken and length of foraging time (Howe, 1979). Birds will react to sudden, strange and dangerous stimuli (Tracey *et al.*, 2007), including the presence of a predator. The immediate response to fear stimuli is flight, although the next response may be that of

curiosity and the bird will gather information on whether the threat is real or not, leading to habituation to the stimulus and the potential threat becomes invalid (Tracey & Saunders, 2003; Tracey *et al*., 2007).

1.5 Biological Control using birds of prey: a cheaper, readily available, and safer solution to bird control?

Ecological engineering is a possible, yet little researched, alternative. Engineering or managing populations of predator bird species into vineyards to act as biological control agents may provide a solution. Birds of prey are a possible economically and ecologically sustainable solution to the problem of pest bird management, providing an effective ecosystem service in agricultural settings, including viticulture. The possibility of exploiting the innate fear of raptors by passerine birds may be the key to utilising native diurnal New Zealand raptors as biological control agents in agricultural settings. Most birds have an inherent fear of predatory birds, such as raptors (Conover, 1979; Hothem & De Haven, 1982; Göth, 2001; Patzwahl, 2002; Kaplan, 2004; Daugovish *et al*., 2006), and will demonstrate avoidance behaviours to counteract predation.

1.5.1 Passerine bird fear response to birds of prey

Predatory avoidance responses by passerine birds to raptors can vary. The predator-prey interaction is clearly displayed in the relationship between raptor and passerine bird where the presence of a raptor will invoke shelter-seeking behaviour and abandonment of the foraging area (Daugovish *et al*., 2006). In addition, the foraging decision making process both temporally and spatially can also be affected by the presence of predators (Valone & Lima, 1987; Dunn *et al*., 2010). Flocking behaviour is also an example of this predator-prey interaction, demonstrated by starlings, where flocking is an anti-predation response to aerial predators (Carere *et al*., 2009). Other behaviour exhibited in response to aerial predator presence include fleeing to cover after both conspecific and interspecific aerial alarm calls are signaled (Göth, 2001; Magrath *et al*., 2007). Furthermore, passerine bird species densities are often lower near raptor nesting habitat (Norrdahl & Korpimäki, 1998), and they will not usually remain where a high risk of predation is possible (Lima & Valone, 1991).

It is also apparent that the behaviour of the raptor itself can increase or decrease the fear response of smaller birds. A flying raptor instilled more fear into smaller birds than a perching

one and it is suggested that some passerine birds can recognise that flying is the method that raptors use to capture them (Conover, 1979).

1.5.2 Research to date

Birds of prey such as falcons (*Falco* spp.) and hawks (*Buteo* and *Accipiter* spp.) have been utilised around the world as biological control agents for pest bird species other than in agricultural settings (Erickson *et al.*, 1990). Falconry to deter bird strikes of airplanes has shown some success (Erickson *et al.*, 1990; Daugovish *et al.*, 2006). However, Erickson *et al.* (1990) noted that falconry is expensive and there are a limited number of trained falconers.

In an agricultural context, one Californian Napa Valley and Central Coast vineyard study in the United States of America noted a single falcon living in a 202 hectare area reduced pest bird numbers for six weeks (Alley, 2003). Management of Malaysian barn owl (*Tyto alba javanica*) populations have been studied as predators of rats in oil palm (*Elaeis quineensis*) plantations. With the erection of nest boxes in the plantation environment, barn owl numbers increased rapidly and a reduced number of rats followed (Duckett, 1991).

1.5.3 The New Zealand falcon (*Falco novaseelandiae*)

Using raptors to protect vineyards has already been initiated in New Zealand in the "Falcon for Grapes" project. The "Falcons for Grapes" project in Marlborough, New Zealand, has a two-pronged focus (Fox *et al.*, 2006); conservation of a threatened (see Holland & McCutcheon, 2007) endemic raptor, the New Zealand falcon, and protection of grapes from bird damage through the falcon's ability to predate on passerine bird species that decimate vineyard crops.

The falcon's habitat is native and exotic forests, hilly and rough farmland (Heather & Robertson, 1996) and it is not abundant in the land that is utilised for traditional viticulture practice. The "Falcons for Grapes" project translocated falcon chicks into artificial nests in Marlborough vineyards where establishment of this predatory species mitigated grape damage caused by pest passerine bird species (Saxton, 2010, Kross *et al.*, 2011) While successful, difficulties have arisen, such as the low numbers of birds to breed from, lack of commitment from winegrowers to look after the falcons, economic support for further research and consequent industry uptake (Saxton & Keane, 2010). Given the difficulties that have arisen with the falcon project, the perhaps next obvious choice would be inquiry into the suitability

of another New Zealand raptor, the non-threatened or common Australasian harrier (*Circus approximans*) in a similar role.

1.6   Study subjects

1.6.1 Bird species

The Australasian harrier is a self-introduced, diurnal, raptor that is the focus of this research (see chapter 3 for further discussion). In New Zealand vineyards the major contributors to grape damage are the introduced starling, blackbird, song thrush and the self-introduced silvereye (Watkins, 1999; Saxton, 2004) and these are the focal pest bird species for this project (see chapter 2 for further discussion).

1.6.2 Grape variety

Grapes are attacked by birds during the ripening period, and Saxton (2004) outlined that there are many factors that contribute to a bird's decision to attack grapes. These include both endogenous motivators such as hunger, nutritional requirements, and mimicking behaviour. The other motivation includes exogenous factors such as grape abundance and environmental factors (Saxton, 2004).

As different grape varieties sustain different levels of damage (Fisher, 1992; Tracey & Saunders, 2003; Saxton, 2004), one particular cultivar was selected to provide a uniform approach to grape damage assessment. Pinot Noir sustains more bird damage compared to some other varieties such as Sauvignon Blanc (Saxton, 2010), and is a prominent cultivar in this study sites' location. It has a low yield, high consumer demand, and therefore net worth, and is highly valued in this area, making it a priority for protective measures.

1.7   Preliminary procedures

For this project to commence, a Lincoln University animal ethics application(AEC approval no. 306) was required along with input from the Rūnanga (governing council or administrative group of Maori) related to the area in which the study vineyard sites were to be located. The harrier or, in Maori, kahu, have spiritual significance to Maori. Rūnanga in both the Canterbury and Martinborough regions approved this project. A banding permit (2010/006) and wildlife low-impact research and collection permit (WE27341/FAU) was applied for and granted by the Department of Conservation.

1.8   Study site/location

The research sites included two different geographic locations. The initial study site chosen for this project was Bentwood Wines a 3 hectare vineyard, 5.4 km south-east of Tai Tapu, Canterbury, New Zealand. The site is situated in a valley surrounded by macrocarpa (*Cupressus macrocarpa)* trees with some native vegetation within it and grazed farmland. Grape varieties grown were Pinot Blanc, Pinot Noir, and Gewürztraminer. The vineyard was divided into two sections by a boundary of large trees and a private road, which provides a visual screen between the two sections (Fig. 1.1). Harriers were seen regularly both in the vineyard and surrounding farmland.

Figure 1.1: Bentwood vineyard, Tai Tapu, Canterbury. Retrieved using Google Earth, 6 Feb, 2012. Picture centred on coordinates 43°42'20.14"S, 172°34'14.17"E, viewed from 636m.

Secondary sites (*n*=9) were located in Martinborough, Wairarapa, lying east of the Rimutaka Range in a valley in the southern part of the North Island (Fig.1.2). The vineyards are part or fully surrounded by large, mostly exotic trees, which act as a shelterbelt for the grapevines.

This area features small boutique, often family-owned, vineyards with notable, award-winning Pinot Noir grapes dominating the wine varieties grown here. Many of the vineyard sites were located in close proximity to domestic dwellings. Harriers were seen frequently around the Martinborough landscape, along roadways, pastureland, and over vineyards.

Figure 1.2: Martinborough, Wairarapa vineyard study sites 2010-2011 retrieved using Google Earth, 6 Feb, 2012. Picture centred on coordinates 41o14'51.51"S, 175o28'20.47"E, viewed from 13.83km.

1.9   Research Aims

This research aims to present an economically and environmentally-sound solution to passerine bird damage to grapes by attracting populations of the Australian harrier into vineyards by providing them with an important food source, animal carcasses. Whether this in turn will reduce pest bird numbers in vineyards and associated grape damage, is the focus of this research. If successful, this would lead to a potential reduction of variable costs in vineyards, e.g. netting, shooting, labour, and a reduction of external costs, e.g. environmental health. This research is underpinned by a biological exploration of a potential ecosystem service, i.e. a wild native aerial predator, which may provide an ecological solution to an economic problem.

1.9.1 Questions addressed

The research will address questions relating to the fundamental query of whether a wild bird can change its typical ecological behaviour in response to supplementary feeding. It will aim to answer whether an Australasian harrier's normal hunting and feeding behaviour can be manipulated and at the same time, answer whether it has preferential food choices between

seasons. The research also examines whether passerine bird behaviour can be modified; investigating the relationship between harrier presence (due to supplementary feeding) and passerine bird densities. Lastly and importantly, it investigates whether or not this has the flow on effect of decreasing grape damage.

1.10   Structure of the thesis

To answer the above questions the structure of the thesis is as follows:

Chapter 1: *Introduction, background, research aims, and research questions*.

Chapter 2: *Identification and ecology of damage-causing passerine birds found in New Zealand vineyards*: Identification of individual pest bird species is essential to manage the problem of birds in vineyards. Differences in biology and behaviour of pest passerine birds in vineyards have different effects on damage to grapes and are important factors in implementing control methods.

Chapter 3: *The Australasian harrier as a biological control agent*: This chapter outlines the ecology of the focal species of the thesis. It includes food resource availability on harrier populations and the effects of supplementary food and its potential to provide biological control in vineyards.

Chapter 4: *Neophobia to Neophilia: Manipulating the hunting and feeding behaviour of the Australasian harrier*. Manipulating the Australasian harrier to feed off a raised table, which is not a normal behaviour, could be difficult. Hunger caused by seasonal lack of availability of food and the bird's life cycle, e.g. nesting or juvenile hunting skill may be the catalyst for it to overcome its neophobic tendencies and initiate feeding from a raised table. Here, the goal was to discover if it is possible to maintain a regular feeding regime for Australasian harriers from raised feeding tables. This step would be integral to the success of the project.

Chapter 5: *Spring/Summer food choice*: In New Zealand in the spring and summer, there is much reliance on eggs and nestlings by the harrier as a food source (Baker-Gabb, 1981). This may be because they are easy to transport to nest sites. Anecdotal reports have suggested that the harrier prefers chicks (*Gallus domesticus*) to their other favoured food, rabbits (*Oryctolagus cuniculus*) at breeding times.

Chapter 6: *Australasian harrier presence and passerine bird densities in vineyards*: It is hypothesised that with the increased presence of the Australian harrier due to a regular supplementary feeding programme within the vineyard, population densities of pest passerine birds will be decreased within vineyards.

Chapter 7: *Grape damage assessment pre-harvest*: Assessment of pest bird deterrence from the vineyard is a fundamental indicator of the goal of this research. With a decrease in pest birds frequenting the vineyard at the grape ripening period and the increase of harrier presence because of a regular feeding programme it is predicted that grape damage will be reduced.

Chapter 8: *Other predators in vineyards and the effects of supplementary feeding and subsequent decreased pest passerine bird abundance*: The identity of potential predators of passerines will be confirmed (via camera trap), particularly those accessing harrier feeding tables and consuming bait laid out for harriers. Where tables were present, grape damage was shown to be less, however as only one table out of the seven was being visited regularly by harriers over the grape-ripening period it was hypothesised that these other visiting predators could also be responsible for the decreased grape damage effects.

Chapter 9: *Problems and challenges addressed and discussed*.

Chapter 10: *Summary of findings, future directions, and conclusion*.

Chapter 2

Identification and ecology of damage-causing passerine birds found in New Zealand vineyards

2.1 Introduction

Grape damage caused by birds varies spatially and temporally within and between vineyards (Somers & Morris, 2002; Tracey & Saunders, 2003). While it is important to assess the area in the vineyard that is most susceptible to bird damage, in order to initiate a successful control programme identification of individual pest bird species is also crucial (Somers & Morris, 2002). This chapter identifies the main damage-causing passerine bird species in New Zealand vineyards, including individual ecological aspects of each species particularly related to vineyard environments. Differences in biology and behaviour of the birds have different effects on damage to grapes and are important factors in implementing control methods (Boudreau, 1972; Jarman, 1990; Fisher, 1992; Flaherty, 1992; Tracey *et al.*, 2007; Herrmann & Anderson, 2007). Jarman (1990) emphasized that there should be long-term studies on pest bird behaviour which would then act as the foundation for behaviour manipulation and consequent damage control in vineyards.

Understanding a bird's ecology enough to recognise their role in grapevine interference and identifying areas in the vineyard where the damage actually occurs may provide clues to damage reduction (Bomford, 1992). Some bird species, such as the European blackbird (*Turdus merula*), live within a small area, while others, such as the silvereye (*Zosterops lateralis*) and the European starling (*Sturnus vulgaris*), are seasonally migratory and move freely around landscapes. Some live in small groups and others, such as the starling and silvereye, can form large flocks (Heather & Anderson, 1996; Tracey *et al.*, 2007). Tracey *et al.* (2007) pointed out that species that are more mobile, such as starlings and silvereyes, should be easier to scare, as they are not strongly attached to any particular territory.

Anti-predator strategies, such as use of vegetative cover and flocking behaviour, differ among passerine bird species (Lima, 1990; Carere *et al*., 2009), and these factors can determine different responses between species to methods of control, while differing foraging strategies and patterns of movement can affect the severity and type of damage to grapes (Tracey *et al*.,

2007). Stanley & Lill (2001) noted that plant morphology could affect avian frugivore foraging, as can the morphology (e.g. bill shape) of the individual bird species. Some fundamental knowledge of such factors in individual bird species may give an indication as to whether the presence of the Australasian harrier (*Circus approximans*) can mitigate and modify the damaging behaviour of these birds in the vineyard.

The major pest passerine bird species that are responsible for most damage to grapes and subsequent economic loss in New Zealand vineyards include European starlings, European blackbirds, song thrushes (*Turdus philomelos*) and self-introduced silvereyes (Watkins, 1999; Saxton, 2004). All of these species are responsible for differing types and levels of damage and/or loss to wine grapes due to their biological and ecological characteristics, which are outlined below.

2.2   Starling

The starling, a member of the Sturnidae family is a common, introduced, small to medium-sized bird (21cm), with both sexes having a glossy black plumage, with a red- purple sheen and white spots (Heather & Robertson, 1996; Tracey & Saunders, 2003). Starlings may have up to three broods per year, with 4-6 offspring per clutch (Feare, 1984). Nesting takes place in holes of trees, buildings, or cliffs and while they do not normally defend their feeding areas, they will defend their nesting habitat rigorously (Heather & Robertson, 1996). Starlings are a gregarious species that feed in flocks, which can comprise up to 1,000 birds (Heather & Robertson, 1996), and congregating at roosts, they will converge at dusk and disperse again at dawn (Feare, 1984; Heather & Robertson, 1996; Bentz *et al*., 2007).

Tracey & Saunders (2003) identified the European starling as the most abundant species in Australian vineyards, reporting them to be responsible for 80-90% of all bird damage in central New South Wales vineyards. Other reports have implicated the starling; as well as being responsible for widespread damage to other crops such as olives and stone fruit; it is the most destructive introduced grape damaging bird species in Australasia (Somers & Morris, 2002; Bomford & Sinclair, 2002; Tracey *et al*., 2007; Bentz *et al*., 2007).

Development of a diverse and omnivorous diet (Feare, 1984; Tracey & Saunders, 2003) and the evolution of an anatomy and physiology that has adapted a complex foraging ability, which includes eating almost anything when food resources are scarce (Beecher, 1978; Tracey

& Saunders, 2003), have enabled the starling to survive in harsh dry and environments. These factors may provide a good indication for explaining their evolutionary success as a colonising species.

In the vineyard

Starlings tend to forage in cultivated areas, perching in large, open canopy trees and power lines (Porter *et al*., 1994) that often surround vineyards, approaching the vines aerially and descending into the vines to feed (Somers & Morris, 2002). Plucking grapes, including unripe fruit (Mason & Clarke, 2000), they will carry the grape back to a perch to feed (Somers & Morris, 2002), and are able to remove more grapes in a shorter time than other species (Boyce *et al*., 1999). Preference for red grape varieties has been reported (DeHaven, 1974) amongst starlings, while another study (Tobin *et al.*, 1991) on bird damage to cherries found no specific difference in preference to darker-coloured cultivars.

Starlings and other birds often feed in large flocks and this behaviour may be interpreted as an anti-predator response to birds of prey (Tracey & Saunders, 2003; Carere, 2009), while larger, more compact flocks often signify greater predation pressure (Carere, 2009). Often using the same foraging sites for extended periods, the appetite of the starling is not only diverse, but also voracious and once it establishes a feeding pattern, it may be difficult to frighten away, (Flaherty, 1992; Tracey & Saunders, 2003). During the ripening period for grapes, starling flocks tend to increase (Tracey & Saunders, 2003), which may be due to the greater food availability (Feare, 1984). Unfortunately, for vineyards, large numbers of juvenile starlings congregate after the breeding period and this often coincides with the véraison period (Tracey *et al*., 2007).

A South African study by Herrmann & Anderson (2007), found that many pest bird species in vineyards displayed a bimodal feeding pattern, which showed peak feeding times on grapes early to late morning and again in the late afternoon. However, according to Tracey & Saunders (2003), it is difficult to target starling feeding times, because, unlike other pest birds in vineyards, they do not appear to have a consistent peak feeding period.

2.3 Blackbird

The blackbird, a member of the thrush (Muscicapidae) family, is another common introduced bird found in both suburban and rural habitats. The adult male (25 cm) is black with a bright orange bill and the female, dark brown with a paler throat and a brown and duller orange bill (Heather & Robertson, 1996). Most pairs nest 2-5 times per year, raising 2-3 broods, averaging 3-4 eggs per clutch (Heather & Robertson, 1996). Primarily a solitary, ground-dwelling species (Heather & Robertson, 1996; Watkins, 1999; Saxton, 2004; Herrmann & Anderson, 2007), it is crepuscular, favouring the cover of undergrowth for foraging (McCann, 1953; Watkins, 1999; Jensen, 1974; Porter *et al.*, 1994). Part of the blackbird's foraging time is not spent essentially eating; instead, it appears to be vigilantly observing for predators (Saxton, 2004).

The blackbirds' predominant food choice is earthworms (Oligochaeta), followed by other invertebrates, and supplemented by fruit in autumn (Heather & Robertson, 1996; Hampe, 2001; Chamberlain *et al.*, 2007; Tracey *et al.*, 2007). They defend their territory from April to January and will often assemble at a good food source in the autumn (Heather & Robertson, 1996). Hampe (2010) observed that the blackbird concentrated in large trees during the nesting period, which is late August to December in New Zealand (Heather & Robertson, 1996). In New Zealand, they are most commonly found nesting in forks of shrubs and hedges that are at least 1-10 m above ground (Heather & Robertson, 1996).

In the vineyard

Blackbirds can be found in vineyards throughout the year and are a serious pest (Heather & Robertson, 1996; Saxton, 2004; Tracey *et al.*, 2007), darting up into vines from the ground, plucking a whole grape, removing it from the underside of the bunches, immediately consuming or taking it back to cover (Watkins, 1999; Saxton, 2002, 2004; Herrmann & Anderson, 2007). Saxton *et al.* (2004) suggested that blackbirds are sensitive to ripening cues in grapes, such as aroma, which may be one factor in their increased depredation on grapes at the véraison to harvest period. Grapes located closer to the ground receive more damage from blackbirds and song thrushes than from other bird species (Watkins, 1999).

Blackbirds are often found in scrubby sites in vineyards that do not appear to provide optimum cover, and they take both unripe grapes and ripe grapes with increased pressure as winter approaches (Saxton, 2004). This behaviour is possibly signalling an overriding

physiological/nutritional need to gain weight in preparation for the winter (Bairlein, 2002, Saxton *et al.*, 2011), which may supersede risk perception or avoidance of danger, making them difficult to eradicate from vineyards due to this requirement.

Frugivorous bird species including blackbirds often forage on red-black fruits (Sorenson, 1981;Willson *et al.*, 1990) and may not in effect be due to preference, instead merely to the prevalence of this colour in many fruits (Willson *et al.*, 1990). Blackbirds in vineyards appear to prefer purple grapes in the winter months (Saxton *et al.*, 2011). This finding may be relevant to this thesis, as the grape variety studied is the Pinot Noir cultivar, which is a purple grape when ripe.

2.4   Song Thrush

The song thrush, another member of the Muscicapidae family, is found in both suburban and rural habitats. Its ecology and foraging behaviour are similar to the blackbird. The song thrush (23 cm) has a mid- brown dorsal side and a whitish underside with conspicuous dark brown spots on its breast. Like the blackbird, it nests 2-5 times per year in late August- December, raising 2-3 broods, with an average of 3-4 eggs per clutch. Nests are similar in aspect to the blackbird (Heather & Robertson, 1996).

Along with earthworms (Heather & Robertson, 1996; Gruar *et al.*, 2003; Peach *et al.*, 2004), their favoured foods include snails (Gastropoda) (Nye, 1975; Heather & Robinson, 1996). Like the blackbird, thrushes supplement their diet with fruit, including grapes in vineyards (Heather & Robinson, 1996). Unlike the blackbird, there is a paucity of literature on actual levels of damage caused by the thrush, and damage data are difficult to separate between the two species.

In the vineyard

Scrubby vegetation is an important cover for the thrush (Mason, 2000). Song thrushes feed on the ground (Heather & Robertson, 1996; Herrmann & Anderson, 2007) and will consequently take grapes that are located closer to the ground (Watkins, 1999). One study has shown that song thrushes prefer white grapes to red/purple ones (Watkins, 1999).

2.5   Silvereye

The silvereye a member of the Zosteropidae family, is a small (12 cm) self-introduced species to New Zealand from Australia and the South-Western Pacific, and is semi-protected (see N.Z Wildlife Act, 1953) (Heather & Robertson, 1986). It has a small olive green/yellow head and upper surface of wings, rump, and tail with abdomens that vary from light brown to grey-brown or white. It has a characteristic white eye ring (Heather & Robertson, 1986; Tracey *et al.*, 2007). Nesting takes place 1-15 m above ground towards the outermost branches of a tree, shrub, or tree fern.

Laying their eggs from September to February, they may raise 2-3 broods annually, averaging 3 eggs per clutch. Nests are suspended from twigs and foliage (Heather & Robertson, 1986). Establishing pairs, they are territorial during nesting, however later in the summer they form flocks. They are fast moving, seasonally migratory, and elusive and can be found in native and exotic forest, scrub, orchards from sea level to the tree line, and often in suburban gardens during the winter months (Heather & Robertson, 1986).

Silvereyes will congregate around an important food source and will feed in flocks, which may be an anti-predator strategy. Diet is varied, and includes invertebrates, nectar, seeds, and fruit (Heather & Robertson, 1986). Although mostly taking fruit from native trees, they do inflict substantial damage to commercial crops, including grapes (Heather & Robertson, 1986; Tracey & Saunders, 2003; Tracey *et al*., 2007). They feed off the ground and in high canopies, puncturing fruit with sharp bills, which create a small diamond-shaped peck mark, lapping at the flesh with brush tipped tongues (Tracey & Saunders, 2003). Peck marks attract wasps due to the exuding sugar and allows for entrances of serious diseases such as *Botrytis cinerea*, threatening many commercial crops (Tracey *et al.*, 2007).

