Breeding biology and threats to the blue penguin (*Eudyptula minor*) in South Westland, New Zealand

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A thesis
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Master of International Nature Conservation

by
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Blue penguin at Nile River Colony in Buller (Photo by Andrea Murillo).

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The Blue Penguin (*Eudyptula minor*) is assumed to be declining over much of its range, largely due to introduced predators. Anecdotal evidence suggests that one of the areas of declining population is the West Coast of the South Island.
The purpose of this study was to determine the reasons for the assumed decline of blue penguins in South Westland. This was done by studying breeding ecology at several blue penguin colonies to assess the importance of breeding success and adult mortality on the penguin population.
Three blue penguin colonies in South Westland, at Five Mile and Three Mile beaches south of Okarito, and at the Wanganui River mouth near Harihari, were monitored throughout the 2008/09 breeding season. During each burrow visit the number of eggs and chicks were recorded as well as the date of laying, hatching or fledging. Five colonies of blue penguin were also monitored in Buller over the same breeding season in a study conducted by the West Coast Blue Penguin Trust, a community trust based on the West Coast. The results of both studies were compared to determine the effect of predator control on breeding parameters, such as breeding success.

Of 137 eggs laid in South Westland, 108 chicks survived until fledging, giving an overall breeding success of 78.8%. In Buller, 64 chicks survived to fledging from 101 eggs laid, resulting in an overall breeding success of 63.4%. Breeding success was significantly higher at penguin colonies in South Westland, compared to the Buller colonies. There was no evidence that predator control had an effect on breeding success in South Westland or Buller.
The mean number of chicks fledged per pair that produced eggs was 1.55 in South Westland and 1.16 in Buller.

The overall proportion of occupied breeding burrows compared to the total number of suitable burrows at the South Westland sites was 73.8% (n = 103). At the Buller sites, only 60.3 % (n = 151) of the total number of burrows was occupied.

Road kills are a major threat to blue penguins in Buller due to the proximity of colonies to the state highway. Fortunately, incidences of road death in South Westland are rare and due to the distance from roads, do not pose a significant threat to South Westland blue penguins.

Further study of blue penguin colonies in South Westland is needed to learn more about annual variation in breeding productivity and to determine if breeding success is consistently high over an extended time period. If this is the case, then the cause of blue penguin decline on the West Coast is unlikely to be due to problems with breeding as the breeding success during this study is one of the highest recorded for blue penguins. Although there was no apparent effect of predator control on breeding productivity during this study there is evidence from other locations that predators, in particular stoats, have contributed to the decline of blue penguin populations. More research into the impact of predators on penguins over a longer period of time is needed on the West Coast before a change is made to how predators are managed.

Keywords: Blue penguin; *Eudyptula minor*; South Westland; breeding timing; predator control; adult mortality; threats; breeding success; weights; burrow occupancy; West Coast Blue Penguin Trust

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1. Introduction

1.1 Blue penguin ecology

The blue or little penguin (*Eudyptula minor*; Maori name: korora) is the world's smallest penguin at 40-45cm long, and weighing about 1 kg (Reilly 1994). It belongs to the family Spheniscidae (Order Sphenisciformes) and accurate classification at the species level is still unclear. There has been little consensus in the past over whether blue penguins represent two distinct species, (Kinsky 1960) one species (*Eudyptula minor*) with six subspecies (Kinsky & Falla 1976), or a single, morphologically variable species (Turbott 1990). Recent evidence suggests that the species can be divided into two separate groupings, the first consisting of Otago (New Zealand) and Australian populations, and the second consisting of populations from the rest of New Zealand (Banks *et al.* 2002; Banks *et al.* 2008).

Blue penguins are widely distributed in Australia and New Zealand. In Australia they are found along the southern coast from Western Australia to New South Wales on the eastern coast. In New Zealand they can be found along most of the coastline from Northland to Stewart Island and the Chatham Islands, and stragglers have been found as far south as Snares Island (Davis & Renner 2003; Stahel & Gales 1987).

The blue penguin is different from other penguins as it is the only species nocturnal on land, waiting until dusk to come ashore and generally leaving to feed at sea before dawn. This species is opportunistic and generally feeds in shallow waters (Stahel & Gales 1987). The birds dive to a mean maximum depth of 30m (Montague 1985) and their diet consists mainly of small schooling fish, squid and to a lesser degree, krill (Stahel & Gales 1987; Davis & Renner 2003). The length and distance of foraging trips vary but this species generally stays within 20km of the coast although blue penguins have been known to travel larger distances depending on food availability (Reilly 1994). The upper limit to the daily range of a blue penguin is 30km, which means that they can swim up to 60km in a day (Collins *et al.* 1999).

Most foraging trips of breeders during incubation and chick rearing last less than a day, but trips of up to a week are not unknown at certain locations (Davis & Renner

2003). Juveniles dispense widely after fledging and journeys of over 1000km from the natal area have been recorded (Stahel & Gales 1987).

Blue penguins nest in a variety of habitats including burrows, under trees, in rock crevices and sometimes in caves (Davis & Renner 2003). They have also been known to breed under buildings and among discarded materials, such as corrugated iron (per. obs.). Nests are usually clustered to form colonies but single breeding pairs are not unknown (Davis & Renner 2003).

Blue penguins are unique among penguin species in their ability to lay up to two clutches in a season, with the potential to produce four fledglings a year (Williams 1995). While there is evidence of double clutching in Australia (Reilly & Cullen 1981) and Otago (Perriman *et al.* 2000; Johannesen *et al.* 2003), there is no evidence of double clutching by blue penguins in the Buller region of the West Coast (Heber *et al.* 2008).

This species also has a variable breeding season where onset and length of the season can vary greatly annually and geographically (Davis & Renner 2003; Stahel & Gales 1987). Throughout the range of this species, the breeding season generally begins between late June and September (Davis & Renner 2003) and may continue until December or January. In Western Australia the breeding season begins in April (Davis & Renner 2003). In many parts of New Zealand the onset of the breeding season occurs from September to November.

The breeding productivity of a population is dependent upon the hatching and fledging success rate and whether one or two clutches are laid (Perriman *et al.* 2000). The onset of breeding, length of breeding season or probability of a pair successfully rearing two clutches, can be affected by ecological conditions such as food supply or climate (Perriman *et al.* 2000). A recent study by Heber *et al.* (2008) found the breeding season in the Buller region of the West Coast to fall between July and December. A later breeding onset and the lack of double clutching on the West Coast when compared to the East Coast may be indicative of a difference in ecological conditions, particularly a more restricted food supply.

The duration of egg laying may vary between 8 and 28 weeks. Clutch size is normally two eggs, but singular clutches are not uncommon. In the case of a two-egg clutch, eggs are laid an average of 2.8 days apart (Davis & Renner 2003; Stahel & Gales 1987). Incubation generally lasts 33-37 days, with the male usually taking the first shift of several days while the female leaves the nest and forages to build up her fat reserves.

After hatching, chicks are guarded for 20-30 days but this can be as little as eight days in some situations (Davis & Renner 2003). Fledging usually occurs 48-63 days after hatching. Blue penguins, like most other penguin species, moult at the end of the breeding season. The moult generally lasts 2-3 weeks during which time the penguins are restricted to land and are unable to forage. The increased energy costs of the moult are reflected in the high rate of weight loss during this time (Stahel & Gales 1987). In one study at Taiaroa Head in Otago, average blue penguin weights dropped from 1324g (pre-moult) to 1197g (post-moult) (Johannesen *et al.* 2002).

1.2 Climate and Bathymetry

New Zealand is situated in the mid-latitude westerly wind belt, known as the 'Roaring Forties' (Figure 1). Being over 1600km from any large landmass it has a maritime climate characterised as moist and temperate, and a mountainous terrain with a high axis extending, nearly unbroken, across the entire length of the country. Depressions and low frontal troughs generally approach from the west and are preceded by warmer winds from the north. These troughs may have high moisture content and can bring very heavy rains to areas exposed to them e.g. Taranaki, Nelson and Westland.
The main mountain range in the South Island, the Southern Alps, causes precipitation and temperature gradients across the South Island. The Southern Alps force the westerly winds to rise, cool, and release most of their moisture in the form of rain and snow on the westerly side of the mountain range. The winds then continue east leaving a dry 'rain shadow' east of the mountains and resulting in a much drier climate along the East Coast (Williams 1973). The West Coast is generally wetter and milder than the East Coast. As depressions approach from the west, areas further south often receive more rain. This results in a higher rain gradient on the southern West Coast of the South Island compared to the northern West Coast (Williams 1973).

The coastal surface waters of the West Coast of New Zealand originate in the Tasman Sea and the southern part of the New Zealand mainland lies across the boundary between the subtropical and subantarctic waters known as the Subtropical Convergence (Kuschel 1975). Oceanic subtropical surface waters approach New Zealand from the west and separate into two currents in the vicinity of Jackson Head in South Westland (Darby *et al.* 2003). The Southland current containing Subtropical Convergence Water and Australasian Subantarctic Water travels through Foveaux Strait and around Stewart Island, to move northwards along the Otago Coast and up to Canterbury. The Westland current of Subtropical Convergence water moves northwards along the West Coast of the South Island (Kuschel 1975). As the convergence region lies off the southern part of the West Coast, the northern West Coast does not benefit from the nutrient-rich Subtropical Convergence water, whereas the Southern Current carries the water to the East Coast (Kuschel 1975). The coastal waters vary from warm, salty, sub-tropical currents in the north and west, to cold, sub-Antarctic currents in the far south and southeast (Taylor & Smith 1997).

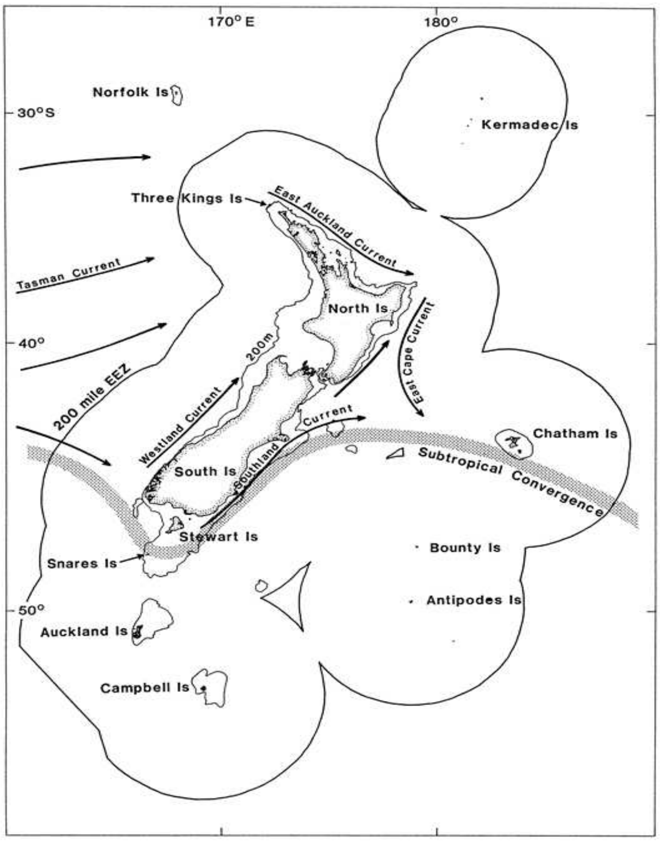


Figure 1. Currents and convergences in the New Zealand region (from Taylor and Smith, 1997).

It is possible that the Buller and South Westland regions have significantly different offshore conditions due to these different currents, which could affect penguin productivity.

Quantities of phytoplankton and zooplankton are generally much higher off the East Coast compared to the West Coast (Bradford and Roberts 1978). This is an indicator of greater productivity along the East Coast as these organisms are at the bottom of the marine food chain and have a direct impact on marine productivity. As the food supply on the West Coast is less favourable than on the East Coast (due to lower productivity), it is possible that blue penguins will have to travel further to forage for food. This may result in a higher occurrence of egg desertion or nestling starvation on the West Coast. The higher rainfall on the West Coast may lead to a higher rate of chick mortality through drowning or hypothermia.

1.3 West Coast Habitat

The podocarp-hardwood forests are New Zealand's major forest type and are the predominant forest in Buller and South Westland. Podocarp-hardwood forests are referred to as 'lowland' forests as they often predominate at lower altitudes i.e. below 650m in large parts of the South Island. They contain a mixture of podocarps or 'softwoods' and many species of 'hardwoods' or 'broadleafs' (Taylor & Smith 1997). The podocarps include rimu or red pine (*Dacrydium cupressinum*), which is often the dominant species in a forest, and the kahikatea or white pine (*Dacrycarpus dacrydiodes*).

Other prominent podocarp species are totara (*Podocarpus totara*) and Hall's totara (*P. hallii*); pink pine (*Halocarpus biformis*); silver pine (*Manoao colensoi*); matai and miro (*Prumnopitys taxifolia* and *P. ferruginea*); yellow-silver pine (*Lepidothamnus intermedius*); tanekaha or celery pine; toatoa and mountain toatoa (*Phyllocladus trichomanoides, P. toatoa* and *P. alpinus*). Hardwood species include northern and southern rata (*Metrosideros umbellate* and *M. robusta*); tawa and taraire (*Beilschmiedia tawa* and *B. tarairi*); hinau (*Eleaocarpus dentatus*); kamahi (*Weinmannia racemosa*); black maire (*Nestegis cunninghamii*); pukatea (*Laurelia novae- zelandiae*); puriri (*Vitex lucens*); and rewarewa (*Knightia excelsa*) (Taylor & Smith 1997).

On the West Coast of the South Island, blue penguins nest in a wide range of habitats. Burrows are generally located at the rear of sand dune systems, under or around rocks or in caves and are usually found within 100m of the sea (Blyth *et al.* 2006). Blue penguins will nest in coastal forest and gorse and are most abundant in areas where the habitat features provide some cover, such as under driftwood or amongst flax roots.

A survey by Blyth *et al.* (2006) on blue penguin distribution and timing of the breeding season in the Buller region found that there is a discontinuous population of penguins along the West coast. There are a few large colonies (around 50 burrows) and many smaller clusters and isolated pairs. Based on anecdotal evidence, it is assumed that blue penguins once occupied a larger area, although there is no evidence of a recent decline in the Buller region. Penguin numbers are generally higher in areas where human activity is low.

Blyth *et al.* (2008) recently conducted a survey of blue penguin along the West Coast from the Heaphy River mouth in the Buller Region down to the Haast River in South Westland. This study provides important information about the distribution and abundance of blue penguin colonies on the West Coast.

1.4 Threats

There are a number of threats to the blue penguin in New Zealand.
Predation by mustelids (*Mustela* sp.) and dogs (*Canis familiaris*) is the biggest threat to penguins throughout all coastal parts of New Zealand (Taylor 2000b). Ferrets (*Mustela furo*) and stoats (*Mustela erminea*) take eggs and chicks and may sometimes even attack adults. Unrestrained dogs will attack adult birds and have destroyed entire colonies of blue penguins in a short period of time (Taylor 2000b).

Other predators include feral cats (*Felis catus*) and, near human settlement, potentially domestic cats, as well as Norway rats (*Rattus norvegicus*) and Ship rats (*Rattus rattus*). Norway rats are more likely to prey on penguins than ship rats as they are primarily ground foragers and are known to enter burrows (King 2005). Cats have been known to kill chicks and adult birds whereas rodents will take eggs and small chicks. European rabbits (*Oryctolagus cuniculus*) and Brushtail possums

(*Trichosurus vulpecular*) may compete with penguins for burrows. Feral pigs may also dig out burrows and kill adult birds or at the least disrupt the breeding success of the nest (Taylor 2000b).

Weka (*Gallirallus australis*) have been recorded taking Yellow-eyed (*Megadyptes antipodes*) and Fiordland Crested Penguin (*Eudyptes pachyrhynchus*) eggs, and entering burrows of other birds such as Brown Kiwi (*Apteryx australis*) (Marchant & Higgins 1993). Weka are likely to prey on blue penguins, but as Weka are more vulnerable than the blue penguin (IUCN, 2008), they are not controlled.

