Translocation techniques for fluttering shearwaters (*Puffinus gavia*): establishing a colony on Mana Island, New Zealand

FRIENDS OF
MANA ISLAND Inc.

Department of Conservation
Te Papa Atawhai

Translocation techniques for fluttering shearwaters (*Puffinus gavia*): establishing a colony on Mana Island, New Zealand

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Title page photo: Lynn Adams collects a fluttering shearwater chick from Long Island.
Photo: Richard Gill.

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CONTENTS

Abstract

A total of 225 fluttering shearwater *Puffinus gavia* chicks were transferred from Long Island across the Cook Strait to Mana Island, central New Zealand, in three January operations during 2006–2008. The translocation project was initiated by the Friends of Mana Island Incorporated Society, and supported by the Department of Conservation, as a planned method to re-establish a colony of fluttering shearwaters on the island. The project follows previous successful efforts to establish common diving petrels *Pelecanoides urinatrix* and fairy prions *Pachyptila turtur* there, in an attempt to restore an ecosystem influenced by burrow-nesting seabird activity.

Fluttering shearwater chicks were selected for transfer from the source colony using wing length and weight criteria developed and modified during the project. Chicks, ranging approx. 2–5 weeks from fledging, were housed in specially designed artificial burrows above the southern cliffs of Mana Island, close to other naturally occurring and reintroduced burrowing seabirds. The site was next to one of two sound attraction units on the island, that broadcast vocalisations from a range of species. Burrow blockades were installed to prevent chicks leaving burrows prematurely; removal of blockades proceeded on an individual basis, using wing length, weight, and down coverage criteria, to allow chick emergence behaviour prior to fledging.

All chicks were hand-fed once a day with tinned sardines in soya oil, blended with water and delivered via syringe and crop-tube—a diet and technique used in other seabird chick translocation projects in New Zealand. Meal size was refined for this species during the course of the project.

At least 191 chicks (85% of chicks transferred) were presumed to have fledged successfully from the Mana Island colony site, and were considered to be in good condition to survive post-fledging. These chicks departed at a mean weight exceeding that achieved in previous New Zealand transfers of the species, and stayed on Mana Island for at least the recommended optimum period, giving them a high chance of returning as adults.

A further 20 chicks may also have fledged but were potentially compromised at or after fledging: they disappeared prematurely from the burrow site and were not fed on the days leading up to their respective departures.

Five chick mortalities were confirmed on Mana Island—four chicks died as a result of entrapment within blockaded burrows, and one chick to a pathological condition. In addition, nine chicks were considered to have either perished before, or been seriously compromised during any fledging attempt following their early and permanent disappearance at relatively light weights.

Keywords: Fluttering shearwater, *Puffinus gavia*, translocation, re-introduction, colony establishment, burrow-nesting, hand-feeding, Mana Island, New Zealand.

1. Introduction

1.1 RESTORING SEABIRD COLONIES ON MANA ISLAND

Mana Island is a 217 ha scientific reserve administered by the Department of Conservation (DOC) (Fig. 1). Ecological restoration of the island commenced, with active support from the Royal Forest and Bird Protection Society and (later) the Friends of Mana Island Incorporated Society (FOMI) under the guidance of the Mana Island Ecological Restoration Plan (Miskelly, 1999), following the elimination of introduced mammals.

Re-establishing colonies of burrow-nesting seabirds, to provide marine-sourced nutrient input to the terrestrial ecosystem (droppings, regurgitations, failed eggs, corpses) and habitat (burrows) for invertebrates and reptiles, is considered to be of major ecological benefit to Mana Island and is a key task identified in the restoration plan (Miskelly, 1999; Miskelly and Gummer, 2004; Miskelly et al., 2009). The principal Procellariidae species listed for reintroduction are abundant in New Zealand coastal waters (Heather and Robertson, 2000): native common diving petrels *Pelecanoides urinatrix* and fairy prions *Pachyptila turtur*, and the endemic fluttering shearwater *Puffinus gavia*. All three species have been assigned a ‘relict’ conservation status (Miskelly et al., 2008), and all are likely to have been present on Mana Island before the island was inhabited and farmed: this is based on the discovery of bones in middens there, and presence on other islands within the Cook Strait (Miskelly, 1999).

The FOMI and DOC collaboration has already been successful in seeding new colonies of common diving petrels and fairy prions on the south-western cliff-tops of Mana Island, near a natural colony of c.100 pairs of sooty shearwaters *Puffinus griseus* (Miskelly et al., 2009). Both projects played a vital role in enabling seabird conservationists to evolve techniques for transferring petrel chicks and managing them at the release site prior to fledging, providing a base method for subsequent refinement and adaptation to suit a total of eight different petrel and shearwater species translocation projects in New Zealand (Miskelly et al., 2009).

Of 118 common diving petrel chicks that were transferred to Mana Island and presumed to have fledged successfully during 1997–1999, 20 birds were recovered as adults at the site with 15 reported as breeding by 2003 (Miskelly and Taylor, 2004). All 240 fairy prion chicks transferred during 2002–2004 were presumed to have fledged successfully (Miskelly and Gummer, 2004), with 19 of these birds recovered as adults by December 2008 (Miskelly et al., 2009) and several of their chicks successfully raised in recent seasons. The use of sound attraction to lure in both species is considered to have played a major part in their successful establishment, particularly for diving petrels with 83 unbanded recoveries made by August 2009 (C. Miskelly, pers. comm.). The arrival of four unbanded immigrant fairy prions coincided with the return of birds that had been translocated to the site as chicks, suggesting that they were attracted by the returning birds. There had been no prions detected at the site during 1993–2003, despite their calls being broadcast continuously for over 11 years (C. Miskelly, pers. comm.).

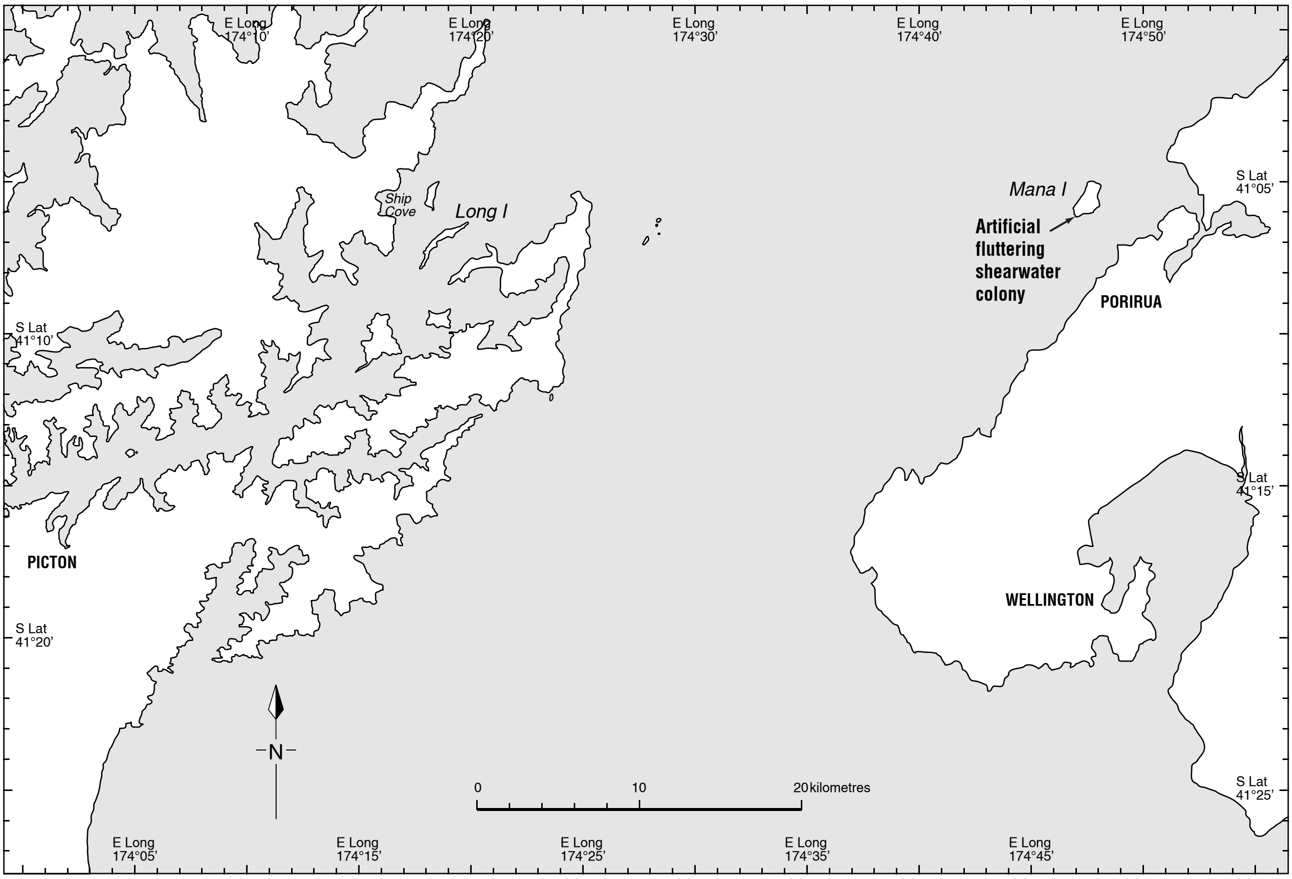

Figure 1. Map of Cook Strait region showing source location (Long Island) of transferred fluttering shearwaters and their destination (Mana Island).

1.2 FLUTTERING SHEARWATER BIOLOGY

The fluttering shearwater (pakaha) is a medium-sized shearwater that breeds in dense or scattered colonies on islands from the Three Kings south to East Cape, and within the Marlborough Sounds (Marchant and Higgins, 1990; Heather and Robertson, 2000). Adults are largely sedentary in New Zealand coastal waters year-round, while juveniles disperse to waters off the southern and eastern Australian coasts (Marchant and Higgins, 1990). The total population is estimated at 100,000+ breeding pairs with the largest colonies in the Hauraki Gulf (Heather and Robertson, 2000).

Fluttering shearwaters breed in burrows or cavities in coastal slopes and cliffs, often under grass or shrubs, and are nocturnal on land (Marchant and Higgins, 1990). Most return to their colonies in August, with a single egg laid from early September to mid-October, although some will visit throughout the year (Heather and Robertson, 2000). They forage over the continental shelf and inshore waters, and feed by pursuit-plunging, taking predominantly fish as prey (Marchant and Higgins, 1990). Chicks are fed by both parents. This gregarious species is commonly seen feeding and loafing on the sea in flocks.

Few biological studies have been made of the fluttering shearwater (Bell, 1994). An unpublished research project by Peter Hodum provided adult and fledgling weight and wing measurement data collected on Long Island in the 1988–1989 breeding season only. Information on age of first return to colonies, age of first breeding, chick recruitment and other population dynamics is poorly known (Taylor, 2000), although the species is thought to breed at 5+ years old, and typically prospect during the year before nesting (Bell et al., 2005).

1.3 PREVIOUS SHEARWATER CHICK TRANSLOCATIONS

Shearwater chick translocation experiments have been undertaken in Australia between 1954 and 1971 (short-tailed shearwater *Puffinus tenuirostris*) and in the United Kingdom in the 1980s (Manx shearwater *Puffinus puffinus*) (Gummer, 2003). The limited success of these projects, i.e., low adult return rates, was attributed to the method of transferring chicks relatively close to fledging, following parental desertion and coinciding with the period when chicks emerge from burrows—many birds were likely to have developed an attachment to their natal colony before transfer.

In New Zealand, fluttering shearwaters have been the subject of a previous translocation project, led by members of the Ornithological Society of New Zealand (OSNZ) (Bell et al., 2005). Unlike the previous overseas projects, Bell et al. included the concept of moving chicks at a younger age and substituting parental meals with hand-feeding. A total of 334 chicks were transferred from Long Island to Maud Island, Marlborough Sounds, from 1991 to 1996; they were housed in artificial burrows and hand-fed a diet based on whole salmon smolt. Bell et al. anticipated that chick emergence behaviour prior to fledging would be similar to that of the well-studied Manx shearwater; chicks of this species visit the surface nightly during the 8.5-day adult desertion period before departure (Brooke, 1990, cited in Bell et al., 2005). An adult desertion period was not simulated for transferred fluttering shearwaters on Maud Island as chicks required feeding twice daily right up to fledging, in order to achieve optimum fledging weights.

Fledging success was reported as 82%, with 34 of the 273 chicks that fledged returning to Maud Island in subsequent years, and 30 breeding for the first time at an average of 6.8 years (Bell et al., 2005; Miskelly et al., 2009). Chicks returning to Maud Island as adults had fledged at the heavier end of the fledging weight range for this species, and had spent relatively longer on Maud Island than the non-returning chicks prior to fledging. Bell et al. concluded that transferred chicks have a higher chance of returning as adults if they fledge at more than 387 g and after at least 18 nights at the release site.

1.4 STUDY OBJECTIVES

The Mana Island fluttering shearwater translocation project, funded by FOMI and with logistical support and technical advice from DOC, planned to transfer 200–250 chicks over a 3-year period to a new colony site on

Mana Island. Long Island, Marlborough Sounds, (Fig. 1), the largest—several thousand breeding pairs—and closest colony within the same ecological district, was identified as the most suitable source colony. Fewer birds were transferred in the first year while techniques for the species were developed. Using the most recent diet and hand-feeding techniques developed in New Zealand, the project aimed to fledge chicks at or above the target minimum fledging weight suggested by Bell et al. (2005) and after the suggested length of time following transfer, to maximise both survivorship and return rate of birds as adults to the release site.

This paper presents methods developed and refined over three successive transfer years to determine the best techniques to: select and transfer fluttering shearwater chicks using optimum weight and wing measurement criteria; and, manage chicks safely and effectively at the release site prior to their fledging. A new burrow design suited to the species, habitat and project requirements is described. Details of a practical diet and hand-feeding regime for this species are also provided.

The paper also presents data that improves our knowledge of chick size and condition at fledging, and reports previously unpublished details on pre-fledging emergence behaviour.

2. Methods

2.1 ASSESSING THE SOURCE COLONY

The Long Island fluttering shearwater colony was visited on 21–24 November 2005 primarily to: sample birds within this population for infectious pathogens that could put transferred chicks or species already present on Mana Island at risk (Section 2.9.1); identify the timing and state of breeding; and, determine chick accessibility within burrows. Recordings were also made of vocalisations for broadcasting on Mana Island (Section 2.2).

2.1.1 Finding chicks

The vast majority of fluttering shearwater burrows on Long Island are located to the north-east on steep slopes above the coastal scarp in a colony comprising an estimated 3–4000 pairs (M. Bell, pers. comm., Oct 2009). We chose a core search area at the less rocky southern part of this main colony area where burrow density was highest. Within this core area there were 100 burrows that had been replaced with artificial burrows—four-sided wooden box, inspection lid and PVC pipe tunnel/entrance—in 2007 as part of an on-going study initiated by the OSNZ. Other species known to be nesting at low densities in the area were diving petrels, sooty shearwaters, and blue penguins *Eudyptula minor*.

Outside the core area, burrows were scattered at relatively low density through grass and low-growing vegetation. These, and several smaller discrete colonies described by Hodum and observed during this study, were not visited due to the fragile nature of the terrain and/or their inaccessibility.