Tracey & Saunders (2003) identified the silvereye as contributing up to 25 % of the total bird damage to Australian horticultural crops. Losses are greater when nectar sources become scarce and during migration when high-energy sources are required (Tracey & Saunders, 2003; Tracey *et al.*, 2007).

In the vineyard
Silvereye numbers in vineyards have increased with the expansion of vineyards in New Zealand, with increased fruit resources supplementing their nutritional requirements (Saxton,

2004). Although grapes may not be a nutritional necessity for silvereyes, they may supply the extra water and energy that is required at a dry time of year (Saxton, 2004). While other pest-bird species are found in vineyards throughout the year, silvereye presence is mostly common in the autumn as the grapes ripen, likely being driven by environmental factors such as colder temperatures in their summer habitats (Stanley & Lill, 2001, 2002; Saxton, 2004).

Large flocks congregate in vineyards (Tracey & Saunders, 2003; Tracey *et al.*, 2007), foraging higher in the canopy than other pest birds (Saxton, 2002), and are not often seen foraging on the ground. They appear to spend more time feeding than other pest species (e.g. blackbirds, Saxton, 2004), darting in and out of the vines (Tracey *et al.*, 2007) and pecking at the grapes (Fig. 2.1). Pecking grapes is considered worse than taking the whole grape, as it can be the catalyst to introducing diseases, which taint the wine (Tracey & Saunders, 2003; Saxton, 2004).

Figure 2.1: Pinot Noir grape bunch displaying peck damage caused by silvereyes

Silvereyes choose medium leafy trees to perch in around the vineyard and exhibit a strong preference for accessible fruits, attacking fruit that that can be easily pecked (Stanley & Lill, 2001). Peck-damaged grapes are an indirect measure of silvereye presence. A study by DeHaven (1974) demonstrating the damage that pecking can produce from species like the

silvereye, found almost 80% of grape bunches damaged had peck damage, rather than whole grapes missing, highlighting the destructive presence of this species in vineyards.

There are different opinions on what colour fruit preference silvereyes have. Puckey *et al*. (1996) noted they preferred red, to white or yellow fruit with Watkins (1999) finding that silvereyes were attracted to purple grapes over green and Saxton (2004) finding that they preferred green, to purple/black in the autumn/winter months only.

2.6   Other passerine species

Other passerine bird species commonly found in New Zealand vineyards but are not implicated in grape damage include; finches (Fringillidae), Australian magpies (*Gymnorhina tibicen*), and sparrows (*Passer domesticus*), although there is some discrepancy over sparrows causing significant damage to grapes, particularly in Australia (see chapter one). Mynas (*Acridotheres tristis*), have an equally damaging presence in vineyards, but are found only in the northern North Island of New Zealand, so they are not pertinent to this thesis.

Chapter 3

The Australasian harrier as a biological control agent

3.1 Introduction

The focus of this thesis is the Australasian harrier (*Circus approximans*) and its potential capability as a biological control agent, in the management of pest passerine bird species, found in New Zealand vineyards. Hoddle (2004, p.39) described biological control as "the intentional use by humans of parasitoid, predator, pathogen, antagonist, or competitor populations to suppress a pest population, thereby making the pest less abundant and damaging than it would be in the absence of these organisms". Biological control in the context of this project is slightly different in that the harrier is not essentially expected to "suppress" passerine bird populations. However, the harrier's predatory behaviour, which is not usually lethal, and passerine birds' inherent fear response (Conover, 1979; Hothem & De Haven, 1982; Göth, 2001; Patzwahl, 2002; Kaplan, 2004; Daugovish *et al*., 2006) to all raptors may result in a change of local distribution, making the passerine bird population in vineyards "less abundant and damaging" as Hoddle described.

Conservation biological control (CBC) uses habitat management to increase the number of natural predators in an area (Cullen *et al*., 2010). The Australasian harrier is often located in the same habitat (vineyards in this case) as pest birds and therefore has the potential to provide an effective biological control presence in this area. CBC offers an alternative to other methods of pest passerine bird control (see chapter 1). It uses environmental modification or ecological engineering to increase the potential for the natural enemy (in this instance the harrier), to make an impact on pest species (passerine birds), by providing the harrier with ecological resources, such as supplementary food (DeBach, 1964; Ehler, 1998; Gurr *et al*., 2003).

Birds of prey (raptors) have been used around the world as biological control agents in various settings. Most pest bird populations have an innate fear of predatory birds (Conover, 1979; Hothem & De Haven, 1982; Göth, 2001; Patzwahl, 2002; Kaplan, 2004; Daugovish *et al*., 2006), and will demonstrate avoidance behaviours to counteract predation. While Australasian harriers do not generally take prey on the wing (Baker-Gabb, 1978; Robertson,

1980; Marchant & Higgins, 1993), it is anticipated that the generalised inherent fear response of prey, rather than an increased risk of predation could be exploited.

Studies of other harriers have highlighted their biological control potential by noting that the harrier's daily activity patterns (i.e. hunting times) overlap with passerine birds foraging times, and therefore the probability of them encountering each other is high (Terraube & Arroyo, 2011). Herrmann & Anderson (2007) reported that pest bird species display a bimodal feeding pattern, feeding more regularly on grapes early to late morning and in the late afternoon, while harriers finish hunting three hours after sunrise and commence again four hours before sunset (Simmons, 2000), coinciding with passerine bird activity.

This chapter discusses the ecology of the Australasian harrier, highlighting the effects that food resources have on raptor ecology and outlining the effects of supplementary feeding on members of other raptor species, which may translate to the Australasian harrier. Supplementary feeding will attempt to attract and maintain Australasian harriers in vineyards and this will provide the foundation for effective biological control activity; decreasing passerine bird populations and subsequent grape damage.

3.2   The ecology of the Australasian harrier

The Australasian harrier is the only member of the Accipitridae family to breed in New Zealand (Wong, 2002). It can also be found in Southeastern Australia, and other islands of the South Pacific (Marchant & Higgins, 1993; Wong, 2002). The diurnal Australasian harrier is common amongst the small contingent of New Zealand raptors, is self-introduced, likely arriving between Maori and European arrival (Holdaway & Worthy, 1997), and is semi-protected (may be hunted or killed only if it is causing damage to land or property, including crops, N. Z. Wildlife Act, 1953). Unlike most native New Zealand birds, the harrier has benefited from clearing of native forest for pastureland, which has increased optimal habitat for searching for small prey, such as rats (*Rattus* sp.), mice (*Mus musculus*), lizards, (Scincidae/Gekkonidae) invertebrates and nestlings (Heather & Robertson, 1996). Much of the harrier's natural diet is supplemented by animal carcasses, which is the result of road-kill, readily available from New Zealand roadways (Marchant & Higgins, 1993**;** Heather & Robertson, 1996).

3.2.1 Description

The Australasian harrier is sexually dimorphic; the females (850 g) are larger than the males (650 g). It is a large brown slim-bodied raptor with long-fingered wings held in a "V" shape; the tail is long and slightly rounded. Juveniles are a dark brown, almost chocolate colour with a distinctive white patch on the nape and have a rich brown upper tail and brown iris, while the adult form is lighter coloured. Adults have a pale facial disc and head, with upper body parts dark brown. The underbody is buff to reddish brown, streaked heavily with blackish brown on the breast, abdomen, and flanks. The under wings are barred at the tips. The upper tail is white and the lower is light-brown barred with dark brown. Adults have a yellow iris; the female iris is a paler yellow than the male. Harriers become paler with age and very old males can be identified by frosty-grey upper parts, pale buff under parts, and white under wings (Marchant & Higgins, 1993; Heather & Robertson, 1996**).**

3.2.2 Feeding

Hunting by day, the harrier uses a hovering, slow-quartering movement, and then a drop-and-pounce mode of hunting (Marchant & Higgins, 1993; Heather & Robertson, 1996) or, as sBaker–Gabb (1978) describes, a short dive backwards or a hover and dive forwards, mode of attack, on ground dwelling prey/carrion. The harrier rarely catches prey on the wing unlike the New Zealand falcon (*Falco novaeseelandiae*) that actively pursues its prey (Baker-Gabb, 1981a; Heather & Robertson, 1996).

The diet of the Australasian harrier includes hares (*Lepus europeus*), rabbits (*Oryctolagus cuniculus*), birds' eggs, large invertebrates, frogs, fish, and reptiles. In New Zealand, a large proportion of their diet includes animal carcasses, particularly road-kill (Marchant & Higgins, 1993). Robertson (1980) found that the Australasian harrier preferred brown rats (*Rattus norvegicus*) and domestic pullets (*Gallus domesticus*) to rabbits. He also reported that brushtail possums (*Trichosurus vulpecula*), short-finned eel (*Anguilla australis*) and skinned rabbits were all preferred to unskinned rabbits. Fennell (1980) reported that Australasian harriers preferred hare to rabbit, although rabbits were still preferred to brushtail possum. Wong (2002) found that lagomorphs were the preferred food, comprising 36% of the diet, with rats at 15% and possums at 14%. The rest of the mammalian prey taken in his study consisted of mice (*Mus musculus*), sheep (*Ovis aries*) (afterbirth after lambing and dead lambs) and hedgehogs (*Erinaceus europaeus*). In New Zealand in the spring and summer, there is much reliance on eggs and nestlings as a food source (Baker-Gabb, 1981a).

3.2.3 Breeding

The male harrier establishes its territory from May-June. However, the female does not return to the breeding territory until June-August (Heather & Robertson, 1996). Courtship begins in June and this may continue until October. The courtship ritual involves a series of semicircular dives, often with a loud call and is often the only time a harrier can be heard calling (Marchant & Higgins, 1993).

Nest building begins in September/October and usually consists of building a low platform of bracken (*Pteridium* spp**.)**, manuka (*Leptospermum scoparium*), raupo (*Typha* spp.), and flax (*Phormium spp.)* stalks that may be topped with cabbage tree (*Cordyline australis*) leaves, grass and rushes. Nests are usually found in swampy areas covered in rushes, bracken fern, long grasses, or young pine plantations (Heather & Robertson, 1996). From September-December, 2-7 eggs are laid and the female incubates the eggs for approximately thirty days. The male feeds the female throughout this time until the fledging of the chicks. Chicks fledge at 43-46 days and remain with their parents for approximately one week after fledging. Females may breed at 1 year, but the male may not commence breeding until it reaches 2-3 years. Pairs will return to the same territory year after year and occasionally the male may be polygynous (Baker-Gabb, 1981b; Heather & Robertson, 1996).

3.2.4 Social behaviour

The harrier is a solitary bird and only becomes territorial during the breeding season. In the winter they may congregate in large communal roosts in secluded swampy areas (Baker-Gabb, 1981b; Heather & Robertson, 1996).Where abundant food sources are located, harriers have been noted in loose flocks of 2-5 birds. The core and home territories appear to differ between breeding and non-breeding seasons. In Wong's (2002) study, radio-tracked harriers showed the movement of the Australasian harrier at both breeding and non-breeding periods. The breeding core home range was 158 ha (50% MCP), while the entire home range was 373 ha (100% MCP). The non-breeding core range was 566 ha (50% MCP) and the home range was 763 ha (100% MCP).

3.3 Food resource availability effects on Australasian harrier populations

Adequate food resources are without doubt the fundamental requirement for any avian population. Limited food–supplies may affect raptors' range sizes, breeding biology and

ultimately population densities (Newton, 1979; Newton, 1980; Baker-Gabb, 1981a; Kenward, 1982; Knight & Anderson, 1990).

3.3.1 Density and range size

Newton (1979), found that the availability of food was essential to explain population levels, but was evidenced more subtly by its effects on spatial behaviour and reproduction. A clear example of a correlation between food resource availability and raptor density was demonstrated by Village (1982) where he found that kestrel (*Falco tinnunculus*) numbers varied in relation to vole (*Microtus agrestis*) abundance. Baker Gabb (1981a) suggested that a raptor would hunt where they find a particular prey species at its highest density and Thirgood *et al*. (2003), where they can attain the highest energy gain.

Where food may have once been in abundance, prey stocks can become exhausted due to over-predation, inclement weather and related inadequate food supplies for the prey themselves, or diseases. When prey density diminishes, it is expected that individual raptors could be compelled to move out of a familiar hunting area or territory in search of greater food supplies. Raptors' range size is dependent on prey availability (Kenward, 1982) and when food supplies become scarce, the harrier range size widens (Newton *et al*., 1986). In a radio-tracking study of the ranging behaviour and dispersion of the European sparrowhawk (*Accipiter nisus*), Newton & Marquiss (1982) found the greater the quantity of food supplied by the male bird to the female the more sedentary the female hawk became. Habitats that provide more prey may influence harrier range sizes retaining them in a smaller area or territory (Wong, 2002).

3.3.2 Breeding

Raptors represent some of the most stable breeding populations found in all bird species and many raptor species will nest in the same place year after year, and will occasionally, use the same nests where stable food supplies are present (Newton, 1979). Among other factors, such as nesting habitat and territorial behaviour, availability of food has an effect on raptor breeding success, including the rate of breeding and the rate of recruitment (Newton, 1980; Johnson, 1996; Salamolard *et al*., 2000). Egg size is also affected by food availability (Baker-Gabb, 1981b; Simmons, 2004) and the number of eggs and fledgling success are directly related to food provision by the male to the female during the breeding season (Baker- Gabb, 1981b).

3.3.3 Dispersal from natal site

Birds will disperse from areas that have fewer resources (Greenwood & Harvey, 1982; Todd *et al*., 2007). Many factors may influence whether an animal chooses to disperse from its breeding/natal area and if so, how far they travel. While juvenile dispersal from the natal area is expected, premature dispersal from the nesting area can result due to food shortages (Kenward, 1996) and birds may not return to their natal or previous breeding area because of food availability restraints (Greenwood & Harvey, 1982). Additionally, food availability due to competition from other community members may have effects on whether a bird leaves its breeding/natal areas (Greenwood & Harvey, 1982; Todd *et al.*, 2007).

3.4 Supplementary feeding effects on harrier biology

"Feeding influences almost every aspect of bird ecology, including reproduction, behaviour, demography, and distribution" (Robb *et al.*, 2008). Therefore, it could be argued that where abundance of prey is low, or access to prey is limited, due to constraints, such as height and density of surrounding vegetation (Simmons, 2000), supplementary feeding could enhance harrier population numbers in a particular location.

Supplementation or augmentation of food supply to raptors by human intervention was previously discussed by Houston (1996). Houston (1996) found that raptors, (old-world vultures, Accipitridae: Aegypiinae)**,** responded well to "vulture restaurants", where food was provided regularly. Feeding stations not only provided supplementary food, but also became a reliable resource. In times of low-food resources, these stations were fundamentally important in maintaining birds in the area of the station (Houston, 1996).

The aim of this thesis was to encourage into selected vineyards populations of the Australasian harrier and to retain them by supplementary feeding off raised tables. By providing suitable food sources at regular intervals to harriers, it is thought this might engender fidelity to vineyards where feeding tables are located, including establishing breeding areas in or near vineyard areas that have suitable habitat. Vineyards often do not have suitable breeding habitat, however the environment around many vineyards in this study could provide this. Additionally, having feeding stations established may lessen the need for the female to leave her breeding grounds; the female Australasian harrier, when no longer being fed by the male, will leave the area and disperse in search of food (Baker-Gabb, 1981b).

Marchant & Higgins (1993) reported the Australasian harrier was usually faithful to summer and winter breeding grounds and therefore having a constant food supply in place may provide the necessary incentive for the individual to stay in the area (near a vineyard) before, during, and after breeding.

3.4.1 Density and range size

Supplementary feeding is linked to increased raptor population densities (Houston, 1996; Amar & Redpath, 2002; González *et al.*, 2006; Robb *et al.*, 2008). Additionally, supplementary feeding has a positive effect on over-winter survival of harrier populations, including both juvenile and adult populations (Thirgood, *et al.*, 2003; Robb *et al.*, 2008), and it can be responsible for grand-scale changes in general bird population dynamics and migratory behaviour affecting harriers' range size (Robb *et al.*, 2008). Knight & Anderson (1990), reported that establishing a feeding programme increased numbers of bald eagles (*Haliaeetus leucocephalus*) by shifting the population from an area of low food to areas of higher food availability.

3.4.2 Breeding

While not all studies concur with every aspect of the breeding biology of harriers and other raptors and their relationship to plentiful food supplies, the consensus appears that an adequate food supply where supplementation by humans has been implemented, has enhanced breeding success. Examples include a greater number of breeding females, advancement of egg laying, clutch size, hatching rate and fledgling success (Dijkstra *et al.*, 1980; Korpimaki, 1985; Simmons, 1994; Redpath *et al.*, 2001; González *et al.*, 2006; Robb *et al.*, 2008). Supplementary feeding can also have an effect on when the juvenile raptors will disperse from the natal site. Kenward *et al.* (1993) found that juvenile hawks (*Accipiter gentilis*) when provided with supplementary food, dispersed later than those that did not receive supplementary food.

3.5 Conclusion

While encouraging Australian harriers to feed in the vineyard with the aid of regular supplementary feeding, it is hoped that these individuals will exhibit philopatric behaviour; engaging in breeding and nesting activities in and around the vineyard areas season after season. With the regular food supply, this may negate the need for widening the harrier's range in search of prey and it will encourage juvenile subjects associated with the vineyard to

delay dispersal and remain within the vineyard surrounds. Increasing harrier densities will expectantly provide an effective biological control service and could result in greater protection for the vineyard from passerine birds and the consequent grape damage.

Chapter 4

Neophobia to Neophilia: Manipulating the hunting and feeding behaviour of the Australasian harrier

4.1   Abstract

A regular supplementary feeding programme from raised tables was attempted to attract Australasian harriers into a Canterbury vineyard and several Martinborough vineyards in order to deter pest passerine birds from foraging on grapes in vineyards. For feeding from the table to become established, the harrier would first need to overcome any neophobic tendencies toward the table. Regular feeding behaviour from the raised table which ranged from 3-5 months only occurred in two out of the ten sites, while at other sites intermittent or no feeding was observed. Neophobic tendencies and the lack of motivation to exploit the bait provided on the raised tables may have been related to several factors. Abundant non-manipulated food sources for the harrier were available at many sites, including the surrounding landscape, and along with human presence and intervention at some sites, and negative interspecific relationships at others, these factors may account for the low success rate of this trial.

4.2   Introduction

Attracting harrier populations, by providing a consistent food source, particularly during the grape ripening period may be the key to mitigating grape damage caused by pest passerine birds in New Zealand vineyards. Evidence that raptors could have a role in mitigating bird damage in vineyards has been demonstrated by the "Falcons for Grapes" project which has employed the use of another New Zealand raptor, the New Zealand falcon (*Falco novaeseelandiae*), in Marlborough vineyards to address the significant pest bird problem (Saxton, 2010). Translocated from its natural habitat to vineyards, the falcon was supplementary fed with day-old cock chicks and its increased presence in vineyards has shown positive results in the war against grape damage, helping to control pest passerine bird populations (Saxton, 2010; Kross *et al*., 2011). However, the endemic New Zealand falcon is rare and translocation is a complex process.

Anecdotal evidence of Australasian harriers being attracted to a Hawke's Bay vineyard by supplementary food on a raised feeding table and consequent decreased grape damage, caused by passerine birds has been reported. Feeding off a raised table elevated the harrier and gave a greater field of view for passerine bird species to sight the harrier, thus deterring them from entering the vineyard (Beard, R., viticulturalist, pers. comm., July 2009).

An abundant, diurnal, medium- sized, native New Zealand raptor, the Australasian harrier (*Circus approximans*) is a generalist and opportunistic feeding raptor, which may provide an explanation for its ecological success throughout New Zealand. It is found in open country slowly quartering areas of long grass, reeds, rushes, and crops on the lookout for prey species (Baker-Gabb, 1981). Harriers hunt by gliding low over the ground and surprising their prey, using a dive-and-attack approach on unsuspecting ground prey and will rarely attack prey on wing (Baker-Gabb, 1981). Raptors, including harriers will patrol and hunt where they find a particular prey species at its highest density and where they can attain the highest energy gain (Baker Gabb, 1981; Preston, 1990; Thirgood *et al*., 2003; Lambertucci *et al*., 2009).

For a change in feeding behaviour, i.e. feeding off a raised table, the Australasian harrier would need to exhibit signs of behavioural flexibility or ecologically-innovative behaviour (Greenberg, 2003). The Australasian harrier has already demonstrated this to some degree. Foraging behaviour flexibility has been demonstrated by its successful adaptation to anthropogenic changes, as seen in the New Zealand landscape, where animal carcasses found on New Zealand roads after collisions with vehicular traffic, now plays an important role in food provision (Robertson, 1980; Baker-Gabb, 1981). Harriers are frequently seen patrolling the roadways for animal carcasses, which have been the victims of speeding vehicles, and are often witnessed feeding unperturbed on roadsides with large volumes of traffic passing by.

Neophobia is the aversion behaviour an animal initially displays to a place, object, or food source and neophilia is the natural attraction an animal displays to a place, object, or food source (Greenberg, 2003). Greenberg (1990, 2003)suggested that the neophobic response to a novel object is not necessarily a permanent behaviour, and that generalist avian species tend to exhibit lower neophobic tendencies (Greenberg & Mettke-Hofmann, 2001; Mettke-Hofmann *et al.*, 2002). The Australasian harrier is a generalist species so it could be assumed that these findings might be relevant to its response to elevated feeding tables.

The need or motivation to feed presumably affects the neophobic response (Mettke-Hofmann, *et al*., 2002), where habitat selection by a species with respect to food resources is affected by the level of energy required (hunger level), and perceived mortality risk (Grand & Dill, 1999; Lambertucci *et al*., 2009). The quantity of food and perceived mortality risk will also affect bird distributions in heterogeneous environments (Lambertucci *et al*., 2009). An environment that is supplemented with accessible valuable food resources, including quality and quantity (Matthiopoulos, 2003), may be of greater benefit than any perceived risks proposed in that environment. In such a scenario, supplementary feeding may eventually contribute to an increased population of harriers in one particular area. Profitable feeding is an experience that animals can learn (Greenberg, 1983), and for the harrier to feed from a raised table it must first overcome its fear of novel objects, in this case the feeding table, and the attraction to the novel object (table) needs to be established through provision of regular and abundant food resource supplies.

Feeding other harrier species off raised tables or poles has been successful. Simmons (2000) supplemented the diet of selected pairs of the African marsh harrier (*Circus ranivorus*) with mice (*Mus musculans*), mole rats (*Bathyergus* spp.) guinea pigs (*Procavia* spp.), fish, and birds. These were placed on 1-2 metres high posts at typical feeding sites where he reported that all prey were readily accepted. Redpath *et al.* (2001) noted in a study of supplementary feeding of hen harriers (*Circus cyaneus*), that when harriers were fed on perches 1.5 metres high, 91% of the food disappeared by the next day. Amar & Redpath (2002) also found harrier feeding successful with the use of 1.5 metres high feeding tables.

In a study by Reinert (1984), on the use of introduced perches by raptors, ten species opted for dead trees and only four used man-made perches for activities such as resting, hunting and feeding. The northern (American name) harrier (*Circus cyaneus*) in Reinert's study differed from most of the other raptor species; while it did rest on the man-made perch, it did not consume prey on any of them. Supplementary food was not placed on these perches.