Another key threat to blue penguins is human disturbance. The demand for coastal development has greatly increased in the last 40 years (Taylor 2000a) and remote parts of the New Zealand coast have been opened up for development. This in turn has can lead to an increase in human activity on the coast and reduces the availability of some breeding habitats to nesting seabirds. For colonies close to human settlements, there is the risk of disturbance by walkers, motorbikes, 4WD vehicles and the increased proximity of roads to nesting birds, increasing the likelihood of road deaths.

In addition to on-land threats, blue penguins are also threatened while they are foraging at sea. Penguins have frequently been caught in near-shore set nets, although other types of fishing, like trawling and line fishing do not seem to pose much of a danger to the penguins (Taylor 2000b). Net fishing is less likely on the West Coast than on the East Coast, as rougher seas provide poorer access and there are fewer small boat owners.

As blue penguins mainly eat shoaling fish such as pilchards and anchovies and most commercial and recreational fishing takes prey from the sea floor, there is no evidence that this type of fishing has a large impact on prey availability or penguin mortality (Taylor 2000b).
Other at-sea threats may include oil spills or pollutants. Little is known about the effects of pollutants such as plastics and chemical contaminants on penguins both in terms of mortality or foraging efficiency. Recent oil spills in Australia have shown that blue penguins are a primary victim of oil spills (Hull *et al.* 1998). Oil is known to

affect the insulation, waterproofing and buoyancy of birds, with damage to plumage being the most common form of injury (Goldsworthy *et al.* 2000). The probability of oil spills near the West Coast is likely to be small, except near the two main ports of Westport and Greymouth, where there are low volumes of shipping.

Other threats include long-term changes to feeding grounds as sea temperatures rise, and localised pressures from pollution and toxic algae blooms (Taylor & Smith 1997).

In South Westland, many colonies are located in isolated areas away from main roads and human settlements. In the Buller region, many colonies are located close to roads resulting in a higher likelihood of road mortality. Human encroachment in the Buller region may also be more of a threat to penguin survival than in South Westland. Breeding failure associated with human disturbance may be lower in isolated colonies although predation may be higher as the presence of people may deter mustelids.
In this study the incidence of road mortality will be compared between the two regions to determine if this threat has a significant impact on the number of animal birds killed and subsequently on any decline in the penguin population in this region. The abundance of introduced predator species may influence the breeding success between colonies in the two regions but this is unlikely to have a significant effect in the case of widely distributed predator species. For species such as Western Weka (*Gallirallus australis australis*) that are patchily distributed and believed to prey on penguin eggs and chicks (Blyth *et al.* 2006), breeding success in an area populated with Weka could be adversely affected. Weka are common in the Buller region but are now virtually absent in South Westland (IUCN, 2009).

1.5 Purpose of Research

Blue penguins are classified as a species of 'least concern' in the International Union for Conservation of Nature (IUCN) Red List and are not believed to approach the threshold for population decline (IUCN, 2008). Despite this, blue penguin (*Eudyptula minor*) colonies are believed to be declining in many areas in Australia and New Zealand (Dann 1994; Blyth *et al.* 2006; Challies & Burleigh 2004; Dann 1992). In parts of New Zealand, including predator-free offshore islands, penguin populations have also declined (Taylor 2000b), which suggests that declines may be linked to events in the marine environment and are not due solely to on-land threats. Anecdotal evidence suggests that one of the areas of declining population is the West Coast of the South Island.

1.6 The West Coast Blue Penguin Trust

In 2004, the West Coast Blue Penguin Project (WCBPP) was initiated with the aim of conserving the West Coast blue penguin and its habitat. The project included representatives of the West Coast District Councils, West Coast Regional Council, Department of Conservation, and residents' groups. In 2006 a charitable trust, the West Coast Blue Penguin Trust, was formed. This ensured a longer-lasting commitment to the conservation of blue penguin on the West Coast.

The aims of this group are to initiate research, to monitor the long-term changes in the population of blue penguins on the West Coast, monitor breeding ecology, and determine colony sizes and breeding pair numbers. Consequently, effective management plans can be put in place to ensure the conservation of the blue penguin on the West Coast and educate people of the problems faced by blue penguins in this region.

Local residents have indicated a decline in penguin numbers in recent years. In a recent survey of the distribution of blue penguins in the Buller region (Blyth *et al.* 2006) many local people indicated that penguin numbers had decreased in the last 30-40 years.

The purpose of this study of blue penguins in South Westland was to determine the reasons for the assumed decline in this region. This was done by studying the breeding ecology at blue penguin colonies in South Westland to assess the importance of breeding success and adult mortality to the assumed decline of penguin numbers. The importance of on-land threats, such as human disturbance and predators, was also studied through comparison of colonies at sites with and without predator control, and colonies near human settlements and in isolated areas.

The breeding ecology of the South Westland colonies was compared with a similar study conducted in the Buller region by the West Coast Blue Penguin Trust in the same breeding season, to determine the importance of differences in marine conditions on breeding productivity.

1.7 Contribution to our knowledge of the species

Although a lot is known about the blue penguin in both Australia and New Zealand, there is a lack of information about the ecology of the blue penguin on the West Coast and particularly for the southern region of the West Coast. The population of blue penguins in this region has never been studied and most aspects of their ecology, such as the timing of the breeding season, are unknown. To date, there has been only one single year study (Heber *et al.* 2008) on the breeding biology of blue penguins in the Buller region and none at all in the South Westland region.

A second West Coast study on blue penguin breeding ecology was necessary to investigate differences in breeding ecology in the Buller and South Westland regions. Potential differences between the breeding ecology of the Buller and South Westland populations may be the result of different food resources leading to a change in the timing or length of the breeding season, breeding success and the condition of the fledglings or adults measured by seasonal variation in weights.

The West Coast Blue Penguin Trust will conduct a weekly monitoring study in the approaching breeding season in the Buller region, and data from both regions will be compared. A comparison of the breeding success between the two regions in the same season may identify the importance of different threats in the two regions, any differences in the timing of the breeding season and reasons for breeding failure. A comparison of breeding biology in the two regions can highlight the relative importance of food supply and at-sea or on-land threats on population decline.

2. Aims and Objectives

2.1 Aim

To determine the reasons for the assumed decline in the blue penguin population in South Westland and compare breeding productivity with that of the Buller region.

2.2 Objectives

The aim will be achieved by fulfilling the following objectives:

Breeding biology

- To determine the dates of the breeding cycle of blue penguins in South Westland and compare these to the Buller Region.

- To determine whether South Westland penguins lay replacement clutches when an initial nest fails, or double clutch when an initial nest is successful

- To determine rates of breeding success at sites with and without predator and/ or possum control, and its contribution to the population decline in this region, and compare these to the Buller region

Reasons for breeding failure

- To identify threats to blue penguins in the study area and compare them to penguin populations in the Buller Region

- To investigate the importance of at-sea and on-land threats on adult mortality.

3. Methods

3.1 Study site selection

Study sites were selected based on information in a distribution study of the West Coast of the South Island (Blyth *et al.* 2008). The three selected sites were known to have blue penguin colonies and were accessible for field study (Figure 2). Monitoring began on 23 July 2008 and continued until the 21 December 2008, as breeding occurs within this time period in the Buller region (Heber *et al.* 2008) and there was no information on the timing of breeding elsewhere on the West Coast.

The Three Mile beach colony was visited three times a week throughout the breeding season, as this site was the largest and easiest to access. This site was important for determining the timing of the breeding cycle and the breeding success at a predator-controlled site. Two other sites at Five Mile beach and the mouth of the Wanganui River, northeast of Harihari, were monitored at least once a week. Monitoring at Five Mile Beach finished on 7 December and at the Wanganui river mouth on the 6 December, when the last chick had fledged. These two sites were visited less often as they had fewer burrows and were more difficult to access.

An initial search for burrows at Three Mile Beach was conducted in mid-June 2008 and all burrows found were numbered and tagged. In addition to burrows found during this time, a number of burrows had been marked during a distribution study conducted in 2004/05 (Blyth *et al.* 2006). Several of these burrows were found, renumbered and included in this study. These burrows had not been intensively monitored prior to this study.

After monitoring began, searches were conducted approximately once a week to find additional burrows at each of the sites. Searches for new burrows continued throughout the breeding season as vegetation in some areas made burrow location difficult. Burrows found late in the breeding season provided information about hatching and fledging dates, and success.

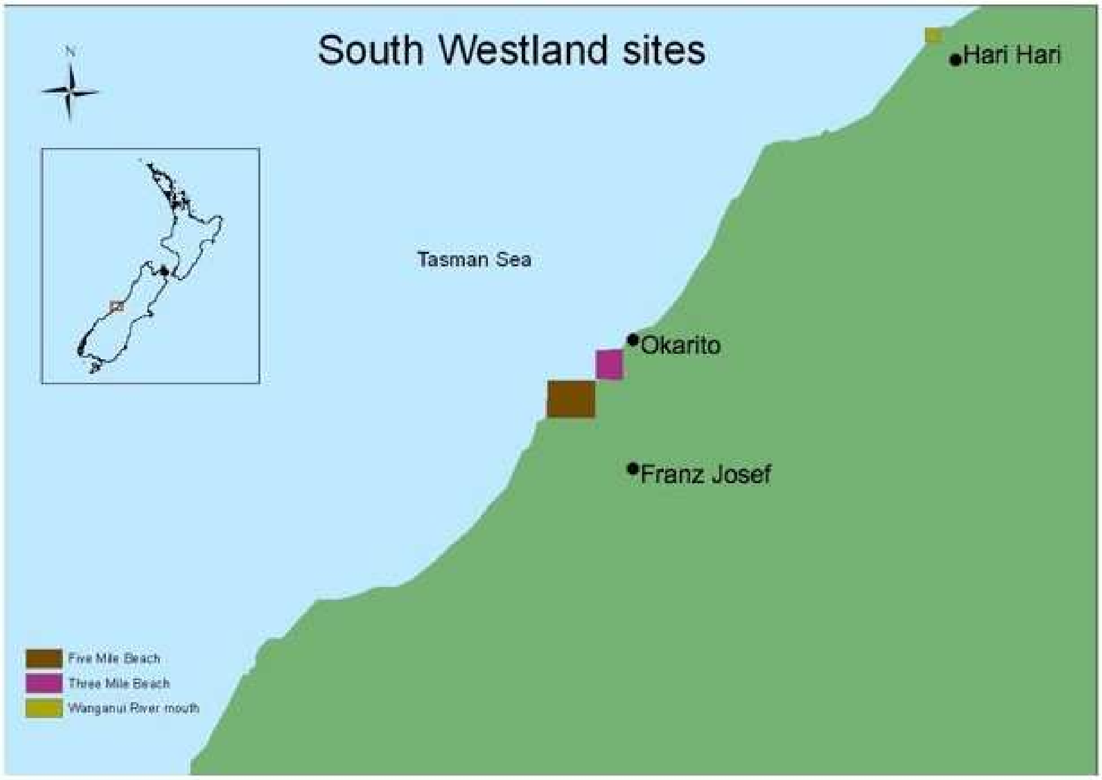


Figure 2. Map of study sites in South Westland.

3.2 South Westland sites

3.2.1 Three Mile Beach

The town of Okarito is located on the West Coast of the South Island of New Zealand. It is situated 8kms from the main highway, 25km northwest of Whataroa and 28km north of Franz Josef, the closest towns. Okarito is situated on the coast at the southern entrance of Okarito lagoon. Okarito lagoon is a coastal lagoon on the low-lying area between the mouths of the Whataroa and the Waiho rivers, which open out to the Tasman Sea. Three Mile Beach is located 4.6 km along the coast south of Okarito (Figure 3).

Burrows at this site are spread along a 3.2 km long narrow stretch of beach that is bordered by wide sand dunes with a lagoon on the eastern side of the beach. There are coastal cliffs at both ends of the beach and a smaller cliff dominates the middle of the beach. The geography of this site means that most of the burrows are within 100m of the beach, a swamp forms the inner margin of the colony. During heavy rains the Three Mile lagoon floods, creating a river that runs out to the sea.

Figure 3. Map of Three Mile Beach site.

Burrows are spread over the length of the beach and not concentrated into any one area. Most of the burrows are easily accessible to the penguins through gorse or scrub. The dunes are colonised by Golden sand sedge (*Desmoschoenus spiralis*), Knotted Club-rush (*Scirpus nodosus*) and introduced Marram grass (*Ammophila arenaria*). The beach ridge is covered in scrub vegetation dominated by gorse (*Ulex europeaus*), with New Zealand flax (*Phormium tenax*; harakeke), and Swamp astelia (*Astelia grandis*). The majority of burrows are found further inland within coastal forest containing mostly mahoe (*Melicytus ramiflorus*), Pigeonwood (*Hedycarya arbore*), akeake (*Olearia avicenniaefolia*), Soft tree fern (*Cyathea smithii*), and kiokio (*Blechnum novae-zealandiae*). Hook grass (*Uncinia uncinata*), Bracken fern (*Pteridium esculentum*, rahurahu), Bush rice grass (*Microlaena avenacea*), and kiekie (*Freycinetia banksii*) are also found in the coastal forest.

This site has a mustelid trap line that was established in November/December 2007 and runs along the top of the beach between the sand dunes and the bush edge. It consists of 15 DOC 200 stoat traps placed at approximately 150m intervals behind the fore-dune. Ian James, a supporter of the West Coast Blue Penguin Trust checks the traps fortnightly. A walking track has also been made between the bush edge and the swamp, which runs parallel to the trap line. This track is used as a poison line with 23 Kiwicare Cholecalciferol Gel Bait stations placed at intervals of approximately 150m, which are also checked fortnightly. These baits are intended for possums and are nailed at a maximum height of 1m high on tree trunks. From observations made by local residents this has already resulted in a decrease in possum numbers at this site. In 2008, a total of 26 stoats, one rat, and an unknown number of possums were killed from both trap and poison lines (I. James pers. comm.).

During the 2008/09 breeding season a total of 85 burrows were monitored, of which 56 were occupied. The majority of burrows were found near the beginning of the breeding season and were monitored throughout the whole season. Most burrows were located at the southern end of Three Mile Beach between two cliffs, while the remaining burrows were located between the sand dunes and the Three Mile Lagoon near the northern end of the beach.

The main on-land threats to penguins at this site are rats and stoats. The site is only accessible via the beach or a walking track, which ends at the northern end of the beach approximately 400m from the nearest penguin burrow. Penguin burrows are difficult to find so human disturbance is minimal. Many local residents of Okarito access the beach on ATVs but this is generally below the fore dunes and generally during daylight hours. Human associated problems, such as predation by dogs, are unlikely due to the distance from the nearest settlement.

3.2.2 Five Mile Beach

Five Mile Beach is approximately 4 km long and located directly to the south of Three Mile Beach (Figure 4). Its geography is similar to Three Mile Beach as it has coastal cliffs at both the northern and southern ends and is bordered by a large lagoon. In heavy rains the lagoon floods, creating a river that runs out to the sea and, making this beach inaccessible. Wide sand dunes run the length of the beach, except at the northern end where the beach is rocky. As at Three Mile Beach, the fore dune is mainly colonised by golden sand sedge. The beach ridge is dominated by gorse and Blackberry (*Rubis fructicosus*), which creates a wide shrub band between the beach and the coastal forest. The composition of the forest community is similar to Three

Mile Beach, although stands of Tree fuchsia (*Fuchsia excorticata*) are also found in the forest behind the bush line.

Figure 4. Map of Five Mile Beach site.

During the 2008/09 breeding season a total of seven burrows were monitored, of which six were occupied. Burrows were located on the northern half of the beach and were dug into sand beneath gorse or New Zealand flax. This site was searched on a number of occasions but the dense vegetation made finding of further burrows difficult.

There are few threats to penguins on Five Mile Beach, as it is seldom visited by walkers and is often inaccessible due to flooding. There is a gold mining claim at the southern end of the beach but this is unlikely to disturb the birds as it is only visited several times a year and is located in a habitat unsuitable for penguin burrows.

3.2.3 Wanganui River mouth

This site is located on the beach on the southern side of the Wanganui river mouth, 30km north of Three Mile Beach (Figure 5). The beach is approximately 500m long and has a cliff at the northern end, Mt Oneone (65m), a remnant of terminal moraines, and a swamp further inland.