To determine how accessible fluttering shearwater chicks were in natural burrows, we first set up a 30 × 30 m quadrate within the core area, and inspected all 140 burrows found within the quadrate. Only five chicks could be reached (within arm's length), after modest amounts of burrow excavation (widening burrow tunnels). A total of 81 burrows had unknown occupancy, 46 were unoccupied, four were occupied by adults only, and four contained chicks that could not be safely extracted—chicks were heard calling or were felt. We concluded that it would be difficult to collect up to 100 chicks during a transfer operation without excavating burrows to some degree, and that there would be few adverse effects resulting from minimal excavation at entrances.

2.1.2 Planning transfer dates

Weights and wing measurements were recorded for nine chicks, and their age and fledging date estimated, based on previous data collected for the species (Table 1).

TABLE 1. WEIGHTS AND WING MEASUREMENTS OF FLUTTERING SHEARWATER CHICKS RECOVERED FROM BURROWS ON LONG ISLAND ON 23 NOVEMBER 2005.

CHICK WEIGHT (g)	WING LENGTH (mm)	ESTIMATED AGE* (DAYS)	ESTIMATED FLEDGE DATE* (2006)
239	60	30	7 Jan
170	40	16	21 Jan
170	39	15	22 Jan
138	30	11	26 Jan
123	30	11	26 Jan
74	28	10	27 Jan
94	28	10	27 Jan
105	27	9	28 Jan
53	24	8	29 Jan

* Estimates based on data collected from known age chicks by P. Hodum on Long Island in 1988/1989.

With a rearing period of around 74 days (P. Hodum, unpubl. data), the majority of chicks handled in November 2005 were expected to fledge during late January 2006, consistent with the mean fledging date—31 January—in Hodum's study (cited in Bell et al., 2005). We planned the first transfer of chicks for 15 January 2006, with the aim of housing birds for at least 10 days on Mana Island before they fledged. We anticipated that chicks would require a pre-fledging emergence period of at least 8 nights, based on Manx shearwater emergence behaviour.

For the 2007 and 2008 transfers, we identified that the oldest birds needed to be transferred no later than 10 days (estimated) before fledging to give chicks an appropriate pre-emergence settling period at the release site, and to allow them to reach heavier fledging weights. The younger birds needed to be transferred no earlier than 35 days (estimated) before fledging to limit their stay on Mana Island to the planned project duration. These younger chicks were required to boost the size of each transfer cohort. Transferring sufficient numbers of chicks in different age classes would allow us to determine the ideal size at which to transfer chicks of this species.

Based on an average wing growth of 3 mm per day (P. Hodum, unpubl. data), we estimated that transferring chicks 10 days earlier than in 2006 would mean that the majority of 2007 and 2008 chicks would fit our transfer weight and wing length criteria.

2.2 PREPARATION OF MANA ISLAND ARTIFICIAL COLONY SITE

2.2.1 Colony location and sound attraction

Two burrow sites for fluttering shearwaters were created on Mana Island: the first site, where chicks were housed following the 2006 small-scale transfer, proved unsuitable to use for subsequent, larger-scale transfers. A second site was specifically designed and constructed to accommodate the greater number of chicks brought to Mana Island in 2007 and 2008.

The first burrow site, created in winter 2005, was located to the south of the fairy prion/diving petrel artificial colony site, several metres beyond the southern most sound-system speaker (broadcasting calls of relevant species), and just to the north of the natural sooty shearwater colony. Burrow numbers continued on in sequence from the fairy prion artificial burrows, i.e., >105. This site was chosen because of its close proximity to other burrow-nesting species, with the aim of intensifying general seabird activity in one location, thereby concentrating the resulting beneficial ecological effects (C. Miskelly, pers. comm.). During the first transfer, it became apparent that a much larger area was required to install the additional burrows needed (up to 100 in total) for subsequent operations. In addition, the close proximity of burrows to those of other species presented problems during the management of chicks at the site; fluttering shearwater chicks were occasionally found occupying fairy prion burrows, and there was a risk that chicks could enter breeding burrows of the larger sooty shearwaters, and be attacked or disappear down their deep burrows. We anticipated burrow competition issues in later years, following colony establishment.

A new fluttering shearwater colony site was constructed in August 2006 at South Point, south of the natural sooty shearwater colony, and 300 m from the artificial fairy prion/diving petrel colony and nearby site of the 2006 fluttering shearwater transfer. We installed 100 burrows within a 190 m^2 area on a grassy slope approx. 60–70 m above sea-level, close to regenerating flax *Phormium tenax*, *P. cookianum* and tauhinu *Ozothamnus leptophylla*

(Appendix 1). A new automated solar-powered sound-system, configured to switch on at dusk and off at dawn, was set up at the site in November 2006 to broadcast a range of predominantly fluttering shearwater vocalisations (flight and ground calls recorded on Long Island) most nights of the year. Two weather-proof speakers were positioned just uphill from the burrows, 20 m apart and facing out to sea in a westerly direction.

2.2.2 Burrow design

At the first colony site, 40 burrows were dug by hand, each consisting of 110 mm (external diameter) PVC drainage pipe tunnels leading to natural chambers with turf roofs—a design based on the burrows used to accommodate transferred fairy prions and diving petrels (Miskelly and Taylor, 2004). Inspection hatches were positioned over the chamber in the form of thick pieces of timber. Burrows were roughly 0.5 m in length from entrance to back of chamber. This design later proved inadequate for fluttering shearwaters for several reasons. A considerably larger chamber size and inspection hole was required for this species, and the ground around many of the shallow burrows, built on gentle sloping terrain, became rapidly unstable. These fragile burrows were also more susceptible to over-heating in hot sun, and to flooding in heavy rain—five chicks had to be held overnight in transfer boxes (26 January and 8 February 2006) when their burrows flooded, and another two chicks had to be moved to drier burrows.

We designed an artificial burrow suited to species nesting on steep sloping terrain and in exposed conditions on top of a cliff (Appendix 2). Burrows needed to be safely and easily accessible to allow for daily monitoring and management of chicks during translocation years, and attractive to adult birds prospecting in future seasons.

Each burrow consisted of a tunnel—straight length of ridged PVC drainage pipe—sunk horizontally into a channel along the slope, leading to the front (side) of a rectangular chamber 450 × 250 mm. Three chamber walls were made of treated timber, but the back (short) wall, set furthest into the bank was earthen to allow further digging by birds. Wooden walls were 150 mm high, but there was effectively up to 200 mm height at the back of the burrow once a scrape had been made. The accessible front end of the chamber was fitted with a thick wooden access lid (with water-proof hinge) just above ground level, while the rear of the chamber had a fixed roof buried beneath turf to optimise stability and insulation.

We dug a trench leading to the well-concealed tunnel entrance of each burrow to effectively extend the tunnel length, shelter the entrance from wind, keep the burrow darker inside and provide a drainage channel away from the burrow. Use of longer lengths of plastic piping was undesirable from a chick management perspective (e.g., searching for missing chicks), and pipe bends were avoided because we were concerned the larger chicks of this species could get stuck.

We took measures to reduce the risk of chambers flooding in severe rain conditions by adding 10 litres of fine beach gravel to each chamber and under every tunnel to provide drainage, and ensuring that all burrows were set solidly in the ground just off level, i.e., sloping very slightly downhill towards the burrow entrance, to improve water run-off. Installing burrows during the winter allowed several months for the turf to settle and grow over the seams before burrows were occupied by chicks.

2.2.3 Site and burrow preparations

Prior to the arrival of chicks each transfer year, scrapes were made in the chamber gravel and lined with a layer of dry grass as nesting material. Burrows were not used to accommodate chicks if there was evidence of occupation by other seabirds (feathers, droppings, nest material)—adults potentially lured in by sound attraction.

Plastic mesh blockades were firmly installed at burrow entrances (although see Section 3.5.2) to prevent chicks disappearing prematurely, a strategy employed in all New Zealand seabird translocation projects since 1997. Allowing chicks to settle is important to reduce the risk of birds wandering away from the burrow site and missing important hand-feeding events. Plastic mesh allows ventilation of the burrow, and chicks still have visual access to the environmental features outside the burrow when sitting at the entrance.

The occasional spear-grass *Aciphylla squarrosa* was removed from the colony area, particularly those at burrow entrances, to avoid potential injuries to emerging chicks. Overhanging vegetation was also cut away from entrances and trenches each year so that entrances could be easily seen.

A mobile caravan was anchored in position above the colony site for use as a feeding shelter, equipped with benches, tables, storage areas and gas-stove (Appendix 1). All surfaces were disinfected and hand-washing facilities set up nearby.

2.3 COLLECTING CHICKS FROM LONG ISLAND

In all years, a chick collection team arrived on Long Island 4 days prior to the planned transfer dates to allow 3 days for finding and selecting chicks. Search time was reduced by a day in 2007 because the transfer operation was brought forward to avoid unfavourable weather forecast for 5 January. Team size was generally limited to 4–5 people to minimise the impacts on the colony.

2.3.1 Finding chicks

During 2007–08 when OSNZ study burrows were installed, we inspected these first to determine the number of easily accessible chicks available. We then commenced systematic day-time searches of natural burrows within the core burrow area of the main colony. All burrows were examined and where necessary tunnels were widened to allow an arm-length inspection; burrow entrances were otherwise disturbed as little as possible. Where necessary, burrows with bends were excavated to straighten the burrow allowing greater access to the nest chamber. In most cases, burrows were too long for chicks to be reached and inspections abandoned. Scattered burrow sites away from the main colony, and discrete areas within the main colony, were not visited to minimise burrow damage.

Chicks that could be reached were carefully pulled out, weighed, measured (wing length), and banded, with percentage down cover estimated, after which they were returned to burrows. This data was then used to determine if a chick could be selected for transfer, and how the burrow should be marked.

2.3.2 Selecting chicks

To estimate wing lengths for the transfer day, we added 3 mm daily growth to wing lengths recorded on the day the chicks were first handled.

In 2006, chicks with wing lengths between 130 and 190 mm (in four arbitrary age classes from 'small' to 'extra large') on the transfer day were deemed suitable, based on growth rates and fledging wing lengths recorded by Hodum (unpubl. data). Selection criteria included chicks with wings as long as 190 mm because of the generally advanced state of chicks on Long Island around the planned 2006 transfer date—the majority of chicks captured were considered to be too advanced for transfer and likely to be already emerging at night. The heaviest birds (all >300 g) within each age class were selected, where possible, to optimise fledging weights at the release site.

In 2007, the transfer wing length criteria were modified to 130–180 mm, and chicks in each of three arbitrary age classes had to exceed minimum weights on the transfer day (see Section 3.1.2). Again, no maximum weight limit was set as the heavier chicks were likely to fledge in the best condition. Feathered chicks with less than 90% down coverage (upper body only, i.e., visible when chick in resting position) were not transferred as they were predicted as being too close to fledging to allow an appropriate emergence period on Mana Island.

Criteria were further refined in 2008 by raising the minimum weight of older chicks at transfer, to ensure that chicks with less time to adapt to conditions at the release site could still fledge in optimum condition (see Section 3.1.2).

Burrows containing chicks considered suitable for transfer were marked with a white pole and a track marker (different colour for each age class in 2007 and 2008)—with band number—at the entrance. Burrows were left unmarked if chicks were clearly too old or too small for transfer.

2.3.3 Transferring chicks

On each transfer day, chicks from all marked burrows were gently pulled out, weighed and measured, and down coverage reassessed. Selected chicks were placed in cardboard (2006) or white, i.e., heat-reflective Corflute™ (2007 and 2008) pet carry boxes (380 × 200 × 265 mm, and 425 × 240 × 310 mm respectively). Diagonal dividers allowed two chicks to be carried per box. Additional ventilation holes had been made in box lids to reduce the risk of over-heating. Boxes were lined with newspaper or shredded paper. Chicks not meeting selection criteria were returned to their burrows. All burrow markers were left in place in case changed circumstances required all chicks to be returned to natal burrows.

Boxes were carried down the hill and placed under shady canopy to prevent chicks over-heating, and then on to the coast to be loaded onto a boat. Chick collection took up to 7 hours. Chicks were ferried to Ship Cove (30 minutes) where there was a suitable helicopter landing site.

Chicks were loaded into one Squirrel helicopter in 2006. Two Squirrel helicopters were employed to carry the larger 2007 cohort, but a single larger BK helicopter was able to stow the 2008 chicks. At least one passenger accompanied the chicks on the c. 30 minute flight to Mana Island.

2.4 ARRIVAL OF CHICKS AT MANA ISLAND

On 15 January 2006, chicks were unloaded from the helicopter on the helipad adjacent to the Mana Island boatshed at approx. 1300 hrs—high fire risk meant that landing was not permitted near the colony site—, then transported up to the colony by trailer around 1500 hrs, when the heat of the day had passed. Chicks arrived late afternoon on 4 January 2007 (1830 hrs) and 5 January 2008 (1615 hrs) as the larger cohorts took more time to collect on Long Island.

Transfer boxes were unloaded near the caravan in shade ready for chick processing. The physical state of all birds was assessed to check for injuries that might have occurred during transit. Band numbers were recorded and chicks were given 10 ml of fresh water (boiled then cooled) to compensate for any dehydration following the stress of the transfer, then placed individually in numbered burrows.

All unoccupied burrows, including those with any suspected adult activity, were left without entrance blockades.

2.5 DAILY BURROW MONITORING

Chick roll-calls were undertaken at the start of each day, with all burrows monitored in numerical order to: visually check presence, health and welfare of each chick; and, note key behavioural events—emergence and fledging—by recording the status (intact or knocked down) of a two-stick 'fence' erected at each burrow entrance once blockades were removed. At blockaded burrows, we checked for evidence of digging in chambers by the occupant, and for presence of resident chicks in pipes if the chamber was empty, which we formally recorded in 2008 only. Tunnel lengths of all burrows without blockades were carefully checked for resident and/ or other visiting chicks.

Inspections of burrows for a build-up of excrement and the presence of maggots were made opportunistically: there was no established invertebrate fauna to break down chick waste products. Soiled nest material was removed from most burrows and replaced towards the end of the second week to eliminate any risk of maggots transferring to chicks in warm damp weather. Nest material from burrows of emerging chicks (i.e., those without blockades) was not removed in case this interfered with the ability of chicks to return to home burrows using scent.

2.6 MONITORING CHICK GROWTH AND DEVELOPMENT

All chicks were weighed prior to being fed to obtain a daily base weight. In 2006 and 2007, wing measurements were recorded for most chicks every third day, and every 1–2 days during the emergence period to obtain fledging data. In 2008, wings were measured less frequently as follows: 5 days after transfer, then opportunistically if required, to monitor progress; on the date chicks were predicted as having wings of approx. 190 mm (based on growth of 3 mm/day) so that blockade removal could be scheduled (see Section 2.8.1); every 2–3 days for emerging chicks; and, daily leading up to a chick's departure until growth appeared to stop. Patterns in weight change and wing growth influenced individual chick management (meal size and blockade removal).

Down coverage (upper body only, i.e., visible when chick in resting position) was recorded every third day in 2006, and less frequently in other years, and down presence used to assist with decision-making regarding blockade removal (see Section 2.8.1). The amount of down remaining on chicks just before they fledged was noted for birds in 2006 and 2008, to determine if chicks of this species depart with some down still attached to feathers; and, to help us distinguish chicks that were likely to have moved away from the burrow site (i.e., missing but still on Mana Island), from those that fledged when expected.