Ecologically-successful raptor species have low neophobic tendencies (Biondi *et al.*, 2010) and it could be argued that for the Australasian harrier to have become ecologically successful (evidenced by the abundant populations in New Zealand) it may demonstrate low neophobic tendencies and can display ecological innovation. The Australasian harrier has demonstrated ecological plasticity particularly related to its generalist dietary adaptation to the New Zealand

environment. Because of this factor and assuming its ability to overcome any possible neophobic tendencies, along with hunger caused by seasonal lack of availability of food and the bird's life cycle, it was expected that feeding from a raised table was achievable. First, we wanted to discover if it was possible to establish this novel feeding behaviour and second, to maintain a regular feeding regime where the harrier would frequently visit the vineyard where the table was located. It was envisaged that it would take time for harriers to overcome any neophobic tendencies toward the table, however it was assumed that by the beginning of the grape ripening period when bird pressure is greatest, regular feeding by harriers from the raised feeding tables would be achieved. As a result, it was anticipated that the regular presence of the harrier would then act as a deterrent to passerine bird in vineyards by exploiting their innate fear of raptors and latterly decreasing grape damage (see chapters 6 & 7).

4.3   Methods

The initial pilot study site was Bentwood Wines, Tai Tapu, Canterbury and the project was then expanded to include nine Martinborough, Wairarapa, vineyards (see chapter 1). Study sites were chosen in consultation with the winegrowers principally because past grape damage had been prevalent in these areas. Increased harrier presence in these areas would provide the most benefit to the vineyard because pest bird pressure was the greatest in these areas. The Canterbury site was chosen in a Pinot Blanc cultivar block and the Martinborough sites were all Pinot Noir cultivars to enable comparability.

In an attempt to reflect the success anecdotally reported in the Hawke's Bay vineyard, where several harriers were visiting the feeding table regularly, feeding tables were constructed in a similar pattern. Tables were constructed of a 900 mm by 900 mm white painted wooden board that could be detached from a 2.0 m pole on a tripod stand (Fig. 4.1). The wooden board was attached so that it could be raised and lowered to a desired height to aid with the habituation process of feeding off a raised table.

Figure 4.1: Feeding table attached 200mm off the ground to 2.0m pole, with rabbit carcasses as bait, at Bentwood Vineyard, Tai Tapu, Canterbury.

4.3.1 Bentwood Vineyard, Tai Tapu, Canterbury

The trial began in mid August (late winter) and finished end of December (summer) in 2009. The feeding table stand (Fig 4.1) was placed in the headland (i.e. at the end of the vine rows) of the vineyard close to a strainer post so that it could be tied by cable tie to the post to provide stability. Bird damage appears to be prevalent at the outer vines or edge of the vineyard and decreases towards the interior of the vineyard (Saxton, 2008) and having the harrier feeding at this location would provide increased protection for the exterior grapes. Hare (*Lepus europeus*) or rabbit (*Oryctolagus cuniculus*) carcasses, opened to expose flesh (Robertson, 1980; Baker Gabb, 1981; Knight & Anderson, 1990), were placed on the ground. Bait was replaced every two-three days to keep the food source relatively fresh. Robertson (1980), reported harriers in an unpublished field study, had indicated they preferred fresh animal carcasses.

Largomorphs or hares and rabbits are reported to be the harrier's preferred foods (Fennell, 1980, Baker-Gabb, 1981), and it was hoped these items would provide maximum attraction to the site. In the initial stages, the removable table was placed on the ground next to the hare. A 24-hour time-lapse video camera was placed 6 metres from the table site. As it was a large apparatus, it was placed against a backdrop of vegetation in attempt to disguise its presence,

or at least integrate it into the natural landscape, and to minimise further harrier shyness to a novel object/situation. A daily assessment was made to see whether bait had been nibbled, while time-lapse vide (Panasonic VHF VCR) equipment provided direct evidence of harrier presence at the study sites. Video footage was downloaded daily and harrier activity was recorded along with visual assessment of the animal carcass provided.

After evidence of regular feeding was established for one week the hare/rabbit were placed on the table and wired down to prevent the harrier from dragging it off the table onto the ground. Hares/rabbits were replaced depending on amount of flesh consumed or if they were no longer fresh. After establishing regular feeding off the grounded table for one week, the table was attached to the 2.0 m metal stand, reaching 200 mm off the ground, when connected. Tables were raised in 0.5m increments after feeding was established at each height increment, until reaching grapevine canopy height (2.0 m). Tables were raised in increments of 0.5m as anecdotal evidence suggested that Australasian harriers in a Hawke's Bay vineyard responded to a slower elevation of the table, rather than immediately to canopy height (Beard, R., viticulturalist pers. comm., July 2009).

4.3.2 Martinborough vineyard sites

This trial took place from mid-October 2010 until mid-March 2011, in Martinborough, Wairarapa. This was seasonally later than the site in Canterbury as a trapping and banding programme was attempted in all vineyards over the winter (see chapter 9), but with little success. Similar methods were employed in the Martinborough vineyards ($n=9$) as were used in the Canterbury vineyard. Table placement was in consultation with individual winegrowers, some were placed at the end of a vine row, some at the fence line, however all tables were located at least three m from the damage-prone vines. Not all vineyards commenced the feeding trial simultaneously, as new sites were recruited over time and some vineyards sites were abandoned after three months because there was no harrier activity despite bait being offered constantly.

Attempts to get harriers feeding off the elevated tables were completed over a period of five months. However, a number of steps had to be omitted, and brush fencing (a type of commercial landscaping material that is made of sticks and brush) was stapled to the table. This was an attempt to reflect the natural ground surface that the harrier is accustomed to, and also to provide grip for the harrier's talons and encourage it to prolong its feeding time on the

table. Once establishment of feeding off the grounded table had taken place the table was connected to the stand. It was then raised immediately to canopy height because of the number of vineyards located in urban areas and the risk of predatory domestic animals that were observed in the study site vicinity that could access the tables, which could potentially confound results. For the Martinborough study Bushnell Trophy Cam™ motion-sensored cameras (model 119456) were also set up halfway through the trial (due to initial unavailability). They were located approximately three metres from the table, strapped on to vineyard posts or trees and helped to establish exactly what was taking the bait.

Data from the cameras was downloaded every two days, and it was noted whether bait was taken. Bait this time consisted of hare, rabbit and one day-old cock chicks (*Gallus domesticus*) in the spring season, as a previous study at Bentwood vineyard in Canterbury, showed harriers preferred chicks to rabbit in the springtime (see chapter 5).

4.4   Results

4.4.1 Bentwood Vineyard, Tai Tapu, Canterbury

Regular daily bait uptake (i.e. bait was taken every day) established approximately three months after the commencement of the trial. Percentage of bait uptake per month (i.e. the day of days when bait was taken per month) ranged from 16.7 % (5 days out of 30) in the second month of the trial to 100 % (30 days out of 30 and 31 days out of 31) for the last two months of the trial (Table 4.1).

Table 4.1 Days per month that bait was taken from the feeding table, at Bentwood Vineyard, Tai Tapu, Canterbury, 2009. #of days= number of days per month bait was placed on the feeding table, N= number of days per month bait was taken and % per month = the percentage of bait uptake per month.

Month	# of days	N	% per month
August	19	14	73.7%
Sept	30	5	16.7%
Oct	31	15	48.4%
Nov	30	30	100%
Dec	31	31	100%

The number of days delay until feeding after different feeding treatments were implemented ranged from two-eleven days (Table 4.2). Feeding took place after only two days when the

hare was initially placed on the ground next to the table. There was a three-day delay before the bait was accessed again after the hare was wired to the table. After attachment of the table to the stand (200 mm), no feeding took place for six days. After a site change was implemented due to feral cat (*Felis catus*) activity, resumption of feeding then took eleven days. When the table was to raised to 1.0 m delay to feeding was two days; at 1.5 m it took 4 days and at final grapevine canopy height (2.0 m) there was a delay of 2 days. Regular daily feeding was established at this point.

Table 4.2   Number of days delay until feeding after different feeding treatments at Bentwood Vineyard, Tai Tapu, Canterbury, 2009.

Bait Placement	No. Days
Ground, next to table	2
Wired on to table	3
Table attached to stand (200mm off ground)	6
Site change (table attached to stand)	11
Table raised to 1.0m	2
Table raised to 1.5m	4
Table raised to 2.0m	2

Martinborough Vineyards

Initially it was unclear what was taking the bait from the tables until the camera was employed. Bait placed on the ground was not taken in one vineyard, taken intermittently in another and seven vineyards showed bait taken regularly. When bait was then placed on the elevated table, five sites had no bait uptake by harriers, three had bait taken intermittently and only one vineyard had harriers feeding regularly where 100 % of bait was taken every two days. (Fig.4. 2) & (Table 4.3).

Table 4.3: Bait uptake by Australasian harriers at nine vineyards in Martinborough, Wairarapa (2010-2011), showing number of vineyards where bait was either not taken, intermittently, or regularly, when placed on the ground or placed on the elevated table.

Bait Placement	Bait Uptake	# of vineyards
Ground	Not taken	1
	Taken intermittently	1
	Taken regularly	7
Elevated(2m)	Not taken	5
	Taken intermittently	3
	Taken regularly	1

Figure 4.3: Australasian harrier feeding on rabbit carcass on a raised table at Pond Paddock vineyard, Martinborough, Wairarapa, 2011.

4.5 Discussion

Despite the success of the pilot study in Canterbury, it proved difficult in Martinborough to attain the desired effect of harriers feeding from most of the raised tables. This was considered a fundamental behavioural requirement for the project and integral to attempt mitigation of bird damage in the vineyards. Apart from the Canterbury site and one Martinborough vineyard site, establishment of a consistent feeding pattern from all tables was not achieved. Only one site in Martinborough established regular feeding when the table was raised to canopy height straight from ground level, however there was still an initial reluctance to feed, but was eventually achieved. One vineyard had no bait taken from the ground by the harriers although two individuals were sighted flying over the study site. This site was abandoned early in study; even though bait was not being taken after two weeks of trial on the ground a table was still erected with bait supplied for another week in the anticipation of attracting the harriers that had been seen flying over the vineyard. However, no bait was taken from the table. Another vineyard had bait taken intermittently from the ground but no sightings were witnessed when the table was attached to the pole and raised. When

tables were elevated to canopy height no harrier feeding occurred in five vineyards and three showed sporadic or intermittent feeding activity on the raised tables.

Cats and magpies (*Gymnorhina tibicen*) were also witnessed (latterly in the study period when cameras were set up) taking bait from the study sites on both ground and table treatments. A cat was witnessed taking bait from the lowered table (200 mm) at the Bentwood vineyard, but was despatched by the vineyard owner. Magpies may have also had an effect on harrier behaviour (see below). The role of other predatory presence in vineyards related to passerine birds will be addressed in more detail in chapter 8.

The Canterbury site had several harriers regularly feeding from the raised table, but only one out of the nine sites at Martinborough established a regular feeding pattern from the raised tables. Reluctance to feed might be related to fear or at least a wary response to an unnatural manipulated environment (Mettke-Hoffman *et al.*, 2002), and/or the possibility of the availability of easily accessible alternative food sources. Neophobia in the form of bait shyness or reluctance to feeding from a novel object, such as the table used in this trial, could be related to many factors.

While harriers were observed near all vineyard sites and appeared to be engaged in an exploratory circling of the table sites, this did not result in taking any of the bait provided on raised tables in five sites where earlier bait had been taken from the ground. Greenberg & Mettke-Hofmann (2001) pointed out exploratory behaviour involves cost and a neophobic response may be more beneficial to the bird. An unknown object, such as the table, may expose the bird to predators or injury, and along with being less vigilant, the subject consumes time and energy in this exploring process with perhaps no reward at the end. A cost/benefit analysis is often weighed up by birds before accepting a new site or food resource, where it is usually approached, explored and then sampled (Greenberg & Mettke-Hofmann, 2001; Mettke- Hoffman *et al.*, 2002).

Marples *et al.* (2007) indicated that with unfamiliar food sources birds may respond with "diet wariness" and may even show reluctance to food consumption for extended periods, which was evidenced at many sites in this trial. Perhaps not enough time and persistence were assigned to the feeding trial and the "extended period of diet wariness" (Marples *et al.*, 2007), was just that: an extended period, which would eventually result in regular feeding at all sites. Additionally, when feeding treatments were changed, as highlighted at the Canterbury site

(see table 4.2) reluctance to feed was noted and it is likely that regular feeding in all vineyard sites may have occurred much sooner if food was offered on the ground only.

The site in Canterbury proved successful in terms of establishment of regular feeding from the raised table. The trial was commenced at the end of winter where food sources were probably scarce and the spring flush of nestlings was yet to be evident. The only site in Martinborough to establish a regular harrier feeding was a late addition to the trial. This late addition was due to the winegrower's interest in harriers and enthusiasm to be part of the project. It was difficult to determine whether this later commencement had any effect on this sites' successful feeding establishment of harriers. Supplementary feeding at this site was commenced in summer where the hot, dry climate also yielded a diminished contingent of food sources (Simmons, 2000). Water sources, such as the many ditches, drains, and transitory creeks/streams that are fed by the winter rains, were also depleted at this time. At all the other sites supplementary feeding commenced in late spring, when there were increased natural food sources such as nestlings, young mammals and lambing was in progress. At these other sites, a regular feeding pattern was not established, or only intermittently but did not remain consistent until grape ripening.

Spring is a time where food resources for harriers are in good supply. Many water sources in the Martinborough area, which provide food in the form of invertebrates, frogs, nestlings, are still full at this time of year. Baker-Gabb's (1981) found that the Australasian harrier adapted its diet to seasonal availability of prey species, where they took food according to availability not preference. Additionally, springtime is concurrent with the lambing period.

Martinborough, before the advent of the wine industry, was predominantly a sheep farming area, and while much land is now allocated to wine growing there still remains a considerable (c. 3.5 million sheep in 2002 http://www.teara.govt.nz/en/wairarapa-region/7) proportion of sheep and some cattle farms interspersed amongst the vineyard areas. Anecdotal reports have suggested that harriers will eat the dead lambs and afterbirth of the lambing process and Baker-Gabb (1981) found that the largest proportion of the harriers' diet in late winter/spring was ovine (*Ovis aries*) carcasses. Harriers were seen in large numbers over farmland during the lambing period. All these factors may explain the latency to feed by harriers in most vineyards in this area. If a heightened sense of hunger is not a driving factor due to other

easily accessible food sources, the costs of exploring, approaching and exploiting a novel object, such as a feeding table, may well outweigh the proposed benefits.

Harrier reluctance to feed from the tables could also be related to the provision of yet another reliable food source. Road-kill, as it is commonly called, was seen around many vineyard sites, particularly those situated by open road speed limits. Harriers were observed frequently foraging on animal carcasses that had fallen victim to speeding traffic in both the Canterbury and Martinborough locations. However, the sites (Canterbury and Martinborough) that saw harriers feeding regularly contrasted in both volumes of traffic and speed and consequent presence of road- kill. The Canterbury site was in close proximity to a main highway with frequent road-kill observed, and The Martinborough site was situated on a gravel road that was remote from any major highway and road-kill was sparse.

One vineyard that did not record harriers taking food off the ground was situated in an urban area attached to a vineyard restaurant. While harriers had been regularly seen, as reported by staff, their reluctance to take bait even from the ground could be related to human disturbance or because other predators were taking the food before the harrier managed to access it. This observation could be relevant to the previous discussion about the availability of other easily accessible food sources located in the surrounding proximate landscape. The cost of the perceived threat from humans may have outweighed the benefit of exploring the presented food sources.

A final factor explaining the reluctance to feed could be related to the large Australian magpie population found in the Martinborough vineyards and the surrounding landscape. These were seen frequently harassing harriers throughout the area. Often two or more magpies could be seen diving at a solitary harrier, moving it out of their territory. Magpies see harriers as a threat as they will often predate on their young and will at times compete with them for other food sources such as carrion (Morgan *et al.*, 2006). Magpies were witnessed via camera trap (n=68) at the study sites and some were observed consuming food put out for the harriers. In the vineyard where regular feeding was established magpie counts were much lower (n=2) and the total number of magpies (n=66) observed in the other vineyards where only intermittent feeding took place was greater.

4.6   Conclusion

While two vineyards (Canterbury and Martinborough) in this trial showed a regular feeding pattern by harriers, several were not as successful, and harrier visits were either intermittent or absent at most sites. It was hoped that motivation to feed, or hunger would negate the fear of a novel object (table). However it was not known at what level of hunger, nor was it within the scope of this project to measure it, would be necessary to overcome neophobic tendencies and exploit the bait provided on the raised tables. Equally, that it was indeed a neophobic response from the harrier not to exploit the feeding tables may be only an assumption and perhaps more time and persistence is required to establish affinity to the feeding tables. Supposedly, in many instances non-manipulated food sources for the harrier were available in greater or lessening quantities throughout its territory and throughout the seasons. Other factors such as anthropogenic disturbance and negative interspecific relationships as demonstrated by the magpie, may also account for this initial reluctance.

Chapter 5

Spring and summer food preferences of the Australasian harrier in vineyards

5.1 Abstract

The Australasian harrier is a generalist feeder whose diet includes animal carcasses as well as live prey, such as birds, mammals, fish, frogs, and invertebrates. In order to attract harriers into vineyards to help control pest passerine bird populations it is important to provide supplementary food that provides maximum attraction qualities. This includes providing food that reflects the choice of the harrier in the wild. Anecdotal evidence has identified that during the spring breeding season the harrier prefers nestlings or chicks to other foods such as rabbit. A two-choice test was performed using pieces of rabbit and day-old dead cock chicks placed on elevated feeding tables in vineyards during the spring and summer seasons. Chicks (86%) were preferred over rabbit (14%) during the spring season and there was no significant preferential choice between chicks over rabbit in the summer season. Reasons for this seasonal behaviour are discussed.

5.2 Introduction

Dietary intake and prey choice amongst raptor populations are seasonably variable. This variation may be related to a number of factors, such as prey availability or density, where prey switching from a favoured food source to a less favoured one may be a necessity when typical prey species numbers diminish (Tome, 1994). Access to prey may be impeded by environmental factors (Korpimäki, 1985), or nutritional driving factors may result in diet variability. Several studies have shown that even in specialist raptor species nutritional intake is dominated by seasonal availability (Newton, 1979; Robertson, 1980; Baker-Gabb, 1981; Aumann, 1988; Goutner & Alivizatos, 2003; Rojas *et al.*, 2005; Kafkaletou-Diez *et al.*, 2008; Seaton *et al.*, 2008; González-Acuña *et al.*, 2009).

Some raptor species display a seasonal difference in prey choices during the breeding period. They may choose small or medium mammals during courtship and egg laying, possibly because the net energy gain is higher when hunting for small mammals compared to birds

(Simmons, 2000). Lewis *et al*. (2006) found that the proportion of juvenile prey, i.e. nestlings, increased in the diet of Northern goshawks (*Accipiter gentilis*) as the nesting season advanced, probably related to juvenile prey emergence in the environment and ease of their predation.

The female Australasian harrier generally does not return to the breeding territory until June/August when courtship begins and may continue until October. Nest building begins in September to October (Heather & Robertson, 1996). From September to November, the female lays 2-7 eggs and she incubates the eggs for approximately 30 days. The male feeds the female throughout this time until the fledging of the harrier chicks. Chicks fledge at 43-46 days old and will remain with their parent for approximately one week after fledging (Baker-Gabb, 1978; Marchant & Higgins, 1993; Heather & Robertson, 1996).

The carnivorous diet of the Australasian harrier is varied. In New Zealand, a large proportion of the diet includes animal carcasses, from road-kill (Marchant & Higgins, 1993). Hare (*Lepus europeus*) and rabbit (*Oryctolagus cuniculus*) have been noted to be the harriers' favoured food (Robertson, 1980; Baker- Gabb, 1981; Wong, 2002), along with small introduced passerine birds and domestic hen chicks (*Gallus domesticus*), remaining seasonally important (Robertson, 1980).

An anecdotal report (Beard, R., pers. comm., 2009) suggested that in a New Zealand vineyard where feeding stations had been established in an attempt to mitigate grape damage caused by passerine bird species, harriers preferred foraging on domestic chicks during the breeding period. Harriers that had established a regular feeding pattern from an elevated feeding table baited with lagomorphs during the winter season, showed a reduced interest in taking hare/rabbit from the table as the spring season (September/October) commenced. Dead day-old cock chicks replaced the hare/rabbit bait and regular visits to the tables resumed. A study by Robertson (1980), examined the food choices of the Australasian harrier by offering a choice of baits. Results showed that domestic hen chicks and Norway rats (*Rattus norvegicus*) were favoured over rabbits, possums (*Trichosurus vulpecula*) and eels (*Anguilla australis*) at the time of the study; however, Robertson did not investigate seasonal choices.

A better understanding of seasonally preferential food sources of the harrier and provision of that seasonal preference when attracting them to feeding tables in vineyards may be required

to achieve increased Australasian harrier numbers in the vineyard. The aim of this study is to establish whether the harrier prefers certain prey types (rabbit or chicks) during the breeding (spring) and non-breeding (summer) season.

5.3   Methods

The study site was located at Bentwood vineyard, in Tai Tapu, Canterbury (see chapter 1). The feeding table (see chapter 4) was placed in the headland (i.e. at the end of the vine rows), of the vineyard close to a strainer post so that it could be cable-tied to the post to provide stability. Bird damage appears to be prevalent at the outer vines or edge of the vineyard and decreases towards the interior of the vineyard (Saxton, 2008). The choice of this feeding location was to maximise protection for ripening grapes in the ensuing seasons.

Hare or rabbit carcasses, both favoured food choices (Fennell, 1980; Baker-Gabb, 1981; Wong, 2002), opened to expose flesh (Robertson, 1980; Knight & Anderson, 1990), were placed on the ground. Bait was replaced every two-three days depending on rate of decomposition. When habituation had taken place the hare/rabbit bait was placed on the feeding table; the table was then attached to the pole and raised gradually to grapevine canopy height (see chapter 4).

At the time of this trial's commencement, regular bait supplies were being placed on the feeding table. Approximately three individual harriers, identified via a time-lapse video camera, visited the feeding table at this time, but visits were only intermittent (approximately 50% of the days per month). The only bait supplied at this stage was dead hare or rabbit. Skinned rabbit pieces, obtained from a pet food company and day-old dead chicks obtained from a poultry-processing factory were then used to assess harrier food choice in the vineyard at breeding time (October-January). To eliminate any effect of mass and size, rabbit pieces were equivalent to chicks (approx. 50 g). Seven pieces of skinned rabbit meat and seven dead one day-old cock chicks were placed on the feeding table at canopy height. This random arrangement resulted in pieces of rabbit and chicks being available at the edge of the table as well as the centre of the table (Fig. 5.1).
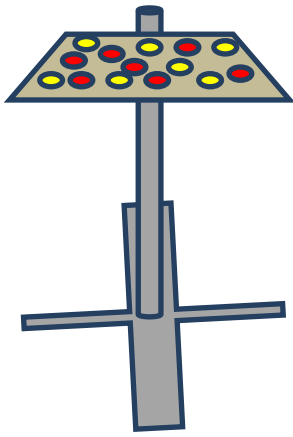
Figure 5.1: Diagram showing example of placement of food items on feeding table (yellow = chicks, red = rabbit pieces). As items were taken by harriers they were replaced i.e. rabbit for rabbit, chick for chick.