Figure 5. Map of Wanganui River mouth site.

The fore dunes are dominated by Marram grass, and large piles of driftwood cover large sections of the dunes and beach. The vegetation at this beach is similar to the vegetation found at Three Mile and Five Mile Beaches, with a narrow band of gorse and New Zealand flax separating the dunes from the coastal forest.
A total of 24 burrows were monitored at this site, of which 14 were occupied during the breeding season. Burrows were located over the length of the beach, with the majority of burrows located in thick kiekie on the steep slope at the southern end of the beach. These burrows were located up the cliff face and were reached via one access point at the base of the cliff. During the breeding season spring storms changed the shape of the beach and created a steep sand bank making access for the birds very difficult.

This site is accessible to walkers as the beach is part of the Harihari Coastal Walkway. During the summer months many walkers use the beach and during spring white baiters frequent the nearby river mouth. Access by ATV or motorbike is limited due to the size and surface of the track. Although walkers are unlikely to disturb penguins or their burrows, dogs may be problem if they are not leashed. There have been no known dog kills of penguins at this site.

There is a small colony of Sooty Shearwaters (*Puffinus griseus)* at the summit of Mt Oneone at the northern end of the beach. A trapping program was started in 2005 and has been run by DOC and community volunteers every summer to reduce the predator numbers near this colony. A total of 24 DOC 200 traps have been placed at intervals of 100m along the walking track from the car park to the southern end of Poerua Beach. These traps are set and baited during the spring and summer months when predators are most active and they are checked fortnightly. In 2008, trapping started on 11th October and continued until April 2009. The trapline ends short of the majority of penguin nests in the colony (~200m) and the majority of eggs had hatched and chicks had begun to fledge when trapping started. Consequently, this site was treated as untrapped for analytic purposes, as any effects of trapping would not have had time to have an impact on breeding success.

3.3 Buller Sites

During the course of this study five blue penguin colonies in the Buller region were also monitored throughout the 2008/09 breeding season (Figure 6). The sites were monitored weekly, starting 3 July 2008 and finishing 8 January 2009. Three of the sites (Nile Knoll, Darkies Creek and Doctors Creek) were also monitored in 2006/07 by Sol Heber (Lincoln University). In 2008/09 all five colonies were monitored by Matt Charteris and Reuben Lane, working for the West Coast Blue Penguin Trust.

3.3.1 Nile River mouth

This colony is located at the northern side of the Nile River mouth and is the largest colony of blue penguins in the Buller Region. The colony is situated on a hill in regenerating coastal vegetation that is predominantly pigeonwood, kamahi, mahoe, kiekie and several species of coprosma (*Coprosma* sp.). Rimu (*Dacrydium cupressinum*), toro (*Myrsine salicina*), and Lancewood (*Pseudopanax crassifolius,* horoeka) are also present.

Burrows are mainly located under tree stumps, in rock crevices or under rock outcrops in the ground. This site contained 58 natural burrows, of which 29 were occupied, and 14 nest boxes (five occupied), all of which were monitored.

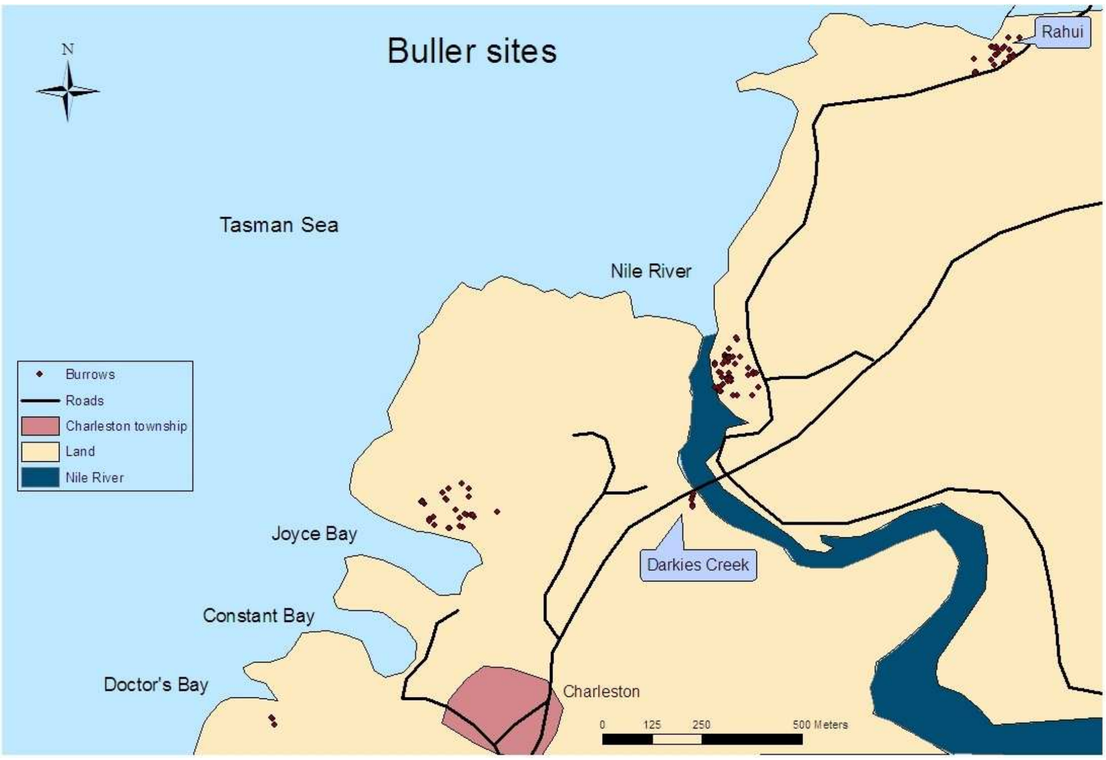


Figure 6. Map of Buller study sites.

3.3.2 Joyce Bay

This site is located north of Charleston township and has similar vegetation to the colony at the Nile River mouth although this site has an abundance of kiekie. The majority of burrows at this site are located in crevices and small caves amongst jumbled rocks, and there are two main penguin access points through rock outcrops. 56 natural burrows were monitored at this site, of which 41 were occupied.

3.3.3 Rahui

This site is located to the north of the Nile River mouth and has similar vegetation to the Nile River colony. There were 19 natural burrows at this site, of which eight were occupied, and ten nest boxes, two of which were occupied.

3.3.4 Doctor's Bay

Doctor's Bay is located to the south of Joyce and Constant Bay in the Charleston area. The bay is surrounded by coastal cliffs and vegetation is characterised by New Zealand flax, hebe (*Hebe elliptica*, korohika), bracken and gorse. At the southern end of Doctor's Bay is a walkway where the scrub opens out into a patch of forest, containing manuka (*Leptospermum scoparium*), rimu, and mahoe. Three burrows were monitored at this site and only one was occupied by penguins.

3.3.5 Darkies Creek

Darkies Creek is a small tributary of the Nile River running parallel to SH 6. The vegetation in this area is characterised by broadleaf (*Griselinia* sp.), mahoe, kiekie, northern rata (*Metrosideros robusta*), supplejack (*Ropogonum scandens*, karewao), kamahi, rangiora (*Brachyglottis repanda*), manuka, New Zealand flax and kiokio (*Blechnum novae-zealandiae*). At this site there were eight burrows, only one of which was occupied.

3.4 Nest monitoring

Burrows were checked with the help of a burrowscope. The burrowscope is a miniature video camera on the end of a tube inserted into the burrow (Figure 7). The camera end of the burrowscope was placed in the end of the burrow and then turned on. The contents of the burrow were viewed by slowly pushing the burrowscope into the entrance and guiding it past any obstacles (e.g. debris or tree roots). Sometimes a burrow had several branches that need to be checked.
Any sounds coming from inside the burrow were recorded as an adult penguin may sometimes make a warning noise to discourage predators.

After inspecting the contents of a burrow, a line of sticks was placed across the entrance/s to form a fence that the penguin would knock down during visits to the burrow. Sticks were placed close enough so that the adult penguin could not squeeze through and had to knock the sticks over.

The number of eggs and chicks were recorded as well as the date of laying, hatching or fledging. When the date of hatching was unknown, for example due to the egg not being observed immediately after laying, the estimated laying date was calculated using either the hatching or fledging date.

Figure 7. Burrowscope and monitor.

The estimated fledging date was determined as the date the chick was last seen if it disappeared more than 49 days after hatching. The laying date was determined by subtracting 90 days from the fledging date. This 90-day period includes a nestling period of approximately 54 days and an incubation period of approximately 36 days (Heather & Robertson 2005).
The laying, hatching and fledging dates were assigned a date value, starting from July 1 = 1 until the last recorded fledging date.

When nest contents were missed due to debris or other obstructions in the burrow, the contents would usually be seen on subsequent visits. If chicks and eggs were not seen in the burrow for two consecutive visits, nest predation (or desertion) was considered as a possible outcome.

Sometimes the adult would remove an egg from a burrow and these were often found outside the burrow. Eggs found outside a burrow were cracked to see if there was any development of the embryo and if an egg showed any development, it was recorded as fertile. When an egg was deserted in a burrow (adult absent) on two consecutive visits, it was removed if possible, and cracked it to see if it was infertile.

3.5 Penguin weighing and measuring

Adult penguins were weighed twice during the 2008/09 breeding season. The first weighing was over four nights between 28th August and 6th September 2008 (Appendix 1).

All birds were caught on Three Mile Beach as this was the most accessible site and had the largest colony. All birds were captured as they returned from foraging as weight can differ significantly before and after foraging.

Weighing the adult birds away from the nest reduces the stress to the animal as well as to any chicks in the nest. It means that non-breeding birds were also caught and weighed.

Beginning at dusk and for a period of 2-3 hours afterwards, the beach was traversed several times and any penguins seen were captured by hand or in a small net. The bill length, width and depth were measured using a vernier calliper (±0.1mm) and the flipper length was measured using a standard ruler. The birds were then placed in a cotton bag and weighed using a Pesola scale (±10g). The birds were released up the beach closer to the start of the vegetation in an effort to prevent them returning straight to the sea. Nearly all birds (90%) moved toward their burrows rather than returning to the sea.

As none of the birds captured were banded it was difficult to determine if they were recaptured on subsequent nights. In an effort to remedy this, GPS coordinates were taken at the location the bird was captured, if still on its original route from the sea. Birds with the same measurements on subsequent nights at or close to the location were discarded from the data pool.

A second attempt was made at the end of the breeding season to weigh the adult birds. The weighing occurred over two nights between 5th and 7th December 2008 (Appendix 2). Only five birds were captured during this time as most chicks had fledged and adult birds were either at sea or moulting. Any birds weighing over 1300g were considered to be moulting birds and were excluded from the data pool. The final data pool contained measurements for 23 birds.

At the South Westland sites, chicks were weighed twice during the breeding season, at the end of the guard stage and immediately before fledging to determine weight gain. 16 chicks from 11 burrows at Three Mile and Five Mile Beaches were weighed at the end of the guard stage (Appendix 3). 10 chicks from seven burrows over the three sites were weighted prior to fledging (Appendix 4). For the first weighing, the chicks were weighed on the first visit after both adult birds had left the burrow. Chicks were removed from the nest, placed in a cotton bag and weighed using a Pesola scale (±10g). The chicks were weighed for the second time 50 days after hatching.

In addition to weighing, bill length, width and depth were measured using a vernier calliper (±0.1mm) and the flipper length was measured using a standard ruler.
As many chicks as possible were weighed during the breeding season, although many burrows were not accessible. Burrows recorded as inaccessible continued to be monitored for outward sign of chick activity.

3.6 Statistical Analysis

A variety of statistical tests were performed on the data to test for differences between the two regions, treatment areas, sites, and breeding seasons. Mean dates and standard errors were calculated and the dates were compared using an unbalanced ANOVA. The hatching, fledging and breeding successes were calculated and compared using a Generalised Mixed Model with a binomial distribution (Schall 1991). A Chi-square test was used to test the proportion of fledglings produced for each burrow, and the proportion of each clutch size. T-tests were used to compare the measurements and weights of both fledglings and adult birds between locations. The statistical models were performed in GenStat 11.1 and graphs were created in Microsoft Office Excel 2004.
Due to the frequency of burrow monitoring at different sites, some of the calculations were made using only the Three Mile site data from South Westland.

4. Results

4.1 Onset of breeding

Egg laying began in late July and continued until the end of October, with most egg laying occurring in August in South Westland. The mean date of egg laying for all sites was 25 August (26 July- 28 October; n = 128). The mean date of egg laying at Three Mile Beach was 27 August (26 July – 28 October; n = 94); at Five Mile Beach 23 August (3 August – 12 September; n= 12); and at Wanganui River mouth 19 August (31 July – 1 September; n = 22).

In the Buller region, egg laying also began at the end of July and continued until the middle of October. The mean date of egg laying for all sites was 4 September (29 July-10 October; n = 99). The mean date of egg laying was 30 August (29 July-10 October; n = 49) at the trapped sites, and 10 September (10 August- 10 October; n = 50) at the untrapped sites.

The latest laid egg that was known to hatch and fledge in South Westland, was laid on the 18 September in a nest at Three Mile Beach. Two chicks hatched in this nest between the 14 and 17 October, and these chicks had both fledged by the 10 December 2008.

In Buller, the latest eggs were laid in several nests in Joyce Bay and Nile River mouth on 10 October. All of these late laid eggs hatched by the 15 November, and fledged by the 8 January 2009.

An unbalanced ANOVA was performed on the data to compare the laying date in each region. The mean laying date in Buller was significantly later than the mean laying date in South Westland ($F = 12.7$; d.f. = 1; $p < 0.001$). The mean laying date for Buller sites over the 2006/07 breeding season was also compared. There is evidence that breeding started earlier in 2006/07 compared to 2008/09 ($F = 5.14$; d.f. = 1; $p = 0.024$), and in trapped sites compared to untrapped sites ($F = 6.14$; d.f. = 1; $p = 0.012$).

The stage at which each nest was found was compared between trapped and untrapped sites in South Westland and Buller to determine if monitoring effort (the

length of time a nest was monitored) had a significant effect on calculated breeding success. Nests were placed into one of three categories depending on when they were first found, 1) before hatching, 2) during incubation, and 3) after hatching (Table 1). The proportion of nests in each category was compared using a chi-square test.
No significant difference was found between the stage that nests were found in trapped and untrapped sites in South Westland (χ^2 = 2.84; d.f. = 2; $p > 0.05$), or Buller (χ^2 = 4.34; d.f. = 2; $p > 0.05$).

Table 1. Stage of breeding cycle when nests were found in South Westland and Buller.

Site	*Before hatching*	*During incubation*	*After hatching*
S. Westland (trapped)	36	3	11
S. Westland (untrapped)	6	2	1
Buller (trapped)	35	0	2
Buller (untrapped)	29	1	9

4.2 Clutch size

Three nests (5.6%) in which a breeding attempt was made and two nests (3.6%) that only produced one chick were excluded from the calculation as it was unknown whether one or two eggs were initially laid.
During this breeding season, 69 clutches of two eggs (95.8%) and 3 clutches of one egg (4.2%) were recorded resulting in a total of 141 eggs laid by 72 breeding pairs in South Westland. In the Buller region, 50 clutches (94.3%) of two eggs and 3 clutches (5.7%) of one egg were laid by 53 breeding pairs. Where only one egg was found it is possible that two eggs were laid and one disappeared before it was observed in the nest. If only one egg was observed in a nest, it was assumed that only one egg was laid.

A Chi-squared test of the proportion of clutch sizes found that there was not a significant difference between the number of two- and one egg-clutches in each region during the 2008/09 breeding season. These results were also compared to the number of clutches from the 2006/07 breeding season in Buller, and there is evidence of a higher than expected number of one-egg clutches in 2006/07 in Buller compared to 2008/09 ($\chi^2 = 11.57$; d.f. = 2; p = 0.003).

The mean number of eggs laid per breeding pair was 1.96 in South Westland, and 1.94 in Buller in 2008/09.