2.7 HAND-FEEDING CHICKS

2.7.1 Diet and food preparation

Chicks were fed daily on a diet of tinned Brunswick™ Canadian sardines in soya oil, and fresh water. For the first 10 feeding days in 2006, tins were labelled as containing 77% fish, 22% soya oil and ≤1% salt—remaining stock from the fairy prion translocation project. After this, we found the more recent (bulk) order of the same product was labelled as containing 89% fish, 10% soya oil and salt—the same stock used for other national seabird translocation projects carried out in 2004–2006.

Food was freshly prepared each day. Sardines and soya oil were blended with cold, fresh water (pre-boiled >3 minutes for sterilisation) to a smooth mix, to the recipe of 1 tin (net weight 106 g) to 50 ml water. For every chick's first two meals in 2006, the food mix was slightly more diluted (75 ml water per tin of fish) as part of a gradual process to introduce the new diet. In 2007 and 2008, this more dilute mix was fed only on the first feeding day. Blended food was poured into plastic containers with screw-top lids and cooled in the freezer for up to 30 minutes before being placed in an insulated bin, with freezer blocks, to keep the food cool during the day—a measure to prevent contamination. Up to four 2-litre thermos flasks of boiling water were required daily at the colony site to fill hot-water baths for warming the food prior to feeding.

Hygiene standards were maintained throughout all steps during food preparation. Measures included: washing hands with antibacterial soap; ensuring all equipment in contact with food was thoroughly washed (very hot soapy water) and sterilised (antibacterial solution) prior to use; discarding all left-over mix at the end of each feeding day.

2.7.2 Meal size

We used meal sizes presented in Bell et al. (2005) to help us determine suitable food volumes to deliver to fluttering shearwater chicks on Mana Island. Bell et al. delivered their salmon smolt based diet in initial meal sizes of 30 ml (twice a day) to chicks transferred to Maud Island, with food volume increasing to 50 ml (twice a day) by the third day. Based on our experiences with hand-feeding chicks of other species on the tinned sardine and soya oil diet, we were confident that only a single meal would be required by the Mana Island chicks each day to sustain growth and development, and to ensure chicks had adequate reserves over the emergence period and for fledging. In all years, chicks were fed with the aim of reaching target fledging weights of 385+ g, as recommended by Bell et al.

For the first transfer, we took a cautious approach when making the transition from natural to artificial diet, to reduce potential digestion problems. Too rapid an introduction of the tinned fish diet to chicks in sub-optimal condition has proved fatal in transferred grey-faced petrel *Pterodroma macroptera* chicks, with young birds unable to process large volumes (H. Gummer, pers. obs.). Weight gain in the early stages of a transfer does not necessarily indicate a gain in body condition; with some chicks this weight can be unprocessed food accumulating (and fermenting) in the gut.

The 2006 chicks were given introductory feeds of 20–30 ml on the first two feeding days. During the first few days, we carefully observed weights and general condition of each individual chick, and monitored the presence of fresh faeces in the burrow. Daily meal sizes then increased gradually in 5 ml increments until chicks still present at the colony were receiving 70 ml meals by the end of the second week. We were able to determine daily weight changes in chicks receiving different volumes of food. A few chicks whose weight remained stable on 70 ml meals were given 80 ml feeds to test their capacity for this volume. Crop content of an adult fluttering shearwater has been recorded as weighing 75 g (Tarburton, 1981); this provided a useful guide for potential capacity of fully grown chicks of this species.

Two hand-feeding regimes (A and B) were employed for fluttering shearwaters in 2007, and three regimes (A–C) in 2008 (Table 2). Chick weights taken on the first feeding day were used to determine the regime used for each bird. For most chicks, introductory meals began at 30–40 ml (regimes A and B), increased by 10 ml increments every second day, until maximum food volumes of 70–80 ml were reached (if appropriate), after which volumes were adjusted daily to attain an approx. 5–10 g weight gain per chick per day. For the more advanced chicks (wings >170 mm) in 2008, food volumes were increased more rapidly as chicks had a shorter period of time to make the appropriate weight gains before fledging.

In all years, meal sizes were gradually reduced (usually by 10 ml increments) when: chicks showed signs of overflowing during feeding; and/or, chicks were not emerging when expected, especially if wing growth had slowed down or ceased and down coverage had reduced; and/or, chicks appeared to be gaining weight during the emergence period. In contrast to regurgitation (a clear rejection of a substantial proportion of the meal), an 'overflow' could be identified as a small proportion of the meal lost towards the end of food delivery.

Food volumes were rarely increased once a chick's meal sizes were reduced, especially if it was emerging. Meal sizes were kept the same if the chick was losing weight through exercise (around 5 g per night acceptable). The smallest meals delivered to chicks just before fledging were 10–20 ml; the exception was the last chick to leave the colony in 2007 which was not fed on its last day as it only accepted 10 ml of food on the previous day.

TABLE 2. INTRODUCTORY FEEDING REGIME FOR FLUTTERING SHEARWATER CHICKS HAND-FED WITH BRUNSWICK™ SARDINES IN SOYA OIL, ON MANA ISLAND IN 2007 AND 2008.

FEEDING DAY	FEEDING REGIME—CHICK WEIGHT / WING LENGTH		
	A <300 G / ALL WINGS	B >300 G / ALL WINGS	C (2008 ONLY) >300 G/ >170 MM WING
1*	30 ml	40 ml	40 ml
2	30 ml	40 ml	50 ml
3	40 ml	50 ml	60 ml
4	40 ml	50 ml	70 ml
5	50 ml	60 ml	70 ml
6	50 ml	60 ml	70–80 ml**
7	60 ml	70 ml	
8	60 ml	70 ml	
9	70 ml	70–80 ml**	
10	70 ml		
11	70–80 ml**		

* One tin sardines to 75 ml water. Thereafter, one tin sardines to 50 ml water was used.

** Meal sizes varied between 70 and 80 ml from day to day to attain an approx. 5–10 g weight gain per chick per day. The largest volume of 80 ml was generally not fed to chicks weighing <350 g. Never were two 80 ml meals delivered on successive days.

2.7.3 Feeding chicks

Food was delivered to chicks via custom-made, clear Teflon™ crop tubes (3.2 mm internal diameter × 1.5 mm wall thickness × 120 mm long) screwed directly into 50 ml Plexiglass™ syringes. During assembly, castor oil was applied to the syringe plunger for lubrication, and to the screw thread of the crop tube to make an airtight seal.

Containers of food were placed in a small insulated bin in up to 1 litre of hot water to warm up (i.e., in small batches at a time). A clean spatula was used to stir the food regularly (to attain even temperature and consistency), and the food temperature tested on the inner wrist or by inserting a food thermometer into the well-stirred mixture at least 10 seconds before taking a reading. Food was delivered at 30–35°C as large volumes of a cool mix (<30°C) may be rejected by chicks, and a hot mix (>35°C) may damage internal tissues.

Chicks were collected individually from burrows in a weigh bag placed inside a dark carry box (c. 400 × 200 × 200 mm). The nesting chamber was checked for possible regurgitation and for presence and appearance of excrement. The burrow lid was replaced to keep the chamber cool (in hot weather) and dry (in rain), and a coloured marker placed on the empty burrow to help clearly identify it when returning the resident chick. Chicks were held in the shade at the feeding caravan ready for weighing (and measuring if required) prior to feeding.

After loading the syringe and ensuring all air bubbles were removed, the feeder wiped the crop tube with a clean tissue to remove residue food. Two syringes were used to feed meals >50 ml to a single chick, to avoid food contamination.

During feeding, a handler restrained the chick securely, yet not too firmly (crop area unrestricted), on a towel-covered level surface; the bird was prevented from moving forward at all times. The feeder grasped the base of the upper mandible with one hand, extending the head and neck up and outwards (c. 45° angle) to straighten the oesophagus as illustrated by a photograph in Miskelly et al. (2009). With the other hand holding the syringe, the crop tube was inserted into the back and side of the throat, avoiding the opening of the trachea. Once in place, the plunger was slowly and steadily pushed. The crop tube was gently withdrawn if there were signs of discomfort or if food began to appear at the back of the throat (beginning of overflow), and the chick allowed to settle before any further feeding attempts.

Food delivery time was typically 30 seconds for a 50 ml syringe, often in two or three attempts, with rests in between and before introducing a second syringe load (larger meals). Food delivery stopped at the pre-determined amount or earlier if there were signs of over-flowing. The feeder recorded the food volume successfully delivered to the chick.

Chicks were rested briefly after feeding, then carried back to the burrow in the carry box to be returned directly to the back of the burrow.

Measures to maintain hygiene during the feeding process included: washing hands with antibacterial soap before and after each session; wiping soiled hands with antibacterial hand-wipes between chicks if necessary; wiping, sterilising (chlorhexidine solution) and rinsing (water boiled >3 minutes) crop tubes between chicks, and syringe barrels intermittently, using methods specifically developed to suit the feeding apparatus; and disinfecting work surfaces at the end of each day. Weigh bags were replaced as soon as they were soiled, and all were washed at the end of each day.

2.8 MANAGING CHICK EMERGENCE

2.8.1 Removing burrow entrance blockades

Chick emergence behaviour was managed by retention or removal of burrow blockades in order to minimise premature chick disappearances and allow target fledging weights to be reached through feeding birds daily right up to their departure. Burrows were blockaded for a minimum of 2 nights (2006) and those of younger chicks as long as 25 nights (2008). Once blockades were removed, a two-stick 'fence' was erected at each entrance to monitor chick emergence behaviour.

The timing of blockade removal was experimental in 2006: 22 blockades were removed in two sets, 2 and 4 days after the transfer day, from burrows housing chicks with wings ≥190 mm and some with wings 180–190 mm. Chicks from nine of these burrows disappeared on their first visit to the surface; at least five of these were unlikely to have survived to fledging, and the remainder will have been compromised at eventual fledging—low body weights through missing hand-feeding events. Subsequently, in all years, blockades were removed on an individual basis to minimise the risk of chicks disappearing too far in advance of their expected departure dates, i.e., maximising fledging condition, while still attempting to allow an appropriate emergence period for chicks to explore the environment—exercise, find take-off points, and site-fix to Mana Island. We also anticipated that chicks would be stressed trying to exit blockaded burrows too close to fledging.

In 2007 and 2008, blockades were removed according to development criteria (Table 3). In 2008, blockades to a few burrows had to be removed a little earlier because a chick showed: rapid down loss likely to be caused through movement within the burrow; evidence of digging within its burrow or chick found regularly in its pipe; or, slowed wing growth (<3 mm/day). The wing length criterion was also reduced for particularly heavy chicks that were more prone to misadventure in blockaded burrows (see Section 3.5.2).

In 2007 and 2008, blockades were not removed if chicks had >70% upper body down cover unless there was clear evidence of digging within the burrow. Down cover was never relied on as a sole guide to blockade removal as it can be prematurely lost during transit, or through handling, especially in wet weather.

TABLE 3. CHICK SIZE CRITERIA USED TO SCHEDULE REMOVAL OF BLOCKADES FROM BURROW ENTRANCES ON MANA ISLAND IN 2007 AND 2008.

CHICK SIZE	CRITERIA FOR BLOCKADE REMOVAL		
	2007 (INITIAL)	2007 ([1]MODIFIED)	2008
Wing length (mm)	190	190–200	[2] ≥200
Weight (g)	>350	>385	[3] ≥400

[1] Criteria modified after two chicks disappeared prematurely using initial criteria.

[2] 195–200 mm long—a few cases only.

[3] 380–400 g—a few cases only.

2.8.2 Searching for missing chicks

All artificial burrows at the colony, including those not currently accommodating chicks—i.e., unused burrows and those belonging to chicks already fledged or missing—were inspected daily in case chicks had moved from their own burrow, or returned to the burrow site after a period of absence. Routine tunnel checks of all occupied burrows ensured that the presence of two or more chicks in a single burrow was not over-looked.

Chicks found in burrows other than their own were returned to 'home' burrows to avoid confusion with meal sizes at feeding time, and to enable missing chicks retrieved on the surface to be returned to their own vacant burrows. In a few cases, chicks found regularly in another particular burrow were left there, providing it was not required by another bird.

Chicks not found in any other artificial burrow were searched for under the surrounding vegetation within and up to around 10 m beyond the burrow area depending on search time available before feeding commenced. Search focal points included the area immediately around the subject burrow and in flax vegetation close to the sound system speakers.

2.9 CHICK HEALTH AND MORTALITY

2.9.1 Screening birds on Long Island

Because of the difficulty in obtaining screening results of selected chicks prior to their transfer, we chose to sample adult fluttering shearwaters on Long Island to reflect the general state of health of the population, with the advice that further screening of chicks would only be necessary if the results revealed anything of concern. We identified the infectious diseases and parasites most likely to be present and of risk to birds—transferred chicks and other species on Mana Island—at a population level, and that could be practically tested for, based on knowledge from other New Zealand seabirds. These included: poxvirus, salmonellosis, yersiniosis, erysipelas, haemoparasites, and proventricular nematodes (*Contracaecum* species).

During the evening of 23 November 2005, samples were taken from 25 adults as follows: cloacal swabs from 25 birds for microbial culture; faecal samples from 11 birds to examine for gastrointestinal parasites by faecal flotation; whole blood samples from 18 birds to examine for haemoparasites and *Erysipelothrix rhusiopathiae*; and fresh blood smears from eight birds to assess white cell count and differential, and haemoparasites. All birds were physically examined, weighed and measured. Apart from significant loadings of Coccidia in some birds (see Section 2.9.2), all test results were negative.

2.9.2 Treatment for Coccidia

Coccidia oocysts were found in 45% of adults sampled. It was anticipated that chicks of affected adults would also be infected, and that these parasites could pose a risk to individuals during the stress of transfer when intestinal loadings could increase, potentially leading to illness. Therefore, the precautionary treatment of all transferred chicks with an oral coccidiostat, to limit potential infections, was advised following their arrival on Mana Island. A recommended repeat dosing 3 weeks later was received by 154 chicks that were still present at the colony at this time.

3. Results

3.1 COLLECTING CHICKS FROM LONG ISLAND

3.1.1 Finding chicks

During the three collection trips to the source colony, a total of 261 person-hrs were spent searching to find a minimum of 456 chicks including 65 banded chicks found in OSNZ study burrows. Just under half of these were suitable to transfer. In many cases, the smallest chicks found were immediately returned to burrows without being recorded. Thirty-seven chicks were taken from OSNZ study burrows in 2 years only (12 chicks in 2007; 25 in 2008).

We estimated that burrows containing chicks that could not be reached, and those confirmed as unoccupied, comprised approximately three-quarters of all burrows found in 2007. We suspected that some of these were burrows that we modified to aid inspection in 2006 and had subsequently been extended by burrowing birds.

3.1.2 Transferring chicks

Over 3 years, a total of 225 chicks was transferred to Mana Island in four arbitrary age classes based on wing length (Table 4). This included (actual weight ranges in brackets): 131 'small' chicks (300–515 g); 38 'medium' chicks (320–540 g, with all but one chick weighing >340 g); 39 'large' chicks (300–560 g, with all 2007 and 2008 chicks except one weighing >385 g); and 17 'extra large' chicks in 2006 only (320–515 g). While we hoped to have even numbers in each age class, this was not possible due to the limited number of chicks that met the transfer criteria.

Chicks weighed a mean ± SD of 397 ± 52 g (n=221) on the morning of transfer, and had wings measuring a mean of 158 ± 16 mm (n=223) (Table 5; Appendix 3). All 2007 and 2008 chicks had >90% down coverage at transfer.