The spring period for this trial was one month (30 observations, mid October to mid November 2009). Bait items were observed daily, usually mid afternoon, and number of rabbit pieces/chicks taken was recorded, and any missing items were replaced with the same item that was taken i.e. rabbit for rabbit and chick for chick. Where items were not taken, they were replaced every two days to maintain freshness of the bait. The same procedure was repeated for the later breeding period in the summer (30 observations, late December to late January 2009/2010).

The data were analysed using a paired *t*-test where test statistic was the proportion of pieces taken per day for each bait type out of the total available. The test was run using Microsoft Excel® version 2007.

5.4   Results

Harrier visits to the vineyard were intermittent at the beginning of this trial. With the addition of the chicks, the harrier visits showed an increased feeding pattern from approximately 50% of days up to 100% during the spring trial period (Table 5.1).

Table 5.1: Time taken for feeding establishment from feeding table, at Bentwood Vineyard, Tai Tapu, Canterbury, 2009. N= number of days per month bait was taken. % = percentage of bait uptake per month. With the addition of chicks in October harrier visits increased from approx. 50 % to 100%.

Month	Days	N	%
August	19	14	73.7%
September	30	5	16.7%
October	31	15	48.4%
November	30	30	100%
December	31	31	100%

As the visits became more regular, the choice of food indicated a significant preferential bias in the spring period ($t = 9.52$; df = 20; p<0.001), with 85.7% of the chicks taken compared with 14.3% of the rabbit pieces (Fig 5.2).
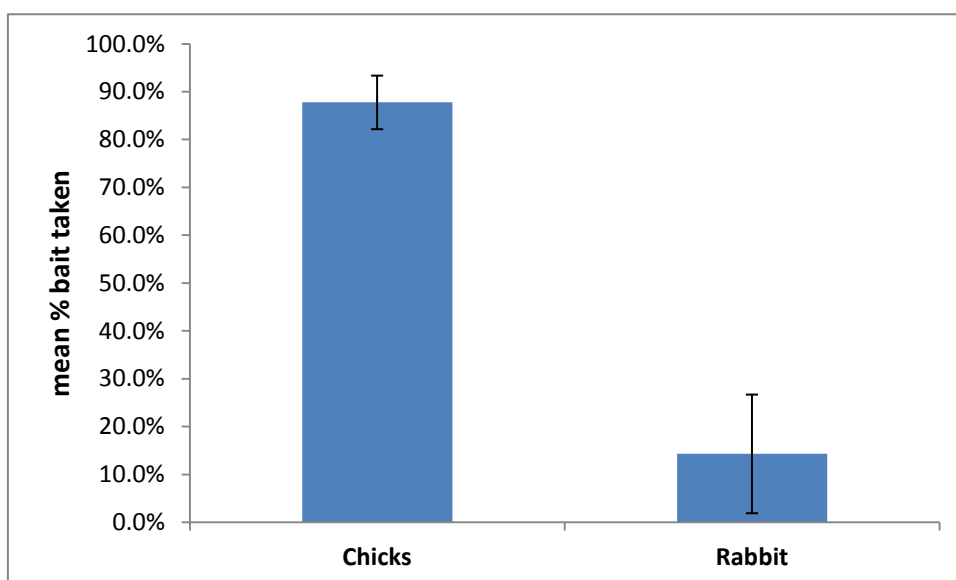
Figure 5.2: Mean (+ SEM) percentage of chicks and rabbit taken by Australasian harriers from a raised feeding table in spring (mid-October to mid-November) 2009.

During the summer breeding period, there was no significant difference with 100% of the chicks taken and 98.6% of the rabbit pieces taken ($t = 1.02$; df = 20; p = 0.34, Fig. 5.3).
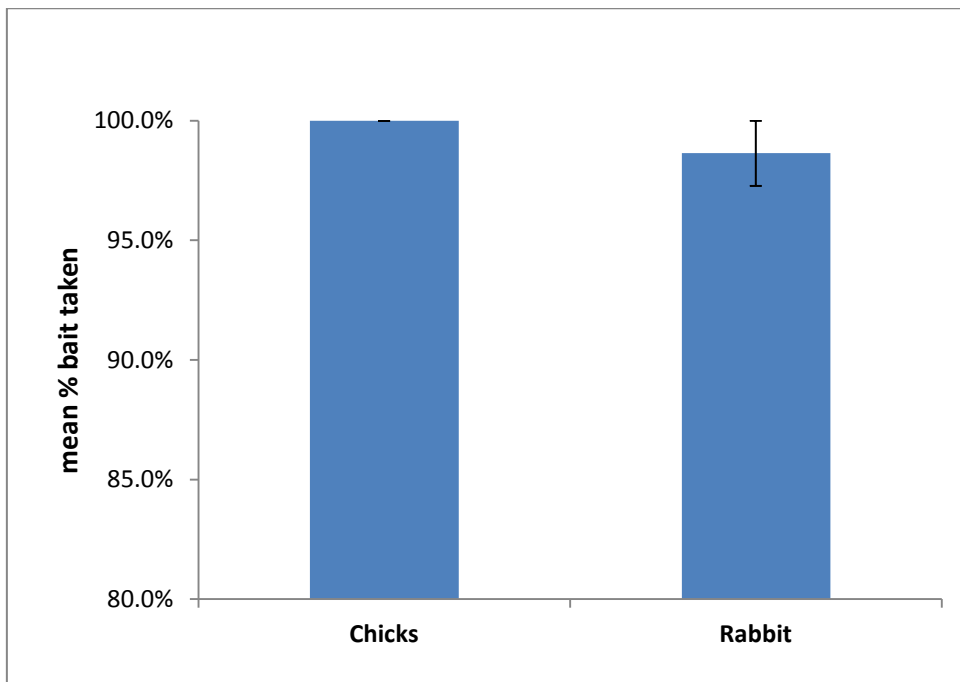
Figure 5.3: Mean (+ SEM) percentage of chicks and rabbit taken by Australasian harriers from a raised feeding table in summer (late-December to late-January) 2009/2010.

5.5 Discussion

Chicks were preferred over pieces of rabbit meat during the spring trial period but there was no significant food choice difference between rabbit and chicks over the summer trial period. The seasonal diet of the Australasian harrier is changeable. Both winter and summer can become a time of food scarcity for many harriers and, as the spring season approaches, food supplies became more abundant (Simmons, 2000). Mammalian animal carcasses are an important part of the harrier's diet during winter and early spring (Baker-Gabb, 1978). Baker-Gabb (1978, 1981) reported that in spring and summer, Australasian harriers rely on eggs and nestlings as a food source. Spring preference for eggs and nestlings may be because these prey items are easy to transport to nest sites or possibly other factors as discussed below.

5.5.1 Nutritional requirements

Newton (1979) suggested that quality of food may be just as an important as quantity and that the nutritive values of some prey species may differ. In optimal foraging theory a predator's diet should include a food resource that provides the highest net energy gain, maximizing lasting energy input, or reducing starvation and/or predation risks (Preston, 1990; Beissinger *et al.*, 1994). Beissinger *et al.* (1994) expanded on this by noting that when a predator is

choosing a potential prey item, it is dependent upon the predator's physiological state, energy cost to obtain the prey, predator avoidance and energy/nutritional benefits of the prey.

While retrieving prey items from the feeding table, little energy cost was required of the harrier, as the prey were immobile and therefore, easily accessed. The fear of perceived predators, such as human presence, (which was frequent at this site) was not deemed important or overcome, as prey was being taken, initially intermittently, but then regularly from the table. This regularity of feeding is also likely to be related to the habituation process where a harrier became accustomed to taking food from the table. In the light of the Beissinger *et al*. (1994) study, prey choice may be driven by instinctive driving factors that recognise the energy/nutritional benefits of the chicks, which in turn became the catalyst in the uptake of chicks over rabbits in the spring.

The female harrier requires greater amounts of protein immediately prior to egg formation, relative to other lifetime periods (Simmons, 2000; Durant *et al*., 2000). Protein levels were found to be higher in day-old chicks than mammalian species, such as rats and mice (Forbes & Flint, 2000) although rabbits were not studied. Tollan (1988), examined the energy requirement for maintenance, including energy assimilation efficiency, in the Australasian harrier on three different prey items; laboratory mice (*Mus* spp.), day-old chicks and fish (*Gobiomorphus cotidianus*.). Day-old chicks had the highest protein levels but metabolisable energy came second to the rat, and harrier energy assimilation efficiency was lowest when fed chicks. The higher protein levels in the chicks may help to explain why the harriers in this trial preferred chicks to rabbits in the spring months. Although energy assimilation efficiency was lowest when fed chicks in Tollan's study it could be suggested that the nesting harrier does not require vast amounts of energy when sitting on eggs.

5.5.2 Neophobia and food choice

It was expected that the chicks' appearance or general morphology on the table was clearly recognisable as a prey item to the harrier, more so than the equally sized rabbit pieces. This may account for the earlier uptake of chicks over rabbits in the spring. The rabbit pieces may have been unrecognisable, (although they do take animal carcasses from roadways) as a food choice compared to the chick, and neophobic tendencies (see chapter 4), may account for its reluctance to take the rabbit. However, if this were the case it could be presumed that after regular chick uptake, i.e. by the end of the spring 30-day trial, there may have been some switch to rabbit meat as the harrier had time to identify the rabbit meat as an easily accessible

"safe" food source. By the end of the 30-day spring trial, chicks remained significantly higher in terms of uptake, than rabbit.

5.5.3 Search image and prey seasonal abundance

Another reason for the preferential selection of chicks in spring may be related to a specific search image (Tinbergen, 1960) that the harrier has for chicks at this time of year. Diet specificity is a consequence of seasonal variation in prey availability (Newton, 1979; Robertson, 1980; Baker-Gabb, 1981; Aumann, 1988; Goutner & Alivizatos, 2003; Rojas *et al.*, 2005; Kafkaletou-Diez *et al.*, 2008; Seaton *et al.*, 2008; González-Acuña *et al.*, 2009), and this availability (e.g. nestlings or chicks) may reinforce the harrier's search image at this time.

Seasonal prey availability is a factor in food choice for raptors. Rojas *et al.* (2005), found that falcons (*Falco femoralis*) consumed more (in terms of numbers and biomass), passerine birds than rodents in the spring and summer, and that this was probably related to seasonal abundance of species. Aumann (1988) found that the brown goshawk (*Accipiter fasciatus*) preyed on rabbits more in spring when they were in greatest abundance and birds were mostly taken in summer when they were in greatest abundance. When the Northern harrier's (*Circus cyaneus*) own eggs begin to hatch, they switch to the new season nestling passerines, as they became increasingly available (Simmons, 2000), and in New Zealand, nestlings increase in the landscape during the spring months and are an important part of the Australasian harrier's diet (Baker-Gabb, 1981; Marchant & Higgins, 1993; Wong, 2002).

Tinbergen's (1960), concept of "search image" describes how insectivorous birds had learned to look for only one type of prey. Several studies have addressed this concept for selection of prey choice related to prey searching, but do not appear to factor in seasonal characteristics (Mueller, 1977; Pietrewicz & Kamil, 1979; Bond & Kamil, 1999; Blough, 2001; Giovanni & Bird, 2011). This concept was underlined by Robertson's (1980) study on the Australasian harrier and its selection of carrion. Robertson found that an individual harrier presented with a choice of prey types chose domestic chicks considerably more than rats. His suggestion was that the harrier was searching for this prey type (chicks). Robertson's (1980) study did not indicate which season of the year he carried out his field studies, so it would be difficult to make any assumptions on seasonal preference.

The specific preference or specific search image could be related to this trial as chicks were selected over pieces of similar-sized rabbit meat. However, the search image factor (i.e. the

chick) may have attracted the harriers to the table, but if they landed on the table, they would still be confronted with two choices; rabbit or chick. During this experiment, video camera footage showed harriers flying swiftly over the table grasping at food items and carrying the item away without lingering at the table.

It could be assumed that for the Australasian harriers in this trial chicks/nestlings are an abundant recognisable prey item in the harriers' spring natural environment and the seasonal search image for this item is possible. The rabbit meat in this trial was presented in no recognisable form that is reflected in a harriers' natural environment, so that may account for chick over rabbit choice. However, harriers often consume animal carcasses obtained from vehicular road-kill (Marchant & Higgins, 1993), and although the victims' morphology is not often unrecognisable, depending on the damage that the vehicle has caused to the body of the animal, rabbit pieces may look similar to a much-damaged carcass. The repeated encounters the harrier has with chicks in the springtime in a non-manipulated environment may activate the search image for harriers in this season and not the summer season.

5.6   Conclusion

Chicks were introduced to the feeding table in October as part of the rabbit/chick prey preference trial where visits to the table were intermittent. With the addition of chicks to the feeding table feeding visits became regular in the following month, November. The selection for chicks over rabbit in the spring seasons and the relatively equal prey choice over the summer season has been identified in this trial. Factors such as inherent need for foods with differing nutritional benefits for the breeding period may be an indicator, however a much more in depth enquiry into this would have to be initiated to substantiate this claim. Alternatively, it could be that the rabbit pieces due to their presentation and morphology were a novel object and neophobic behaviour prevented the harrier from taking the rabbit bait earlier in the spring season and this took some time to overcome. Seasonal prey abundance where the harrier chooses the chicks in the spring as a reflection of the environmental availability could reinforce the search image concept. A behavioural characteristic of many avian species reflected in preferential prey items, it might also have had a part to play in food choice of chicks over rabbit.

These findings may provide a guideline for attracting harriers to vineyards, as it has shown harrier preferential food choice dependent on season. Food that is put out to attract harriers in the spring (i.e. chicks) may be an important factor in establishing a regular feeding programme for harriers in vineyards, while for other seasons it may not be of importance which food is used.

Chapter 6

Australasian harrier presence and passerine bird abundance in vineyards

6.1   Abstract

Raised feeding tables where supplementary food was provided were set up in Martinborough vineyards prior to grape harvest to attract Australasian harriers, in attempt to decrease pest passerine bird species that forage on ripening grapes. A previous study had identified that harriers were visiting some vineyards intermittently and others regularly. Pest passerine bird abundance was significantly less in vineyards that had feeding tables present on average by 56%. Birds did not appear perturbed by the tables themselves, as there was no significant effect of table presence and distance that birds were observed from it. It is likely that increased harrier presence and activity induced by the tables' presence may have had an effect on the wider vineyard area. Passerine birds were observed flying in all sites with and without tables, rather than having net contact or within the nets. Starlings were the most common species found in the vineyards and blackbird abundance was influenced the most by the presence of feeding tables.

6.2   Introduction

The scaring ability of predator species can reduce population densities of pest species, and this ability has been exploited since ancient times (Conover, 1979; Erickson *et al*., 1990). Several studies have suggested harriers (*Circus* spp.), have been responsible for limiting game-bird populations (Redpath *et al.*, 2001; Amar & Redpath, 2002; Baines *et al.*, 2008), while population densities of mammalian pest species have shown a decrease in the presence of other avian predators (Mũnoz & Murúa, 1990; Kay *et al*., 1994). Humans have exploited this natural form of biological control, where birds of prey (raptors), such as falcons (*Falco* spp.), and hawks (*Buteo* and *Accipiter* spp.), have been utilised as biological control agents for pest bird species in agricultural and non-agricultural settings (Erickson *et al*., 1990; Duckett, 1991; Alley, 2003; Daugovish *et al.*, 2006; Saxton, 2010; Kross *et al*., 2011).

In the wine-growing industry, there is an ongoing and pressing need to find an effective and longer-lasting scaring mechanism that has the capacity to impact grape-foraging passerine bird numbers that contribute to significant economic loss. Bird-scaring methods in vineyards have previously been employed, such as hawk-kites, raptor models, eye-spot balloons and gas guns, but these devices rapidly lose effectiveness as pest birds become accustomed to them (Hickling, 1995; Daugovish *et al.*, 2006; Tracey *et al.*, 2007).

Predator presence is important in the community ecology structure of a species, even when the predator may only cause low mortality rates on a particular prey species (Cresswell, 2008; Cresswell, 2011). Despite the lack of real danger for many individuals, there remains an inherent fear response to all raptors in passerine birds (Conover, 1979; Hothem & De Haven, 1982; Göth, 2001; Patzwahl, 2002; Kaplan, 2004; Daugovish *et al.*, 2006).

Fear of predation that a predator instils can have an indirect effect on a prey species population. For example, fear of predation may limit areas in which prey choose to forage (Whittingham & Evans, 2004). The passerine bird, when foraging, has to evaluate its trade-off options; whether to gain required energy from an abundant food source, in this case a ripe grape, by foraging in an area where a known predator frequents, or avoid the area and exhaust more energy reserves to locate safer food sources. Abrams (1984) reported that for foragers, mean energy intake is affected by the quantity of food available and predator presence. The risk is also amplified by the length of foraging that may take place in an abundant food source area. Although more food provides greater fitness, it increases mortality rate risk, as the longer the period of foraging facilitates a greater vulnerability to predation (Abrams, 1984).

Behavioural adaptation to minimise the risk of predation may have a great significance for populations, communities and ecosystems and such adaptations may include an alteration in habitat use along with foraging behaviour (Lima, 1998; Cresswell, 2008; Dunn *et al.*, 2010). Decision making by prey as to where and when to forage may be affected by the presence of predators (Howe, 1979; Valone & Lima, 1987; Thomson *et al.*, 2006; Dunn *et al.*, 2010). For example, small birds may forage nearer vegetative cover to avoid predation (Lima, 1990). Behaviour exhibited in response to aerial predator presence includes fleeing to cover after both conspecific and interspecific alarm calls are signaled (Göth, 2001; Magrath *et al.*, 2007) and flocking behaviour, which is displayed by species such as starlings (*Sturnus vulgaris*) (Devereux *et al.*, 2008; Carere *et al.*, 2009). Furthermore, passerine bird species densities are

often lower in raptor nesting habitat (Norrdahl & Korpimäki, 1998) and birds will often abandon locations where a high risk of predation is possible (Lima & Valone, 1991). Unlike the endemic New Zealand falcon (*Falco novaeseelandiae*), another diurnal raptor which actively pursues birds on the wing (Heather & Robertson, 1996), the Australasian harrier (*Circus approximans*) is more commonly a carrion or animal carcass feeder, including road-kill. It will take small mammals and birds, but rarely takes birds on the wing (Baker Gabb, 1978; Robertson, 1980; Marchant & Higgins, 1993). Flocks of birds, both grape foraging (e.g. starlings) and non-grape foraging (e.g. house sparrows, *Passer domesticus*), that inhabit vineyards, flee when the Australasian harrier is observed (pers. obs.), and its presence may have an impact on passerine bird behaviour, including movement and foraging tactics.

In order to decrease grape damage in vineyards caused by pest passerine birds it is important to decrease their populations, or at least inhibit them from foraging on the grapes. At the time of this study, harriers had been observed feeding off raised tables where bait had been provided (see chapter 4). It is assumed that the table's presence with the harrier feeding off it (albeit intermittently) might have a Pavlovian effect (Griffin *et al*., 2000), where the table's presence for the passerine bird species signals a threat and avoidance behaviours are exhibited. It was predicted that the increased predatory presence of the Australasian harrier, regularly or intermittently, feeding off the table, would reduce populations of pest birds in vineyards, or at least disturb the birds and therefore diminish foraging time on grapes.

6.3   Methods

The experiment was conducted at seven Martinborough, Wairarapa, vineyard sites. Five-minute bird counts were completed during February and March 2011 just prior to grape harvest. All sites where bird counts took place grew Pinot Noir grape cultivars. Vineyards were located adjacent to shelter tree lines where pest birds perch and may nest. As this was the grape-ripening period, all vines were netted using single or multi-row type netting. All tables and subsequent bird count sites were located in the headland of the vineyard within 6 m of the edge of the vines. Edge vines are the most vulnerable to bird attack and generally sustain more damage (Tracey & Saunders, 2003; Saxton, 2004). This measurement allowed for a uniform placement of tables from the vines, as some placement of tables were dictated by vineyard management and were required to be cable-tied to the fence line.

Four sites with harrier feeding tables had been erected approximately five months before this study, and were baited with several different types of bait depending on availability. Bait was wired down on the table to prevent the harrier from dragging the bait off and onto the ground. Bait included harrier-favoured foods (Robertson, 1980; Baker-Gabb, 1981); hare (*Lepus europeus*), rabbit (*Oryctolagus cuniculus*), day-old cock chicks (*Gallus domesticus*), and, the occasional brushtail possum (*Trichosurus vulpecula*). The tables stood at grapevine canopy height (approx. 2.0 m), so that pest passerine bird species could see any harrier that may be feeding off the table. The other three sites did not have feeding tables erected, although a central point for a notional table was nominated and acted as the non-treatment control.

6.3.1 Five-minute bird counts

A modified version of the five-minute bird count method (Dawson & Bull, 1975) was used to assess bird activity from fixed monitoring points. As Dawson & Bull, (1975) suggest, the observer stands at a count station and records the number and species of all birds seen and heard. In this study as the sites were relatively small and binocular magnification could identify bird species, all identification was done by visualisation rather than auditory identification.

The five-minute bird counts at each vineyard consisted of an 80 m radius half circle. This area was chosen to make all the monitoring areas consistent, as the smallest vineyard width of rows measured 80 m. The feeding table/notional tables were located at the front-centre of the half circle area in the headland of each vineyard. Within this 80 m site the vineyard was divided into 4 x 20 m sections or count areas, 0-20 m, 20-40 m, 40-60 m, 60-80 m distance from the table, forming a semi-circular arrangement (Fig. 6.1). These areas were marked by different coloured pegs (for each of the four distances, to help with easy visualisation), placed on top of the vine pole and netting as inconspicuously as possible, but still visible when using binocular magnification. The count point was at least (depending on vineyard vegetation to provide cover for the observer) 6 m from the table/notional table in the vineyard. .
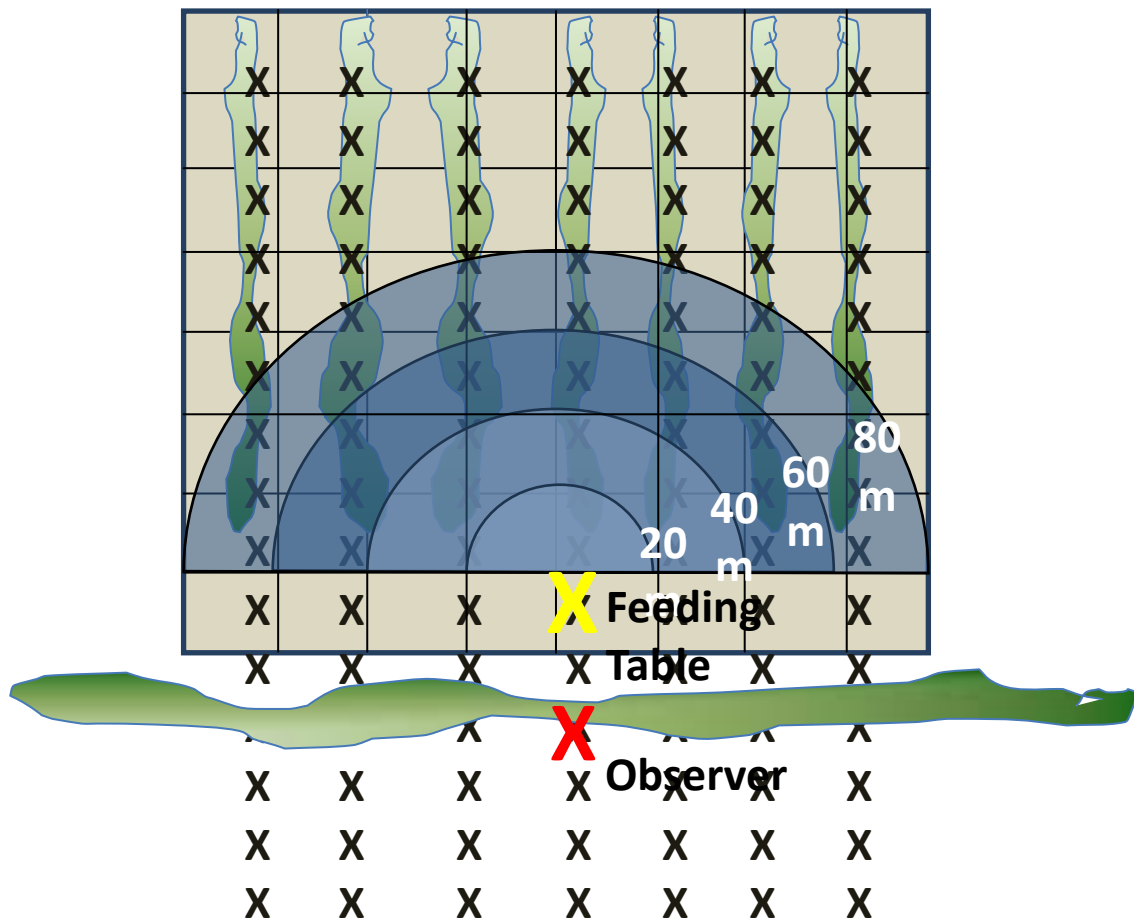
Figure 6.1: Vineyard plot showing counting distances from feeding table/notional table sites (0-20 m, 20-40 m, 40-60 m, 60-80 m) for five-minute bird counts with observer point located in vineyard vegetation/shelterbelt.