4.3 Double Brooding

A second clutch was laid in one burrow at Three Mile Beach in South Westland on 28 October. Two eggs were laid in the burrow when the chicks from the first clutch were 5 weeks old. These eggs were deserted 15-17 days after laying as the adult birds visited the burrow daily but the eggs were only incubated for a short period. The eggs failed to hatch and it is unknown if they were laid by the breeding pair occupying the burrow or by a visiting adult.

4.4 Hatching dates

The hatching dates ranged from 31 August to 20 November 2008 in South Westland, with the mean calculated hatching date being 30 September (n = 103). At Three Mile Beach the mean hatching date was 1 October (31 August- 20 November; n = 73); at Five Mile Beach the mean hatching date was 2 October (6 September -19 October; n = 12); and at Wanganui River mouth the mean hatching date was 22 September (5 September -11 October; n = 18).

In Buller, the mean hatching date was 12 October and ranged from 2 September until 15 November (n = 84). The mean hatching date was 6 October (2 September- 15 November; n = 44) at the trapped sites, and 18 October (15 September- 15 November; n = 40) at the untrapped sites.

Due to the later onset in breeding in Buller this breeding season, hatching dates were also significantly later than in South Westland (F = 13.67; d.f. = 1; $p < 0.001$). In a comparison between hatching dates in Buller from 2006/07 to 2008/09, hatching occurred significantly later in 2008/09 (F = 20.71; d.f. = 1; $p < 0.001$).

4.5 Hatching success

The hatching success was defined as the proportion of eggs in a nest that hatched relative to the number of eggs laid. Out of 135 eggs laid in South Westland, 109 survived to hatching, resulting in an overall hatching success of 80.7%. At the Three Mile site, a total 77 out of 96 eggs survived to hatching resulting in a hatching success of 80.2%. At the Five Mile site 12 eggs were laid and all hatched, giving a hatching success of 100%. At the Wanganui River site, 20 out of 27 eggs survived to hatching, resulting in a hatching success of 74.1%.

In Buller, 62 eggs hatched, giving an overall hatching success of 76.5% (n = 81). The untrapped sites were found to have a hatching success of 78.4% (n = 37). The trapped sites had a hatching success of 75% (n = 44).

A Generalized Linear Model (GLM) for a binomial distribution was performed on the data to determine differences in hatching success between areas and treatments. In Buller, trapped sites had a slightly higher hatching success whereas in South Westland untrapped sites had a higher hatching success. However there was no significant difference in hatching success between location ($F = 0.64$; d.f. = 1; $p > 0.05$), or treatment ($F = 0.18$; d.f. = 1; $p > 0.05$).

There was also no difference between the hatching success in Buller in this study and the hatching success over the 2006/07 breeding season ($F = 1.58$; d.f. = 1; $p > 0.05$).

Eight nests at Three Mile Beach were excluded when calculating the hatching success. In 5.6% (n=3) of these nests, two eggs were laid but only one chick fledged and it is unknown whether the egg failed to hatch or the chick was taken at a young age before it was observed in the nest. At 5.6% (n=3) of the nests, a breeding attempt was known to occur but the exact number of eggs and chicks were never observed due to the angle and/or length of the burrow. Two burrows (3.6%) were excluded because they were found late in the breeding season and each contained only one chick, so it was unknown whether one or two eggs had been laid initially.

In total, 27 eggs failed to hatch or were deserted on the nest over the three sites. Of these, 29.6% (n = 8) were collected from the nest for further inspection. The remaining eggs disappeared and were either removed by the parent or a predator and never found, or crushed into the nest floor. Of the eight eggs recovered, seven were found to be infertile (87.5%) and one contained a well-developed embryo (12.5%).

The cause of death of this fertile egg was unknown. The age of the egg was unknown and the egg may have been deserted by the parent and subsequently expelled from the nest at a later date or the embryo may have ceased development for some other reason. Predation is unlikely as the egg was undamaged when found outside the nest. For 50% of the recovered eggs (n = 4) the laying date was unknown so it is possible that the eggs were deserted or expelled from the nest at an early age before development occurred. The eggs with known lay dates were incubated for between 34-69 days before being abandoned. Of the eggs that were deserted in burrows and were not recovered, three eggs were incubated for 46, 72 and 77 days each before being abandoned.

In two cases, an egg was found outside that could not be attributed to a nearby nest. In this case each egg was regarded as coming from a separate unknown burrow.

4.6 Guard period

The guard stage is defined as the period between the date of hatching of the first chick and the date the chick(s) are first left alone in the burrow while both parents forage at sea. In South Westland, the mean length of the guard period was 21 days (21.3 ± 1.6; n = 23) and ranged from 14 to 39 days. The mean length of guard period for clutches with one chick was 29 days (28.6 ± 2.6; n = 8) and for clutches with two chicks, 17 days (17.4 ± 1.0; n = 15) (Figure 8).

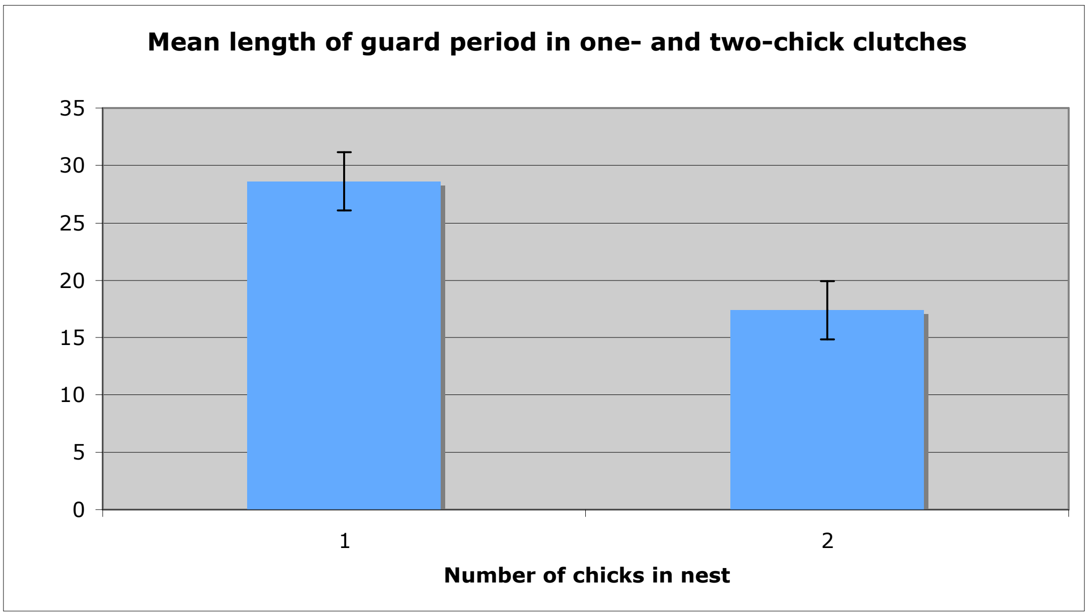


Figure 8. Mean length of guard period in one- and two- chick clutches.

A Mann-Whitney U test was performed on the data to see whether the number of chicks in a clutch influenced the length of the guard period. The length of the guard period was found to be significantly longer ($U = 6.5$; d.f. = 1; $p < 0.001$) in burrows that only had one chick compared to burrows containing two chicks.

A regression analysis was performed to determine if the length of the guard period in a nest was influenced by the hatching date of the chicks (Figure 9). There was no significant trend between the length of the guard period and hatching date ($F = 0.722$; d.f. = 1; $p > 0.05$).

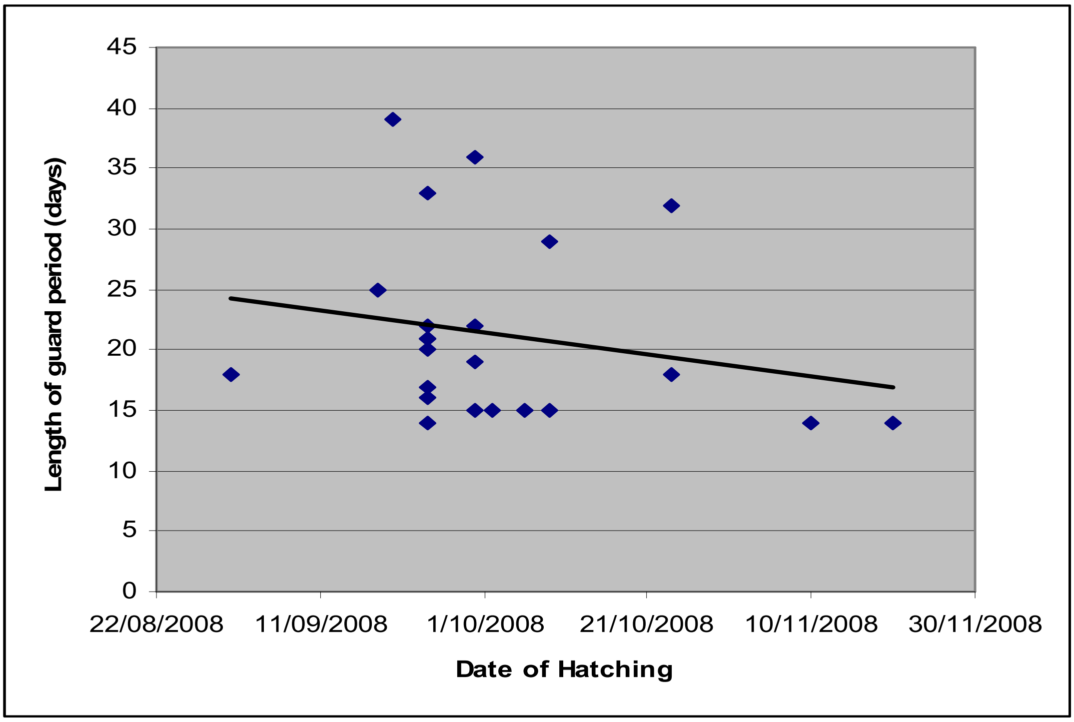


Figure 9. The relationship between date of hatching and length of guard period.

4.7 Fledging dates

The fledging date at South Westland sites ranged from 21 October to 10 December 2008, with the mean fledging date being 19 November (n = 99). At Three Mile Beach, mean fledging date was 20 November (21 October to 10 December; n = 75); at Five Mile Beach the mean fledging date was 11 (30 October to 7 December; n = 10); and at Wanganui River the mean fledging date was 15 November (29 October to 6 December; n = 14).

The Buller sites had a combined mean fledging date on 7 December and dates ranged from 7 November to 8 January 2009 ($n = 79$). The mean fledging date at the trapped sites was 3 December (7 November- 8 January; $n = 41$). At the untrapped sites the mean fledging date was 11 December (8 November- 8 January; $n = 38$).

The mean fledging date was significantly later in Buller compared to South Westland ($F = 49.36$; d.f. = 1; $p < 0.001$), and later in 2008/09 in Buller compared to 2006/07 ($F = 30.14$; d.f. = 1; $p < 0.001$).

4.8 Fledging success

The fledging success was defined as the proportion of chicks that left the nest relative to the number of chicks that hatched. A chick was recorded as fledged if it disappeared from the nest no earlier than 7 weeks after hatching. Out of 106 chicks that hatched in South Westland, 105 chicks survived to fledging, resulting in an overall fledging success of 99.1%. At the Three Mile site a total of 73 out of 74 chicks survived to fledging, resulting in a fledging success of 98.6%. At the Five Mile and Wanganui River sites, all chicks survived to fledging giving a fledging success of 100% ($n = 12$ and 20, respectively).

In Buller, 54 chicks survived to fledging, resulting in an overall fledging success of 88.5% ($n = 61$). The untrapped sites (Joyce Bay, Doctors Bay and Darkies Creek) were found to have a fledging success of 86.2% ($n = 29$) and the trapped sites (Nile Knoll and Rahui), had a fledging success of 90.6% ($n = 32$).

The fledging success was significantly higher in South Westland compared to Buller ($F = 5.70$; d.f. = 1; $p = 0.017$). There was no evidence that treatment in either location had an effect on fledging success ($F = 0.078$; d.f. = 1; $p > 0.05$), and there was no significant difference ($F = 1.69$; d.f. = 1; $p > 0.05$) between the fledging success in Buller during the 2006/07 and 2008/09 breeding seasons.

A number of nests were excluded from the calculation of fledging success. One nest still contained unhatched eggs when burrow monitoring finished and consequently the fate of this nest is unknown. In one other nest, it was unclear whether the chick fledged as the burrow was too long to see into.

Chicks from the same nest fledged on average 2 days apart (mean 1.63 ± 0.5, $n = 19$), with fledging intervals ranging between 0 and 8 days (0 days 52.6%; 2 days 15.8%; 3 days 21.1%; 5 days 5.3%; and 8 days 5.3%) (Figure 10). Only nests with accurate fledging dates were used in this calculation and only data from the Three Mile site were used as these nests were checked every 2 to 3 days.

One chick was found dead outside a nest on Three Mile Beach. Predation was ruled out as a cause of death as the chick was undamaged. The chick was approximately 28 days old and came from a two-chick clutch. Although the chick was not weighed, it was very small (20-25cm long) compared to its sibling, which was captured and weighed five days later. Cause of death is likely to be due to starvation caused by competition for food between chicks or another natural cause.

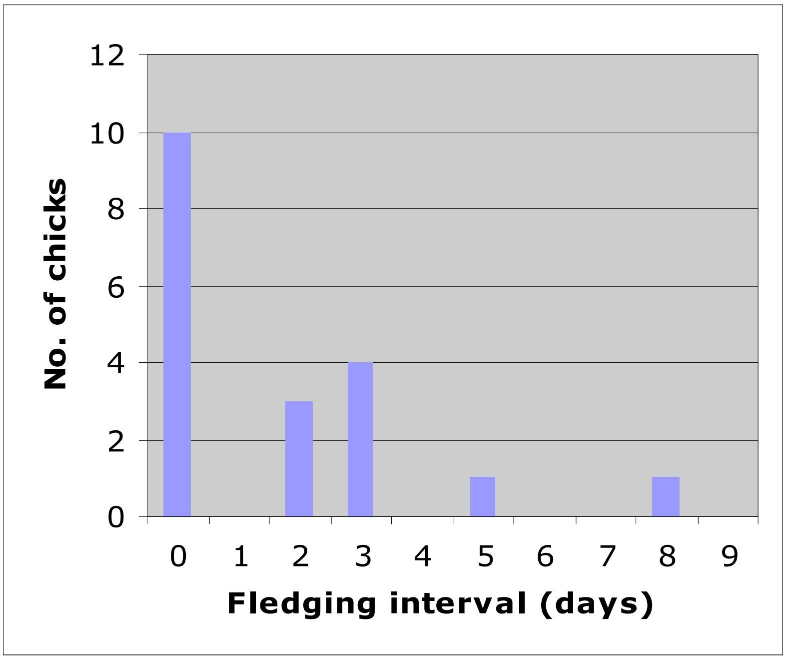


Figure 10. Length of fledging interval for chicks from the same nest with known fledging dates.

4.9 Breeding success

Breeding success is defined as the number of chicks that fledged relative to the number of eggs laid. Out of 137 eggs laid in South Westland, 108 chicks survived until fledging, giving an overall breeding success of 78.8% (Figure 11). At the Three Mile site, 76 chicks fledged, resulting in a breeding success of 77.6% (n = 98). At the Five Mile site, all eggs laid survived to fledging, giving a breeding success of 100%. At the Wanganui River site, 20 chicks from 27 eggs survived to fledging, giving a breeding success of 74.1%.

In Buller, 64 chicks survived to fledging from 101 eggs laid, resulting in an overall breeding success of 63.4%. The untrapped sites were found to have a breeding success of 64.4% (n = 45) and the trapped sites had a fledging success of 62.5% (n = 56).

A GLM was used to determine whether breeding success differed between the two sites with no predator control in South Westland (Five Mile Beach and Wanganui River mouth). These two sites were found to have no significant difference ($F = 2.62$; d.f. = 1; $p = 0.757$) and were combined in further statistical tests to determine the effect of predator control. Sites in Buller that underwent predator control were combined into one site as were sites that had no predator control.