No chicks died during transfer operations. Chicks were recorded as losing an average of 63 ± 26 g (n=220) over an approximate 24-hr period after removal from natal burrows on Long Island, and prior to the first hand-feeding event on Mana Island (Table 5).

TABLE 4. TRANSFER CRITERIA FOR FLUTTERING SHEARWATER CHICKS, AND NUMBER OF CHICKS TAKEN IN ARBITRARY AGE CLASSES.

ARBITRARY AGE CLASS	WING LENGTH (mm) ON TRANSFER DAY	MINIMUM WEIGHT (g) CRITERIA ON TRANSFER DAY			NUMBER OF CHICKS TAKEN		
		2006	2007	2008	2006	2007	2008
'Small'	130–160	300	300	300	7	60[2]	64
'Medium'	161–170	300	330	340	6	16	16[3]
'Large'	171–180	300	350	380	10	15	14
'Extra large'	181–190	300	n/a	n/a	17[1]	0	0

[1] Includes three chicks taken with 192 mm wing.

[2] Includes three chicks taken with 129 mm wing.

[3] Includes one chick taken at 320 g.

TABLE 5. TRANSFER WEIGHTS AND WING LENGTHS OF FLUTTERING SHEARWATER CHICKS (LONG ISLAND), AND WEIGHT LOSS OVER 24 HRS AFTER REMOVAL FROM NATAL BURROWS.

	TRANSFER YEAR		
	2006	2007	2008
Number of chicks transferred	40	91	94
Mean transfer wing length ± SD (mm)	174 ± 15	(n=89) 154 ± 14	154 ± 14
Range of transfer wing lengths (mm)	132–192	(n=89) 129–180	130–179
Mean transfer weight ± SD (g)	(n=38) 372 ± 55	(n=89) 385 ± 40	419 ± 53
Range of transfer weights (g)	(n=38) 300–515	(n=89) 300–470	305–560
Mean weight loss 24 h after transfer ± SD (g)	(n=38) 46 ± 23	(n=88) 55 ± 18	76 ± 27
Range of weight loss 24 h after transfer (g)	(n=38) 0–95	(n=88) 20–100	20–140

3.2 ADULT BIRD ACTIVITY ON MANA ISLAND

Stick 'fences' at burrows #99 and #100 at the South Point colony site were regularly knocked down from mid-December 2007 onwards (G. Timlin, pers. comm.). Two burrows were then reported with clear signs of bird activity on 4 January 2008. Burrow #1 contained white breast feathers, and burrow #100 contained a grass nest and an assortment of brownish-grey and white feathers. All three burrows are in close proximity to the sound system speakers. All feathers were considered to be from a fluttering shearwater. Later video footage confirmed that a fluttering shearwater was visiting burrow #100; the same bird was thought to be visiting the adjacent burrow #99. This bird, banded on 22 April 2009 (X-11897), continued to visit on a regular basis during 2009 with the latest recapture in #100 recorded on 11 August 2009.

In March 2009, it was reported that a burrow was being dug directly under the southern speaker, the speaker base effectively forming the entrance tunnel roof. A second, prospecting adult (new recovery banded X-7579) captured on the ground right by this speaker on 11 August 2009 was later found in this burrow.

Both birds were identified by DNA analysis of feather samples as females.

3.3 HAND-FEEDING CHICKS

A total of 2774 tins of sardines was prepared during the 3-year project to provide 5111 fluttering shearwater chick meals. All birds responded well to the sardine-based diet and feeding technique, but there may have been some dietary issues with some of the chicks fed for the longer periods (see Section 3.5.1).

After the initial introductory feeding regime, we found that 70 ml volume of the sardine diet delivered once per day maintained the weight of the more advanced, emerging chicks, while younger chicks achieved a steady 5–10 g daily weight gain.

Based on the response of chicks during feeding events, we considered 80 ml to be a maximum single meal size for this species (using our delivery techniques), only to be fed to an individual on occasional days, and only to those weighing >350 g if required to attain necessary weight gain. Although the proventriculus of seabirds is particularly large and distensible, we were wary of introducing an artificial meal amounting to more than a quarter of a bird's body weight in the relatively short time that each bird was handled.

We found that a gradual decrease in meal sizes prevented chicks falling too rapidly below the optimum departure weight before they fledged.

Very few regurgitation incidences were recorded throughout the entire project. These were usually by heavy chicks ready to start the decreasing meal size regime up to fledging.

3.4 MANAGING CHICK EMERGENCE

3.4.1 Chicks in blockaded burrows

A single chick escaped from its blockaded burrow by digging under the inspection lid on the second night after the transfer on Mana Island in 2006. This bird was not recovered and still estimated to be at least several days from fledging; it is possible that it had previously emerged on Long Island. With a new burrow design used for subsequent transfer cohorts, and the refinement of chick transfer criteria to avoid moving such advanced chicks, no similar escapes occurred.

A total of 66 recoveries of 28 live chicks from within pipes of blockaded burrows was recorded during the 2008 morning chick roll-calls (Table 6).

It was obvious that in most cases, chicks were unable to reverse back along the pipe, or turn around within the pipe, to return to the chamber. This was fatal for four chicks in 2 years (see Section 3.5.2). All chicks found in pipes were returned to chambers.

TABLE 6. NUMBER OF TIMES INDIVIDUAL CHICKS WERE FOUND IN PIPES OF BLOCKADED BURROWS ON MANA ISLAND IN 2008.

	NO. OF TIMES CHICK FOUND IN PIPE DURING MORNING BURROW CHECK						
	1	2	3	4	5	6	7
No. of chicks found in pipes	15	1	6	2	2	1	1

3.4.2 Chicks visiting other artificial burrows

Chicks were frequently found away from their 'home' burrows on Mana Island in all 3 project years; 72 chicks were found in other artificial burrows on a total of 260 occasions, including two 2006 chicks found in five different nearby fairy prion burrows (Table 7). Nearly three-quarters of these chicks were only ever found in one or two other burrows, but some were found changing burrows up to six times (Table 8).

Two chicks were sometimes found at the same time inside one burrow (30 burrows; 39 occasions): two chicks were found once in 23 burrows, twice in five different burrows, and on three occasions in two other burrows. Chicks were either found together in the chamber (often vocalising) or with one in the tunnel. Aggressive behaviour between chicks was never observed. Three chicks were found together in a single chamber on only one occasion, in 2008.

TABLE 7. NUMBER OF TIMES INDIVIDUAL CHICKS WERE FOUND IN OTHER ARTIFICIAL BURROWS ON MANA ISLAND (2006–2008).

	NO. OF TIMES CHICK FOUND IN BURROWS OTHER THAN THE 'HOME' BURROW										
	1	2	3	4	5	6	7	8	9	10	11
No. of chicks found in other burrows	17	14	11	8	6	6	4	2	1	2	1

TABLE 8. NUMBER OF DIFFERENT BURROWS INDIVIDUAL CHICKS VISITED DURING THEIR EMERGENCE PERIOD ON MANA ISLAND (2006–2008).

	NO. OF DIFFERENT BURROWS VISITED (EXCLUDING THE 'HOME' BURROW)					
	1	2	3	4	5	6
No. of chicks found in other burrows	34	19	10	3	5	1

3.4.3 Chicks recovered away from artificial burrows

Searches for chicks that were considered to have disappeared before their expected fledging date were non-productive in 2006 and 2007: not one of the 21 chicks missing in these years was found. The majority went missing on their first night emerging from the burrow. 'Fence' status at burrow entrances indicated that two chicks in 2007 were possibly returning to their burrows, but they were never present by day.

Up to 2 person-hrs of searching each morning in 2008 resulted in 37 recoveries of 22 chicks that had failed to return to any artificial burrows but were not yet ready to fledge. Most of these were away from their 'home' burrow on one occasion each, but others were recovered away from their burrow up to four times. Chicks were found on most mornings from mid-January onwards, mostly under flax and occasionally beneath other vegetation. Searching stopped on 5 February when no chicks were recorded as prematurely missing and feeding by volunteers had declined. A single chick was opportunistically found on the surface during the day, moving through flax above the burrow area.

3.4.4 Chicks recovered after a period of absence

Thirteen chicks were recovered after absences ranging from 1–4 days (2007 and 2008). Six of these were found in vegetation and seven returned of their own accord to their 'home' burrow. Nine chicks lost a mean of 24 ± 7 g (range 15–35 g) over a 48-hr period after missing one feed; two chicks each lost 40 g over a 72-hr period after missing two feeds; and two chicks each lost 65 g over 96 hrs after missing three consecutive feeds. Blockades (internal and external) were reinstated for 5 days/nights at the burrow of one of the latter chicks in 2008, to allow it to regain lost weight prior to fledging so that post-fledging survival was not compromised.

3.5 CHICK HEALTH AND MORTALITY

3.5.1 Chick ailments

A single chick only (2008) died as a result of a non-infectious pathological condition. This chick was found dead in its burrow 7 days after transfer to Mana Island; no symptoms had been reported before this. Necropsy indicated aspergillosis as the most likely cause of death; A*spergillus* spores were probably present in the bird at the time of transfer with stress bringing on the pathological condition.

Three chicks were observed with different ailments that may have compromised welfare and fledging success if left without treatments described below. Treatments were administered by wildlife vets on two occasions (*ex situ* and *in situ*).

One chick was noted to have a small swelling on the side of its bill on 25 January 2007. The area of inflammation increased in size over several days. The chick (>400 g) was taken off the island on 2 February, without being fed, for diagnosis and treatment at Massey University Veterinary Clinic (Palmerston North). It was anaesthetised, the scab tissue removed, and the swelling cleared of infectious material. Vets suspected that a feather follicle was infected and advised that the chick was likely to fully recover. The chick was returned to Mana Island on the same afternoon and given 20 ml of water only on its return. The wound, flushed with saline as required, quickly healed, and the chick departed the colony 6 nights later at a size and weight appropriate for successful fledging.

A second chick in 2007 was found to have small crusty build-ups on its ear covert feathers, likely to be caused by an ear infection. Crusts were removed on three occasions between 24 January and 1 February, by which time sufficient air-flow reached the ear opening and the infection was able to clear naturally. No other symptoms were observed.

One chick arrived on Mana Island with a sealed eye in 2008. Daily flushing with saline solution and application of a veterinary eye ointment (to soften the lids) failed to facilitate the eye opening. After 10 days, on veterinary advice the eye lids were gently worked apart but a membrane had formed between the upper and lower lid, with two small gaps in each corner. The DOC vet visited the colony on 22 January, and was able to lift the skin away from the eyeball and cut the membrane with surgical scissors without any apparent pain or bleeding. The chick appeared to have normal vision and eye-lid function in this eye, and fledged normally and in good condition.

Ticks were observed by handlers on the head region of many of the 2008 chicks on arrival, particularly around the base of the bill, and ticks had also been seen on at least 15 (16%) of the 2007 chicks and some of the 2006 chicks. These fell off within the first week after transfer. Only one chick had a small swelling under its lower mandible—a likely result of tick presence—that healed in subsequent days.

Seven chicks (three in 2007; four in 2008) were observed to pass unusually green faecal matter in the week prior to fledging. These chicks had all been hand-fed at the release site for a mean of 28 ± 2.1 days (range 25–31 days). In most cases, the green component was the faeces, but in at least two birds the fluid component of the excrement was also bright green (with normal white urates). All chicks noted with green faeces appeared otherwise healthy and we presumed they fledged successfully (see Discussion).

3.5.2 Chick misadventure in tunnels

In 2006, a chick was found dead at the pipe entrance of its blockaded burrow on 5 February. We considered this to be a result of misadventure, so *post mortem* examination did not proceed. The chick—one of the heaviest chicks (425 g) with no previous signs of ill-health—was wedged against the blockade. There was no evidence of regurgitation in the burrow and there were fresh, normal faeces present. We concluded that a combination of heavy chick weight (and lesser agility) combined with the relatively steep downward slope of this particular tunnel prevented the bird from reversing back up the pipe, resulting in its entrapment overnight. We suspect suffocation may have resulted from the neck being restricted (body weight pushing on it), or the bird died of stress, or even exposure, because it was trying to emerge. Blockade removal was scheduled to occur in the next day or two, but had been postponed because the chick still had 80% down coverage when last recorded.

Apart from this single incident, there were no further occasions where chicks were found to be suffering or to have died within pipes during the first and second years of the project. However, similar incidences were reported in the final project year.

Three chicks were found dead in January 2008 within pipes at the entrances of their respective blockaded burrows. Two of these chicks had regurgitated through the gate mesh and appeared to be pushed up against the mesh. One of the heavier chicks had abrasions on both carpals indicating some physical stress within the pipe. Even though measures were taken to keep all corpses cool, they soon began to decompose due to presence of maggots, and cause of death was inconclusive at *post mortem* examination.

A fourth chick—one of the youngest chicks in the 2008 cohort—was found at an early age within the blockaded entrance of its burrow one morning, weak and damp. This chick required recovery time and was blockaded into its chamber using an internal blockade to prevent it entering the pipe, avoiding any risk of further misadventure in the tunnel. Although the chick was generally lethargic over the following couple of weeks, and seemed to take a while to emerge from its burrow when the blockades were eventually removed, it appeared to regain strength and attitude, and fledged normally after a relatively short emergence period.

All other live chicks found in pipes during the morning roll-call appeared to tolerate the experience, probably because there were no severe weather conditions (rain or cold temperatures). Many of these chicks were too young to visit the surface, and at risk of disappearing, so we could not use these in-pipe occurrences to trigger blockade removal.

3.6 EMERGENCE BEHAVIOUR

A total of 220 chicks emerged from burrows (Table 9). First visits to the surface occurred as early as 8 January (2007) and as late as 14 February (2006).

3.6.1 Delayed emergence

Eighty-one chicks (26 in 2006; 13 in 2007; 42 in 2008) emerged from burrows on the night following gate removal, and may have had their first emergence delayed—hence, total emergence period reduced—because of being restrained. This includes: two chicks in 2006 that had to be boxed up in the caravan overnight prior to their first emergence due to burrow flooding, and who emerged on the following night after being returned to their respective burrows; one chick in 2007 whose emergence was deliberately delayed following recovery from veterinary treatment; and one chick in 2008 whose emergence was accidentally delayed because the right wing had dropped two outer primary feathers and the chick's true advanced state was not realised until this was noticed and the left wing measured.

3.6.2 Missing chicks

Twenty-nine chicks (13% of all emerging chicks) were considered to have disappeared from burrows prematurely, based on last records of wing growth and down coverage (mostly >40% coverage on upper body), and were not recovered again (Table 9). Missing chicks most commonly disappeared on their first night outside the burrow: 20 out of 24 missing chicks in 2006 and 2007; one of five missing chicks in 2008. All of these chicks, except the single 2008 bird, had been restrained in burrows until their first emergence.

TABLE 9. WEIGHTS AND WING LENGTHS OF TRANSLOCATED FLUTTERING SHEARWATERS THAT DISAPPEARED FROM BURROWS PREMATURELY ON MANA ISLAND.

	TRANSFER YEAR		
	2006	2007	2008
Number of chicks emerging	39	91	90
Number of chicks prematurely missing	14	10	5
Mean weight at disappearance ± SD (g)	337 ± 44	397 ± 19	423 ± 13
Missing chick weight range (g)	255–420	365–415	400–430
Mean wing length at disappearance ± SD (g)	(n=12) 196 ± 9	(n=8) 202 ± 7	213 ± 8
Missing chick wing length range (g)	(n=12) 180–213	(n=8) 188–210	200–222
Time on Mana Island prior to disappearance ± SD (days)	6 ± 3	14 ± 5	19 ± 3
Range of days on Mana Island prior to disappearance	2–12	6–24	16–24

Five chicks in 2006 are highly likely to have perished before or during any fledging attempt because they were unable to be hand-fed for long enough to reach even the lowest appropriate fledging weights. A further four chicks (three in 2006; one in 2007) were also likely to have been severely compromised at departure. Twenty chicks disappeared at weights that may have sustained them through to an eventual fledging attempt in less-than-optimum condition, i.e., at light weights after various periods without food—six in 2006, nine in 2007, and all five in 2008.