Ten counts on ten mornings were performed at each vineyard (*n*=7, 70 counts) between 0730- 0930 hours (to allow for travel between vineyards). Time of count starts were varied to allow for possible differences in bird activity related to time of day (0730-0930) at different vineyards i.e. if vineyard one was started first, it was started second on the next day's count, in an orderly sequence which ensured that all vineyards were counted at different times throughout the 0730-0930 hours period. Counting was done in a covert location, allowing for differing landscape characteristics in each vineyard, but still allowing for identification of bird species using binocular magnification. Number and type of pest passerine birds, distance from the table/notional table, and activity type (i.e. flying in the area, contact with the net, or caught within the net) were recorded for a five minute period. At the end of each count, observations for birds caught within the net, or foraging on the ground, which may have not been detected from the count point, were made by walking through the study area.

Count data was typically non-normal in its distribution. Accordingly, the effect of the table (presence-absence), abundance, species, and the distance from the table (m) were analysed using a generalised linear model with a poisson error distribution and a log-link function. The tests were run using the GenStat statistical package (Version 13).

6.4 Results

6.4.1 Abundance

Pest passerine bird abundance was less in vineyards with tables present (μ=12.75) compared with tables absent (μ=39). Three out of the four vineyards sites with harrier feeding tables present had a much lower number of pest passerine birds than those without, with Burnt Spur and Craggy Range showing very few birds present (Table 6.1). Overall mean pest passerine bird numbers where a feeding table was present were found to be significantly less than where the feeding table was absent (X^2=4,345, df=1, p=0.04 see: Fig 6.2).

Table 6.1: Total number of pest passerine birds present in vineyards (per 5 minute bird count), with and without feeding tables.

	Vineyard	No. Counts	Number Birds
Table present	Cirrus	10	32
	Burnt Spur	10	4
	Craggy Range	10	3
	Pond Paddock	10	12
	Total	**40**	**51 (μ=12.75)**
Table absent	Waiora	10	18
	Martin's Rd	10	53
	Te Rehua	10	46
	Total	**30**	**117 (μ=39)**
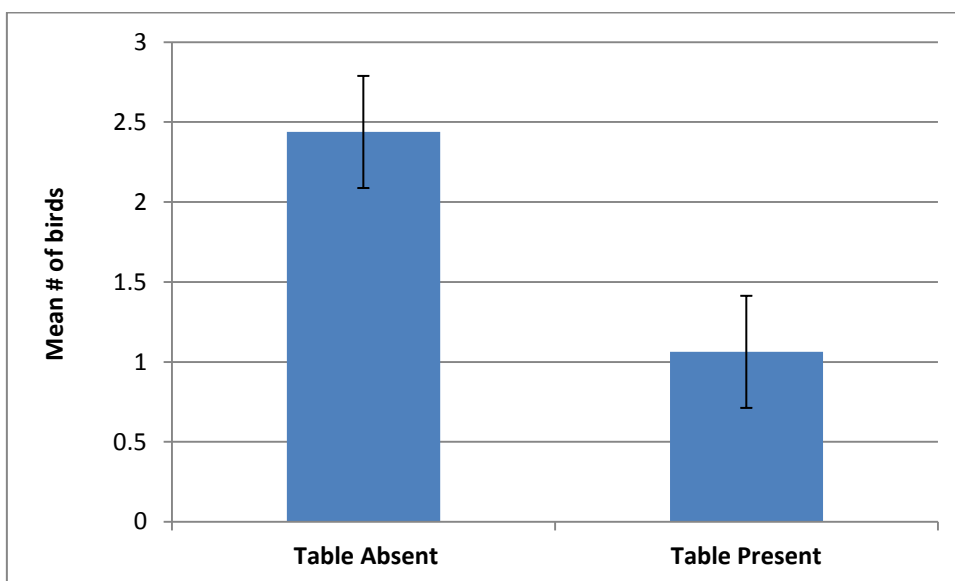
Figure 6.2 Mean number of pest passerine birds (± SEM) in Martinborough vineyards with Australasian harrier feeding tables absent and present.

6.4.2 Distance from table/notional table site

Whilst the presence of the feeding table influenced the overall mean bird counts, the distance (0-20,20-40,40-60,60-80 m) pest birds were sighted from the table/notional table site was not significant (X^2=8.188, df=3; p= 0.69), with birds observed at all distances even when the table was present (Fig. 6.3).
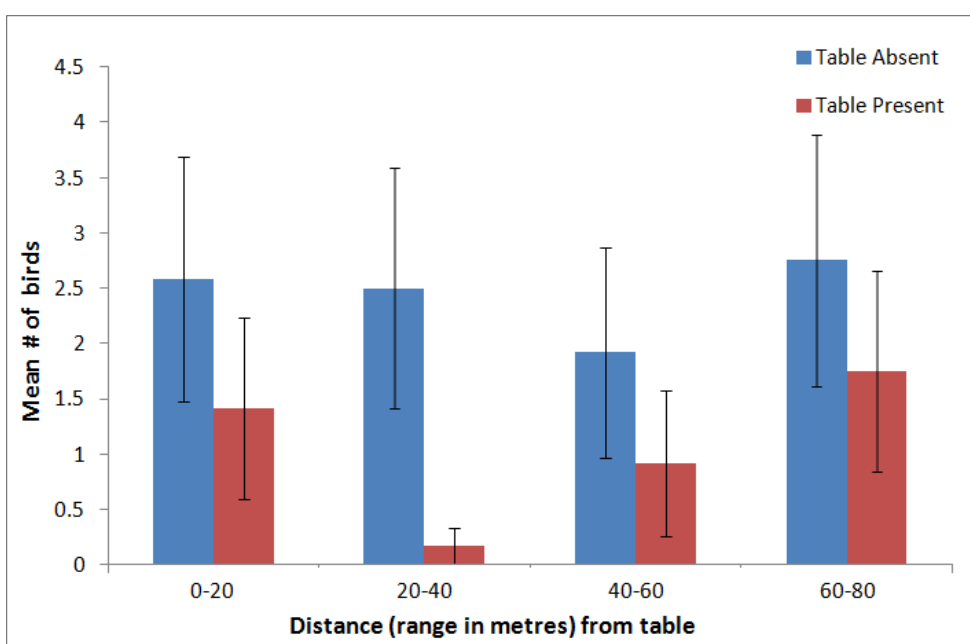
Figure 6.3: Mean number (± SEM) of pest passerine birds and distance from the feeding table/notional table site in vineyards.

6.4.3 Bird Behaviour:

Most birds were observed flying in the bird count area with tables present ($n=39$, 76%) and tables absent ($n = 99$, 85%). Smaller numbers of birds were observed having net contact with tables present ($n= 6$, 12%) and tables absent ($n= 18$, 15%). No birds ($n =0$, 0%) were observed within the nets where tables were absent, where tables were present ($n = 6$, 12 %) a small number was observed ($X^2= 14.38$, df= 2; p<0.001) (Table 6.2). No birds were observed foraging on the ground.

Table 6.2: Numbers of pest passerine birds flying, in net contact, or within the net, with and without feeding table present.

	Behaviour						
	Flying		Net Contact		Within Net		
Table	N	%	N	%	N	%	**Total Bird Numbers**
Present	39	76%	6	12%	6	12%	51
Absent	99	85%	18	15%	0	0%	117

6.4.4 Species

Species of birds were counted and starlings and blackbirds (*Turdus merula*) were the most abundant species found (Fig. 6.4). Starlings were more abundant than blackbirds in vineyards both with tables ($n=34$) and without tables ($n=81$). The presence of a table appeared to have the biggest effect for blackbirds with their numbers decreasing by 82% compared to only 58% for starlings. Tables did not appear to affect the numbers of song thrushes (*Turdus philemon*) and silver eyes (*Zosterops lateralis*), but the numbers were too low for any robust analysis for the interaction between species and table.
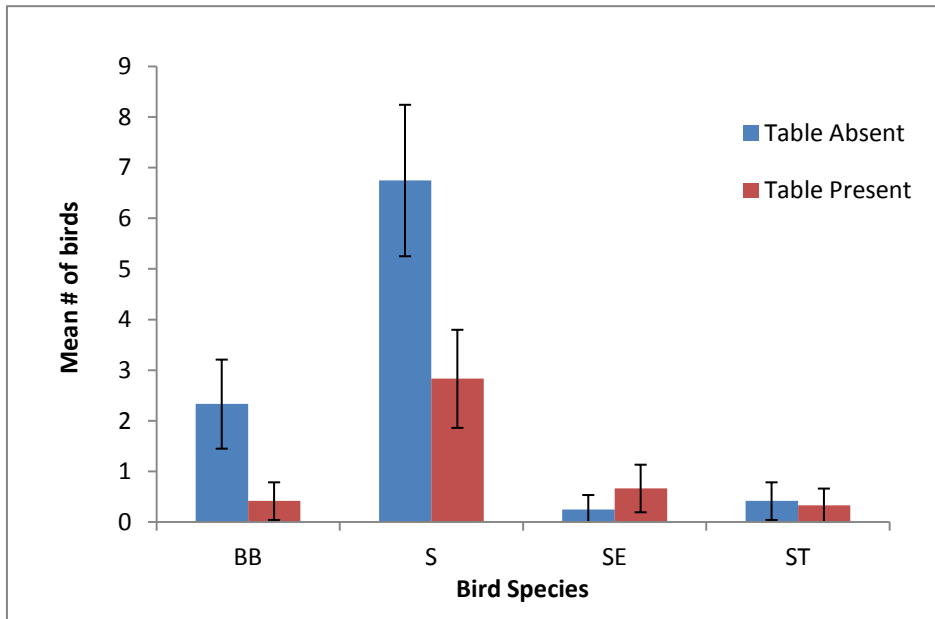
Figure 6.4: Mean number (± SEM) of pest passerine bird species (BB= blackbird, S= starling, SE= silvereye, ST= song thrush) found in vineyards with Australasian harrier feeding tables absent and present.

6.5   Discussion

6.5.1   Abundance of pest passerine birds and harrier presence

At the vineyards where the feeding tables were present, mean recorded pest passerine bird numbers were lower. The decrease could be because the incumbent bird populations were deterred from foraging in the vineyard, as there were increased harrier activity/numbers due to bait-laden tables.

The predator-prey interaction is clearly displayed in the relationship between raptors and passerine birds where the presence of a raptor will invoke shelter-seeking behaviour and abandonment of the foraging area (Daugovish *et al*., 2006). Lima & Valone (1991) found that predators were responsible for affecting communities of grassland birds, where birds would not inhabit areas where there was high predatory risk. Results are in concurrence with the findings that passerine birds that perceive an increased risk from predators may alter habitat use, including foraging behaviour, which affects the length of foraging time and volume of food taken, and subsequent flow on effects for reproductive success and future population dynamics (Howe, 1979; Dunn *et al*., 2010).

Harriers were occasionally seen flying in and around the vineyard in five of the seven vineyards during the five-minute bird count observation period. After a harrier feeding trial had been commenced (see chapter 4), of the four vineyards with tables present, bait was intermittently taken and one table, bait was consumed regularly. However, no harriers wekre observed feeding on the tables and the possible reasons for this sporadic behaviour are outlined in chapter 4.

Although harriers were not regularly feeding in three out of four vineyards, the baited tables probably attracted them to the vineyards inducing inquisitiveness to the tables, which produced a repeated and importantly lingering presence in the vineyards, enhancing the fear response behaviours of the pest birds. If, harriers were even only intermittently exploring the vineyard and the table with the bait presented on it, it was possibly enough to deter some more predator-wary birds, or perhaps other predatory species may have been accessing bait from the tables affecting overall passerine bird abundance. Other predatory species had been sighted within and around the vineyards, including magpies (*Gymnorhina tibicen*), cats (*Felis catus*), and dogs (*Canis lupus familiaris*) and the effect of these is discussed in chapter 8.

6.5.2 Distance from the feeding table and harrier presence

Although results have shown that mean and total pest bird numbers were lower, there was no significant difference based on the distance of bird activity to the tables. The passerine bird species in this study that were present did not appear to be perturbed by the table itself, as they did not avoid it. Furthermore, there were more birds observed around the table and the central location than expected, given that the area around the table (0-20 m) only occupies approximately 6 % of the total area under observation. This observation could be illustrative of how birds prefer the edges of vineyards (see Tracey & Saunders, 2003; Saxton, 2004).

Saxton (2010) found that falcons fed supplementary food off feeding trays could provide protection for some grape varieties up to 4 ha. In this study, it is likely the effect of the harriers' presence (even intermittently) in and around the vineyard, because of the provision of food on the tables, probably extended well beyond the 80 m distance, to the greater vineyard area.

6.5.3 Passerine bird behaviour and harrier presence

While it would be optimum in an economic sense for pest passerine species to be eliminated from the vineyard, a reduction in pest bird numbers brought about by increased harrier density/activity that resulted in lower levels of grape damage would be of benefit. However, lower numbers may not necessarily be the only solution; behavioural modification of the passerine bird may also bring about a decrease in grape damage. Anecdotal reports (Beard, R., viticulturalist, pers. comm., July, 2009) suggested that with harriers present in the vineyard, pest birds were continually on the move, and when they are on the move, they do not have the opportunity to forage on the grapes. Lima & Valone (1991) support this, noting when birds perceive a high predation risk they will not settle. Results showed that most of the birds in the vineyard 5minute bird counts were flying rather than settled on, or within, the vines in both the table and control sites. Flying behaviour was reasonably similar in both treatment and control sites. Accordingly, no conclusions can be made with regard to the effects on bird behaviour of the presence or absence of feeding tables.

6.5.4 Species type and harrier presence

Different bird species are reported to perceive risk differently, which results in differing behavioural responses, including feeding and anti-predator escape behaviour (Valone & Lima, 1987; Lima & Valone, 1991; Tracey *et al.*, 2007). Tracey *et al.* (2007) noted that there are different ecological behaviours between species and the severity of damage they cause to grapes in vineyards differs (see chapter 2). In this study, starlings represented the greatest abundance in both treatment vineyards and controls. The presence of a table appeared to have the largest effect on blackbirds with their numbers decreasing by 82% in vineyards where harriers were taking bait from feeding tables, compared to only 58% for starlings. There is an important biological difference between the two species. Starlings forage in flocks, presumed an anti-predator behaviour (Tracey & Saunders, 2003; Carere, 2009), while blackbirds (who were overall less abundant at all sites) are a solitary species, foraging on the ground and are more likely to stay in one area as they are territorial (Heather & Robertson, 1996; Watkins, 1999). Interestingly, blackbirds in this study were not observed foraging on the ground, however this could have been related to poor visibility due to vineyard foliage.

An assumption could be made that blackbirds may perceive the risk of predation as greater, due to harrier presence, and will abandon a profitable foraging site more readily than the starling. Alternatively, blackbirds may be able to find alternative food sources that meet their

nutritional requirements, so the trade off for safety over food is greater. The blackbirds' predominant food choice is earthworms (Oligochaeta), followed by other invertebrates, and supplemented by fruit in autumn (Heather & Robertson, 1996; Hampe, 2001; Chamberlain *et al.*, 2007; Tracey *et al*., 2007). Starlings are voracious feeders and once they have established a feeding area are difficult to relocate (Flaherty, 1992; Tracey & Saunders, 2003). They are found in large numbers and the nutritional need induced by intraspecific competition may outweigh perceived predation risk. As count numbers were low, particularly song thrush and silvereye numbers, it is difficult to generalise with regard to the wider population of these species, however it represents value as a preliminary analysis.

6.6   Conclusion

While mean pest passerine bird densities were lower where bait-laden tables were present, it is difficult to come to any definite conclusions as to why this may be. As harriers, apart from one site out of four, were only taking bait intermittently, it may be also difficult to assume that harriers are the sole reason for this (see chapter 8). While abundance of passerine birds was less in vineyards with feeding tables, than those without, the tables themselves (in four vineyards) did not appear to deter bird presence as there was no significant effects on bird presence and distance from the table. This finding may simply suggest that increased harrier presence (perhaps combined with other predatory species) in the treatment vineyards and the surrounding landscape, albeit intermittently, may have been the reason. Further bird counts and closer surveillance of all consumers accessing the feeding tables before and during subsequent grape ripening seasons would be worthwhile.

Chapter 7

Supplementary feeding of the Australasian harrier and the impact on grape damage in vineyards

7.1   Abstract

Vineyards around the world sustain significant economic losses due to grape loss and damage caused by frugivorous passerine birds. Attracting birds of prey into vineyards is a possible tool in integrated pest management of pest bird species. In 2010, a preliminary grape damage assessment was completed in Martinborough vineyards to ascertain levels of bird-induced grape damage sustained in the area. Grape damage sustained in all vineyards surveyed, ranged between 20 and 30 %. In 2011, a further grape damage assessment was completed after baited feeding tables had been erected five months prior in vineyards, to attract the Australasian harrier to help mitigate grape damage caused by passerine birds. While harriers were visiting some tables intermittently and one regularly, grape damage was lower in the vineyards with feeding tables present compared to those without. Overall mean damage for sites with tables was 10.3% compared with 25.3% for sites without feeding tables. Camera data showed harriers were not the only predator accessing bait from the feeding tables and it is likely that the suite of predators was responsible for decreased passerine bird abundance and subsequent lowered levels of grape damage.

7.2   Introduction

With the intensification of cropping practice in New Zealand, many crop pest bird populations have increased (Saxton, 2004) and the threat to the horticultural industry, including the viticulture industry, has also increased. Vineyards around the world sustain significant economic losses due to grape loss and damage caused by frugivorous passerine birds (Plesser *et al.*, 1983; Somers & Morris, 2002; Berge *et al.*, 2007a; Tracey *et al.*, 2007). Tracey & Saunders (2003) argued that cost analyses indicated that if bird damage is greater than 40%, vineyards are not economically viable.

It has been suggested that attracting birds of prey to horticultural settings may provide economic benefits, including to the wine industry (Tracey & Saunders, 2003; Tracey *et al.*,

2007). Consequently, employing the Australasian harrier (*Circus approximans*), whose presence may reduce local passerine bird numbers, as a biological control agent in New Zealand vineyards may be a cost-effective solution to grape damage.

Hawk kites and raptor models have been employed for many years as an attempt to reduce pest populations in horticultural land (Yim & Kang, 1982; Jarvis, 1985; Dzhabbarov, 1988; Fleming, 1990; Sinclair, 2002; Taber, 2002; Bomford & Sinclair 2002; Komeda *et al.*, 2005; Spurr & Coleman, 2005; Berge *et al.*, 2007a; Berge *et al.*, 2007b; Fukuda *et al.*, 2008). These measures have worked on the assumption that passerine birds have an innate fear of predatory birds, such as raptors (Göth, 2001; Patzwahl, 2002; Kaplan, 2004). However, devices such as hawk-kites and raptor models rapidly lose effectiveness as pest birds become accustomed to them (Conover, 1979; Daugovish *et al.*, 2006; Tracey *et al.*, 2007)**.** Other bird scaring methods, such as eye-spot balloons, while demonstrating a measure of success initially, are often short-lived as the pest birds begin to habituate to the balloons after one to two weeks (Hickling, 1995).

Conover (1979) noted that mobile hawk kites rather than stationary ones, which birds habituated to very quickly, have provided a measure of crop protection. He suggested that birds might be more afraid of mobile hawk models as they depict a more natural representation of the predatory behaviour of raptors in the wild, rather than models that were in a stationary position. Nevertheless, none of these solutions has produced the desired long-term effect to reduce passerine bird populations and the damage they incur in various horticultural settings.

Raptors are a possible solution to the important problem of grape-nmjforaging birds in vineyards. Several studies have highlighted the biological control role of raptors in both agricultural and non-agricultural settings (Erickson *et al.*, 1990; Redpath *et al.*, 2001; Daugovish *et al.*, 2006; Baines *et al.*, 2008; Saxton, 2010; Kross *et al.*, 2011). Mitigation of grape damage using the endemic, and in gradual decline (Holland & McCutcheon, 2007), New Zealand falcon (*Falco novaeseelandiae*) has shown positive results. The introduction of the falcon to Marlborough, New Zealand, vineyards has resulted in a decreased abundance of pest passerine bird species and an overall reduction in grape damage (Saxton, 2010; Kross *et al.*, 2011). However, only small numbers of falcons are available for translocation into the vineyard, and translocation is a complex process.

The Australasian harrier is an abundant self-introduced diurnal raptor that has benefited from the European clearing of native forest for pastureland (Heather & Robertson, 1996). Today, they frequent pastureland, wetlands and tussock-land where small prey, such as rats, mice, lizards, invertebrates and nestlings are located. They forage around New Zealand roadways where animal carcasses from road-kill are readily available (Marchant & Higgins, 1993; Heather & Robertson, 1996) and considerable numbers of harriers are regularly seen around New Zealand agricultural land (pers.obs.).

In New Zealand vineyards, the major contributors to grape damage are the introduced European starling (*Sturnus vulgaris*), European blackbird (*Turdus merula*) song thrush (*Turdus philomelos*) and the self-introduced silvereye (*Zosterops lateralis*) (Watkins, 1999; Saxton, 2004). The blackbird, starling, and song thrush take the whole grape while the silvereye due to its smaller size, pecks the grape. Peck damage is much more widespread and insidious and can result in quality downgrade of the fruit (Tracey & Saunders, 2003; Tracey *et al.*, 2007). Peck damage can entice the entrance of Hymenopteran insects such as wasps, honeybees (Fig.7.1) and ants, helping to provide the establishment of bacteria and various fungi including botrytis (*Botrytis cinerea*) (Boyce *et al.*, 1999; Tracey & Saunders, 2003; Saxton, 2004).