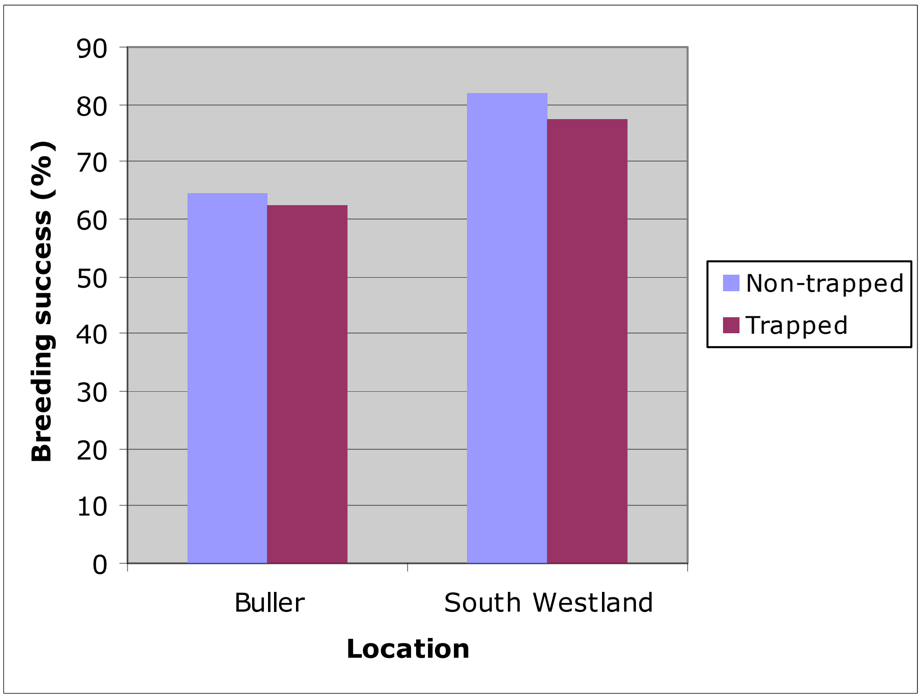


Figure 11. The breeding success at each treatment site in South Westland and Buller.

A comparison of study sites and treatments areas, i.e. trapped and untrapped, using a GLM, found that breeding success was significantly higher in South Westland, ($F = 7.08$; d.f. = 1; $p < 0.05$) compared to the Buller sites. The breeding success was generally higher in untrapped areas compared to trapped areas but was not significantly different ($F = 0.29$; d.f. = 1; $p > 0.05$).

The breeding success was slightly higher over the 2006/07 breeding season in Buller compared to this season, but not significantly so ($F = 0.26$; d.f. = 1; $p > 0.05$).

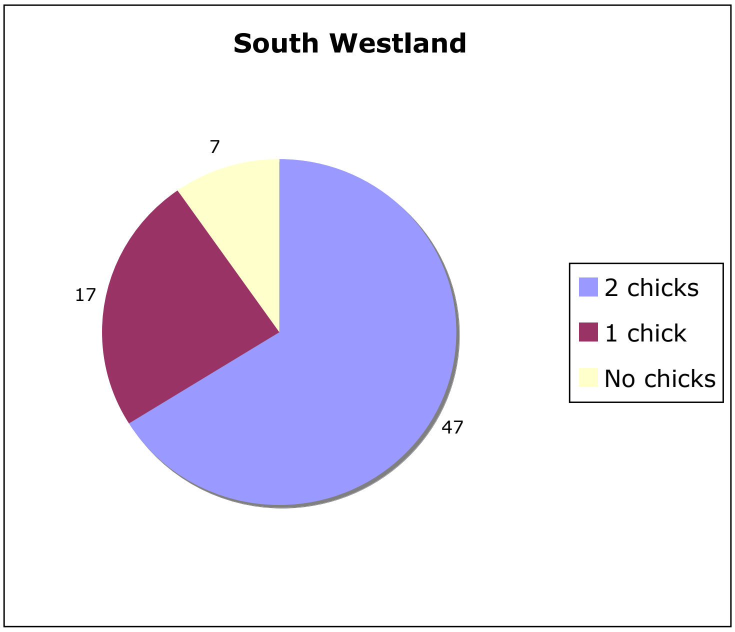
Seven burrows were excluded from the calculation of breeding success. One late breeding burrow still contained unhatched eggs when burrow monitoring finished and consequently the fate of this burrow is unknown. In one other burrow, it was unclear whether the chick fledged as the burrow was very difficult to see into. Two burrows were excluded because they were found late in the breeding season and each contained only one chick, so it was unknown whether one or two eggs had been laid initially. In three of the burrows, a breeding attempt was known to occur but the exact number of eggs and chicks were never observed due to the angle and/or length of the burrow.

From a total of 71 breeding pairs at South Westland sites, 66.2% produced two fledglings ($n = 47$), 23.9% produced one fledgling ($n = 17$), and 9.9% produced no fledglings ($n = 7$) (Figure 12).
At the Buller sites, out of a total of 74 breeding pairs, 29.7% produced two fledglings ($n = 22$), 56.8% produced one fledgling ($n = 42$), and 13.5% produced no fledglings ($n = 10$).

A comparison of the numbers of fledglings produced found that the proportion of nests that only produced one chick was higher in Buller than South Westland, over the 2008/09 breeding season ($\chi^2 = 21.63$; d.f. = 4; $p = 0.001$). There was no significant difference in the number of fledglings produced in each burrow over the 2006/07 breeding season compared to 2008/09.

The number of fledglings produced per pair is a common measure used to indicate breeding productivity. The mean number of chicks fledged per pair that produced eggs was 1.55 ($n = 71$) in South Westland and 1.16 ($n = 74$) in Buller. Four nests were excluded from this calculation, as the number of fledglings in each was unknown although there was a breeding attempt in each nest. Another nest was excluded because the chicks were due to leave late in the breeding season after monitoring had finished.
The mean number of fledglings produced for all pairs (breeding and non-breeding) in South Westland was 1.38 ($n = 80$) and in Buller, 0.96 ($n = 90$). The breeding pairs

excluded from the fledging-per-pair analysis were added to this calculation as well as four adult pairs that didn't breed this season.



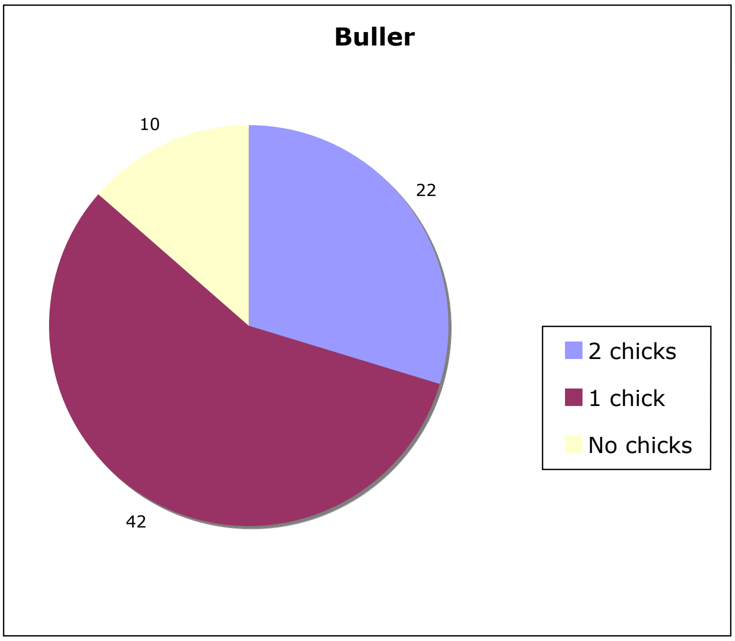


Figure 12. Fledglings produced per breeding pair in South Westland and Buller during the 2008/09 breeding season.

4.10 Occupied burrows

The proportion of occupied burrows out of the total number of burrows at a site is another indicator of the productivity of the site. A burrow was considered to be occupied if a breeding attempt was made, regardless of whether it was successful or not. The proportion of occupied burrows at each site was compared to determine the effect of location or treatment on breeding productivity. The overall proportion of occupied breeding burrows compared to the total number of suitable burrows at the South Westland sites was 73.8% ($n = 103$). The proportion of occupied burrows was 69.0% ($n = 29$) for the combined non-trapped sites and 75.7% ($n = 74$) for the trapped site (Three Mile Beach). At the Buller sites, only 60.3 % ($n = 151$) of the total number of burrows was occupied. In the untrapped sites 64.2% ($n = 67$) of burrows were occupied and in the trapped sites only 57.1% ($n = 84$) of burrows were occupied.

There were a significantly higher proportion of occupied burrows at South Westland compared to Buller 2008/09 ($F = 5.27$; d.f. = 1; $p = 0.022$) over all sites. No significant difference was found between the proportion of occupied burrows in trapped and untrapped sites ($F=0.53$; d.f. = 1; $p > 0.05$) within locations. The higher proportion of occupied burrows in trapped sites at Buller compared to the non-trapped sites resulted in a near-significant Wald statistic ($F = 3.317$; d.f. = 1; $p= 0.069$) for location-treatment interaction.

A GLM with a Bernoulli distribution was used to determine if there were any differences between the proportions of occupied burrows between breeding seasons from 2006/07 to 2008/09 in Buller. There was a significant difference in number of occupied burrows over the years ($F = 23.10$; d.f. = 2; $p < 0.001$).

The burrows where no breeding attempt was made were further categorized as being occupied by a non-breeding pair, visited throughout the breeding season, or not visited. The number of visits to each burrow was determined by the number of times the control fence had been knocked down and how often birds were observed or heard in the burrow. Burrows were considered to be occupied if they were visited at least once a week throughout the breeding season. A burrow was recorded as visited if the control fence was knocked over at least once during the breeding season.
Twelve burrows that were monitored in South Westland were suitable for breeding but were not occupied by a breeding pair. Of these, 67% ($n = 8$) of the burrows were considered to be occupied by a non-breeding bird or pair (Figure 13).

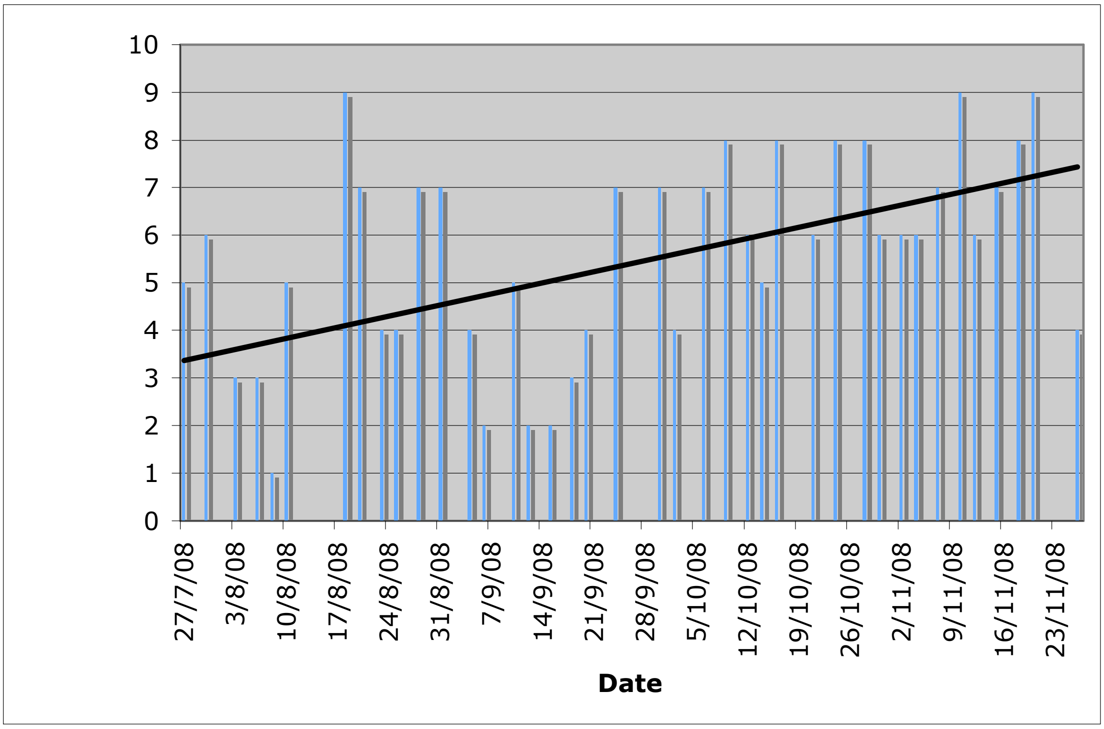


Figure 13. The number of burrows visited throughout the breeding season.

There was a significant effect of date on the number of visits to a burrow ($F = 13.83$; d.f. = 1; $p < 0.001$). This indicates that the frequency of burrow visits increased throughout the breeding season.

A number of unoccupied burrows were considered to be unsuitable for breeding. There were several criteria by which a burrow was deemed to be unsuitable. If the burrow was in a location that was prone to flooding, such as near a swamp or had a downward sloping entrance, and was seldom, if ever, visited throughout the season, it was unlikely to attract a breeding pair. Burrows that were very short (<0.5m) were also considered unsuitable.

Of the burrows considered to be unsuitable for breeding in South Westland, 8.3% (n = 1) were occupied by another species (possum), 17% (n = 2) were prone to flooding, 58% (n = 7) were too short, 8.3% (n = 1) had collapsed, and 8.3% (n = 1) was originally a rabbit burrow. Of the total number of burrows monitored in South Westland, only 10.4% (n =12) were unsuitable for breeding pairs.

At the Buller sites a total of 22 burrows were considered unsuitable for breeding. Nearly half the burrows (45.5%; n = 10) were too short (< 0.5m). Another 36.7% (n = 8) were not enclosed burrows and were likely to be used as corridors to other burrows. One burrow (4.5%) was too tight to be suitable for penguins. The remaining three burrows (13.6%) were too wet and easily flooded to allow penguins to breed inside.

There were no nest boxes at any of the sites in South Westland. At the sites monitored in Buller there were 14 nest boxes at the Nile River mouth and ten nest boxes at Rahui. Nest boxes were first placed in the Nile River mouth in early 2004 and the last nest boxes were put in place in February 2006 (Heber 2006). At Rahui the nest boxes were put in place in July 2008 at the beginning of the breeding season (M. Charteris, pers. comm.). During the 2006/07 breeding season, two of the 14 nest boxes at Nile River mouth were occupied (Heber 2006). During 2008/09, five nest boxes were occupied at Nile River mouth and two were occupied at Rahui. Although an increase from 2006/07, these results are not necessarily indicative of an increase in penguin numbers at this site as during the 2006 breeding season, seven of the 14 nest boxes at the Nile River mouth colony were occupied at some stage during the study period (Blyth *et al.* 2006). The breeding success in nest boxes at the Nile River mouth was 70% (n = 5) compared to a breeding success of 51% (n = 18) in natural burrows. At Rahui, the breeding success could only be calculated for one of the nest boxes, which was 100%, as it is not known how many eggs were initially laid in the second nest box. The natural burrows at Rahui had a breeding success of 89% (n = 6).

4.11 Weights and Measurements

A total of 23 adult penguins were weighed at Three Mile Beach over three nights from 28 August to 6 September at the end of egg laying (Table 2).

Table 2. Mean weights and measurements of adult penguins at Three Mile Beach.

	Weight (g)	***Bill length (mm)***	***Bill depth (mm)***
Mean	1240.6 ± 37g	33.65 ± 0.64mm	18.11 ± 0.42mm
Range	880-1540g	29-41mm	14-22mm
N	23	23	22

Adult penguins were weighed twice at several sites in Buller during the breeding season. Six birds were weighed at Charleston Knoll on 20 August, 22 birds at Joyce

Bay on 21 August, and six birds at Pahautane Beach on 23 August 2008 (Appendix 5).

The mean adult weight in Buller over all sites at the beginning of the season was 1116.5g ± 27 (n = 34). At Charleston Knoll the mean weight was 1005g ± 74 (n = 6), at Joyce Bay mean weight was 1163.2g ± 29 (n = 22), and at Pahautane Beach mean weight was 1056g ± 66 (n = 6).

The birds were weighed again at the end of the season at Charleston Knoll on 12th and 17th December, and at Joyce Bay on 12th and 15th December 2008 (Table 3) (Appendix 6).