Chicks that disappeared prematurely in 2006 were considered as having the least chance of surviving because they disappeared during or just after the introductory phase of the new diet, when birds were still experiencing a weight loss trend following the transfer. Those that disappeared in 2008 probably had the greatest chance of surviving to fledge, because birds had been blockaded into burrows and hand-fed for longer and were, therefore, heavier upon disappearance.

3.7 FLEDGING DATA

We analysed the emergence and fledging data of 191 chicks we considered to have made a successful fledging attempt based on a combination of base (pre-feed) weight, wing length, down coverage and wing growth rate on the day before they left the colony, so that we could determine size and weight of departing fledglings under normal circumstances (Table 10; Appendix 3). Chicks that we considered to have prematurely left burrows, and were not yet ready to fledge, were analysed separately (Table 9).

TABLE 10. FLEDGING DATA FOR TRANSLOCATED FLUTTERING SHEARWATERS ON MANA ISLAND COMPARED WITH DATA FROM OTHER STUDIES

	TRANSLOCATIONS				
	[1]LONG I. 1988/89	[2]MAUD I. 1991/92 TO 1996/97	MANA I. 2006	MANA I. 2007	MANA I. 2008
[3] Number of chicks fledging	31	273	25	81	85
[4] Mean fledging weight ± SD (g)	411	364	375 ± 32	400 ± 17	404 ± 20
[4] Fledging weight range (g)	315–520	205–495	300–425	355–445	345–455
[4] Mean fledging wing length ± SD (mm)	215	No data	(n=24) 214 ± 7	218 ± 5	(n=84) 217 ± 4
[4] Fledging wing length range (mm)	204–225	No data	197–225	205–227	206–226
[5] Mean emergence period ± SD (nights)	No data	No data	5 ± 3	7 ± 3	9 ± 3
[5] Emergence period range (nights)	No data	No data	1–11	2–14	2–16
Mean time at release site ± SD (days)	n/a	14	19 ± 7	27 ± 5	27 ± 6
Time range at release site (days)	n/a	0–36	9–33	15–38	16–38

[1] Unpublished data from P. Hodum.

[2] Data from Bell et al. (2005).

[3] Sample sizes from Mana Island include chicks presumed to have successfully fledged only.

[4] Fledging data recorded on day preceding night of departure from burrows.

[5] Emergence period includes fledging night.

The earliest fledging date recorded over all three project years was 17 January (2006) and the latest was 16 February (2006). Chicks spent a mean ± SD of 26 ± 6 days on the island (n=191) including transfer day, and departed with mean base weight of 399 ± 22 g (n=191) and wing length of 217 ± 5 mm (n=189) after spending a mean of 8 ± 3 nights outside burrows on the surface prior to and including the night of fledging (Table 10). Mean wing growth rate for 187 fledging chicks was calculated as 2.4 ± 0.2 mm/day during their stay on Mana Island.

Approximate daily wing growth rate in the days leading up to departure was recorded for 182 chicks to ascertain if wing growth was completed by departure. At least 103 chicks fledged after their wings had completed growth, 45 chicks departed with wing growth reduced to ≤1 mm/day, 28 chicks departed with wing growth ≤2 mm/day, and six chicks left with growth last recorded at ≤3 mm/day. For the remaining birds, it was unclear if growth had been completed or not by fledging time.

Of 108 chicks assessed for presence and coverage of down in the few days leading up to fledging, 46 birds had no down present by fledging time, 23 had up to 5% upper body coverage, 21 had up to 10% coverage, eight had up to 15% coverage, and 10 birds had up to 20% coverage.

4. Discussion

4.1 ADULT BIRDS VISITING MANA ISLAND

The colonisation of the South Point burrow site on Mana Island by at least two adult fluttering shearwaters to date (December 2009) is encouraging news. There is little doubt that their arrival is a result of acoustic attraction—there was no transferred chick activity when signs of the first visits were recorded, and both birds were unbanded at capture. In addition, the prospecting activity of both birds is focused around a loud speaker.

We suggest several likely reasons why fluttering shearwaters landed and stayed at South Point and have not been found at the fairy prion/diving petrel colony site where fluttering shearwater calls are also broadcast and where we transferred chicks in 2006. At South Point, it is mainly fluttering shearwater calls that are broadcast, giving the impression of a significant colony, whereas playback at the other site features predominantly diving petrel, fairy prion, and some white-faced storm petrel *Pelagodroma marina* calls with only around 5% of playback containing fluttering shearwater vocalisations (G. Taylor, pers. comm., Oct 2009). The South Point recordings feature a range of calls by many individuals of local Cook Strait dialect, whereas the earlier sound system mostly broadcasts calls of birds from northern New Zealand. In addition, easier landing and take-off opportunities, and a colony odour introduced by larger numbers of transferred chicks, may also make the South Point site more attractive to the species.

4.2 FLUTTERING SHEARWATER BURROW DESIGN

We are encouraged that at least one prospecting adult is finding the artificial burrows at South Point attractive enough to visit on a regular basis, and that nesting material has been noted within these burrows. We suggest that the motive for the female immigrant burrowing nearby under the loud speaker may be related to her instinct to follow the sound in search of a mate rather than a lack of attraction to the artificial burrows.

The design of burrows at the South Point colony worked very well for fluttering shearwater chicks. Burrows appeared to be adequately insulated in the exposed conditions, most importantly from the heat of the sun. There were no incidences of burrows flooding at South Point in inclement weather—an issue which has caused chick mortality in other seabird translocation projects—whereas five chicks in 2006 had to be removed from their burrows overnight at the first colony site because chambers had filled with water. The extra effort involved in improving drainage during burrow installation is also likely to benefit productivity of adults using them for future breeding. A single chick was able to escape from its blockaded burrow at the original site, but there were no reports of restrained chicks escaping from the more robust burrows at South Point.

After a single chick mortality caused by entrapment within a pipe at the first colony site where chicks were transferred to in 2006, none was reported in 2007 at South Point. We considered that the risk, associated with steeply angled pipes, had been eliminated by setting all tunnels of burrows at this colony site only very slightly off the horizontal (for drainage). We attributed mortalities associated with chick entrapment in pipes in 2008 to blockade design (see Section 4.6).

4.3 COLLECTING CHICKS FROM LONG ISLAND

Measures were taken to minimise impacts to natural burrows on Long Island by restricting team size, search area and effort, although damage to some burrows still occurred. Nest boxes with inspection lids were installed at many of the active burrows in the targeted search area (by OSNZ) before the second transfer year, and these proved to be of great value to our project. These study burrows significantly helped to minimise burrow damage through reduced search time in the steepest and most fragile part of the colony, and reduced the time required to find each suitable chick to 0.9 person-hrs. They also yielded 16% of all transferred chicks, and these were relatively quicker to collect on the transfer day than those in natural burrows.

We developed and refined transfer criteria which we consider suitable for use in future translocations of this species. By reducing maximum wing length in the latter two transfer years, we were able to avoid collecting chicks that may have already emerged on Long Island, since it proved impossible to tell if chicks of this species had emerged from their burrows—no obvious down present at the burrow entrance, and use of stick 'fences' was of little value since some parents were visiting. Increasing minimum weights of chicks at transfer in 2008 meant that chicks with less time to adapt to the feeding regime at the release site could still fledge in optimum condition, even after a potential mean loss of 63 g over 24 hours following transfer. Higher weights were also likely to improve the potential fledging success rate of chicks that disappeared before their expected fledging date, i.e., those unable to receive meals right up to fledging. We recommend increasing the minimum wing length of chicks at transfer from 130 mm to 150 mm (but ideally 160 mm) to reduce chick time at the release site on the artificial diet (see Section 4.5), while recognising this may reduce the total number of chicks able to be collected in one season. To find enough chicks at this closer-to-'medium' size, it might be necessary to select a transfer date slightly later than the 2007 and 2008 dates (e.g., 10 January) in this geographical region as 67% of all chicks transferred in these 2 years were in the 'small' age class on 4–5 January. Knowledge that wings of transferred, hand-fed chicks grow an average 2.4 mm/day in the last 26 days before fledging, will also be relevant in future projects (as opposed to Hodum's mean 3 mm/day growth recorded over the entire natural chick rearing period).

Information from collecting trips regarding search effort will be invaluable for planning future translocations of this species, at least at this site. We conclude that more than twice the number of fluttering shearwater chicks proposed for translocation need to be found at the source colony to provide a big enough sample from which to select chicks suitable for transfer and that the colony search area may need to be much larger in order to minimise impacts on the colony.

4.4 CONDITION OF CHICKS ON MANA ISLAND

All 225 fluttering shearwater chicks transferred were in excellent condition on arrival at Mana Island. Four of five confirmed mortalities were attributed to misadventure and could have been avoided if we had used a different burrow blockade design (see Section 4.6). A minimum of 191 chicks (85% of chicks transferred) were presumed to have fledged successfully from Mana Island with a good chance of post-fledging survival—25 chicks in 2006 from the first colony site, and at least 166 birds from the South Point colony in 2007 and 2008. A maximum of 211 birds (94% of chicks transferred) are considered to have left the island with the additional 20 birds that may have flown to sea in less-than-optimum condition.

Over 3 years, chicks left Mana Island with a mean fledging weight slightly lower than the mean Hodum collected from naturally raised chicks on Long Island (Table 10), but exceeding the mean recorded for adults by 8 g, and with a range similar to Hodum's adult weight data (n=46; mean 390 g; range 335–446 g). As with most seabird translocation projects, there was an increase in mean fledging weight with each project year.

Chicks left Mana Island with wing lengths close to the mean (218 mm) and range (211–226 mm) of wing measurements taken from beach-wrecked adults at Kaikoura Peninsula (Tarburton, 1981). Wings of chicks on Mana Island were longer than of adults measured by Hodum on Long Island (n=46; mean 212 mm; range 204–220 mm); this may be attributed to a difference in measuring technique, but is more probably due to feather wear of adults given that Hodum's chick wing length ranges (Table 10) were similar to those on Mana Island.

At least 154 birds considered to have fledged under normal circumstances departed ≥385 g, the minimum target fledging weight indicated by Bell et al. (2005) for survival. Over 82% of these had either already completed wing growth or primary feathers' growth had slowed to ≤1 mm/day, and hence likely saved energy that might otherwise have been required to complete growth at sea after leaving the colony. In addition, 95% of these 154 chicks stayed ≥18 days at the release site, the optimum duration indicated by Bell et al. We predict that this particular group of birds will have the best survival rate, and a higher rate of return as adults to Mana Island.

4.5 DIET AND HAND-FEEDING

Fluttering shearwaters responded well to the diet—Brunswick™ sardines in soya oil blended with fresh water—and to the crop-feeding technique employed. Chicks departed in a condition we considered appropriate for successful fledging and post-fledging survival following periods of up to 37 days on this diet, with only a single meal required each day to achieve this. Daily wing growth rate was less than the 3 mm/day found in Long Island chicks, but this is likely to reflect the tendency in many species for growth rates to slow naturally towards fledging time.

Our only concern was the fact that several of the younger chicks in 2007 and 2008 produced excrement with an abnormally green appearance as they approached fledging. We were unable to determine the underlying reason for this, but discussions with wildlife vets pointed at a dietary cause with potential long-term implications. These symptoms have not been observed in translocated *Pterodroma* chicks and we suggest that this may be because they are not daily feeders and take relatively smaller volumes of food. Nor were these symptoms recorded during the fairy prion translocation where many chicks were hand-fed large volumes daily for proportionally almost as long as fluttering shearwaters in terms of their total rearing period. It may, however, be significant that the Brunswick™ product had changed in content composition (proportion of fish to soya oil) after the fairy prion translocation project was completed. Abnormally green excrement has, however, recently been noted in a very small number of translocated diving petrel chicks fed on a daily basis for around 40% of the rearing period for this species (H. Gummer, pers. obs.), with the same product used for fluttering shearwaters. For future translocations we recommend that further investigation be made to determine the cause of green excrement and whether this compromises chick welfare.

We know, at least, that short-term survival is not affected by hand-feeding for 25 days, as we received notification from the Australian Bird and Bat Banding Scheme that a deceased chick was found 2507 km away at the mouth of the Powlett River in Victoria, just over 13 months after it had fledged from Mana Island in 2008 after 25 days' hand-feeding (Hardy, 2009). We suspect that the diet in its current form is not ideal to feed to chicks on a daily basis for as much as 50% of the rearing phase and would avoid transferring any fluttering shearwater chicks estimated to be >25 days from fledging in any future operations, so that birds are only subjected to the artificial diet for up to one-third of their nestling period. We also recommend adding a seabird vitamin/mineral supplement to replace any dietary components that might have been eliminated during the sardine canning process.

Chicks readily took to the refined feeding regimes in 2007 and 2008, responding well to the faster transitions onto the artificial diet, resulting in at least 89% of the two large cohorts fledging at excellent weights. We found that the more advanced chicks (wings >170 mm) responded well to a faster increase in introductory meal size; we consider that the more rapid weight gain increases would have benefited any of the older chicks that disappeared before expected fledging time, within the first

1–2 weeks at the release site. There is scope for further experimentation with meal size, particularly with chicks transferred at lighter weights. Weight stabilisation and a faster initial weight gain may be achieved if >30 ml is fed in the first meal. It must be noted, however, that daily weight gains greater than 10 g are undesirable, and birds peaking at heavy weights seem to have to wait anyway, extending the emergence period, to lose weight prior to fledging.

4.6 MANAGING CHICK EMERGENCE BEHAVIOUR

From our experience with eight petrel species translocated within New Zealand to date (Miskelly et al., 2009), fluttering shearwaters appear to be one of the most prone to wandering into other burrows or away from the burrow site during their emergence period, often never to be recovered again. In 2006, chicks had lost a lot of weight during the transfer and were receiving relatively small volumes of food in the first few days on Mana Island with our precautionary approach to introducing the new diet. We speculated that these hungry chicks had a sense of urgency to depart early (advanced chicks), or to visit the surface much earlier than normal (younger chicks). In addition, they may have found the relatively small burrows at the first colony site less attractive to return to.

The wandering behaviour continued to be observed in the second and third transfer years when the quality of chicks transferred was improved and transition onto the hand-feeding regime faster, and also towards the end of each project when there were plenty of open, vacant burrows available. Chick disappearances were more numerous in the earlier weeks of each project; we anticipated that the earliest emerging chicks had fewer options regarding spare burrows to take refuge in, since the majority of other burrows were still occupied and blockaded. Incidences of chicks permanently disappearing in fact decreased with each project year—28% of all emerging chicks in 2006; 11% in 2007; and 8% in 2008—we attribute this in part to the improved feeding regime (combating weight loss incurred at transfer sooner), but also to the investment of greater search effort for missing chicks, as the project progressed. Allocating time for daily chick searches proved to be a crucial part of the management process for this species at this particular release site.