Passerine bird attack on grapes in New Zealand vineyards occurs from the véraison (colour-change) to harvest period, a period of 8-10 weeks (Saxton, 2004). During the véraison to harvest period, it is assumed the frequency of harriers in the vineyard will be increased due to an established supplementary feeding programme (see chapter 4). Assessment of pest bird deterrence from the vineyard is fundamental to this project (see chapter 6). Regardless of the affect on bird densities, where harriers are supplemented on feeding tables in the vineyard, identification of decreased levels of grape damage will be the economic measure of its success. With the increased activity and abundance of harriers in the vineyard study areas with tables, and the expected decrease in pest passerine bird abundance, it is predicted that there will be decreased grape damage in vineyards with feeding tables present.

Figure 7.1: Peck damaged grape bunch with a honeybee (*Apis* sp.) feeding on juice.

7.3 Methods

Five vineyard sites in Martinborough, Wairarapa, were selected to a complete a preliminary assessment of grape damage in 2010, and to confirm that each vineyard had similar levels of damage warranting the use of these vineyards for future study sites. Vineyards were located in both peri-urban and rural areas with each vineyard surrounded by a variety of exotic and native vegetation that act as shelterbelts for the vineyards, but also provide perching and nesting habitat for pest passerine bird species. All sites grew Pinot Noir grape cultivars, which suffer moderate-high levels of damage during the grape-ripening to harvest period, even with netting in place.

Damage assessment was completed immediately before harvest when grapes were at their ripest and bird pressure is at its greatest. Close liaison with vineyard management regarding when the grapes were to be harvested was maintained. Grapes were sampled in the week of the 15th of March, 2010. All vines had been netted using single or multi-row netting (Fig. 7. 2).

Figure 7.2: Grape damage caused by pest passerine birds despite netting. Missing grapes from the bunch can be seen with exposed pedicels, close to the edge of the netting.

For the 2010 grape damage assessment, sampling sites were selected in consultation with vineyard management; sites with the Pinot Noir grape variety that were subject to considerable bird pressure in the pre-harvest period. These sites were also selected as sites where harrier feeding tables could be erected after the 2010 harvest. Vine sampling was commenced either side of a notional (where tables would be erected later) table site. Because of the variable size and layout of the vineyards and access to the vines due to various netting methods, e.g. multi-row or single row, distance of row selection either side of the notional table site was not always uniform and was independent from other vineyard site measurements. In an attempt to standardize rows, they were sampled at either side of the notional feeding table site in equal increments of distance, i.e. 10 m either side of the notional feeding table site.

Sampling of vines commenced at the edge of each row, moving toward the interior of the vineyard. Grape damage is not consistent in vineyards, decreasing towards the interior of the vineyard (Saxton, 2006), whereas vines at the edge of the vineyard are more vulnerable to

bird attack and sustain more damage due to ease of access and a quick escape route to the vegetation surrounding the vineyard (Somers & Morris, 2002; Saxton, 2006).

Ten vines were assessed for grape damage from each selected row; 20 rows from each vineyard resulting in 200 grape bunches and an estimated average of 1000 grapes sampled for each vineyard, with 1000 bunches sampled in total for all the vineyards. Sampling method followed the Saxton (2006) methodology. Vineyard, row number and estimated percent damage were recorded onto a data sheet. Because damage assessment is visual, one bunch from each of the ten vines that had sustained at least 30-70 % damage was selected for calibration (Saxton, 2006). This involved bagging each bunch for calibration, labelling with the corresponding data from the data sheet, and visually estimating damage sustained, which was then compared with the actual damage when grapes were counted later. At calibration two types of damage were recorded, missing grapes and pecked grapes, which gave an overall indication of the avian species that had caused the grape damage.

Grape damage assessment was then repeated in the week of the 28th of March 2011, using the same methodology as above. Seven vineyards were surveyed, four with harrier feeding tables present, where intermittent or regular feeding from the table was occurring (see chapter 4), and three control sites, without feeding tables. Bushnell Trophy Cam™ motion-sensor cameras (model 119456) were positioned approximately three metres from the feeding tables which gave an indication of harrier activity. For the control sites, vines were sampled from a notional table site, i.e. a site that had similar relief to the treatment sites and an area that also sustained predation pressure as identified by vineyard staff.

Grape damage data was analysed for both seasons using ANOVA (as the data was normally distributed and had constant variance), calculating SEM for each mean. Where the ANOVA indicated significant differences, post-hoc pairwise comparisons were undertaken using Fishers Protected LSD test ($\alpha=0.05$). All statistical analysis was undertaken using the GenStat statistical package (Version 13).

7.4   Results

In the 2010 preliminary survey, grape damage to edge vines ranged from 20-30 % (Fig 7.3). There were significant differences ($F_{4,95}=3.97$; $p < 0.005$) in grape damage occurrence between some vineyards. Te Rehua (30.15 ± 1.9 %), sustained the most damage and was

significantly higher than the other four vineyards surveyed. Craggy Range followed (25.5 ± 2.2 %), differing significantly to the three lower vineyards. Burnt Spur (20.39 ± 1.99 %), Waiora (20.87 ± 2.66 %) and Vynfields (21.17 ± 1.49 %) all had similar levels of damage and were not significantly different to each other (Fig.7. 3).
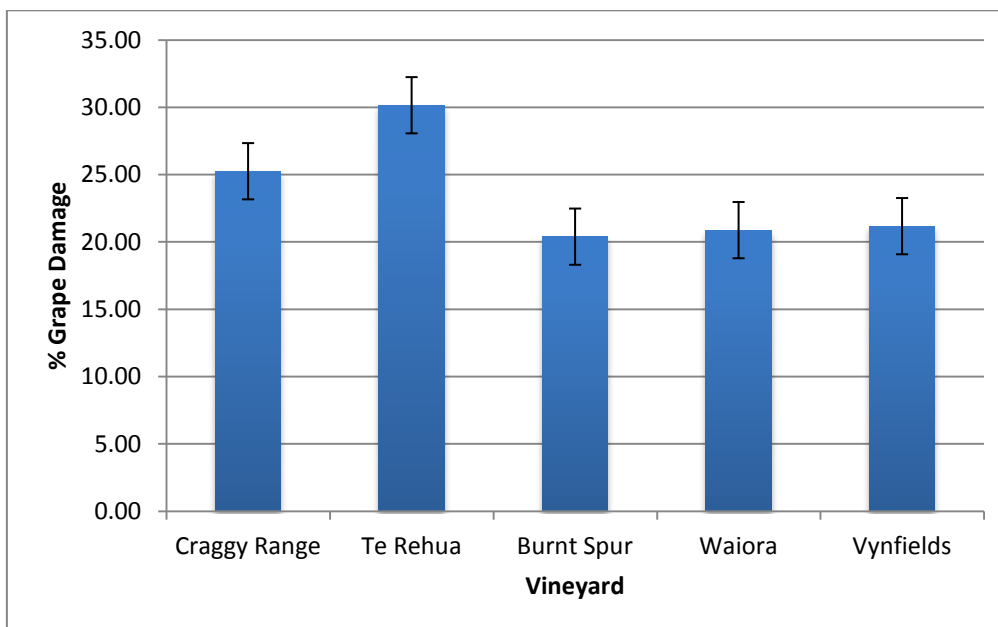
Figure 7.3: Mean (+SEM) percentage grape damage in Martinborough vineyards 2010 (without Australasian harrier feeding table present).

Results for the 2011 grape damage survey where feeding tables were present showed significantly less grape damage in sites that had harrier feeding tables ($F_{1,132}$=106.45; p<0.001; Fig 7.4) with an overall mean for sites with tables of 10.33% (±1.1) vs. 25.30% (± 0.95 %) for sites without feeding tables. Pond Paddock sustained the least percent of damage (3.6 ± 0.60%) compared with Cirrus Estate (23.5 ± 1.72 %) that received the most in the treatment sites. The other two treatment sites were not significantly different to one another. One of the control sites, Martins Road (17.2 ± 1.43 %) had significantly less damage than a site with a table, Cirrus Estate.
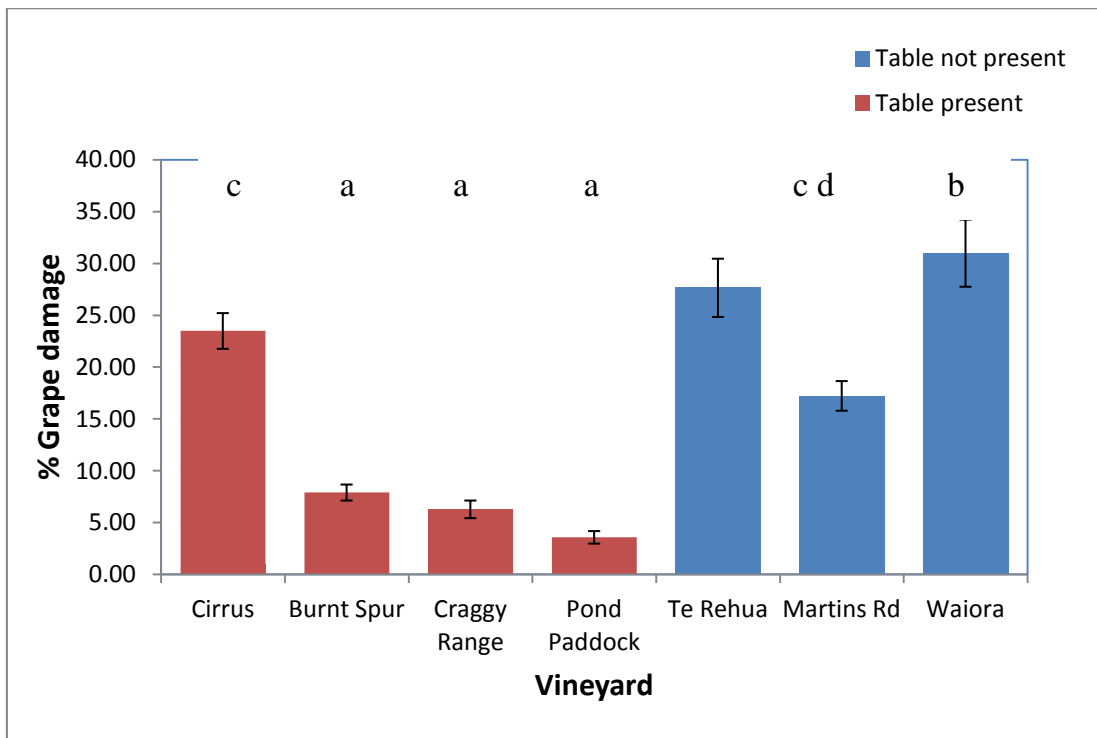
Figure 7.4: Mean (+SEM) percentage grape damage with and without Australasian harrier feeding tables present. Letters above the means indicate significant site differences using Fishers LSD test (α=0.05).

Camera data showed harrier visits to Pond Paddock vineyard were daily while the other vineyards recorded either no bait uptake, harriers on the table, or other predators/competitors, such as magpies (*Gymnorhina tibicen*) and cats (*Felis catus*), accessing the bait on the table (Table 7.1). Further discussion on this is in chapter 8.

Table 7.1: Harrier, cat and magpie visits to baited harrier feeding tables in Martinborough vineyards immediately prior to harvest 2011.

	Burnt Spur			Craggy Range			Cirrus Estate			Pond Paddock		
Date	Cat	Magpie	Harrier	Cat	Magpie	Harrier	Cat	Magpie	Harrier	Cat	Magpie	Harrier
Feb-17	1	0	0	0	0	1	0	0	1	0	0	0
Feb-19	0	0	0	0	0	0	0	0	0	0	0	0
Feb-21	0	0	0	0	0	0	0	0	0	0	0	0
Feb-23	0	0	1	1	0	0	0	1	0	0	0	0
Feb-25	1	0	0	1	0	0	0	0	0	0	0	2
Feb-27	0	0	0	1	0	0	0	1	0	1	0	2
Mar-01	0	0	0	1	0	1	0	0	0	0	0	2
Mar-03	0	0	0	1	0	0	0	1	0	0	0	2
Mar-05	0	0	0	1	0	1	0	0	0	0	0	2
Mar-07	0	0	0	1	1	1	0	0	0	0	0	2
Mar-09	0	0	2	0	1	0	0	1	1	0	0	2
Mar-11	0	0	2	1	0	0	0	0	0	0	0	2
Mar-13	0	0	0	1	0	0	0	0	0	0	0	2
Mar-15	0	0	0	1	1	0	0	0	0	0	0	2
Mar-17	1	0	0	1	0	0	0	0	0	0	0	2
Mar-19	0	0	0	1	0	0	0	0	0	0	0	2
Mar-21	0	0	0	1	0	0	0	0	0	0	0	2
Totals	**3**	**0**	**5**	**13**	**3**	**4**	**0**	**4**	**2**	**1**	**0**	**26**

7.5   Discussion

Grape damage caused by pest passerine birds to Pinot Noir grapes in Martinborough was identified by the preliminary study, and it indicated small but significant differences in damage amongst different vineyards. This damage highlights the need for a greater level of protection than just netting and gas guns that is currently used in these vineyards.

The vineyard location that sustained the most damage was small (1.1 ha), situated in a semi-urban area, surrounded by adjacent vineyards and separated by stands of shelterbelt trees. Grape damage sustained by birds, is not consistent throughout vineyards (Somers & Morris, 2002; Tracey & Saunders, 2003), varying spatially and temporally within and between vineyards (Somers & Morris, 2002). This is supported by Saxton (2004) who observed the interior vines in a vineyard do not generally sustain much damage from bird pressure, but vines that are at the edge of the vineyard are more vulnerable to bird attack and generally sustain the most damage. In this case, smaller vineyards, with higher edge to interior area ratios will suffer greater economic losses than larger ones (Tracey & Saunders, 2003; Saxton, 2004) and what has been observed in the Martinborough vineyards may not be representative of other vineyards.

Additionally this vineyard area, along with vines, supported several introduced fruiting trees, peach (*Prunus persica*), apple (*Malus* sp.), and plum (*Prunus prunus*). The presence of these food resources may have increased the attraction value of the vineyard to pest passerine birds, and may have encouraged nesting within the vineyard amongst some individuals and consequently increased populations.

Some bird species, such as the European blackbird, which is found in vineyards throughout the year, is a serious pest (Heather & Robertson, 1996; Saxton *et al*., 2004; Tracey *et al*., 2007). Blackbirds live within a small territory and an ample and longer period of food supply provided by the fruiting trees, than grapes alone, may have sustained larger numbers of blackbirds within the vineyard. Blackbirds were seen in greater numbers in this vineyard compared to the other four vineyards. The second most significantly damaged vineyard was large (approx. 40 ha.), rurally-located and the most remote from urban areas out of all surveyed. It is unclear why different vineyards in this area sustained different levels of damage; further enquiry may shed some light on this.

Daugovish *et al.* (2006) noted that the presence of falcons (*Falco* spp.) was a useful integrated pest management tool related to the protection of strawberries in California, U.S.A. where they reported significant reduction in fruit damage. A grape damage survey in Marlborough vineyards in 2009 (Saxton, 2010), and further work by Kross *et al.* (2011) showed a significant reduction in grape damage in association with the introduction of the New Zealand falcon into the vineyards there.

Where Australasian harrier supplementary feeding tables were present in Martinborough vineyards, the grape damage survey also showed a significant decrease in damage compared to control vineyard sites without tables. Numbers of passerine birds were reduced when harrier-feeding tables were present (see chapter 6) which is probably related to the decreased levels of grape damage found in this study. Kross *et al.* (2011) also found that with falcon presence, lower levels of pest passerine bird numbers and decreased grape damage were correlated.

Harriers were feeding only intermittently from most of the tables in this study. Increased presence although intermittent, may have been enough to contribute to the decreased grape damage indicated in the 2011 grape damage survey. Grape-predation reduction is estimated by at least half when tables were present. Although bait was taken only sporadically, in three out of the four treatment sites, this does not negate the possible effect of the harrier and its attraction to the vineyard because of the bait supplied. Interestingly, the vineyard where the harrier was regularly feeding, indicated by removal of bait, daily observation of harriers on the table (Barnett, C., winegrower pers. comm., March, 2011), and cameras, showed the least damage.

The Australasian harrier does not generally take passerine birds on the wing (Baker-Gabb, 1978; Robertson, 1980; Marchant & Higgins 1993). However, its non-lethal predatory presence may still instil fear in passerine bird species (Conover, 1979; Hothem & De Haven, 1982; Göth, 2001; Patzwahl, 2002; Kaplan, 2004; Daugovish *et al.*, 2006) and cause behavioural adaptations used to avoid predators, for example alteration of habitat use and foraging activities (Lima & Valone, 1991; Lima, 1998; Cresswell, 2008; Dunn *et al.*, 2010). Birds will forage near vegetative cover to avoid predation (Lima, 1990) and desertion of a nutritionally beneficial habitat is often a consequence of fear of predation (Lima & Valone,

1991; Daugovish *et al.*, 2006), while foraging longevity and food volume taken, are affected by predatory risk perception (Howe, 1979; Dunn *et al*., 2010).

Camera data showed that not only the Australasian harrier was taking bait from the feeding tables. It provided visual verification of cats and magpies also feeding intermittently from the tables. Grape damage may be reduced because of the additional presence of these predator species. However, these non-target feeders were not the focus of this study and although they may well have been instrumental in the significant grape damage decrease where the feeding tables were present, they may have also confounded the attempts to establish a regular feeding regime for harriers in vineyards. It is difficult to assume that harriers are bothered by cats due to a lack of empirical data; however magpies, often in pairs, were seen regularly attacking harriers (pers. obs.). Kaplan (2004) noted magpies harassing raptors and expelling them from their territory and they are also reported to attack passerine birds (see chapter 8). Magpies are seen abundantly in the Martinborough area.

7.6   Conclusion

While there were conflicting anecdotal reports from winegrowers in 2011 with regard to levels of grape damage sustained that season, results here have shown that the grape damage was present in both treatment and control sites. Where feeding tables were present, grape damage was significantly lower, demonstrating a possible correlation between feeding tables and lowered levels of grape damage. Although this survey had intended to enquire about the correlation between Australasian harrier presence and grape damage caused by passerine birds, its initial focus on the harrier has shifted to the feeding table itself. Other predators also exploited the bait on the table and thus the correlation between decreased grape damage and harrier presence appears also to be linked to other predators as well as the harrier. Further inquiry into the presence of all predators found in vineyards and the relationship to lower levels of passerine birds (see chapter 8) and consequent grape damage may expand on this.

Chapter 8

Supplementary feeding and its effects on predator numbers and pest passerine bird abundance in vineyards

8.1 Abstract

Supplementary feeding has an effect on community dynamics amongst predator and prey species and can cause predatory species to migrate to areas where there are plentiful food resources. With an increased abundance of predators, fear of predation can cause prey species to abandon areas of abundant food resource, altering their affects (e.g. foraging) on the surrounding landscape. Passerine birds that forage on ripening grapes prior to the harvest season may cause serious economic loss to winegrowers. The Australasian harrier had been fed with supplementary food on feeding tables in vineyards in an attempt to provide protection for grapes from passerine birds. Where feeding tables were present passerine bird numbers and grape damage decreased, but it was discovered that not only harriers visited the tables but also, magpies and cats.

This study examined whether placing bait in the vineyards attracted additional predators. Bait was placed in vineyards in attempt to attract all predators into the vineyards. Monitoring of all vineyard sites for predators was completed with and without bait present. Passerine bird counts were also completed where bait was present and absent. When bait was present, predator numbers were significantly higher, than when bait was absent and equally, passerine bird numbers were significantly higher when bait was absent compared to bait present. Harriers and cats were the most frequently observed predators.

8.2 Introduction

Supplementary feeding can be responsible for the immigration of species into an area, including patch occupation, resulting in an increase in local abundance (Law, 1995; Verbeylen *et al.*, 2003). In addition, supplementary feeding of animal carcasses can have an effect on population dynamics and community structure, however, attracting predators to habitats in this way often results in predation on other living members of ecosystems

(DeVault *et al*., 2003**;** Cortés-Avizanda *et al*., 2009a; Cortés-Avizanda *et al*., 2009b**).** Indirect effects on these species, due to fear of predation, may be reflected in their movements and spatial responses, including distribution **(**Cortés-Avizanda *et al*., 2009b).

The fear of predation was responsible for alterations in communities of Arizonan (U.S.A.) grassland bird species as reported by Lima & Valone (1991), where birds would not remain in areas of increased threat of predation. If birds do not perceive a high predation risk they will remain in an area and consume what is available, however, predation risk may still influence foraging decisions, e.g., how and what to feed on (Lima, 1985) and where they choose to eat, sleep and breed (Whittingham & Evans, 2004). Whittingham and Evans (2004) suggested an increase in actual predation as well as perceived predation risk to birds in agricultural landscapes was linked to extensive and critical declines in farmland bird communities in Europe.

Significant economic losses to vineyards are sustained due to loss and damage of grapes caused by frugivorous passerine birds (Somers & Morris, 2002; Berge *et al.*, 2007; Tracey *et al.*, 2007). An attempt to mitigate such losses using a proposed biological control agent the Australasian harrier (*Circus approximans*), a native, diurnal New Zealand raptor has been trialed (see chapters 4-7). Found in considerable numbers, the harrier frequents New Zealand pastoral lands (including vineyards) and roadways, on the lookout for road-kill. Several of these harriers were attracted into vineyards by providing them with an important food source – animal carcasses (Baker-Gabb, 1981; Marchant & Higgins, 1993). It was hoped that the presence of these harriers would exploit the fear of pest passerine birds towards raptors (Conover, 1979; Göth, 2001; Patzwahl, 2002; Kaplan, 2004; Daugovish *et al*., 2006), and provide an effective biological control aid by reducing grape damage within the vineyard.

Animal carcasses were supplied in the form of favoured foods (Fennell, 1980; Wong, 2002); hare (*Lepus europeus*), rabbit (*Oryctolagus cuniculus*), chicks (*Gallus domesticus*), and brushtail possum (*Trichosurus vulpecula*), on elevated feeding tables in vineyards in Canterbury and Martinborough, producing mixed results (see chapter 4). Some harriers fed off the tables intermittently while others used these food resources as a daily feeding routine. With the addition of motion-sensored camera traps at a later stage in this work it became evident that bait was not solely being exploited by the target species, the harrier. Other predators/competitors, such as cats (*Felis catus*) and magpies (*Gymnorhina tibicen*), were

using this resource. Newey *et al*. (2009) and Newey *et al*. (2010) found that many supplementary feeding studies have made assumptions, which are often untested, that supplementary feeding is accessed by the target population, which is not always the case, and this study provides a clear example of this.

Previous studies showed that where harrier-feeding tables were present passerine bird numbers decreased (see chapter 6), and grape damage was less (see chapter 7). With camera data confirming that predators other than harriers were accessing the bait from the raised feeding tables, it was thought useful to examine their contribution to decreased passerine bird numbers and consequently lowered levels of grape damage. Providing supplementary food so that all potential predators of passerine birds located near vineyards could easily access the bait (i.e. carcasses placed on the ground), may attract increased predator numbers into the vineyards. With increased predatory presence, it is suggested that the combination of these species would contribute to decreased passerine bird numbers.

8.3   Methods

The experiment was conducted at seven Martinborough, Wairarapa, vineyard sites where grape damage is sustained at varying levels. Vineyards were located in both peri-urban and rural areas with each vineyard surrounded by a variety of exotic and native vegetation that acted as shelterbelts for the vineyards, but also provide perching and nesting habitat for pest passerine bird species. Four of these sites were locations where supplementary feeding tables had been sited and where harriers, cats, and magpies were either intermittently feeding, or regularly feeding. The experiment was undertaken over three months in the winter season when grapevines are in dormancy and pest passerine birds are not attracted to ripened grapes.