Table 3. Mean weights and measurements of adult penguins in Buller (end of breeding season).

	Weight (g)	*Flipper length (mm)*	*Bill length (mm)*	*Bill width (mm)*	*Bill depth (mm)*
Mean	1098.7	114.9	35.3	11.1	16.2
Range	820- 1260	110-119	31.4-37.5	9.2-15.5	13.9-19.2
N	8	11	12	12	12

A t-test was performed using the adult weight data from the beginning of the breeding season and found that the weight of adult birds in Buller was significantly lower than those in South Westland ($t = -2.76$; d.f. = 55; $p < 0.05$).

The mean weight of post-guard chicks in South Westland was 833.6g (n = 14), with a range of 405-1380g.

Table 4. Mean measurements of pre-fledging chicks at South Westland sites.

	Weight (g)	*Flipper length (mm)*	*Bill length (mm)*	*Bill width (mm)*	*Bill depth (mm)*
Mean	1138 ± 23.7	112 ± 1.5	28.3 ± 1.5	8.2 ± 0.4	12.7 ± 0.5
Range	980-1270	106-117	21.7-30.4	7.2-9.1	11.1-14.4
N	10	6	6	6	6

Table 5. Mean measurements of pre-fledging chicks at Buller sites (Appendix 7).

	Weight (g)	*Flipper length (mm)*	*Bill length (mm)*	*Bill width (mm)*	*Bill depth (mm)*
Mean	950 ± 170	113	28.9	8.7	12.4
Range	780-1120	110- 117	25.7-33.2	7.9- 10.3	11.4- 13.9
N	2	3	3	3	3

A comparison between the weight of chicks at the end of the guard period and pre-fledging, was not possible as the sample size of burrows where both measurements were taken was too small for analysis.

A comparison of fledging weights between chicks in the two regions (Tables 4 & 5), found that there was not a significant difference between them ($t = -1.1$; d.f. = 1; $p > 0.05$), but this may have been due to the small sample size in Buller.

A Mann Whitney U test was carried out to determine if there was a difference in the weight gain between chicks with and without siblings. There was found to be no significant difference ($U = 4$; d.f. = 1; $p > 0.05$) between the weight gain but this may have been due to a very small sample size ($n = 6$).

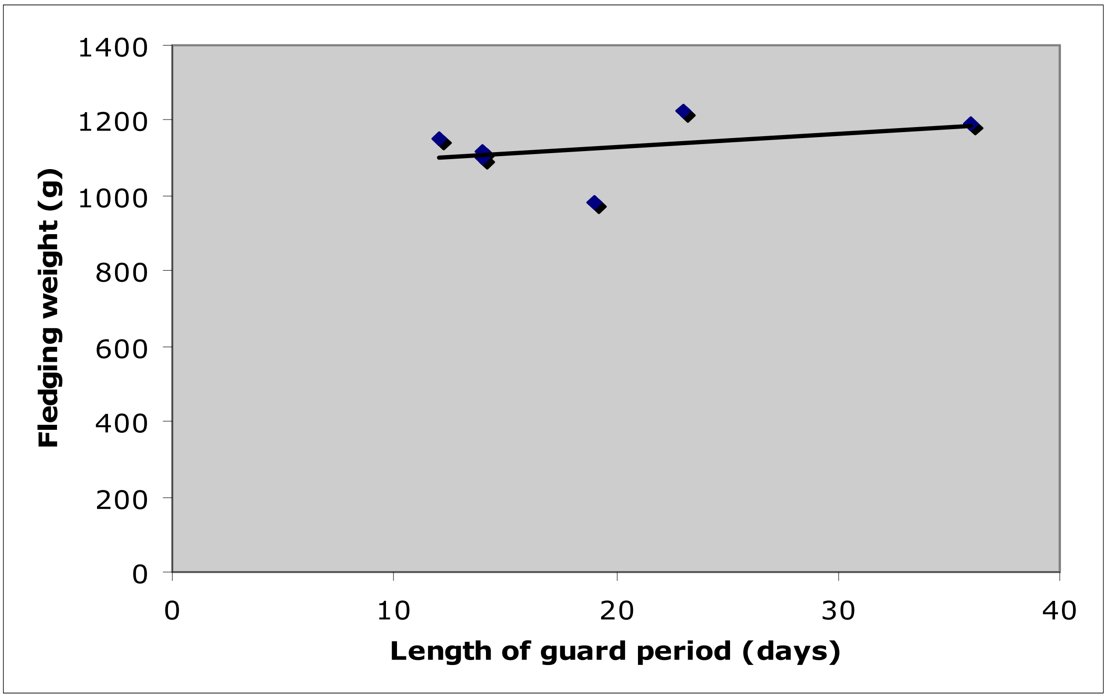


Figure 14. The relationship between length of guard period and fledging weight.

Additionally, the weight of the chicks at time of fledging does not appear to be related to the length of the guard period ($F = 1.19$; d.f. = 1; $p > 0.05$) (Figure 14). Again, this may have been due to the very small sample size ($n = 6$).
A regression of the influence of the length of the guard period on the breeding success in individual burrows found that breeding success is higher in burrows with a longer guard period ($F = 11.24$; d.f. = 1; $p = 0.003$).

4.12 Onset of Moulting

The first moulting bird for the 2008/2009 breeding season was seen in a burrow at Three Mile Beach on 18 November 2008.

5. Discussion

5.1 The Breeding Cycle on the West Coast

5.1.1 Timing of Breeding

Egg laying began at the end of July and continued until October in both South Westland and Buller during this study. This is consistent with the findings of a one-year study in Buller by Heber *et al.* (2008) over the 2006/07 breeding season. Although the mean egg laying date was later in Buller than in South Westland ($F = 12.7$; d.f. = 1; $p < 0.001$) during the 2008/09 breeding season, egg laying occurred over a similar time period of three months.

This is the first year that breeding has been monitored in South Westland, and while this study has produced some useful data, nothing is known about the natural annual variation in the breeding cycle at this location. In Buller, a little more is known about annual variation in breeding timing as colonies in that region have been monitored for two breeding seasons (2006/07 and 2008/09). The later mean egg laying date in Buller during the 2008/09 breeding season (4 September) compared to the 2006/07 breeding season (30 August) ($F = 5.14$; d.f. = 1; $p = 0.024$), suggests that there is natural annual variation in breeding onset within the region.

The onset of breeding can vary greatly from year to year. On the East Coast of the South Island mean egg laying date on the Otago Peninsula varied from July to October over seven years of monitoring (Perriman & Steen 2000). In Oamaru over the 2008/09 breeding season, egg laying began in mid-September and the mean laying date was 20 October whereas the mean laying date there is usually in July (P. Agnew pers. comm.). The onset of breeding in Canterbury is also subject to annual variation with a fluctuation of up to four weeks in the median laying date from 2004 to 2009 (C. Challies pers. comm.). On Phillip Island, in Victoria, the mean laying date has become progressively later by several months (Dann 1992).
The onset of breeding can also vary between colonies within the same region. Perriman *et al.* (2000) found that the mean laying date of first clutches varied by as much as 16 days at colonies in Otago from 1993 to 1998.

Timing of breeding is known to be influenced by environmental factors, such as food availability, and unfavourable marine conditions. Insufficient food resources can delay breeding in blue penguins (Cullen *et al.* 1992). Consequently, this can either prolong or reduce the duration of the breeding season, as well as adversely affecting the onset of breeding, which means that the predictability of food resources are critical in determining the length and timing of the breeding season, and for the successful rearing of chicks (Stahel & Gales 1987).

Very little is known about the foraging behaviour of blue penguins West Coast, South Island colonies. As blue penguins generally forage to a maximum distance of 20 kilometres metres offshore, the foraging areas of colonies in Buller and South Westland are unlikely to overlap, and food resources may be different between the two regions.

During 2008, the SOI (Southern Oscillation Index) indicated there was a weak La Niña perturbation occurring in the tropical Pacific Ocean (NIWA 2008). During a La Niña event, sea temperatures around the South Island are higher than average (Te Ara, 2007). La Niña events in New Zealand are characterized by north-easterly winds which tend to bring reduced rainfall to the south and south-west of the South Island and warmer than normal temperatures over much of the country (NIWA 2008).
El Niño and La Niña events have been shown to affect breeding and mortality of several seabird species including Galapagos penguins (*Spheniscus mendiculus*) and Humboldt penguins (*Spheniscus humboldti*) (Schreiber & Schreiber 1984; Boersma 1998; Hays 1986).

During a La Niña event, blue penguins in Otago started breeding later than average, and there were fewer double-clutches, than during an El Niño event or in years when both weather patterns were absent (Perriman *et al.* 2000).
Despite this, other studies (Perriman *et al.* 2000; Renner & Davis 2001) indicate that the breeding success of blue penguins is relatively independent of climate fluctuations such as the weak La Niña conditions prevailing in 2008.
The similar breeding results for Buller in 2006/07, when El Niño conditions prevailed over New Zealand, and 2008/09 suggests that the effect of the La Niña conditions on the West Coast had little influence on breeding success in 2008/09.

At the Buller colonies, the mean laying date was later at the untrapped sites (10 September) compared to the trapped sites (30 August), whereas in South Westland the opposite was true. In South Westland, this result may have been influenced by the different frequency of burrow monitoring as burrows at all sites except Three Mile Beach were checked once a week, as opposed to three times a week at Three Mile Beach, the only trapped site. It is not known why egg laying started later at the trapped sites in Buller. Hatching and fledging dates were also later in Buller compared to South Westland but no difference between mean hatching and fledgling dates at trapped and untrapped sites suggests that predator control had little effect on breeding timing in this study.

5.1.2 Length of Guard Period

The average length of the guard period in South Westland was well within the ranges found in other studies in New Zealand and Australia. The guard period was difficult to determine in Buller as the nest contents of many burrows could not be observed, especially early in the breeding season before chicks hatched. In South Westland, the longer guard period for burrows that had only one chick is consistent with the results of Numata *et al.* (2004), who showed that the parents of single-brood chicks guard chicks longer than parents with two chicks. This indicates that the parents of a single chick are likely to have less foraging pressure than parents feeding two chicks, and one parent is able to spend more time in the burrow guarding the chick while the other parent forages. The length of the guard period may be determined by the condition of the parents, which in turn is affected by the availability of food (Numata *et al.* 2004).

The relationship between length of guard period and breeding success is due to the influence of clutch size on guard period and not because the length of the guard period has an impact on breeding success.

5.2 Productivity of blue penguins on the West Coast

5.2.1 Eggs produced and hatching success

The hatching success in Buller during this study (76.5%) was similar to the findings of a study in Buller (79%) during the 2006/07 breeding season (Heber *et al.* 2008). The hatching success in South Westland was high but within the ranges determined in other studies in New Zealand and Australia (Table 6). However, the number of chicks that were produced by each breeding pair was much lower than in colonies on the East Coast of the South Island. This is mainly due to the number of eggs laid per breeding pair. In Oamaru during the 2008/09 breeding season (a lower than average breeding year), the number of eggs laid per breeding pair was 2.05 (P. Agnew pers. comm.), compared to 1.96 in South Westland, and 1.94 in Buller in this study. This suggests that the number of eggs produced per pair on the West Coast was consistent between the regions but lower than on the East Coast. This is due to the occurrence of double clutches on the East Coast.

Table 6. Comparison of reproductive productivity among blue penguin colonies.

Location	*Hatching success (%)*	*Fledging success (%)*	*Breeding success (%)*	*Fledglings produced per breeding pair*	*Source*
Nth Harbour, NSW 2002-2005	72		70	1.71*	Priddel et. al. 2008
Wellington, NZ 2005-2006	57	83	47	0.94*	Bull 2000a
Oamaru, NZ 2008	74	91	67	1.39	P. Agnew, 2009
Buller, NZ 2006/07	79	84	66	1.18	Heber, 2008
Buller, NZ 2008/09	76.5	88.5	63.4	1.16	This study
South Westland, NZ 2008/09	80.7	99.1	78.8	1.55	This study

*It is unknown whether this figure represents fledgling produced per breeding pair or all pairs

5.2.2 Double Brooding

There was no evidence of double clutching at either the South Westland and Buller sites this breeding season. In the burrow that contained a second clutch, it is not known whether the second clutch was laid by the same female or by a visiting female. This second clutch was laid in a burrow already containing two 52 day-old chicks. A second clutch is usually laid after the first clutch has failure or the chicks have fledged from the nest. The mean interval between the departure of fledglings from the nest and the initiation of a second clutch is 11 days in Otago (Gales 1985), and in Australia the mean interval is usually three to five weeks (Reilly and Cullen 1981). This supports the idea that the eggs were laid by a visiting female and not by the female occupying the burrow. It is possible that the eggs were laid by first-time breeders as there is evidence that a later laying date is correlated with a lower quality of breeder (inexperienced) in some species (Perdeck & Cavé 1992; Price *et al.* 1988).

The eggs were deserted after approximately one week of incubation and were subsequently trampled by the chicks in the burrow. If the second clutch had fledged, the chicks would have left the burrow in the middle of February 2009. When a second clutch is laid late in the breeding season, the parents may not return to feed their chicks (Stahel & Gales 1987). This fledging date would have been later than any other fledgling date in monitored burrows in South Westland or Buller, and would have delayed the adult penguins moult by over a month if the parents continued to feed the chicks until fledging.

A later than average breeding onset in Oamaru during the 2008/09 breeding season, led to a large decline in the number of second clutches produced i.e. only one second clutch laid and that did not survive to fledging (P. Agnew pers. comm.).
The laying date can be related to fledgling survival rate in blue penguins, indicating that eggs laid later in the breeding season are not as likely to result in fledged chicks as those clutches laid at peak times (Reilly and Cullen 1982, Chiaradia and Kerry 1999).

No replacement clutches, laid after a first clutch failed were recorded in any of the colonies in either West Coast region. The absence of second or replacement clutches in Buller is consistent with the findings of Heber *et al.* (2008).

Blue penguin colonies at several locations in New Zealand exhibit prolonged breeding seasons that are not as variable in length as colonies in Australia. In all New Zealand locations the length of the breeding season should allow sufficient time for the occurrence of double brooding (Gales 1985). Despite this, double brooding does not occur at the majority of blue penguin colonies around New Zealand. In blue penguin colonies around Auckland and Wellington, replacement clutches were occasionally laid by birds that had lost their first clutch but there was no occurrence of pairs laying a second clutch after one had been raised successfully (Kinsky 1960; Bull 2000a). In Canterbury, second clutches have never been observed even after the first clutch has failed (O'Brien 1940). Conversely, in Otago the occurrence of double brooding is common, with 59 % of the total breeding population present in Oamaru laying a double clutch in 2005 (Jones 2006).

The absence of double brooding in Canterbury may be indicative of a difference in marine resources between Otago and Canterbury. The Chatham Rise is located to the east of the Canterbury coast and is a transition zone for the East Auckland current (flowing south) and the Southland Front (flowing north) (Winterbourn *et al.* 2008). These currents bring together Subtropical Surface Waters and Subantarctic Surface Waters, and the boundary between these two water masses has a lower diversity of fish species than on either side of the Chatham Rise (Winterbourn *et al.* 2008).

5.2.3 Clutch Sizes

The proportion of two-egg clutches was very high in both Buller and South Westland in 2008/09 (Table 7). Although higher than most studies at other locations, the proportion of two-egg clutches was lower than in Oamaru, which is considered to be an optimal colony in terms of breeding productivity (Heber *et al.* 2008).
Although the proportion of clutch sizes was similar between South Westland and Buller during the 2008/09 breeding season, the lower frequency of two-egg clutches during the 2006/07 breeding season in Buller ($\chi^2 = 11.57$; d.f. = 2; $p < 0.05$) may be due in part to the exclusion of several of the sites in this study that were previously monitored by Heber *et al.* (2008). Several of the sites in 2006/07 contained burrows in caves that were easy to access and determine the nest contents on every visit, and the largest colony, Nile River, was also monitored more intensively (three times a week). During the 2008/09 breeding season, more burrows containing one chick were excluded during analysis when it was unknown whether one or two eggs had been laid in the burrow initially. The easier access and more intensive monitoring of the

largest colony in 2006/07 may have resulted in a more accurate percentage of two-egg clutches.