Weight loss data from chicks recovered after a period of absence suggest that individuals not subjected to handling stress lose a mean of 24 g over the first 48-hr period with no meal in that period, and that weight loss continues at a similar, or slightly less, rate over any subsequent 24-hr periods without food. From this information, we estimate that a missing chick could drop from the upper end of the fledging weight range to the lowest over a period of a week without food. Therefore, chicks that we consider to have disappeared prematurely were highly likely to be compromised at or after fledging.

Fluttering shearwater chicks need daily feeding right up to their departure to ensure optimum fledging condition, and an emergence period to explore, find take-off points, and optimise the site-fixing process. A blockade removal regime different to those employed for other species had to be developed to avoid compromising either of these requirements. *Pterodroma* chicks appear to develop a stronger affinity to their 'home' burrow, and so blockades can generally be removed before the expected emergence date without the same risk of chicks disappearing. In addition, they do not need to be fed every day and tend to have enough reserves to carry them through longer periods without food intake. Chicks of the smaller species that require daily feeding—diving petrels and fairy prions—tend to fledge on their first night outside the burrow, and blockade removal can generally be left until each chick is considered ready to fledge.

Blockading fluttering shearwater chicks in burrows until they reached good weights, i.e., they could survive up to several nights without feeding if they went missing, was our favoured strategy in order to fledge heavier birds with an improved chance of survival. We may have compromised the chicks' natural emergence behaviour by slightly reducing their overall time on the surface, as 37% of all emerging chicks came out of their burrows on the night immediately after blockades were removed indicating they may have been ready to emerge prior to this. However, the mean emergence period of 8 nights—chicks considered to have fledged successfully—is likely to resemble natural emergence periods for chicks of this species, given that at other burrows, emergence periods may have been slightly over-estimated if stick 'fences' were occasionally knocked down by investigating birds and not the burrow occupant.

Delayed blockade removal also increased the risk of serious trauma caused by entrapment in blockaded pipes, particularly with bulky chicks. We suggest that the four deaths through misadventure in pipes would not have occurred if burrow entrances had not been blockaded, or if the chicks had been denied access into a blocked pipe, and that other chicks found in pipes unharmed may have only escaped ill effects because weather conditions were favourable. Therefore, we recommend that burrows created to house translocated chicks of this species in future be fitted with both internal and external blockades, i.e., at each end of the tunnel, as a measure to prevent any birds entering a dead-end pipe—resident chicks exiting burrows, and chicks on the surface investigating open burrows. We consider that there are more risks associated with fluttering shearwaters sitting at the entrance of a blockaded pipe, especially if that pipe is sloping downwards, than any benefit of chicks being able to see the environment outside the burrow through the mesh blockade, before they emerge. Such visual access is unlikely to be as important for a species with an obvious emergence period as it is for species that fledge on their first or second night outside the burrow and for which site-fixing from the burrow entrance may be of greater significance—e.g., diving petrels and fairy prions. These smaller sized chicks can also easily manoeuvre inside the 110 mm diameter tunnel with little risk of entrapment. We consider the current pipe dimensions used with fluttering shearwater burrows to be the most appropriate, and would be reluctant to use a larger pipe diameter for this species as burrows with large entrances are unlikely to be as attractive to prospecting adults.

We consider that prolonged restraint alone was not a factor influencing the premature and permanent disappearances of some chicks since blockades were effectively removed later in chick development in 2008, and no chicks during this final project year were reported as disappearing on the night immediately after blockade removal. It is, however, possible that chicks in relatively poor condition had less incentive to return to burrows that they had been blocked into.

Wandering behaviour has also been reported for translocated Hutton's shearwaters *Puffinus huttoni* on the Kaikoura Peninsula, although fewer chicks disappeared permanently. A mesh fence encloses this mainland burrow site, thus limiting the area that chicks explore, and there is less vegetation for birds to hide in. In one year, 50 of 100 transferred chicks were found away from their 'home' burrows—in other burrows or on the surface—on a total of 112 occasions, with chicks reported as missing on most mornings (M. Morrissey and P. Bradfield, pers. comm., Oct 2009).

We are unable to explain why these two shearwater species show this wandering behaviour. We consider it unlikely that translocated fluttering shearwater chicks were confused by the numerous burrows positioned close together and with similar orientation and appearance at the artificial colony sites, as burrows at the source colony were densely packed with little to distinguish one from another. It would be useful to investigate adult feeding patterns, chick emergence behaviour, and adult-chick interactions at a natural colony, for comparison with the behaviour we observe at artificial burrow sites following translocation. It seems likely that a few chicks of this species will go missing before expected fledging time in any subsequent transfers.

4.7 CONCLUSION

We conclude that the translocation of fluttering shearwaters to Mana Island was highly successful. Techniques developed for this species have already been applied to translocation projects involving threatened species within New Zealand: translocation of Hutton's shearwaters proceeded once the sardine diet had been tested on the more common fluttering shearwaters; and the blockading strategy at burrows of transferred Chatham petrels *Pterodroma axillaris* has since been modified based on the results of this project.

The first of the transferred fluttering shearwaters could return in the 2009/10 season, but may recruit near the fairy prion/diving petrel colony area, where the 2006 chicks were transferred to. Birds may begin to return to the South Point colony from late 2010 onwards. First time breeding attempts of transferred birds are unlikely to occur before the 2011/12 season.

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Appendix 1

SOUTH POINT ARTIFICIAL FLUTTERING SHEARWATER COLONY SITE, MANA ISLAND (JANUARY 2007)

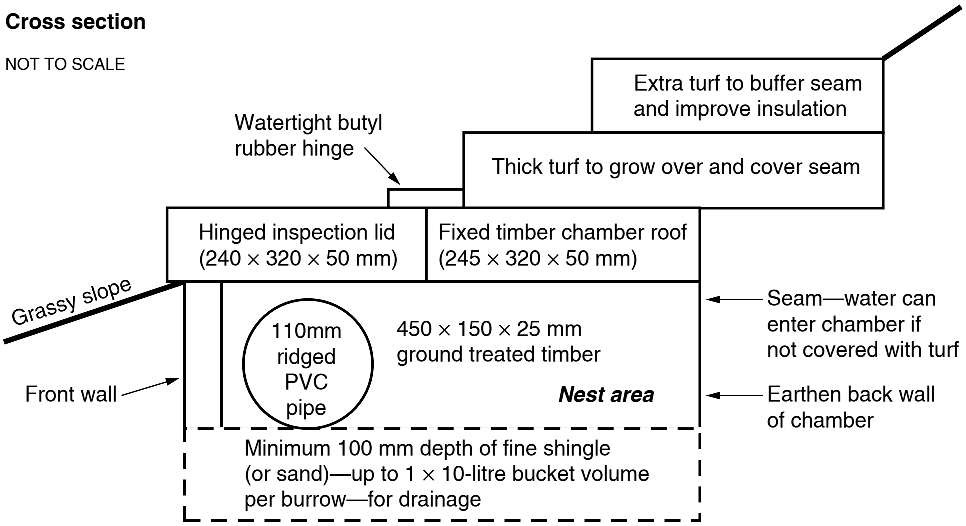
Photos: D. Cornick.

Appendix 2

ARTIFICIAL BURROW DESIGN FOR FLUTTERING SHEARWATER, USED AT THE SOUTH POINT COLONY SITE, MANA ISLAND

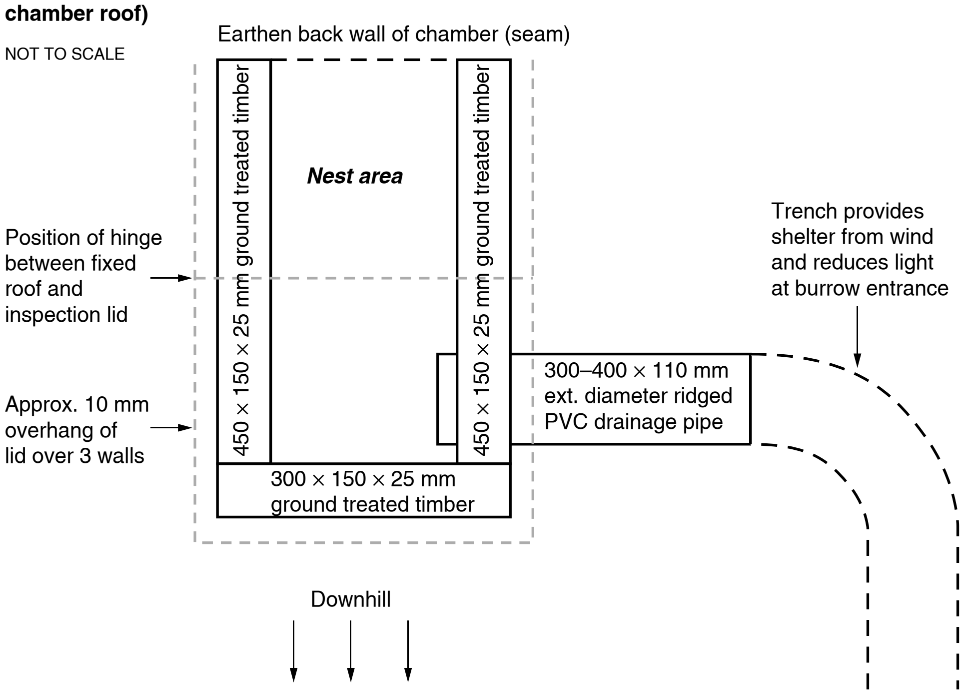
Cross section

NOT TO SCALE



Top view (without chamber roof)

NOT TO SCALE



Appendix 3

TRANSFER AND FLEDGING DATA FOR FLUTTERING SHEARWATER CHICKS TRANSLOCATED TO MANA ISLAND, 2006–2008

Note: Emergence period (nights out) includes fledging night, and total number of days on Mana Island includes transfer day.

BAND (X–)	MANA I. BURROW	TRANSFER WEIGHT (g)	TRANSFER WING (mm)	POST TRANSFER WEIGHT AT 24 HRS (g)	WEIGHT LOSS 24 HRS AFTER TRANSFER (g)	FLEDGING (PRE-FEED) WEIGHT (g)	FLEDGING WING (mm)	DAILY WING GROWTH RATE ON MANA I. (mm)	DATE OF FLEDGING OR *DISAPPEARANCE (PM)	NIGHTS OUT OF BURROW	DAYS ON MANA I.	EMERGENCE POTENTIALLY DELAYED BY BLOCKADE	FINAL DOSE OF COCCIDIOSTAT RECEIVED	WING GROWTH RATE (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	% DOWN COVER (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	COMMENTS
8451	75	340	129	270	70	380	222	2.6	8/02/2007	8	36	N	Y	Complete	–	
8452	72	380	148	310	70	420	218	2.4	1/02/2007	6	29	N	Y	≤1 mm/day	–	
8453	65	455	150	360	95	410	218	2.5	30/01/2007	11	27	N	Y	≤1 mm/day	–	
8454	83	500	151	415	85	405	216	2.5	30/01/2008	9	26	Y	Y	≤2 mm/day	0	
8455	12	365	130	285	80	390	218	2.3	11/02/2008	12	38	N	Y	Complete	0	
8457	25	370	154	330	40	415	217	2.2	2/02/2008	13	29	Y	Y	Complete	<5	
8458	40	430	148	365	65	–	–	–	–	–	–	Y	–	–	–	Dead 21/01/08 (trapped in pipe)
8459	9	385	136	320	65	385	215	2.6	3/02/2008	9	30	Y	Y	≤1 mm/day	10	
8460	14	475	175	365	110	430	213	–	*20/01/2008	≥1	≥16	N	N	2–3 mm/day	50	Disappeared. Probable later fledge
8462	94	430	144	310	120	395	220	2.1	9/02/2008	12	36	N	Y	Complete	0	
8464	79	415	164	345	70	405	215	2.2	27/01/2008	8	23	N	Y	≤1 mm/day	0	
8465	61	480	150	360	120	435	219	2.6	31/01/2008	11	27	Y	Y	≤1 mm/day	20	
8466	89	485	161	395	90	410	217	2.4	27/01/2008	9	23	N	Y	≤1 mm/day	0	Absent (not fed) 1 day; lost 25 g
8467	22	455	178	350	105	385	217	2.1	23/01/2008	6	19	Y	N	<1 mm/day	10	
8468	26	425	165	385	40	430	218	2.3	27/01/2008	7	23	N	Y	≤1 mm/day	5	

BAND (X–)	MANA I. BURROW	TRANSFER WEIGHT (g)	TRANSFER WING (mm)	POST TRANSFER WEIGHT AT 24 HRS (g)	WEIGHT LOSS 24 HRS AFTER TRANSFER (g)	FLEDGING (PRE-FEED) WEIGHT (g)	FLEDGING WING (mm)	DAILY WING GROWTH RATE ON MANA I. (mm)	DATE OF FLEDGING OR *DISAPPEARANCE (PM)	NIGHTS OUT OF BURROW	DAYS ON MANA I.	EMERGENCE POTENTIALLY DELAYED BY BLOCKADE	FINAL DOSE OF COCCIDIOSTAT RECEIVED	WING GROWTH RATE (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	% DOWN COVER (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	COMMENTS
8469	82	430	163	350	80	400	217	2.5	26/01/2008	8	22	N	Y	≤2 mm/day	0	Absent (not fed) 1 day; lost 15 g
8470	77	465	177	415	50	425	217	2.0	24/01/2008	10	20	N	Y	Complete	0	
8471	28	455	160	370	85	390	220	2.1	2/02/2008	13	29	Y	Y	Complete	<10	
8472	80	345	154	275	70	377	212	2.2	30/01/2008	5	26	Y	Y	Complete	0	
8474	63	360	139	310	50	405	220	2.3	8/02/2008	13	35	N	Y	Complete	0	
8475	7	455	156	370	85	410	216	2.3	30/01/2008	13	26	Y	Y	Complete	0	
8476	33	415	177	365	50	405	215	2.1	22/01/2008	8	18	Y	N	≤2 mm/day	<10	
8477	96	435	178	350	85	405	216	2.1	22/01/2008	7	18	N	Y	≤1 mm/day	<5	
8478	15	340	137	295	45	–	–	–	–	–	–	?	–	–	–	Dead 12/01/08 (aspergillosis)
8479	88	370	147	310	60	375	217	2.2	5/02/2008	13	32	Y	Y	Complete	0	
8480	23	440	137	340	100	410	218	2.5	5/02/2008	11	32	N	Y	Complete	0	
8481	56	410	135	315	95	405	220	2.2	11/02/2008	4	38	N	Y	Complete	<20	
8485	45	380	143	340	40	385	220	2.4	5/02/2008	15	32	Y	Y	Complete	0	Absent (not fed) 1 day; lost 30 g
8487	72	345	155	270	75	405	215	2.1	2/02/2008	6	29	N	Y	Complete	5	
8488	60	415	165	325	90	425	215	–	*25/01/2008	≥5	≥21	Y	Y	1–2 mm/day	<70	Disappeared. Probable later fledge
8490	55	465	165	360	105	415	221	2.4	27/01/2008	10	23	Y	Y	Complete	0	
8493	64	400	164	345	55	420	211	2.5	23/01/2008	6	19	Y	Y	≤2 mm/day	5	
8494	46	325	154	275	50	375	218	2.0	5/02/2008	9	32	Y	N	Complete	<20	Absent (not fed) 4 days; lost 65 g; gated in a further 5 nights
8495	49	305	131	280	25	400	224	2.4	11/02/2008	13	38	N	Y	Complete	<10	
8496	87	455	166	370	85	375	223	2.5	27/01/2008	10	23	Y	Y	≤1 mm/day	0	Absent (not fed) 1 day; lost 35 g
8497	48	515	159	395	120	–	–	–	–	–	–	Y	–	–	–	Dead 18/01/08 (trapped in pipe)
8498	10	445	157	340	105	400	200	–	*22/01/2008	≥2	≥18	Y	N	3 mm/day	50	Disappeared. Probable later fledge
8499	16	395	140	350	45	380	223	2.4	8/02/2008	16	35	Y	Y	Complete	0	