Each site had a period of at least 60 days of no supplementary feeding before the trial began. Bushnell Trophy Cam^{TM} motion-sensored cameras (model 119456) were set up to observe what was approaching the bait at the study sites. Three vineyards at a time were surveyed due to numbers of cameras available. For seven days, the sites situated in the headland of the vineyard close to the edge of the vines, were monitored with no bait provided; camera data were downloaded every two days and predator visits were recorded. Five-minute bird counts (see chapter 6 for methods) were also completed after camera data were downloaded every two days .The following seven days included addition of bait. Every two days six deceased

day-old cock chicks were placed on the ground (no feeding tables were used in this study) so that all would-be predators would have an opportunity to access the food with ease i.e., harrier, magpie, and cat. Numbers of chicks taken was recorded; camera data downloaded every two days, predator visits recorded and five-minute bird counts were completed.

Chicks were replaced as numbers taken dictated. This process was repeated again in the seven vineyards in a sequential order resulting in each vineyard being surveyed twice with and without supplementary food (bait). Total numbers of counts in all vineyards surveyed, included 56 five-minute bird counts and 56 camera data collection recordings of predators present in the no bait experiment and 56 five-minute bird counts and 56 camera data collection recordings of predators present in the bait experiment.

To analyse the data all the predator and bird counts were summed over all visits for each vineyard and inspected for normality. Given the small sample ($n = 7$) and the skewed nature of count data, a comparison between fed and unfed median values was made using Wilcoxon Matched-Pairs tests (The predator data was then categorised into four different species: harrier, magpie, cat, and dog (*Canis lupus familiaris*). Comparisons between the median numbers of these species observed for each vineyard were conducted using a non-parametric Kruskal Wallis ANOVA. All data analysis was conducted using GenStat statistical package (Version 13).

8.4   Results

Predators observed included cats, dogs, magpies, and Australasian harriers. Predators in the control sites (total count=13) where no bait was provided were significantly less than those found in treatment sites (total count=376; Wilcoxon Matched-Pairs test; p=0.016). All bait (day-old cock chicks) was taken within a forty-eight hour period and camera data provided verification of what predators were present in the vineyards. Median pest passerine bird densities in the control sites (total count=324) were also significantly higher than the treatment sites (total count=155; Wilcoxon Matched-Pairs test; p=0.016) (Fig. 8.1). Where predator numbers increased, pest passerine bird abundance decreased (Fig. 8.2).
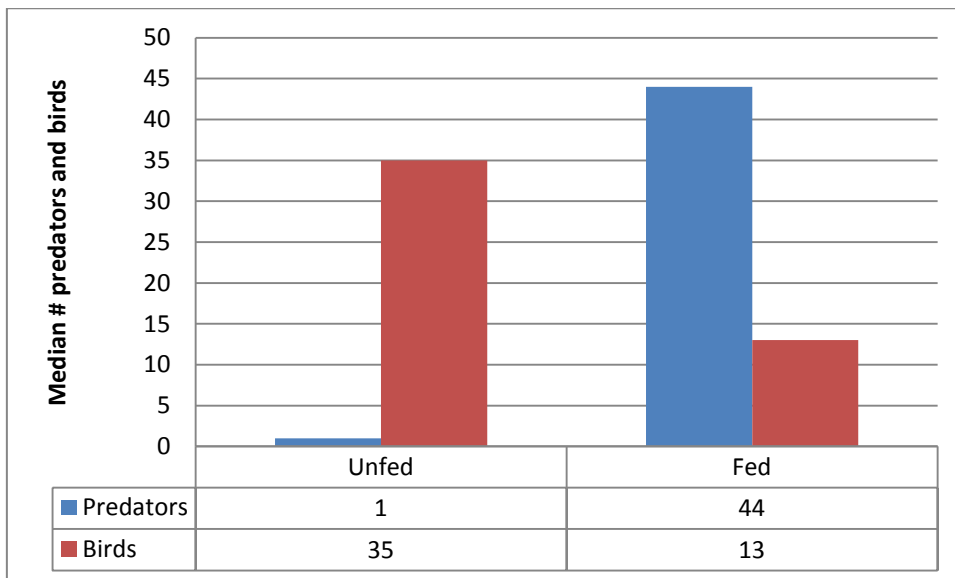
Figure 8.1: Median number of predators and passerine bird abundance in Martinborough vineyards with and without supplementary food.

	Unfed	Fed
■ Predators	1	44
■ Birds	35	13

R² = 0.3242
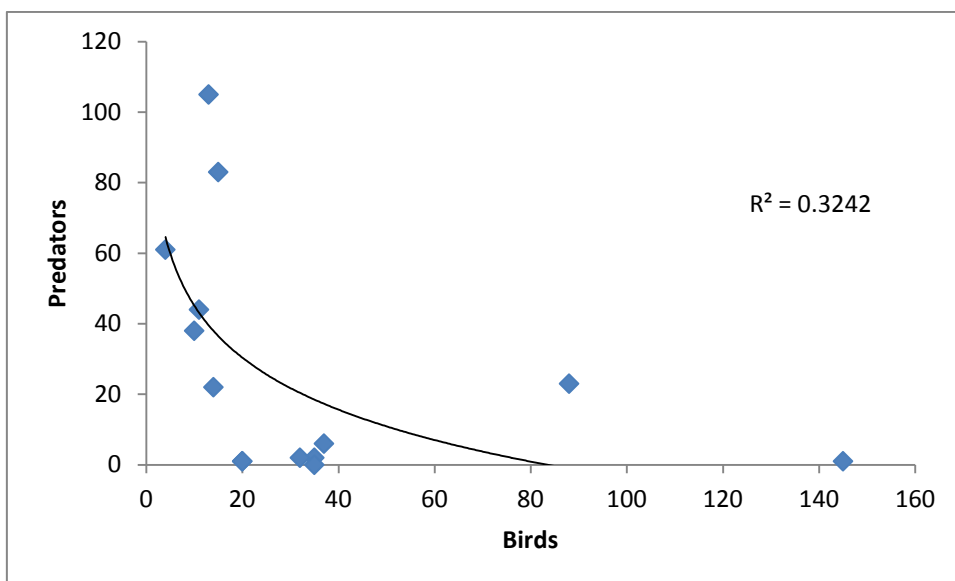
Figure 8.2: Relationship between total predator abundance and total pest passerine bird abundance showing an exponential regression trend line.

Harrier visits to feeding sites (total count = 260) were the most common, followed by magpies (68), cats (46) and one dog. The comparisons of the median count for each predator species at the seven vineyards showed significant differences between species with harriers and cats most frequently observed (Fig. 8.3) (Kruskal Wallis H=11.28; DF=3; p=0.007).
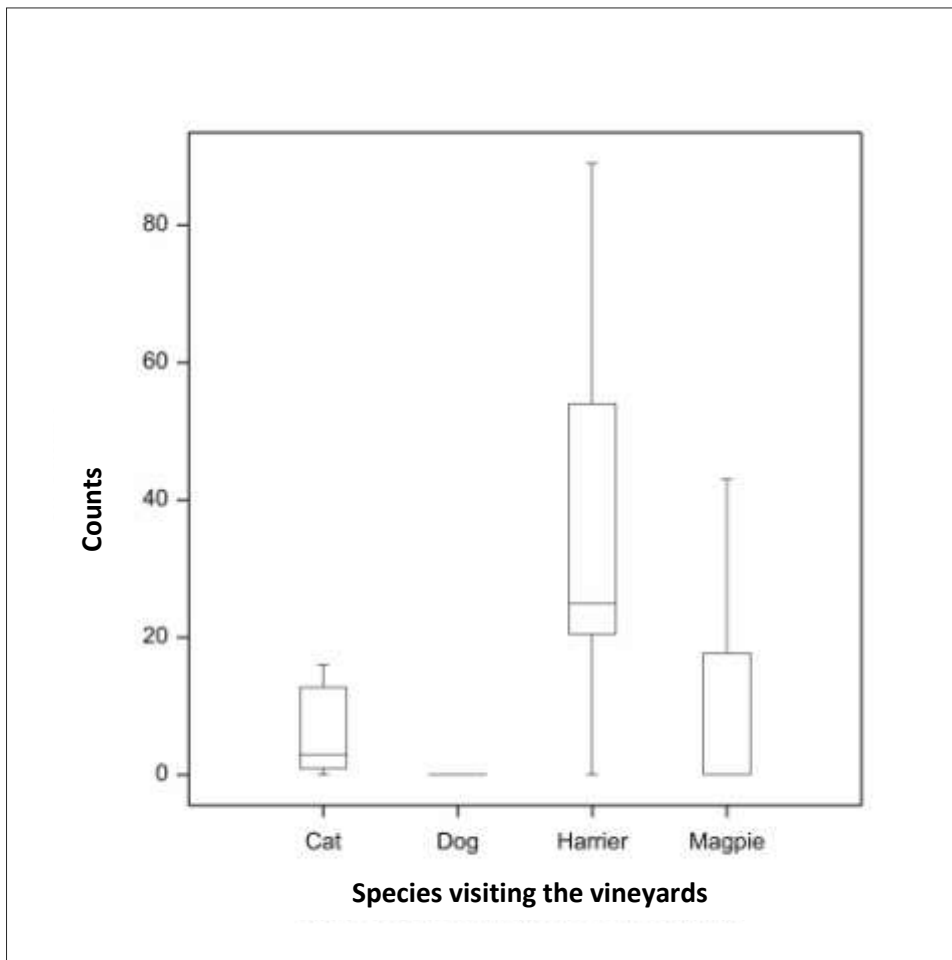
Figure 8.3 Median numbers of different predatory species visiting Martinborough vineyards.

8.5 Discussion

Predators of pest passerine bird species increased significantly in vineyards where supplementary food was supplied. Harriers dominated consumption in this study and other studies have shown that supplementary feeding is linked to increased harrier population densities (Houston, 1996; Amar & Redpath, 2002; González *et al.*, 2006; Robb *et al.*, 2008). Robb *et al.* (2008) suggested that supplementary feeding could be responsible for grand-scale changes in general bird population dynamics, including migratory behaviour and it may influence an individual's range. An earlier study by Houston (1996) reported that feeding stations not only provided supplementary food, but could also become a reliable resource in times of low food resources, and were fundamentally important in maintaining birds in the area of the station.

Supplementary foods increase the density of populations (Boutin, 1990; Knight & Anderson, 1990; Houston, 1996), and habitat occupation is increased by supplementary feeding (Law,

1995; Verbeylen, *et al.*, 2003; Cortés-Avizanda *et al.*, 2009b). Several studies have noted that where there is provision of supplementary food such as animal carcasses, the presence of carnivorous predators increases significantly, particularly during times of prey shortage (DeVault *et al.*, 2003; Wilmers *et al.*, 2003; Cortés-Avizanda *et al.*, 2009b). López-Bao *et al.* (2008) found that when supplementary food was provided at feeding stations, individuals tended to aggregate there.

Australasian harriers were attracted into the vineyards when the chicks were provided as bait (Fig. 8.3), but so were cats (Fig. 8.4), magpies (Fig. 8.5), and one domestic dog. Generalist avian and terrestrial predators, such as harriers, cats, and magpies, which exploited the bait in this study, may not be reliant on the provision of bait for survival means, however providing a small amount of bait, e.g. six chicks every 48 hours, may have provided adequate attraction to the site to maintain numbers of predators and even attract new ones into the vineyard. Their increased presence induced by the supplementary food may have deterred pest birds from entering or inhabiting the study sites.

Figure 8.4: Australasian harrier accessing bait (day- old cock chick) offered on the ground in a Martinborough vineyard.

Figure 8.5: Cat accessing bait in a Martinborough vineyard

Saxton (2004) reported that predators, such as humans, cats and dogs, have a role in biological control of pest species whenever they supplied a constant pressure on the target species. Both feral and domesticated cats were observed in rural and peri-urban areas. Cats are strictly a carnivorous predatory species and will exploit any opportunity to obtain easy access prey species (pers. obs.). Forty six cat visits were observed, they were either walking near the bait or eating it in the study sites where bait was present, compared to only three visits observed, in sites with no bait. It could be assumed that their presence correlated with a decrease in pest passerine bird abundance in the sites with bait provided.

The Australian magpie, as other species of magpies (*Pica pica*), will predate on nesting birds, eggs and sometimes nestlings (Moller, 1998; Kaplan, 2004; Morgan *et al*., 2006; Dunn *et al*., 2010). Diet mainly consists of invertebrates, seeds and at times carrion and vertebrates (Heather & Robertson, 1996). Magpies will attack other birds, but it is unclear whether this is for reasons of direct predation, competition for resources, or a territorial defence response related to the fear of predation on their own nestlings (Morgan *et al*., 2006). Kaplan (2004) argued that there were few reports in Australia of magpies attacking and killing other birds, while in New Zealand McCaskill (1945) and Morgan *et al*. (2005), claimed that magpies instil fear in other bird species, frequently attacking them and occasionally killing them. It could be

assumed that pest passerine birds in vineyards perceive magpies as a threat and display avoidance behaviours when encountering them.

Figure 8.6: Magpies attracted into a Martinborough vineyard after bait was placed on the ground.

Median numbers of pest passerine bird abundance was significantly lower when bait was being supplied to the vineyard sites compared to when no bait was supplied. Cresswell (2011) noted the presence of predatory species can affect prey populations directly and indirectly, whether lethal results take place or non-lethal predator avoidance results. Behavioural adaptation to minimise the risk of predation, or fear of, can have a significant effect on populations, communities, and ecosystems; including an alteration in habitat use along with foraging behaviour (Lima, 1998; Cresswell, 2008; Dunn *et al*., 2010, Cresswell, 2011). Passerine birds naturally fear predation by raptors and will avoid them (Conover, 1979; Patzwahl, 2002; Kaplan, 2004; Göth, 2001; Daugovish *et al*,. 2006) and this was demonstrated by the fleeing behaviour of starlings (*Sturnus vulgaris*) (a significant vineyard pest), observed via motion-sensed cameras on arrival of a harrier to the vineyard site (Figs. 8.6 & 8.7).

Figure 8.7: Starlings foraging unperturbed in vineyard where supplementary feeding site is located and Australasian harrier approaching in the distance.

Figure 8.8: Starlings in vineyard disturbed by approach of Australasian harrier, (caught on camera five minutes after figure 8.6).

In this study while the predators were the target species (i.e. those being supplementary fed), the pest passerine birds had the dual role of being both the non-target and target species. Non-target in that they were not being supplementary fed, but target species in that the increased presence of predatory species decreased their presence in the vineyard, which was one of the major goals of this project. Cortés-Avizanda et *al*. (2009b) reported that direct predation

pressure might have effects on prey species distribution, such as migration to areas that are perceived safer, and abandonment of former habitat.

However, decision-making by prey as to where and when to forage can be affected by the mere presence of predators (Howe, 1979; Valone & Lima, 1987; Thomson *et al*., 2006; Dunn *et al*., 2010). Cortés-Avizanda *et al*. (2009b) also noted where supplementary feeding of predatory species is implemented, residential or transient non-target prey species in the supplementary feeding habitat may be affected with regard to spatial distribution.

8.6   Conclusion

In this study it was shown that when supplementary feeding in vineyards was implemented, pest passerine bird numbers declined. Various predators swiftly (within 48 hours) inhabited areas where food was supplied, reflected in the short time span it took for numbers to increase from a period of no provision to supplementation. Swift habituation may be related to seasonal declines in food resources. As this trial was completed in the winter months, it would be interesting to compare results with spring/summer results when a greater abundance of food resources for all species identified is available. However, this preliminary result demonstrates optimism for future vineyard phenological events such as véraison, when the grapes are beginning to ripen and pest bird populations predate on grapes. Further supplementary feeding trials around the spring/ summer and more importantly, in vineyard phenology, autumn, when greater number of pest birds would be present, would be beneficial.

Chapter 9
Problems and challenges

9.1   Introduction

Although the main theme of this thesis has been adhered to; managing populations of the Australasian harrier to decrease passerine bird damage to vineyards, some of its original aims have been either modified or abandoned. This has been for several reasons which have either been identified shortly after the commencement of this project, or further on because of failures to meet previous objectives, or because of new findings made. While some of the reasons for modification, or ultimately abandonment of original objectives have been outlined here, it was also pertinent to identify other challenges or relevant information that became apparent as the project progressed.

9.2   Trapping and banding of harriers

Trapping and banding of harriers was to be an important initial step in this project. Catching and banding of harriers by a viticulturalist in Hawke's Bay had enabled a closer study of their individual movements and their affinity to the vineyard (Beard, R. viticulturalist, pers. comm., July 2009). Approximately thirty harriers were trapped and banded in Beard's vineyard where an elevated feeding table had been placed. An aim of this study was to band harriers and to assess whether birds would return to the feeding tables and remain in the vineyards where the feeding tables were located. Loyalty to the vineyard would presumably result in harriers foraging, and possibly nesting in suitable habitat in the vineyard, which would result in a greater abundance of harriers in the vineyard during the pre-harvest period, protecting grapes from passerine birds. Banding would also allow data to be gathered on whether individual harriers could be retained in the vineyard study area by a regular supplementary feeding programme. Banded harriers were to be visually observed and videoed to answer research questions such as habituation to feeding tables within the vineyard.

After consultation with local iwi (New Zealand Maori tribe) and receiving support and training by Department of Conservation (DOC) staff, a banding permit and wildlife research and collection permit was applied for and granted by DOC. These permits restricted the

researcher to carry out trapping and banding on the premise that DOC staff were present at all times.

Attempts to trap harriers were not successful. The logistics of arranging mutually agreeable times was difficult; DOC staff were located 45 minutes away from the study sites and had to be on standby, depending on trapping success. Trapping success was often thwarted by the inclement weather that season; harriers were not to be trapped in wet weather for animal welfare reasons. Approximately twenty trapping attempts were made, resulting in only three harriers in one trapping session, caught and banded (Fig. 9.1).

Figure 9.1: One of the three banded Australasian harriers caught by camera trap, returning to Burnt Spur vineyard, Martinborough, where animal carcasses were placed.

Two of these banded birds were caught via camera trap several months later, foraging at the vineyard site that they were trapped. Although there was a lack in sample numbers, it provided some anecdotal affinity data that show territoriality and perhaps loyalty to areas where supplementary food was provided. The aim to attempt trapping again the following season was prevented by the designated harrier banding DOC staff member resigning her position, and no other suitably qualified person was available to assist.

9.3   Failure to establish a regular feeding pattern from the raised feeding table in some vineyard sites

Another aim of this research project was to train harriers to regularly take food from a raised feeding table at vine canopy height. The viticulturist in the Hawke's Bay reported harriers regularly feeding from raised tables in his vineyard, and it was thought that this could be repeated in Canterbury and Martinborough vineyards.

In the Canterbury vineyard, three harriers regularly fed from the tables and the protocol developed to attain this was assumed to be successful in Martinborough vineyards. Anecdotal reports from Martinborough vineyard staff indicated that harriers were regularly seen in all vineyards sites. Confirming these reports, were visual identification of harriers circling and foraging in vineyards. The preliminary method to coax harriers to feed off raised feeding tables was successfully completed at Bentwood (see chapter 4) with at least three individuals feeding regularly from the bait supplied on the table. In the Martinborough sites, only one table was exploited regularly by harriers. Three other sites had harriers and other predators (discovered when cameras were set up) feeding intermittently, and five sites were abandoned after several weeks with no bait uptake from the tables. Attempts to encourage harriers to feed off tables produced a variable success rate and chapter 4 offers potential reasons for these inconsistencies.

9.4   Non-target feeders

A further aim of this thesis was to examine the biological control potential of the Australasian harrier, by regular supplementary feeding. While some vineyards were successful feeding sites and harriers did feed regularly (Bentwood vineyard, Canterbury and Pond Paddock vineyard, Martinborough), others either did not establish any feeding or remained only intermittent throughout the whole study period. Despite this, pest passerine bird numbers decreased (see chapter 6) and grape damage was significantly reduced where feeding tables were present (see chapter 7). With the late addition of motion-sensored cameras, it became apparent that in addition to harriers taking the bait from the table, other predators, such as cats (*Felis catus*) and magpies (*Gymnorhina tibicen*) were also feeding. Cats were shown to be adept at manoeuvring themselves on to the tables and taking the bait (Fig 9.2). This was particularly evident when tables were lashed to fence lines within the vineyards, which was done at the request of vineyard management. This requirement offered few options to move

the table to an area that was less easily accessible to cats. Additionally it would have been optimum to have all tables for all vineyard sites at the same distance from the vines, e.g. in the headland at the end of a row however, some vineyard management dictated where the tables were to be sited to allow for vineyard maintenance activities, such as mowing.

Figure 9.2: Cat accessing bait laid out for harriers on elevated feeding table at Craggy Range vineyard. Table is lashed to fencing as a requirement by vineyard staff.

Magpies were also observed exploiting the bait from the table (Fig. 9.3), which was unexpected, but not unusual behaviour for this species to predate on animal carcasses (see chapter 8). At this time the project changed tack, and experimental focus changed to include effects of supplementary food placed in vineyards, and the attraction of all predatory species including the harrier (see chapter 8).

Figure 9.4: Magpie at Cirrus Estate vineyard, Martinborough, with day-old cock chick (harrier bait) taken from a feeding table, protruding from its beak.

9.5   Sheep, pheasants and human activity

The Martinborough landscape provides wide-ranging foraging opportunities for the Australasian harrier. Situated in a valley this rural landscape, including sheep and cattle farms interspersed with vineyards, is surrounded by braided rivers, all providing potential prey species. Banding attempts and attempts to get harriers to feed off the tables coincided with the lambing season. As previously discussed, afterbirth and dead lambs make up part of the harriers seasonal diet (see chapter 4) and with many vineyards being in close proximity to farming land, harriers were often seen foraging over lambing paddocks and were witnessed several times carrying ovine afterbirth in their talons.

One feeding table trial vineyard that was, according to vineyard staff, frequented by harriers, did not record any bait taken by harriers at any time from the table and was subsequently abandoned as a study site. This site was later identified as being located next to a free-ranging pheasant population, which supplied an abundance of eggs and nestlings as a potential prey source for the harriers. Camera data recorded a pheasant foraging in the vineyard as well as the occasional pheasant chick observed by the researcher.

Later in the study, it was discovered that there were a few vineyards that already were operating their own biological programme, using the harrier. These vineyards were not part of this thesis project. Many vineyard staff looks on the Australasian harrier favourably as a part of the arsenal of weapons aimed at reducing pest bird damage in vineyards. With the rural communities' recreational and obligational extermination of mammalian pest species such as rabbits and hares, carcasses were already being placed on the ground in some of the non-study site vineyards. These sites may well have been regular feeding resources for harriers.

With the provision of all these other food resources for the harrier it could be assumed that some of these factors may have confounded attempts to attract the harrier or to maintain regular feeding visits to the tables. It is conceivable that harriers were not being driven enough by hunger to brave the feeding table, due to adequate and easily accessible food sources in the surrounding landscape (see chapter 4 for further discussion).

9.6 Wasps, flies, and decomposing carcasses

Wasps (*Vespula* spp.) can be a problem in vineyards. There are mixed opinions as to the actual damage that wasps cause. Porter *et al*. (1994) believe that though the oozing grape juice may attract wasps, they also limit the dripping juice by lapping it up, preventing further damage to the rest of the fruit, whereby various fungi may enter. Other reports Gavlan *et al*. (2008) and Cranshaw *et al.* (2011) noted that crops such as wine and table grapes are seriously damaged by wasps, where they will break into the fruit and consume the juice. Anecdotal reports have made it clear that wasps are not a welcome visitor in vineyards and have suggested that when wasps attack the grapes the juice of the damaged grape turns brown and changes the colour of the wine (Johner, P., pers. comm. 2011).