Table 7. Percentage of blue penguin clutches containing one or two eggs.

Location	***1-egg clutch***	***2-egg clutch***	***Source***
North Harbour, NSW	14%	86%	Priddel *et al.* 2008
Phillip Island, VIC	6.6%	93.3%	Reilly & Cullen 1981
Wellington, NZ	25-30%	70-75%	Marchant & Higgins 1990
Oamaru, NZ	2%	98%	P. Agnew 2009
Buller, NZ (2006/07)	22.5%	77.5%	Heber 2008
Buller, NZ (2008/09)	5.7%	94.3%	this study
South Westland, NZ (2008/09)	4.2%	95.8%	this study

5.2.4 Fledging Success

The fledgling rate at all South Westland colonies was very high compared to the fledging success found in other studies in New Zealand and Australia (Table 6). The fledgling success was even higher than recorded in Oamaru in recent years (P. Agnew 2009; Jones 2006) and Oamaru colonies are considered to have some of the most favourable conditions possible for breeding (Jones 2006) due to marine conditions, food supplies and predator control. Chiaradia *et al.* (2007b) concluded that marine conditions are important, but not the only factor, which influences fledging success.

Three nests at Three Mile Beach were not included in the calculation of fledging success. In several cases a two-egg clutch was reduced to one chick after hatching and due to obstructions in the burrows, it was not known whether the egg failed to hatch or the chick died due to natural causes or predation and was removed from the nest by the parent. It is more likely that the eggs failed to hatch then chicks were killed by predators. Firstly, adult blue penguins generally repel predators entering their burrows very efficiently, which suggests that while the adult penguin remains in the burrow it is unlikely the newly hatched chick will be removed from the nest. There were no incidences of predation at this site after the adults had left the burrow, which suggests that predator numbers were low. There was also no evidence of predation in the form of remains or feathers in or around any of these burrows. Additionally, there were no other observed incidences of predation at any of the sites in South Westland, which makes it seem unlikely that predation occurred in these few burrows.

At the colonies in the Buller region, the fledging success was also high but within the ranges found in studies in other regions in New Zealand (Table 6). The fledgling success during the 2008/09 season were similar to that recorded by Heber *et al.* (2008). There was one known chick death to be caused by stoat predation in Joyce Bay in Buller and none in South Westland.

5.2.5 Nest Desertion

Nest desertion is common in many penguin species. There are a number of factors that cause desertion, including a lack of food (Numata *et al.* 2004), delayed nest relief (Davis 1982, 1988), ectoparasite infestation (King 1977a, 1977b), extreme weather conditions (Yorio & Boersma 1994), predation (Shealer and Kress 1991) and human disturbance (Yorio & Boersma 1992, Numata *et al.* 2000).

In South Westland there was only one known incidence of egg desertion during the normal incubation span and no incidence of chick desertion during this study. In six burrows in South Westland, eggs were deserted only when they failed to hatch after they had been incubated for the normal incubation period of 36 days. In Buller, the exact number of nest desertions is unknown due to difficulties observing burrow contents and consequently determining accurate laying dates to identify which eggs failed to hatch and which, if any, were abandoned prematurely. It is possible that the one incidence of egg desertion in South Westland was due to predation or death of a parent, as only one adult was seen on the nest again at a later date.

The likelihood of a desertion of chicks is influenced by the ability of the adult bird to find adequate food supplies and return to their nests to feed chicks regularly. Renner (1998) found the longer the foraging trip duration of the parents, the higher the probability of egg desertion. The low occurrence of egg desertion and absence of chick desertion suggests that adequate food sources were available to penguins at South Westland colonies.

Ectoparasite infestation was also unlikely to be the cause of nest desertions as there was no sign of an infestation on any of the adults or chicks handled in South Westland or Buller. There was also no evidence of ectoparasites, including fleas, in any of the burrows monitored.

There appears to be no difference in the prevalence of nest desertion between colonies that were controlled for predators and those that were not, suggesting that predation was not the main cause of nest desertion. These results are consistent with the results of Heber *et al.* (2008), where there were no incidences of egg desertion and only two cases of chick desertion.

In Oamaru over the 2008/09 breeding season, 8 out of 152 clutches were deserted prior to the due date of hatching (P. Agnew pers. comm.). Although the 2008/09 breeding season started later than normal in Oamaru, the number of nest desertions was unlikely to be affected as the hatching, fledging and breeding success were close to the yearly average (P. Agnew pers, comm.).
An important point to take into account when comparing results from Oamaru and the West Coast is that the majority of Oamaru nests are in nest boxes in which the contents are more accurately recorded than in natural burrows. There are 232 nest boxes in Oamaru compared to 24 in Buller and none in South Westland.

5.2.6 Breeding Success
The breeding success at both South Westland and Buller sites was higher than other sites in Australia and New Zealand including Oamaru (Table 6), despite a lack of predator control at some of the sites.
Due to the lack of previous studies in South Westland it is impossible to know if South Westland has a consistently high breeding success every breeding season or if 2008/09 was a particularly good breeding year, as Fiordland Crested penguins on the West Coast show considerable annual and geographic variability in breeding success (Newton & Tansell 2005).

The number of fledglings produced per breeding pair in Oamaru was 1.39 over the 2008/09 breeding season (P. Agnew pers. comm.) compared to the 1.55 fledglings per pair in South Westland (Table 6). The similar results between these two regions is due

to the very low occurrence of double brooding in Oamaru in 2008/09, as the number of fledglings produced per pair in Oamaru is generally much greater (2.25 in 2006/07; Jones 2006). The number of fledglings produced in Buller in 2008/09 was very similar to the results in Buller 2006/07 (Heber *et al.* 2008).
Evidence from this study and Heber *et al.* 2008 suggests that the cause of decline in blue penguin numbers on the West Coast is unlikely to be due to breeding failure. Blue penguins in both South Westland and Buller appear to have no problem producing sufficient fledglings to ensure a stable population size.

The most vulnerable time, at least at the Buller sites, is during the nestling stage. Breeding failure in blue penguins generally occurs during chick rearing, when parents may struggle to successfully raise chicks if they have to forage further from the colony (Chiaradia & Kerry 1999). Blue penguins in Buller produce fewer fledglings compared to all other sites in New Zealand, even compared to colonies that only produce a single clutch. Blue penguins tend to have a consistently high hatching success as they will persevere with incubating eggs even if they have a low body condition (Kemp & Dann 2001).

5.3 Adult and Chick weights
The adult weights in South Westland at the beginning of the breeding season were higher than other studies in New Zealand, whereas Buller weights were in the middle of the range of other studies (Table 8). Adult weights in Buller at the end of the breeding season were lower than end of season weights in Otago in 2000 (1255g; Johannesen *et al.* 2002).
Unfortunately there were no data on the weights of adult birds in Oamaru taken during the same breeding season. The adult weights could not be compared with previous data taken in Buller in 2006 (Heber 2006) and 2005 (Wilson, unpublished data) as the 2005 and 2006 weights were measured later in the breeding season (August versus October).

A possible explanation for the significant difference in adult weights in Buller and South Westland at the beginning of the breeding season is that although both sets of weights were recorded in August, penguins in each colony started egg laying at different times. Adult weights in South Westland were recorded the week after the mean date of egg laying (25 August), and in Buller they were taken a week prior to the mean date of egg laying (4 September).

Table 8. Comparison of adult weights taken during egg laying and incubation at several New Zealand blue penguin colonies.

Location	***Weight***	***Source***
Motuara, 1998	1020.5g*	Numata *et al.* 2000
Oamaru,1998	1138g**	Numata *et al.* 2000
Otago Peninsula, Sept 1999	1197g	Johannesen *et al.* 2002
Otago Peninsula, August 2000	1160g	Johannesen *et al.* 2002
South Westland 2008/09	1240.6g	This study
Buller 2008/09	1116.5g	This study

*This figure represents the mean weight of males (1070g) and females (971g) during the incubation period.

**This figure represents the mean weight of males (1200g) and females (1076g) during the incubation period.

At the beginning of the breeding season, the female penguin returns to the nest to lay one or two eggs. After egg laying one of the parents, usually the male, remains on the nest for the first incubation shift, usually 1-2 days but can be up to 10 days (Stahel & Gales 1987). The average adult weight (pooled for both sexes) is likely to be higher in adult penguins before egg laying compared to after egg laying, although data on adult weight changes at the beginning of the breeding season are scarce. It is possible that this difference in weight before and after egg laying explains the observed difference between adult weights in South Westland and Buller.

As adult weights were measured after the mean laying date in South Westland and before the mean laying date in Buller, the actual difference in adult weights in the two regions may have been greater than calculated from the data.

Unfortunately it was not possible to link the weights to individual penguins to determine the sex of the penguin, whether it was breeding and if so, what stage of the breeding cycle it was in. The higher body weights of adult penguins in South Westland may be another indicator of adequate food resources, but more information is needed on individual birds to test this assumption.

The number of visits to burrows in which breeding did not occur increased throughout the breeding season. This may be due to the stage of the breeding season as parental attendance on the nest decreases during the post-guard stage of chick development (Stahel & Gales 1987). Later in the breeding season new breeders are more likely to visit burrows later in the season.

Table 9. Comparison of fledgling weights among New Zealand blue penguin colonies.

Location	*Weight*	*Source*
Nth Harbour, NSW	1062g	Priddel *et al.* 2008
Oamaru, 2007/08	1058g	Agnew 2007 (unpub.)
Oamaru, 2009	989g	Agnew (pers. comm.)
South Westland 2008/09	1138g	This study
Buller 2008/09	950g	This study

Unfortunately, fledging weights in the two regions could not be compared due to a small sample size in Buller. Fledglings at South Westland sites were generally heavier than fledglings in other studies conducted in New Zealand and Australia (Table 9). Fledgling weights may indicate the effect of food availability and fledgling body weight correlates with survival in the first year of fledging (Dann 1988), which suggests that fledglings from South Westland colonies will have a high post-fledgling survival rate.

The bill measurements from both Buller and South Westland birds were within the ranges of penguins measured in other studies (Marchant & Higgins 1990) as are the flipper measurements of Buller birds.

5.4 Burrow occupancy

The burrow occupancy in South Westland is within the range of similar studies at other locations. The higher burrow occupancy at Buller sites in 2008/09 compared to 2006/07 is likely to be due to differences in methodology and analysis rather than an increase in penguin numbers in the last two years. Only three of the sites were monitored over both breeding seasons and a comparison of the data indicates that a greater proportion of burrows were considered unsuitable for breeding in 2008/09 than in 2006/07 and were not included in the calculation of burrow occupancy. A number of burrows were originally labeled as burrows in 2006/07 until further investigation identified them as corridors to other burrows.

Table 10. The percentage of suitable burrows occupied by breeding pairs.

Location	Burrow occupancy rate (%)	Source
Taieri Island, NZ 1991/92	78	Dann 1994
Oamaru, NZ 2008/09	65	Agnew (pers. comm.)
Buller, NZ 2006/07	38	Heber *et al.* 2008
Buller, NZ 2008/09	60.3	This study
Sth. Westland, NZ 2008/09	73.8	This study

At Nile River mouth, the breeding success was higher in nest boxes compared to natural burrows. The same results have been found in similar studies in Otago (Perriman & Steen 2000). Nest boxes at other sites have been occupied soon after installation (Perriman & Steen 2000; Klomp *et al.* 1991) and are preferred over natural burrows by penguins. This suggests that if the burrow occupancy were to increase dramatically in the last few years, then nest boxes would be occupied before natural burrows by new breeding pairs. This does not appear to be the case.

The burrow occupancy in Buller in 2008/09 was lower than other studies (Table 10). As discussed in Heber *et al.* (2008), the low occupancy rate might indicate a population decline over the past decades. There is only anecdotal evidence that penguin populations in this region have declined in the past, so there is no way of quantifying this decline. The results from this study suggest that the blue penguin population at the monitored sites in Buller have not declined in the last two years.

5.5. Penguin Mortality

5.5.1 On-land threats

The peak times for stoat kills at Three Mile Beach in 2008 were December-January and March-July (I. James pers. comm.), with 26 stoats caught in 2008 and seven stoats caught by end of April 2009. The area around Okarito was intensively trapped in recent years by the Department of Conservation as part of an effort to save the Rowi or Okarito brown kiwi (*Apteryx rowi*). First established in 2000, the Okarito sanctuary had 1500 traps laid in a pattern across 11,000 hectares of core kiwi habitat (Save the Kiwi, 2009). Due to a change in conservation strategy, trapping was stopped in 2006 and the increase in mustelid numbers since then can be clearly seen in tracking tunnel figures from treatment areas (Appendix 8). The mean mustelid tracking rate increased from 0 in November 2005 to 12 in November 2008 (I. Graham pers. comm.). The results from tracking tunnel monitoring at these sites show a higher than normal number of stoats present in August and November 2008, over the penguin breeding season, compared to the same months in previous years.

Tracking tunnel indices of predators since 2001 indicated that in control sites in South Westland, mustelid and rat numbers in 2008 were lower than average. The mean mustelid tracking rate over eight years was 33 and 23 in August and November respectively, with mustelid tracking rates since 2001 being as high as 84 (August 2004). These control sites are located near Gillespies Beach and Mt Hercules and are not close to any of the monitored blue penguin colonies.

On the other hand, tracking tunnel indices were also measured at three treatment sites, at Tatare, Release Ridge and Okarito. The treatment areas were inside the old south Okarito trapping network and there has been no additional trapping in these treatment areas since 2006 (I. Graham pers. comm.). Although stoat numbers were higher than they have been since 2006 this is more likely to indicate a gradual increase since trapping stopped in 2006, and not a population peak as stoat numbers in these treatment sites are still much lower than in the control areas.

The rate that stoats recolonise an area after trapping depends on several factors, including the level of available food and the sex ratio of the invading stoats. A study by Choquenot *et al.* (2001) found that with only one stoat of each sex, it would take around 2.5 years to attain a population size of 100. This shows that stoat populations can increase rapidly when environmental conditions are favourable.
Despite the lack of influence that predators had on breeding success of penguins during this study, stoats may become a problem for penguins if populations continue

to increase in South Westland. Evidence of adult and chick mortality caused by predators at other locations (Stahel & Gales 1987; Hocken 2000; Perriman & Steen 2000), in Buller (Heber *et al.* 2008; this study) and anecdotal evidence from West Coast residents suggests the potential for long-term predator impacts on adult and chick mortality, which may influence the breeding success of a colony.

Dogs are another predator that can have devastating impacts on blue penguin populations (Dann 1994). There were no recorded attacks of blue penguins by dogs in South Westland during this study, probably due to the distance of colonies from human settlement. In Buller, two penguins were killed by a dog at Carters Beach, south of Westport in October 2008. A dog was also the cause of four blue penguin deaths at Camerons in August 2006 (WCBP mortality database), and at least 12 penguin deaths at the Nile River mouth between September and November 2003 (Heber *et al.* 2008). Dog attacks are a serious problem, particularly at popular beaches and near river mouths during whitebait season.

Road kills are a major threat to blue penguins (Harrigan 1992; Hocken 2000; Bull 2000a). Fortunately, incidences of road death in South Westland are rare and due to the distance from roads, do not pose a significant threat to South Westland blue penguins.

In Buller, road-kills are common due to the proximity of colonies to the state highway. The West Coast Blue Penguin Trust in conjunction with the Department of Conservation have created a West Coast Blue penguin Mortality Database, which records the data, location, and cause of death of blue penguins found on the West Coast.

To date, there are records for 71 penguins killed in Buller since 2000, mostly since 2006. Of the 71 recorded deaths, 53 are attributable to road-kills, with 50 of these on coastal sections of the state highway between Westport and Greymouth. In the Charleston area alone over the 2008/09 breeding season, five birds were found on the road or near burrows where the cause of death was probably due to traffic. These birds were found close to or in the Rahui and Darkies Creek colonies and may have been nesting in one of these colonies.

The majority of penguin road-kills occurred during the breeding season, at a time when the penguins could have been incubating eggs or chicks. As adult survival has the most significant effect on population size (Dann 1992), penguin road-kills are likely to be an important factor in the stability of blue penguin populations.