BAND (X–)	MANA I. BURROW	TRANSFER WEIGHT (g)	TRANSFER WING (mm)	POST TRANSFER WEIGHT AT 24 HRS (g)	WEIGHT LOSS 24 HRS AFTER TRANSFER (g)	FLEDGING (PRE-FEED) WEIGHT (g)	FLEDGING WING (mm)	DAILY WING GROWTH RATE ON MANA I. (mm)	DATE OF FLEDGING OR *DISAPPEARANCE (PM)	NIGHTS OUT OF BURROW	DAYS ON MANA I.	EMERGENCE POTENTIALLY DELAYED BY BLOCKADE	FINAL DOSE OF COCCIDIOSTAT RECEIVED	WING GROWTH RATE (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	% DOWN COVER (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	COMMENTS
9255	110	335	145	285	50	390	214	2.5	11/02/2006	5	28	N	Y	≤1 mm/day	0	
9256	109	320	188	265	55	255	195	–	*17/01/2006	≥1	≥3	Y	N	Unknown	80	Disappeared. Likely to have perished
9257	116	350	178	340	10	345	206	2.5	25/01/2006	1	11	N	N	Unknown	–	
9260	115	–	187	–	–	330	190	–	*16/01/2006	≥1	≥2	Y	N	Unknown	–	Disappeared. Fledging compromised. Dug out of chamber past lid
9261	152	375	184	320	55	355	209	2.3	25/01/2006	7	11	N	N	≤3 mm/day	<15	
9264	162	355	179	315	40	345	214	2.2	30/01/2006	6	16	N	N	≤2 mm/day	5	
9265	128/ 125	330	157	300	30	–	–	–	–	–	–	Y	–	–	–	Dead 05/02/06 (trapped in pipe)
9266	157	500	186	410	90	390	219	2.5	27/01/2006	11	13	Y	N	Unknown	<20	
9268	151	375	185	325	50	325	>189	–	*17/01/2006	≥1	≥3	Y	N	Unknown	80	Disappeared. Likely to have perished
9269	168	440	181	350	90	340	211	2.5	26/01/2006	10	12	Y	N	≤1 mm/day	<5	
9270	121	310	178	265	45	355	215	2.1	1/02/2006	3	18	Y	N	≤2 mm/day	15	
9272	129	515	186	420	95	420	210	–	*25/01/2006	≥7	≥11	Y	N	3 mm/day	<75	Disappeared. Probable later fledge
9273	120	370	173	310	60	405	221	2.2	5/02/2006	1	22	N	N	Complete	15	
9279	144	425	180	370	55	350	191	–	*19/01/2006	≥1	≥5	Y	N	Unknown	<80	Disappeared. Fledging compromised
9282	147	430	192	355	75	345	c.200	–	*17/01/2006	≥1	≥3	Y	N	Unknown	10	Disappeared. Fledging potentially compromised
9291	150	325	159	295	30	400	214	2.4	6/02/2006	5	23	N	N	≤2 mm/day	<5	
9296	113	400	181	345	55	335	204	2.6	23/01/2006	7	9	Y	N	Unknown	<5	Fledged from fairy prion burrows
9297	165	–	168	–	–	380	212	2.0	5/02/2006	5	22	Y	N	Complete	0	
9298	114/ 115	415	162	335	80	405	221	2.6	5/02/2006	4	23	N	N	≤1 mm/day	<5	
9300	154/ 159	300	180	265	35	380	225	2.0	5/02/2006	2	22	Y	N	≤2 mm/day	10	

BAND (X–)	MANA I. BURROW	TRANSFER WEIGHT (g)	TRANSFER WING (mm)	POST TRANSFER WEIGHT AT 24 HRS (g)	WEIGHT LOSS 24 HRS AFTER TRANSFER (g)	FLEDGING (PRE-FEED) WEIGHT (g)	FLEDGING WING (mm)	DAILY WING GROWTH RATE ON MANA I. (mm)	DATE OF FLEDGING OR *DISAPPEARANCE (PM)	NIGHTS OUT OF BURROW	DAYS ON MANA I.	EMERGENCE POTENTIALLY DELAYED BY BLOCKADE	FINAL DOSE OF COCCIDIOSTAT RECEIVED	WING GROWTH RATE (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	% DOWN COVER (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	COMMENTS
16101	117	340	163	305	35	355	202	2.4	30/01/2006	1	16	Y	N	≤2 mm/day	5	
16102	118	380	187	365	15	360	195	-	*17/01/2006	≥1	≥3	Y	N	Unknown	20	Disappeared. Fledging potentially compromised
16103	142/ 143	345	186	325	20	355	213	-	*26/01/2006	≥4	≥12	N	N	2 mm/day	50	Disappeared. Probable later fledge
16105	140	355	183	290	65	275	191	-	*19/01/2006	≥1	≥5	Y	N	Unknown	<80	Disappeared. Likely to have perished
16110	125	415	192	380	35	375	213	2.3	23/01/2006	5	9	N	N	Unknown	15	
16113	119	325	175	290	35	290	180	-	*17/01/2006	≥1	≥3	Y	N	Unknown	80	Disappeared. Likely to have perished
16116	127	340	179	285	55	300	197	2.0	23/01/2006	3	9	N	N	Unknown	15	
16118	124	340	165	280	60	370	218	2.4	5/02/2006	6	22	N	N	≤2 mm/day	0	
16121	139	330	178	315	15	305	191	-	*19/01/2006	≥1	≥5	Y	N	Unknown	<75	Disappeared. Likely to have perished
16124	136	385	192	360	25	365	206	-	*23/01/2006	≥7	≥9	Y	N	Unknown	60	Disappeared. Probable later fledge
16125	134	450	184	380	70	360	193	-	*19/01/2006	≥1	≥5	Y	N	Unknown	<70	Disappeared. Fledging compromised
16127	149	315	155	275	40	415	218	2.3	11/02/2006	3	28	Y	Y	≤1 mm/day	10	Held overnight in box
16131	146	350	149	300	50	400	216	2.5	10/02/2006	6	27	Y	Y	Complete	<10	
16136	138	425	173	380	45	385	196	-	*22/01/2006	≥1	≥8	Y	N	Unknown	80	Disappeared. Fledging potentially compromised
16140	158/ 161	350	164	310	40	400	>209	-	5/02/2006	2	22	Y	N	≤1 mm/day	10	
16147	164	330	185	300	30	330	209	2.0	26/01/2006	6	12	N	N	≤1 mm/day	10	
16148	137	300	146	270	30	400	218	2.3	14/02/2006	5	31	Y	Y	≤1 mm/day	<10	Held overnight in box
16149	133/ 130	465	188	405	60	375	214	2.4	25/01/2006	9	11	Y	N	≤3 mm/day	<10	
16150	160	310	132	310	0	415	217	2.6	16/02/2006	3	33	N	Y	≤1 mm/day	-	
16151	135	405	169	355	50	425	219	2.4	4/02/2006	5	21	Y	N	Complete	<20	

BAND (X–)	MANA I. BURROW	TRANSFER WEIGHT (g)	TRANSFER WING (mm)	POST TRANSFER WEIGHT AT 24 HRS (g)	WEIGHT LOSS 24 HRS AFTER TRANSFER (g)	FLEDGING (PRE-FEED) WEIGHT (g)	FLEDGING WING (mm)	DAILY WING GROWTH RATE ON MANA I. (mm)	DATE OF FLEDGING OR *DISAPPEARANCE (PM)	NIGHTS OUT OF BURROW	DAYS ON MANA I.	EMERGENCE POTENTIALLY DELAYED BY BLOCKADE	FINAL DOSE OF COCCIDIOSTAT RECEIVED	WING GROWTH RATE (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	% DOWN COVER (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	COMMENTS
16152	95	410	150	360	50	410	221	2.4	2/02/2007	6	30	N	Y	Complete	–	
16153	98	400	174	365	35	400	215	2.7	19/01/2007	7	15	N	Y	≤2 mm/day	–	
16154	29	355	145	300	55	390	223	2.4	4/02/2007	4	32	N	Y	≤1 mm/day	–	Green faeces (30/01)
16156	36	350	135	305	45	390	222	2.4	8/02/2007	11	36	N	Y	Complete	–	
16157	35	400	169	345	55	415	219	2.0	28/01/2007	11	25	N	Y	Complete	–	
16159	15	380	147	320	60	405	212	2.4	30/01/2007	7	27	N	Y	Complete	–	
16162	61	340	158	290	50	385	219	2.3	30/01/2007	7	27	N	Y	Complete	–	
16163	16	400	171	340	60	380	199	–	*15/01/2007	≥1	≥11	Y	N	2–3 mm/day	40	Disappeared. Fledging potentially compromised
16164	32	375	168	320	55	395	216	2.5	22/01/2007	7	19	Y	N	Complete	–	
16165	62	405	164	360	45	400	205	2.6	19/01/2007	4	16	Y	N	≤2 mm/day	–	
16166	31	380	149	340	40	410	c.203	–	*22/01/2007	≥1	≥19	N	N	3 mm/day	<40	Disappeared. Fledging potentially compromised
16167	43	330	139	300	30	425	215	2.7	31/01/2007	2	28	N	Y	≤3 mm/day	–	Potentially holed-up elsewhere for extra day(s)
16168	91	375	133	330	45	405	215	2.7	2/02/2007	4	30	N	Y	Unknown	–	
16170	44	300	144	270	30	380	211	2.4	31/01/2007	3	28	N	Y	≤2 mm/day	–	Ear infection (23/01)
16171	2	410	154	340	70	395	217	2.3	31/01/2007	10	28	N	Y	Complete	–	
16172	1	390	139	340	50	415	210	2.6	30/01/2007	8	27	Y	Y	≤2 mm/day	–	
16173	23	440	149	355	85	400	219	2.3	2/02/2007	7	30	N	Y	Complete	–	
16174	86	405	155	350	55	375	220	2.4	30/01/2007	12	27	N	Y	Complete	–	
16175	60	380	163	325	55	390	220	2.2	29/01/2007	12	26	N	Y	Complete	–	Green faeces (29/01)
16176	92	375	154	355	20	420	211	2.4	27/01/2007	8	24	N	Y	Complete	–	
16178	100	340	165	310	30	395	210	2.1	24/01/2007	4	21	N	N	≤1 mm/day	–	

BAND (X–)	MANA I. BURROW	TRANSFER WEIGHT (g)	TRANSFER WING (mm)	POST TRANSFER WEIGHT AT 24 HRS (g)	WEIGHT LOSS 24 HRS AFTER TRANSFER (g)	FLEDGING (PRE-FEED) WEIGHT (g)	FLEDGING WING (mm)	DAILY WING GROWTH RATE ON MANA I. (mm)	DATE OF FLEDGING OR *DISAPPEARANCE (PM)	NIGHTS OUT OF BURROW	DAYS ON MANA I.	EMERGENCE POTENTIALLY DELAYED BY BLOCKADE	FINAL DOSE OF COCCIDIOSTAT RECEIVED	WING GROWTH RATE (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	% DOWN COVER (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	COMMENTS
16179	30	365	145	295	70	380	216	2.4	1/02/2007	7	29	N	Y	Complete	–	
16180	87	360	149	295	65	385	216	2.5	30/01/2007	6	27	N	Y	Complete	–	
16181	8	335	138	285	50	380	219	2.5	4/02/2007	7	32	N	Y	Complete	–	
16183	7	355	160	320	35	410	225	2.4	30/01/2007	8	27	N	Y	Complete	–	Notably aggressive bird
16185	63	440	180	375	65	410	216	2.1	20/01/2007	13	17	Y	N	≤1 mm/day	–	
16186	3	360	143	300	60	380	205	2.1	1/02/2007	11	29	N	Y	Complete	–	
16187	79	390	179	335	55	365	200	–	*13/01/2007	≥1	≥10	Y	N	2–3 mm/day	<80	Disappeared. Fledging potentially compromised. May have continued to visit burrow for 2 further nights
16189	99	365	136	320	45	410	217	2.5	5/02/2007	7	33	N	Y	Complete	–	
16190	57	400	134	325	75	370	217	2.2	10/02/2007	12	38	N	Y	Complete	–	
16192	56	390	176	350	40	420	217	2.0	24/01/2007	7	21	N	N	Complete	–	
16194	77	365	148	305	60	360	215	2.3	1/02/2007	11	29	N	Y	Complete	–	
16196	76	380	142	325	55	415	218	2.6	1/02/2007	3	29	N	Y	≤1 mm/day	–	
16197	4	430	162	410	20	390	216	2.0	30/01/2007	10	27	N	Y	Complete	–	
16198	78	445	171	360	85	395	218	1.8	29/01/2007	9	26	N	Y	Complete	–	
16199	82	390	129	325	65	415	227	2.9	6/02/2007	2	34	N	Y	Complete	–	
16200	37	335	140	295	40	395	218	2.5	3/02/2007	11	31	N	Y	≤1 mm/day	–	Green fluid in faeces (03/02)
16201	44	380	160	330	50	385	212	2.0	30/01/2008	10	26	Y	Y	Complete	0	
16202	43	450	137	350	100	420	220	2.5	6/02/2008	11	33	N	Y	≤1 mm/day	0	
16203	57	465	148	365	100	425	217	2.7	30/01/2008	6	26	N	Y	≤2 mm/day	10	
16204	91	435	154	335	100	415	222	2.3	3/02/2008	13	30	?	Y	Complete	0	
16205	59	415	160	340	75	–	–	–	–	–	–	Y	–	–	–	Dead 21/01/08 (trapped in pipe)