While wasps may directly attack the fruit (Cranshaw *et al.*, 2011) alone, the silvereye (*Zosterops lateralis*), a small self-introduced passerine bird, can be the catalyst for substantial damage to ripe grapes. It pecks the grapes, providing an easy entrance for wasps to feed on the seeping juice, and making the grapes vulnerable to bacterial and fungal diseases, such as *Botrytis cinerea* (Boyce *et al*., 1999; Tracey & Saunders, 2003; Saxton, 2004).

Vespid wasps are often attracted to vertebrate carrion (Moretti *et al*., 2011) and the introduction of the animal carcasses into the vineyards attracted a great deal of wasps,

especially if the carcasses were there for prolonged periods, e.g. more than three days. Numerous wasps were seen feeding on hare and rabbit carcasses, and their presence, as well as being unsightly and potentially hazardous to humans, might have resulted in a switch from carcasses to ripening grapes with an easy access to grapes provided by the damage already caused by the silvereye.

In particularly warmer climate conditions, the acceleration of the animal carcass bait decomposition was greater. Fresh bait in the form of rabbits and hares became difficult to source in the quantity required when feeding stations were set up in several vineyards at one time. Sometimes if bait had not been consumed, or only a small amount taken, it was left for longer periods to conserve bait resources. Bait was usually replaced every two to three days, but even in this period, not only wasps would exploit the carcasses but flies (Diptera spp.) would also lay their maggots on the carcasses. This was unsightly and where swift decomposition of the bait took place an offensive stench would result.

9.7   Conclusion

Despite these various problems and challenges, overall results have shown that where supplementary feeding has been implemented with tables (chapters 4-7) and without (chapter 8), passerine bird species have decreased (chapters 6, 8) and consequent grape damage has decreased (chapter 7). The problems and challenges in this thesis have highlighted opportunities to improve processes and planning, but they have also served to facilitate problem solving skills and flexibility on the part of the researcher.

Chapter 10
Conclusions

10.1 Summary of findings

The theme of this thesis was essentially an animal behaviour study with an applied viticultural focus. It was an inquiry into whether a native free ranging bird could be manipulated into providing an ecosystem service to New Zealand viticulture by decreasing grape damage caused by passerine birds. With the promising results demonstrated by the "Falcons for Grapes" project in Marlborough, and its achievement in simultaneously decreasing pest passerine bird populations, and decreasing grape damage (Saxton, 2010; Kross *et al.*, 2011), it was reasonable to expect that another more common New Zealand raptor, could also have the potential to provide another such successful ecosystem service.

When the project was first conceived, it was an inquiry into whether the Australasian harrier, which is a common presence around New Zealand viticultural landscapes, could achieve similar results to the rarer New Zealand falcon. Supporting this was anecdotal evidence from a Hawkes bay viticulturalist, who reported that where harriers were fed on raised feeding tables, pest passerine bird numbers decreased and grape damage was less in the areas where the tables were located.

Throughout all the study sites (Canterbury and Martinborough) and the surrounding landscape, harriers were seen flying and scavenging off the many animal carcasses that were present on the roadways. Passerine birds, including those in flocks, and singular, were observed fleeing when harriers appeared, providing confirmation in the field that harriers could possibly provide protection for grapes from grape-foraging passerine birds in vineyards.

To attract harriers to vineyards there needed to be an attractant. Supplementary feeding had demonstrated positive results for the New Zealand falcon in Marlborough vineyards. The effects of supplementary feeding on other raptor species around the world showed increasing densities (Houston, 1996; Amar & Redpath, 2002; González *et al.*, 2006; Robb *et al.*, 2008), improved breeding success (Dijkstra *et al.*, 1980; Korpimaki, 1985; Simmons, 1994; Redpath *et al.*, 2001; González *et al.*, 2006; Robb *et al.*, 2008), and range restriction (Knight & Anderson , 1990; Robb *et al.*, 2008). Supplementary feeding was the attraction method used

in an attempt to increase and maintain increased densities of Australasian harriers in the study vineyards.

Attempts to attract harriers and establish a regular feeding pattern from raised feeding tables in some vineyards did not eventuate. Success at the beginning with a preliminary trial in a Canterbury vineyard, where at least three individuals were feeding regularly, did not translate into success later in the Martinborough vineyards. Nine vineyards at some time or another throughout the project were sites where feeding tables were erected. One site resulted in no bait uptake from the ground, and was abandoned earlier on in the trial, four sites were abandoned due to no bait uptake from the raised tables, and three vineyards had harriers feeding intermittently, while only one vineyard experienced harriers exploiting the table daily.

Neophobia may have been an explanation for latency to feed from the tables, coupled with an abundance of other easily accessible prey, which negated the need for the harrier to trade off a neophobic response for food. Neophobia is often an initial response to a novel object and while some harriers overcame a neophobic response to the feeding tables, some harriers continued to avoid the table. Other reasons suggested, were human-induced disturbance, as some of the vineyards were situated in urban areas and negative interspecific relationships with other species found in the vineyards, such as magpies.

The Australasian harrier preferred chicks as supplementary food in the springtime to rabbit pieces, although it is not clear why. Seasonal (spring/summer) preferential food choice was identified in the Canterbury vineyard where harriers were feeding regularly. During the summer, there was no difference in prey selection and equivalent quantities of both foods were taken. Factors that could explain this were seasonally differing nutritional requirements required in the breeding season, the presentation of the bait on the table and an initial neophobic response to its morphology or search image could be a factor where the harrier is tuned into searching for nestlings/chicks in the spring period.

Where harrier feeding tables were present, passerine bird abundance significantly decreased by (56%) compared to sites without tables. In Martinborough vineyards, three out of four tables were visited by harriers intermittently, i.e. bait was not taken daily. Only one table was visited regularly and despite this, five-minute bird counts showed that pest passerine birds were not as common in sites with tables. Most passerine birds in both treatment and control

sites were observed flying, rather than having contact with the netting, or being within the net. The table appeared to have no effect on proximity of birds to it and it was assumed that there was no fear response to the table itself. It was likely the vineyard itself, or at least the area that was in the count area (a half circle with a radius of 80 m) was avoided, possibly due to increased harrier (or as later discovered, other predators as well) activity. The most common species found in both treatment and control sites were starlings followed by blackbirds, which appeared to avoid sites with tables more than starlings did. This could be related to biological/ecological differences between bird species.

With the decreased abundance of birds in the vineyards where feeding tables were present, it was assumed that the goal target of decreased grape damage during the pre-harvest season would follow. Anecdotal reports suggested that grape damage to Pinot Noir grape varieties in Martinborough vineyards was an issue. A grape damage survey pre-harvest in 2010 substantiated these reports showing that outer or edge vines sustained approximately 20-30% damage that year, even with netting present. The following season (2011), when harriers had been supplied with supplementary food on feeding tables, and were exploiting it either regularly or intermittently, a further grape damage survey was completed before harvest. The survey showed that where the tables were present (in four vineyards), there was a significant decrease in grape damage (59%), compared to the vineyards without tables; demonstrating a possible link between feeding tables and lower levels of grape damage.

With the addition of motion-sensored camera data resulting from cameras being trained onto feeding tables, it became apparent that harriers were not the only predator exploiting the feeding tables. Cats and magpies were also frequent visitors to the tables. The correlation between decreased abundance of pest passerine birds and lower levels of grape damage where feeding tables were present appeared to be linked to other predators in the vineyard as well as the harrier.

Further inquiry into the presence of these other predators was undertaken and this revealed a swift influx of magpies, cats, harriers and the occasional dog exploiting supplementary food that was placed on the ground as an attractant to the vineyards. Five-minute bird counts revealed a lower number of pest passerine birds were present when supplementary food was being provided at ground level in all vineyards. This experiment took place in the winter

months and results could be explained by the seasonal lack of food resources for predators, however it seems likely that some predators were also visiting tables in the summer trial.

10.2 Future Directions

This research is at the beginning of answering the question of whether native, wild populations of animals can be manipulated into providing a successful ecosystem service; manipulating the predatory behaviour of one species to mitigate the destructive behaviour of another species in order to moderate economic losses.

Future directions here include further research and/or practical applications for wine growers.

10.2.1 Longer time period of feeding

A longer period of time and greater persistence in encouraging the harriers to feed off raised tables may result, in the long-term, in a greater number of harriers regularly feeding from the raised tables. Although the Canterbury site was easier to establish a regular feeding programme, some sites may simply require a greater persistence over a longer time. A period of approximately 3-5 months was required to get harriers to feed off the two tables that saw regular feeding. This suggestion is supported by Marples *et al.* (2007) who pointed out that with unfamiliar food sources birds may respond with "diet wariness" and may even show reluctance to food consumption for extended periods.

10.2.2 Seasonal timing of a supplementary feeding programme

Commencement of a supplementary feeding programme for Australasian harriers should begin in the winter months after grape harvest and its associated extensive human activity in the vineyard has decreased. Winter is a time when prey species may be limited and harriers may struggle to find adequate food resources. Starting a feeding programme at this time of year also allows time for the harriers to become familiar with the vineyard and the table, encouraging the harrier to forage regularly there. With established feeding over the winter months, the spring season may encourage harriers to breed in or near the vineyard, resulting in juveniles feeding and breeding there as well. An increase in harrier abundance in the vineyard may result in greater numbers of birds protecting the grapes at one of the most important times for the vineyard; in the autumn when grapes are ripening and at their most vulnerable to passerine bird predation.

10.2.3 Supplementary food at all vineyard edges

Since the greatest amount of bird damage is sustained to the outer vines and edges of vineyards it might be advantageous to provide supplementary food at all edges of the vineyard to provide greater protection. In this study food was only placed at one edge area of the vineyard and although all edges of the vineyards were not surveyed it could be assumed that these other areas were less protected. It may be practical first to measure how far the protection of the presence of a feeding table extends before placing food at all edges. Saxton (2010), found that falcons fed supplementary food off feeding trays at a fixed point could provide protection for some grape varieties up to 4 ha.

10.2.4 Control of other predatory populations in vineyards

The focus of this project was the Australasian harrier and its potential to decrease passerine birds in vineyards. However, it was discovered that other predators were also accessing the bait that was intended for the harrier. Other predators may have also been responsible for lowered passerine bird numbers and consequent decreased grape damage. However, magpies are antagonistic toward harriers (see chapter 8) and if a theme of encouraging a New Zealand native species into vineyards is to be adhered to then magpie populations may need to be controlled. Cats were also a problem accessing the vineyard bait, and could equally be preventing harriers from regularly feeding in some situations. If decreased passerine bird damage to grapes is the only goal then attempts to control other predatory populations is not necessary.

10.2.5 Further grape damage assessment after predators have been regularly supplementary fed

Results showed that when all predators of pest passerine birds were supplementary fed, pest passerine bird abundance decreased. This trial was completed in the winter months. Further inquiry into a sustained feeding programme (where bait is easily accessible to all species on the ground) up until harvest, and a pre-harvest grape damage assessment, may provide some further information on the effectiveness of this bird control method.

10.2.6 Harrier activity frequency monitoring in vineyards with and without feeding tables

Investigation of harrier activity frequencies (i.e. flying over the vineyard) in vineyards could be beneficial. A focal point in this project was harrier activity related to landing and foraging off the feeding tables, however with supplementary food provided it would be of interest to

measure the effect of the supplementary food on the frequency of flights made by harriers over vineyards.

10.2.7 Cost / benefit analysis of grape loss cost and the cost of feeding and maintaining harriers in vineyards.

A cost / benefit analysis would be useful to discover how much a 30% grape loss for exterior vines (as seen in one vineyard in chapter 6) costs the vineyard, and how much it costs to supply feeding tables with regular food to attract harriers.

10.3   Final Conclusions

Where feeding tables were present, passerine bird abundance decreased and grape damage was significantly less than when feeding tables were not present. The Australian harrier fed off some tables intermittently and some regularly, and appeared to have a preferential food choice when offered, dependent on season. In essence, it could therefore be stated that it is possible to manipulate the feeding behaviour of a free ranging bird to provide an ecosystem service.

However, using a raised feeding table baited with animal carcasses is not necessarily a reliable method to encourage harrier feeding in vineyards. There are several reasons why this method may be unreliable, such as neophobia, alternative food sources that were easy to access, human disturbance and interspecific competition. The best reason may merely be that the motivation to feed off a raised table was not sufficient. The important aim is to get harriers to spend a longer time in vineyards and to recognise them as places of abundant food resource.

When supplemented with favoured foods the harriers' increased presence appeared to deter pest birds from either entering the vineyard and/or prevented them from foraging on grapes by keeping them on the move. However, although harrier numbers increased in the vineyard it was noted that other predators were accessing the supplementary food that was placed on tables and intended for harriers. At the latter trial where supplementary food was placed on the ground in order to attract all predators, decreased passerine bird numbers also resulted in vineyards where food was supplied on the ground compared to those with no supplementation on the ground. These findings perhaps negate the need for any feeding tables and put simply, supplementary feeding alone may be the key to attracting harriers and other predators into

vineyards to achieve the fundamental goal of decreasing pest passerine bird numbers and consequent grape damage.

If this study were based purely on controlling economic losses, then potentially any predator that frightened passerine birds in New Zealand vineyards would suffice to mitigate economic losses. However, this project was also about using a self-introduced New Zealand bird to control populations of introduced birds that predate on introduced fauna. Although the Australasian harriers' ecosystem service abilities in this area are perhaps only satisfactory, probably as part of an integrated pest management tool to decrease economic losses for the wine-growing industry; perhaps its value also lies in displaying part of New Zealand's native biodiversity in the introduced flora and monoculture of New Zealand vineyards.

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Appendix 1

Thank you letter to participating vineyard owners

Marlene Leggett
486 Lake Ferry Road
R.D.1
Martinborough 5781
Mal1@orcon.net.nz
(06) 3069014

Dear (.........)

This is just a note to let you know that I have now completed my research into managing populations of the Australasian harrier to reduce passerine bird damage in vineyards, and I would like to give you a very brief summary of the main findings.

Firstly, I would like to take this opportunity to offer my sincere gratitude for allowing me to use your vineyards to conduct my research. Without access to your vineyards, I would not have been able to complete this research and I have appreciated the input and advice that I have received from you along the way.

As you are aware, I placed raised feeding tables in vineyards, baited with supplementary food; hares, rabbits, brushtail possums, and dead chicks and while some sites attracted harriers, some attracted them only intermittently and some harriers would not take any bait unless it was off the ground. Throughout my study, there has been discussion on this and we have made various assumptions as to why this may be.

The research went as follows:

- Attracting the harriers to the vineyard with supplementary food and trying to get them to take this food off a raised table. This met with limited success as only one table saw harriers feeding regularly while other tables saw harriers feeding intermittently off them.

- A look at what food harriers prefer: contrasting spring and summer choices (rabbits and dead chicks). Harriers preferred chicks to rabbit pieces at springtime which may be for many reasons (which I have discussed in the thesis), and have no preferential food choice in the summer.

- The numbers and behaviours of pest bird species where the tables have been placed, when harriers have been feeding either regularly, or intermittently off the tables.

- A grape damage assessment was completed just before harvest where the tables were present compared to vineyards with no table present. Grape damage was less where feeding tables were present (see graph, Fig. 2).

- Not only were harriers attracted to the feeding tables, but also magpies and cats, which I managed to catch on cameras, set up in the vineyards, many times. Because of this, an experiment was completed on luring all predators, harriers, cats, magpies into the vineyard with bait placed on the ground this time. The number of predators was counted with no bait supplied and then bait supplied. Additionally, I looked at the number of pest birds present in the vineyards when bait was laid out for predators and when there was no bait laid out. Predators increased (harriers were the most abundant over cats and magpies), and pest bird numbers were lower when bait was laid out for predators.

In short, results have shown that where feeding tables are present and whether the harrier is feeding regularly or intermittently from those tables, pest birds (Fig.1), are less and grape damage decreases (Fig. 2). In addition, when harriers and other predators are present due to supplementary feeding, not from raised tables, but instead, from the ground, there are also less pest birds (Fig 3).
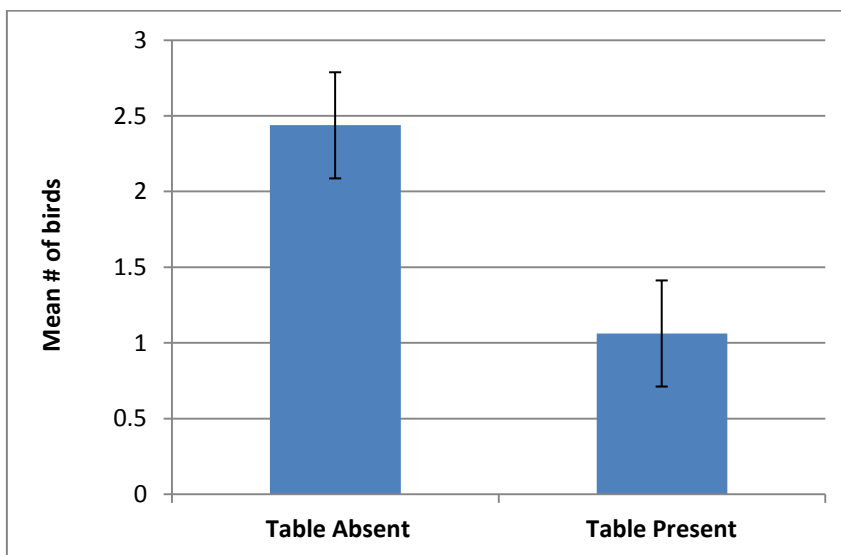

Figure 1 Mean number of pest passerine birds (± SEM) in Martinborough vineyards (2011) with Australasian harrier feeding tables absent and present.
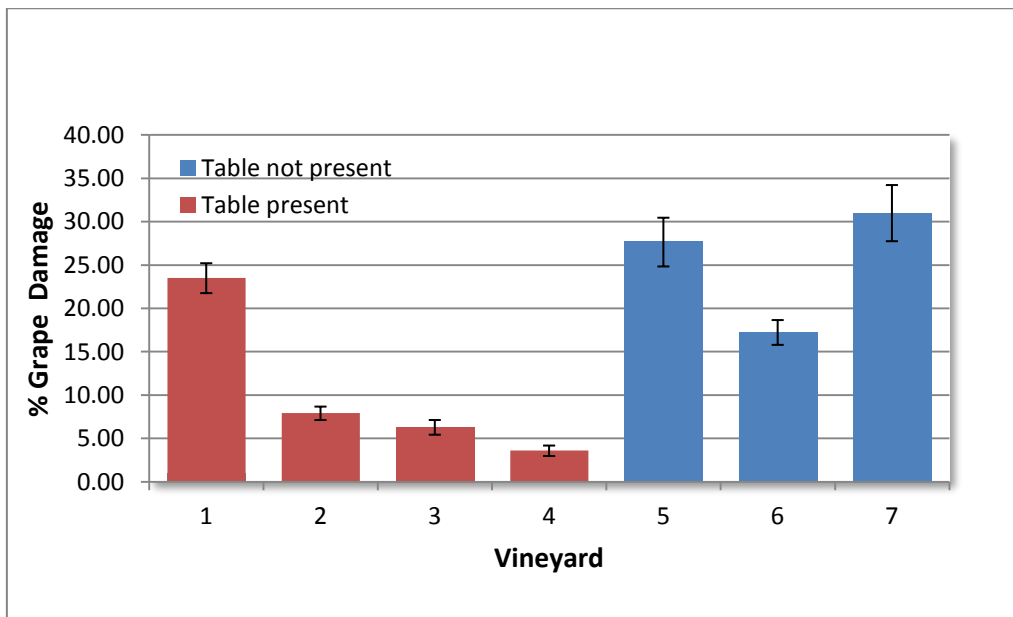
Figure 2: Percentage grape damage to edge vines in Martinborough vineyards (2011) with feeding tables present and absent.

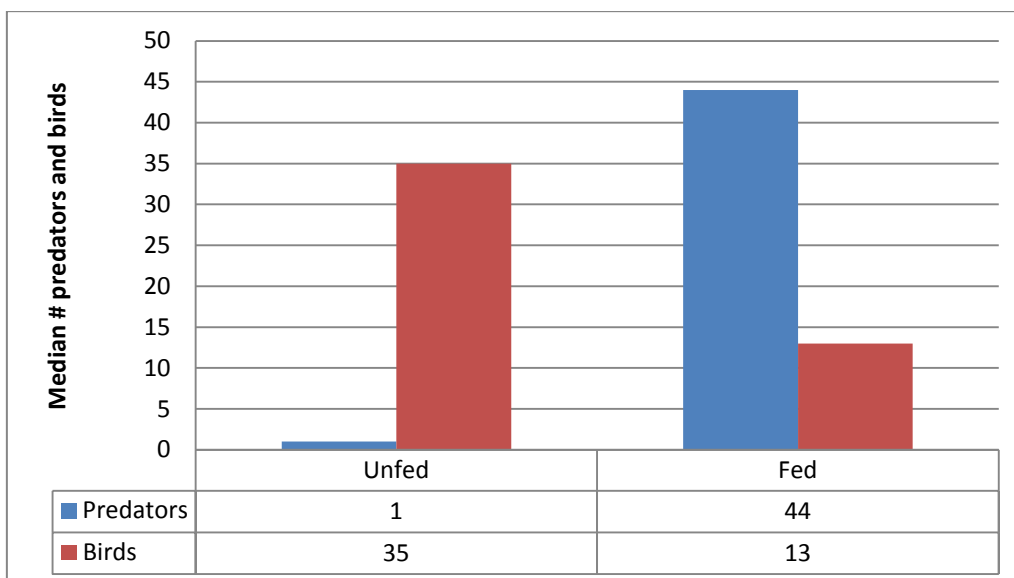|	Unfed	Fed
Predators	1	44
Birds	35	13

Figure 3: Median number of predators and passerine bird abundance in Martinborough vineyards (2011) with and without supplementary food.

Any recommendation that I might give to you after this research, is that feeding harriers rabbits/hare (preferably with some flesh exposed or better still skinned) and chicks is an important attractant for harriers into your vineyard. If you want to take this further, Lepparton hatchery, Taranaki which I have the details for, will courier a bag of 300 dead-day old cock chicks for about $20, including freight! These can be frozen and used as required. I found harriers favour these in the spring. Males feed the female while she sits on the nest in the springtime. Rabbits and hares are fine to put out all year round. Additionally, winter would be a good time to start putting food out, as the harriers are particularly hungry in this season and

this may engender some loyalty to the vineyard in preparation for the later and important seasons, such as summer/autumn.

I do not think the raised table is particularly necessary; a regular supply of food, maybe even every few days placed near your edge vine areas is probably all that is necessary. However, you will also probably attract cats and magpies (studies have shown that magpies will attack smaller birds). While you may attract predators as well as harriers, my results have shown that by providing supplementary foods the most common species taking it was indeed harriers.
If you have any questions about any of this research, you are most welcome to contact me. On behalf of my supervisors, Dr. James Ross, Dr. Valerie Saxton, Dr. Adrian Paterson, Lincoln University and I, thank you again for your support.

Yours faithfully,
Marlene Leggett
Master of Applied Science candidate, Lincoln University.