Habitat loss reduces the habitat available for nesting (Dann 1994; Dann 1992) and in Buller, erosion and development of housing allotments are damaging nesting habitat (Heber *et al.* 2008). Habitat loss through development is less of a problem in South Westland than Buller due to the lower population (8,403 compared to 9,702 people; Statistics NZ, 2009) and the more isolated coastline, resulting in less building development. The coast is more accessible in Buller compared to South Westland, where access for development is restricted to only a few areas, such as Okarito, Bruce Bay and Haast.

Based on anecdotal evidence from local residents, it was believed that Brushtail possums (*Trichosurus vulpecular*) might compete with blue penguins for burrows. During this study, only one possum was observed sleeping under a log within one metre of a blue penguin burrow. Breeding did not occur in this burrow and a penguin was only observed in the burrow at the beginning of the breeding season. There is no evidence that possums are competing with penguins for burrows based on this study.

5.5.2 At-sea threats

At-sea threats to blue penguins include starvation (Harrigan 1992), predation by New Zealand Fur-seals (*Arctocephalus forsteri*), pollution and drowning in fishing nets. The importance of at-sea threats can be difficult to determine as penguins that die at sea are seldom recovered.

The number of penguin deaths from starvation due to inadequate food resources could not be determined during this study although, breeding parameters, such as fledgling success and body weights in both Buller and South Westland suggest adequate food and high survival of breeding penguins. Starvation as a result of fishing difficulties caused by rough weather is possible.

Between Jan and early February 2009, 21 blue penguins were recovered between the Waitangi and Waiho rivers (I. James pers. comm.). Unfortunately body measurements were not taken so it is unknown whether they were adults or fledglings, although the birds were more likely to be fledglings due to the time of year they were found (at the end of the breeding season).

There are no fur seal colonies in South Westland or Buller near the blue penguin colonies monitored in this study and extent of fur seal predation is unknown. A fur seal was seen killing a blue penguin at the mouth of the Nile River in August 2008 and the next day no traces were seen on the beach (R. Lane pers. comm.). There is a small penguin colony of 30 natural burrows and seven nest boxes located in Tauranga Bay, Buller that is adjacent to a fur seal colony. This colony was not monitored in this study and the impact of seals on adult mortality at this site is not known.

Due to the number of dead penguins found in Buller on or near roads, on-land threats appear to have more of an impact on adult mortality than in South Westland.
Adult mortality was not measured in this study but is expected to be low, at least during the breeding season in South Westland, as very few nests were deserted after egg laying. A high occurrence of adult deaths outside of the breeding season is suggested by the number of empty burrows in a colony. In South Westland there were a very low proportion of unused burrows. This suggests that blue penguin numbers have remained stable in recent years at the South Westland sites monitored. There is a lack of historical information about changes in blue penguin numbers in South Westland and this is one area where further studies are needed.

5.6. Conclusions for the reasons for assumed population decline

Due to the lack of population and distribution studies in the area of the West Coast, there is no conclusive evidence that the blue penguin population in South Westland or Buller has declined in recent years. Between 1969 and 1979, blue penguins were recorded in 13 grid squares in both regions compared to penguins sighted in only ten grid squares between 1999 and 2004 (Bull *et al.* 1985; Robertson *et al.* 2007). This does not necessarily indicate a change in penguin distribution in recent years (Robertson *et al.* 2007) as the size of grid squares surveyed increased in the later survey.
Despite this there is anecdotal evidence from long-time West Coast residents that blue penguins are now vacant from previous nesting areas (I. James pers. comm.) This is

true in Okarito where penguins have historically nested within the township and on the adjacent beach. Penguins have not nested within the village for a approximately 50 years and are also absent from the beaches to the north and south of the village. Although absent during nesting periods, blue penguins still occasionally visit Okarito beaches.

The absence of blue penguins from Okarito and other locations near human habitation on the West Coast may not be due to a decline in population but instead a movement to other nesting habitats with less disturbance. Although blue penguins have a high rate of natal philopatry (93% of chicks: Dann 1992), they will avoid an area that has a high rate of disturbance, as on Penguin Island (Klomp *et al.* 1991). In the last fifty years, Okarito has expanded from 3 residents to around 30 residents, in addition to up to 200 visitors nightly during the summer season (Ian James pers. comm.). There has also been an increase in the number of dogs and vehicles in the township. It is not known if nearby blue penguin colonies at Three Mile and Five Mile beach have increased or decreased historically so it is difficult to determine whether penguins have moved to these colonies from Okarito township. After fledglings leave their natal colony, they may eventually breed at colonies other than where they originated. It is more likely that younger birds returned to Three Mile Beach to begin breeding, then older established birds moved from their colony in the Okarito township.

Further study of blue penguin colonies is needed to learn more about annual variation in breeding productivity and to determine if breeding success is consistently high over an extended time period. If this is the case, then the cause of blue penguin decline on the West Coast is unlikely to be due to problems with breeding as the breeding success during this study is one of the highest recorded for blue penguins.

5.7. Implications for research and conservation of West Coast blue penguins

This study provides a baseline for further studies of blue penguins at South Westland colonies so questions about the status of the blue penguin population on the West Coast can be answered.

As little is known about the size of penguin colonies and reasons for breeding success and failure in South Westland, this study will fill gaps in our knowledge of breeding ecology in this region. A greater knowledge about these aspects of penguin breeding in turn can lead to a more targeted focus for the conservation of blue penguins. Although there was no apparent effect of predator control on breeding productivity during this study there is evidence from other locations that predators, in particular stoats, have contributed to the decline of blue penguin populations. More research into the impact of predators on penguins over a longer period of time is needed on the West Coast before a change is made to how predators are managed.

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Appendices

Appendix 1. Details of blue penguin adults caught at Three Mile Beach, South Westland in August 2008.

Bird No.	*Date*	*Location*	*Weight (g)*	*Bill length (mm)*	*Bill depth (mm)*
1	28/08/08	Three Mile Beach	1440	34	17
2	28/08/08	Three Mile Beach	1190	34	-
3	28/08/08	Three Mile Beach	880	29	15.5
4	28/08/08	Three Mile Beach	1390	40	19
5	05/09/08	Three Mile Beach	1190	41	18
6	05/09/08	Three Mile Beach	1090	34	19
7	05/09/08	Three Mile Beach	1540	30	20
8	05/09/08	Three Mile Beach	1040	34	19
9	05/09/08	Three Mile Beach	1390	34	18
10	05/09/08	Three Mile Beach	1240	34	17
11	05/09/08	Three Mile Beach	1440	33	19
12	05/09/08	Three Mile Beach	1290	32	22
13	05/09/08	Three Mile Beach	1540	34	17
14	06/09/08	Three Mile Beach	1190	33	15
15	06/09/08	Three Mile Beach	1090	33	18
16	06/09/08	Three Mile Beach	1390	36	16
17	06/09/08	Three Mile Beach	1240	33	21
18	06/09/08	Three Mile Beach	1240	39	19
19	06/09/08	Three Mile Beach	1215	34	20
20	06/09/08	Three Mile Beach	1040	31	18
21	06/09/08	Three Mile Beach	990	29	14
22	06/09/08	Three Mile Beach	1390	32	20
23	06/09/08	Three Mile Beach	1090	31	17

Appendix 2. Details of blue penguins adults caught at Three Mile Beach, South Westland in December 2008.

Bird No.	*Date*	*Location*	*Weight (g)*	*Bill length (mm)*	*Bill width (mm)*	*Bill depth (mm)*	*Flipper length (mm)*
1	05/12/08	Three Mile Beach	1405	36.0	9.7	19.6	115
2	05/12/08	Three Mile Beach	1220	33.5	11.0	16.1	114
3	05/12/08	Three Mile Beach	990	34.8	13.6	17.7	117
4	05/12/08	Three Mile Beach	1800	38.7	12.7	20.6	114
5	05/12/08	Three Mile Beach	1370	33.7	14.2	17.4	112

Appendix 3. Details of post-guard chicks caught in South Westland during the 2008/09 breeding season.

Bird No.	*Date*	*Location*	*Weight (g)*	*Age (days)*
1	12/10/08	TN 18	405	12
2	16/10/08	T 30	560	14
3	16/10/08	T 30	625	14
4	21/10/08	T 35	825	21
5	21/10/08	T 22	735	27
6	21/10/08	T 22	960	27
7	21/10/08	TN 23	795	30
8	21/10/08	TN 23	850	30
9	30/10/08	T 18	1125	36
10	30/10/08	F 7	1100	?
11	30/10/08	F 7	1150	?
12	02/11/08	T 14	1060	33
13	07/11/08	F 4	690	19
14	07/11/08	F 4	550	19
15	10/11/08	TN 16	1380	32
16	26/11/08	T 11	1110	24

Appendix 4. Details of pre-fledging chicks caught in South Westland during the 2008/09 breeding season.

Bird No.	***Date***	***Location***	***Weight (g)***	***Age (days)***	***Bill Length (mm)***	***Bill Width (mm)***	***Bill Depth (mm)***	***Flipper length (mm)***
1	20/10/08	SW 22	1120	Near fledging	-	-	-	-
2	20/10/08	SW 22	1160	Near fledging	-	-	-	-
3	20/10/08	SW 5	1130	~ 45	28.4	7.3	13.1	112
4	20/10/08	SW 5	1100	~ 45	26.8	8.9	11.7	113
5	10/11/08	TN 23	1180	~ 50	30.4	7.7	13.2	117
6	10/11/08	TN 23	1270	~ 50	-	-	-	-
7	18/11/08	T30	1100	49	-	-	-	-
8	18/11/08	T18	1190	53	-	-	-	-
9	18/11/08	TN 18	1150	50	32.2	9.0	12.6	113
10	20/11/08	Okarito beach	460	Dead fledgl.	29.0	9.6	14.4	99
11	28/11/08	T 7	365	Dead fledgl.	21.7	7.2	11.1	106
12	07/12/08	F 4	980	49	30.1	9.1	14.4	111

Appendix 5. Details of blue penguin adults caught in Buller in August 2008.

Bird no.	*Date*	*Location*	*Weight (g)*	*Tag no.*
1	20/8/08	Nile River Knoll	1010	P36-426
2	20/8/08	Nile River Knoll	710	No tag
3	20/8/08	Nile River Knoll	900	No tag
4	20/8/08	Nile River Knoll	1110	No tag
5	20/8/08	Nile River Knoll	1230	No tag
6	20/8/08	Nile River Knoll	1070	No tag
7	21/8/08	Joyce Bay	1000	No tag
8	21/8/08	Joyce Bay	1110	No tag
9	21/8/08	Joyce Bay	980	No tag
10	21/8/08	Joyce Bay	1190	No tag
11	21/8/08	Joyce Bay	1280	No tag
12	21/8/08	Joyce Bay	1270	No tag
13	21/8/08	Joyce Bay	1450	No tag
14	21/8/08	Joyce Bay	1140	No tag
15	21/8/08	Joyce Bay	1030	No tag
16	21/8/08	Joyce Bay	1220	No tag
17	21/8/08	Joyce Bay	1080	No tag
18	21/8/08	Joyce Bay	1020	No tag
19	21/8/08	Joyce Bay	980	No tag
20	21/8/08	Joyce Bay	1220	No tag
21	21/8/08	Joyce Bay	1250	No tag
22	21/8/08	Joyce Bay	1320	No tag
23	21/8/08	Joyce Bay	1130	No tag
24	21/8/08	Joyce Bay	1180	No tag
25	21/8/08	Joyce Bay	1190	No tag
26	21/8/08	Joyce Bay	1390	No tag
27	21/8/08	Joyce Bay	1200	No tag
28	21/8/08	Joyce Bay	960	No tag
29	23/8/08	Pahautane Beach	780	No tag
30	23/8/08	Pahautane Beach	1070	No tag
31	23/8/08	Pahautane Beach	1050	No tag
32	23/8/08	Pahautane Beach	1240	No tag
33	23/8/08	Pahautane Beach	1010	No tag
34	23/8/08	Pahautane Beach	1190	No tag

Appendix 6. Details of blue penguin adults caught in Buller in December 2008.

Bird No.	***Date***	***Location***	***Weight (g)***	***Bill length (mm)***	***Bill width (mm)***	***Bill depth (mm)***	***Flipper length (mm)***
1	12/12/08	Nile River Knoll	1720	37.5	15.5	19.1	119
2	12/12/08	Joyce Bay	1150	37.5	14.6	16.9	116
3	12/12/08	Joyce Bay	1680	33.2	11.4	14.3	116
4	12/12/08	Joyce Bay	1220	37.2	10.6	14.4	116
5	12/12/08	Joyce Bay	1180	31.4	9.2	13.9	111
6	12/12/08	Joyce Bay	1700	36.5	10.2	14.4	112
7	15/12/08	Joyce Bay	820	36.8	10.1	18.8	113
8	15/12/08	Joyce Bay	1500	35.7	10.4	17.3	-
9	15/12/08	Joyce Bay	1100	33.1	11	19.2	116
10	15/12/08	Joyce Bay	1260	36.5	10	15.9	117
11	15/12/08	Joyce Bay	980	33.5	10.4	15.4	118
12	15/12/08	Joyce Bay	1790	35.2	10.1	14.2	110
13	17/12/08	Nile River Knoll	1320	-	-	-	-
14	17/12/08	Nile River Knoll	1580	-	-	-	-
15	17/12/08	Nile River Knoll	1080	-	-	-	-

Appendix 7. Details of pre-fledging chicks caught in Buller during the 2008/09 breeding season.

Bird No.	***Date***	***Location***	***Weight (g)***	***Bill length (mm)***	***Bill width (mm)***	***Bill depth (mm)***	***Flipper length (mm)***
1	12/12/08	Joyce Bay	-	25.7	8.0	11.8	117
2	12/12/08	Joyce	1120	27.8	7.9	11.4	110
3	12/12/08	Nile River Knoll	780	33.2	10.3	13.9	112

Appendix 8. Stoat and rodent tracking tunnel results in South Westland from 2001 to 2008 (I. Graham, Department of Conservation)
* = mean mustelid tracking rate per line

Month	*Rat treatment*	*Rat control*	*Stoat treatment **	*Stoat control**	*Mouse treatment*	*Mouse control*
March-01	8.00	9.70	0.50	2.20	-	-
May-01	25.90	22.40	6.20	7.60	-	-
March-02	3.57	1.67	0.00	47.69	-	-
August-02	80.00	38.60	0.00	45.00	20.00	2.86
November-02	70.00	30.00	0.00	56.00	17.00	13.00
February-03	79.29	39.23	0.00	63.00	32.14	43.85
May-03	97.86	48.46	0.00	49.00	31.67	39.15
August-03	98.57	69.72	0.00	60.00	20.87	50.65
November-03	46.43	57.14	0.00	66.00	7.86	23.57
February-04	53.57	60.77	1.00	81.00	17.86	19.23
May-04	40.00	40.00	0.00	65.00	13.85	10.83
Aug-04	40.71	36.67	0.00	84.00	9.29	1.11
Nov-04	23.08	20.00	0.00	71.00	8.65	0.00
Feb-05	2.30	8.00	0.00	40.00	5.00	1.00
May-05	14.29	15.38	0.00	54.00	5.71	0.00
Aug-05	21.00	15.00	0.00	56.00	12	1
Nov-05	38.00	23.00	0.00	54.00	18	1
Feb-06	30.00	15.00	0.00	52.00	14	1
May-06	67.00	16.00	0.00	35.00	3	1
Aug-06	81.00	61.00	4.00	31.00	11	9
Nov-06	71.00	67.00	4.00	14.00	30	19
Feb-07	77.00	54.00	28.00	42.00	11	33
May-07	64.00	67.00	11.00	46.00	16	9
Aug-07	25.00	35.00	7.00	48.00	-	-
Nov-07	4.00	12.00	3.00	55.00	0	4
Feb-08	3.00	22.00	12.00	54.00	-	-
May-08	9.00	6.00	0.00	50.00	4	2
Aug-08	7.00	10.00	10.00	33.00	7	4
Nov-08	1.00	6.00	12.00	23.00	5	1