BAND (X-)	MANA I. BURROW	TRANSFER WEIGHT (g)	TRANSFER WING (mm)	POST TRANSFER WEIGHT AT 24 HRS (g)	WEIGHT LOSS 24 HRS AFTER TRANSFER (g)	FLEDGING (PRE-FEED) WEIGHT (g)	FLEDGING WING (mm)	DAILY WING GROWTH RATE ON MANA I. (mm)	DATE OF FLEDGING OR *DISAPPEARANCE (PM)	NIGHTS OUT OF BURROW	DAYS ON MANA I.	EMERGENCE POTENTIALLY DELAYED BY BLOCKADE	FINAL DOSE OF COCCIDIOSTAT RECEIVED	WING GROWTH RATE (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	% DOWN COVER (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	COMMENTS
16206	30	395	140	365	30	400	220	2.7	3/02/2008	10	30	Y	Y	≤1 mm/day	0	Absent (not fed) 2 days; lost 40 g
16207	75	365	145	310	55	350	217	2.4	3/02/2008	7	30	N	Y	≤1 mm/day	0	
16208	81	315	158	300	15	395	215	2.2	30/01/2008	10	26	Y	Y	Complete	0	
16209	24	370	138	310	60	390	218	2.4	6/02/2008	12	33	N	Y	Complete	0	
16210	42	415	157	310	105	425	218	2.0	3/02/2008	9	30	N	Y	Complete	0	
16211	67	420	142	315	105	385	211	2.6	31/01/2008	7	27	Y	Y	≤2 mm/day	20	Absent (not fed) 1 day; lost 30 g
16212	36	400	139	305	95	415	216	2.5	4/02/2008	14	31	Y	Y	Complete	<5	
16213	78	520	173	450	70	455	223	2.2	27/01/2008	12	23	N	Y	Complete	<10	
16214	27	390	157	315	75	405	220	2.4	30/01/2008	10	26	Y	Y	Complete	0	
16216	98	370	149	310	60	395	218	2.4	2/02/2008	12	29	?	Y	Complete	0	
16217	20	400	134	345	55	425	219	2.3	10/02/2008	11	37	N	Y	Complete	<20	
16218	74	395	137	340	55	395	220	2.6	5/02/2008	12	32	N	Y	≤1 mm/day	0	
16220	31	425	172	355	70	422	219	2.0	28/01/2008	11	24	Y	Y	Complete	0	
16221	84	450	174	365	85	415	221	2.4	24/01/2008	8	20	N	Y	Unknown	<10	
16222	3	480	168	380	100	425	224	2.1	31/01/2008	8	27	N	Y	Complete	0	
16223	21	370	140	315	55	415	220	2.3	8/02/2008	13	35	N	Y	Complete	<10	
16224	85	500	145	385	115	425	219	2.6	1/02/2008	12	28	Y	Y	≤1 mm/day	<20	
16302	66	470	163	390	80	420	212	2.3	24/01/2007	7	21	N	N	≤1 mm/day	-	Absent (not fed) 1 day; lost 20 g
16304	68	390	172	365	25	425	217	2.0	25/01/2007	10	22	N	N	Complete	-	
16306	69	405	157	345	60	355	218	2.3	30/01/2007	13	27	N	N	Complete	-	Absent (not fed) 4 days; lost 65 g
16307	38	405	152	345	60	415	216	2.6	28/01/2007	7	25	N	Y	≤1 mm/day	-	Missed 2 nights of emergence
16308	67	450	130	350	100	405	222	2.8	5/02/2007	9	33	N	Y	≤1 mm/day	-	Missed 1 night of emergence
16309	71	430	158	360	70	410	223	2.5	29/01/2007	6	26	N	Y	Complete	-	

BAND (X–)	MANA I. BURROW	TRANSFER WEIGHT (g)	TRANSFER WING (mm)	POST TRANSFER WEIGHT AT 24 HRS (g)	WEIGHT LOSS 24 HRS AFTER TRANSFER (g)	FLEDGING (PRE-FEED) WEIGHT (g)	FLEDGING WING (mm)	DAILY WING GROWTH RATE ON MANA I. (mm)	DATE OF FLEDGING OR *DISAPPEARANCE (PM)	NIGHTS OUT OF BURROW	DAYS ON MANA I.	EMERGENCE POTENTIALLY DELAYED BY BLOCKADE	FINAL DOSE OF COCCIDIOSTAT RECEIVED	WING GROWTH RATE (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	% DOWN COVER (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	COMMENTS
16310	90	435	162	350	85	400	214	2.5	24/01/2007	3	21	N	N	≤1 mm/day	–	Missed 1 night of emergence
16311	88	430	178	360	70	385	c.200	–	*13/01/2007	≥3	≥10	N	N	3 mm/day	<75	Disappeared. Fledging potentially compromised May have continued to visit burrow for 2 further nights
16312	70	385	175	335	50	390	214	1.6	27/01/2007	9	24	N	Y	Complete	–	
16313	83	415	151	345	70	400	217	2.4	30/01/2007	5	27	N	Y	Complete	–	
16314	19	395	164	360	35	425	222	2.6	25/01/2007	3	22	N	N	≤1 mm/day	–	
16316	89	350	169	315	35	395	224	2.1	29/01/2007	6	26	N	Y	Complete	–	
16317	45	415	149	345	70	410	200	–	*20/01/2007	≥1	≥17	Y	N	3 mm/day	75	Disappeared. Fledging potentially compromised
16318	94	330	140	285	45	415	207	–	*27/01/2007	≥1	≥24	N	Y	2–3 mm/day	<80	Disappeared. Probable later fledge
16319	93	365	150	320	45	415	211	2.3	30/01/2007	9	27	N	Y	≤1 mm/day	–	
16320	42	345	160	290	55	390	217	2.6	25/01/2007	4	22	N	N	≤2 mm/day	–	
16321	46	355	140	315	40	390	225	2.7	4/02/2007	7	32	N	Y	Complete	–	
16323	80	445	171	395	50	415	188	–	*9/01/2007	≥1	≥6	Y	N	3 mm/day	<80	Disappeared. Fledging compromised
16324	41	400	157	320	80	405	214	2.1	30/01/2007	8	27	N	Y	Complete	–	
16326	81	450	164	375	75	395	220	2.2	29/01/2007	14	26	Y	Y	Complete	–	
16327	26	325	155	285	40	385	215	2.1	31/01/2007	5	28	N	Y	Complete	–	
16328	20	410	148	355	55	395	216	2.3	1/02/2007	9	29	N	Y	Complete	–	
16329	53	–	–	–	–	415	226	–	29/01/2007	12	26	N	Y	Complete	–	
16330	25	325	149	285	40	410	216	2.2	2/02/2007	6	30	N	Y	Complete	–	
16331	59	365	142	285	80	400	215	2.4	3/02/2007	8	31	N	Y	Complete	–	
16332	21	385	162	335	50	385	218	2.3	27/01/2007	9	24	N	Y	<1 mm/day	–	Absent (not fed) 1 day; lost 15 g

BAND (X–)	MANA I. BURROW	TRANSFER WEIGHT (g)	TRANSFER WING (mm)	POST TRANSFER WEIGHT AT 24 HRS (g)	WEIGHT LOSS 24 HRS AFTER TRANSFER (g)	FLEDGING (PRE-FEED) WEIGHT (g)	FLEDGING WING (mm)	DAILY WING GROWTH RATE ON MANA I. (mm)	DATE OF FLEDGING OR *DISAPPEARANCE (PM)	NIGHTS OUT OF BURROW	DAYS ON MANA I.	EMERGENCE POTENTIALLY DELAYED BY BLOCKADE	FINAL DOSE OF COCCIDIOSTAT RECEIVED	WING GROWTH RATE (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	% DOWN COVER (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	COMMENTS
16333	52	435	178	360	75	395	209	-	*15/01/2007	≥1	≥12	Y	N	3 mm/day	70	Disappeared. Fledging potentially compromised
16334	39	350	161	305	45	380	211	1.9	30/01/2007	13	27	N	Y	Complete	-	
16335	27	350	142	300	50	405	218	2.6	1/02/2007	7	29	N	Y	≤1 mm/day	-	
16336	5	370	156	305	65	385	215	2.6	26/01/2007	3	23	N	Y	≤2 mm/day	-	
16338	58	385	173	335	50	405	227	2.1	29/01/2007	10	26	N	Y	Complete	-	Green fluid in faeces (29/01)
16339	54	450	171	380	70	430	220	2.0	27/01/2007	8	24	N	Y	Complete	-	
16340	6	415	152	330	85	420	216	2.4	30/01/2007	8	27	N	Y	≤1 mm/day	-	Notably aggressive bird
16341	64	445	166	365	80	395	218	2.0	29/01/2007	13	26	Y	Y	Complete	-	Missed 1 night of emergence
16342	28	445	140	370	75	425	215	2.8	30/01/2007	6	27	N	Y	≤2 mm/day	-	
16343	10	365	157	315	50	410	223	2.4	30/01/2007	7	27	N	Y	Complete	-	
16344	9	375	160	325	50	400	221	2.3	30/01/2007	7	27	N	Y	Complete	-	
16346	55	455	174	400	55	420	218	2.9	19/01/2007	6	15	N	N	Complete	-	
16347	40	430	150	350	80	400	219	2.7	29/01/2007	9	26	N	Y	≤1 mm/day	-	
16348	22	405	137	330	75	400	226	2.8	4/02/2007	3	32	N	Y	Complete	-	
16702	13	365	179	330	35	375	210	-	*16/01/2007	≥1	≥12	Y	N	3 mm/day	<75	Disappeared. Fledging potentially compromised
16703	14	345	169	-	-	395	227	2.2	29/01/2007	6	26	N	Y	Complete	-	
16710	17	395	157	340	55	380	219	2.3	30/01/2007	5	27	N	Y	≤1 mm/day	-	Absent (not fed) 2 days; lost 40 g
16711	18	320	129	275	45	380	223	2.6	8/02/2007	8	36	N	Y	Complete	-	
16712	84	420	153	375	45	430	215	2.6	27/01/2007	5	24	N	Y	Complete	-	
16716	12	325	133	285	40	385	215	2.8	1/02/2007	6	29	N	Y	≤3 mm/day	-	
16726	34	-	-	-	-	445	217	-	27/01/2007	7	24	N	Y	≤2 mm/day	-	

BAND (X–)	MANA I. BURROW	TRANSFER WEIGHT (g)	TRANSFER WING (mm)	POST TRANSFER WEIGHT AT 24 HRS (g)	WEIGHT LOSS 24 HRS AFTER TRANSFER (g)	FLEDGING (PRE-FEED) WEIGHT (g)	FLEDGING WING (mm)	DAILY WING GROWTH RATE ON MANA I. (mm)	DATE OF FLEDGING OR *DISAPPEARANCE (PM)	NIGHTS OUT OF BURROW	DAYS ON MANA I.	EMERGENCE POTENTIALLY DELAYED BY BLOCKADE	FINAL DOSE OF COCCIDIOSTAT RECEIVED	WING GROWTH RATE (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	% DOWN COVER (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	COMMENTS
16728	11	415	158	360	55	415	201	–	*19/01/2007	≥1	≥16	N	N	3 mm/day	<70	Disappeared. Probable later fledge. May have continued to visit burrow for 2 further nights
16730	24	310	139	270	40	390	220	2.3	7/02/2007	4	35	Y	Y	Complete	–	Swelling on bill; received vet treatment
16738	85	310	145	285	25	395	219	2.2	6/02/2007	8	34	N	Y	Complete	–	
16756	33	330	139	305	25	380	211	2.6	31/01/2007	5	28	N	Y	≤2 mm/day	–	
17401	73	355	137	325	30	405	210	2.4	5/02/2008	10	31	N	Y	Complete	15	
17403	69	455	174	350	105	415	211	2.3	21/01/2008	4	16	N	N	≤2 mm/day	<10	
17404	34	460	155	345	115	400	214	2.3	30/01/2008	10	26	Y	Y	Complete	5	Absent (not fed) 1 day; lost 30 g
17406	18	445	158	375	70	425	225	2.6	30/01/2008	11	26	N	Y	≤2 mm/day	<5	
17407	32	320	169	280	40	385	217	2.1	27/01/2008	7	23	Y	Y	Unknown	<10	Chick 20 g less than transfer weight criteria minimum
17408	17	435	174	335	100	390	217	2.4	22/01/2008	6	18	Y	Y	≤2 mm/day	0	
17410	66	380	167	325	55	390	207	2.5	20/01/2008	3	16	Y	N	≤2 mm/day	5	
17411	39	455	150	380	75	395	215	2.5	30/01/2008	10	26	Y	Y	≤1 mm/day	<15	
17412	37	345	138	305	40	420	211	2.4	3/02/2008	9	30	N	Y	≤1 mm/day	<5	
17414	54	475	167	380	95	420	–	–	21/01/2008	2	17	Y	N	Unknown	0	Outer right wing primaries found in burrow 19/01/08; left wing 213 mm (late gate removal)
17415	62	480	170	355	125	430	214	–	*22/01/2008	≥4	≥18	N	Y	1 mm/day	<40	Disappeared. Probable later fledge
17416	93	440	134	355	85	420	217	2.6	5/02/2008	11	32	N	Y	Complete	0	
17417	38	430	136	325	105	390	216	2.6	4/02/2008	11	31	Y	Y	Complete	<5	
17419	97	410	145	335	75	410	226	2.6	4/02/2008	14	31	?	Y	Complete	0	
17420	71	370	155	330	40	415	218	2.3	31/01/2008	4	27	N	Y	Complete	<5	

BAND (X–)	MANA I. BURROW	TRANSFER WEIGHT (g)	TRANSFER WING (mm)	POST TRANSFER WEIGHT AT 24 HRS (g)	WEIGHT LOSS 24 HRS AFTER TRANSFER (g)	FLEDGING (PRE-FEED) WEIGHT (g)	FLEDGING WING (mm)	DAILY WING GROWTH RATE ON MANA I. (mm)	DATE OF FLEDGING OR *DISAPPEARANCE (PM)	NIGHTS OUT OF BURROW	DAYS ON MANA I.	EMERGENCE POTENTIALLY DELAYED BY BLOCKADE	FINAL DOSE OF COCCIDIOSTAT RECEIVED	WING GROWTH RATE (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	% DOWN COVER (APPROX.) AT DEPARTURE OR *DISAPPEARANCE	COMMENTS
17422	5	320	133	300	20	405	215	2.6	4/02/2008	6	31	N	Y	≤1 mm/day	20	
17423	58	410	145	340	70	370	210	2.2	2/02/2008	13	29	Y	Y	Complete	0	
17424	70	460	179	375	85	380	215	2.3	20/01/2008	4	16	Y	N	≤2 mm/day	<10	
17425	8	380	148	315	65	345	214	2.1	4/02/2008	11	31	N	Y	Complete	0	
17427	65	540	169	400	140	410	223	2.1	30/01/2008	15	26	N	Y	Complete	0	
17428	95	405	171	355	50	410	211	2.2	22/01/2008	7	18	Y	Y	Complete	5	
17429	86	485	159	375	110	430	222	–	*28/01/2008	≥6	≥24	?	Y	2 mm/day	70	Disappeared. Probable later fledge
17430	19	500	145	380	120	410	212	2.4	1/02/2008	9	28	Y	Y	Complete	0	
17431	35	340	143	300	40	410	217	2.2	6/02/2008	12	33	N	Y	Complete	0	
17432	11	430	159	355	75	395	207	2.5	23/01/2008	6	19	Y	N	≤3 mm/day	20	
17433	68	395	155	315	80	380	215	2.7	26/01/2008	6	22	Y	Y	≤3 mm/day	10	
17434	29	425	136	315	110	430	221	2.7	5/02/2008	8	32	N	Y	Complete	5	
17435	53	415	166	345	70	445	220	2.3	28/01/2008	7	24	N	Y	Complete	5	
17436	76	485	146	395	90	440	218	2.4	3/02/2008	6	30	N	Y	Complete	5	
17438	2	465	154	380	85	385	219	2.0	5/02/2008	11	32	N	Y	Complete	0	
17439	13	335	141	280	55	388	213	2.5	2/02/2008	7	29	N	Y	≤1 mm/day	5	
17440	6	560	175	445	115	450	216	2.2	23/01/2008	10	19	N	Y	Complete	0	
17441	4	410	143	330	80	405	222	2.5	5/02/2008	11	32	N	Y	Complete	0	
17445	92	415	172	340	75	400	224	2.3	27/01/2008	11	23	Y	Y	≤2 mm/day	0	
17447	41	400	165	335	65	410	215	2.5	24/01/2008	8	20	Y	N	≤1 mm/day	0	
17448	47	475	130	385	90	410	206	2.9	30/01/2008	5	26	N	Y	≤2 mm/day	15	Absent (not fed) 1 day; lost 20 g
17450	90	375	146	315	60	390	212	2.4	31/01/2008	11	27	Y	Y	≤1 mm/day	10	