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Pycroft's petrel (*Pterodroma pycrofti*)**

B. Gangloff and K-J. Wilson
Ecology and Entomology Group

SOIL, PLANT & ECOLOGICAL SCIENCES DIVISION

LINCOLN
UNIVERSITY

Te Whare Wānaka O Aoraki



PO BOX 84, LINCOLN UNIVERSITY, CANTERBURY 8150, NEW ZEALAND

**FEEDING FREQUENCY, MEAL SIZE AND CHICK GROWTH IN THE
THREATENED PYCROFT'S PETREL (*PTERODROMA PYCROFTI*)**

B. Gangloff and K-J. Wilson

Ecology and Entomology Group
Soil, Plant and Ecological Sciences Division
PO Box 84, Lincoln University
Canterbury, New Zealand

Prepared for:

Department of Conservation,
Waikato and Christchurch Conservancy

1. ABSTRACT

Many species of gadfly petrel (genus *Pterodroma*) are threatened or endangered, including, in New Zealand, the Chatham petrel (*Pterodroma axillaris*), and Pycroft's petrel (*P. pycrofti*). Conservation actions for these species include the establishment of new breeding colonies on predator-free offshore islands by translocation. Due to the high philopatry of most gadfly petrels, only chicks that have not yet been imprinted with their natal ground can be transferred. Translocation of Chatham petrel and Pycroft's petrel chicks are scheduled in 2002. However, data on the chick stage in these two species, and in small *Pterodroma* in general, are scant, and techniques to age chicks to determine their transferability are needed. The purpose of this study was to examine the feeding frequency, meal size and growth of Pycroft's petrel nestlings, to compare the results with Chatham petrel data and to identify factors that could be used to age a chick of unknown age prior to a translocation.

Fifty Pycroft's petrel chicks were monitored between 17 January and 26 March 2001 on Red Mercury Island, New Zealand. Chicks were weighed every one or two days to determine their feeding frequency and meal size, and had their bill, tarsus, tail and wing length measured at regular interval until they fledged or until 26 March. Thirty other chicks formed a control group and were weighed and measured on 29 January and 15 March. The age of first emergence from burrow was also determined. Similar data on Chatham petrel were also analysed.

Measurements of the Pycroft's petrel nestlings at fledging were similar to mean adult measurements: mean fledging weight (162 ± 2.6 g) was 99% of adult weight, mean wing length (214 ± 1 mm) was 98% of adult wing length, mean bill length (24.9 ± 0.2 mm) was 102% of mean adult bill length, mean tarsus length (29.2 ± 0.1 mm) was the same than mean adult tarsus, and mean tail length (92 ± 1 mm) was 94% of mean tail length of adults. Wing and tail length were very well correlated with age expressed in days before fledging (DBF) ($r^2 = 0.95$ and $r^2 = 0.86$ respectively). Weight was not so closely correlated with age ($r^2 = 0.63$), and bill and tarsus length were not correlated to age ($r^2 < 0.2$). Meal size was between 35 and 40 g, and the probability of being fed ranged from 0.47 between 23 and 16 DBF, to 0.04 between 7 and 0 DBF.

These results are compared with Chatham petrel data and recommendations for the translocation of Pycroft's and Chatham petrel chicks are made.

2. INTRODUCTION

Many species of gadfly petrel (genus *Pterodroma*) are rare or endangered and in urgent need of conservation actions if they are to survive. Many of these species are confined to just one or a few breeding islands. They are therefore more prone to extinction through catastrophic events than species with a wide distribution and high number of breeding sites. Consequently, translocation of birds to additional islands is a primary option for the conservation of many species in the genus.

Translocation has been used successfully for the management and recovery of many landbirds (Armstrong and McLean, 1995; Conant, 1988) but seldom for colonial nesting seabirds. Petrels are highly philopatric (Warham, 1990) and chicks become imprinted to their natal site (Priddel and Carlile, 2001; Warham, 1990). Although the imprinting mechanism is not yet fully understood (Priddel and Carlile, 2001) it seems that young birds develop this attachment to their natal site in the period between the first emergence from the burrow and the fledging date. During that period fledglings explore the surroundings of their burrows. Thus, they can get clues allowing them to recognise the site when they come back to breed (Serventy, 1967; Warham, 1990). It is also possible that chicks get some of these clues while still in their burrows (Serventy *et al.*, 1989). Therefore, for a translocation to be successful, young birds must be moved at the pre-fledging stage to prevent them becoming imprinted to their natal site and later returning to these sites to breed (Priddel and Carlile, 2001; Warham, 1990).

The Chatham petrel (*Pterodroma axillaris*) is endemic to the Chatham Islands. Although it was once distributed throughout the Chatham archipelago, the breeding population is now restricted to South East (Rangatira) Island (West, 1994) and the species is classified as critically endangered by the IUCN (IUCN, 1994). The creation of a new colony on another island by translocation of chicks is a goal of the Chatham petrel Recovery Plan (Aikman *et al.*, 2000). To implement such a translocation a better knowledge of the feeding frequency, meal size, chick development and growth and chick behaviour prior to fledging is required (Taylor, 2000a). Some data exists on Chatham petrel, but due to its endangered status, it is not feasible to conduct a detailed study of chick development on this species. Taylor (2000a) recommended that 'development and improvement of translocation methodology, using an analogue species, to refine techniques for establishing *Pterodroma* petrels at new colony sites' is necessary.

Pycroft's petrel (*P. pycrofti*) is closely related to Chatham petrel (Marchant and Higgins, 1990). It breeds on eleven islands off the eastern coast of the North Island, New Zealand: Ririwha (Stephenson), Poor Knights group (Aorangi), Hen, Lady Alice, Coppermine, Whatupuke, Mauitaha, Red Mercury, Double, Stanley, and Korapuki (Taylor, 2000a). The species is classified as vulnerable (IUCN, 1994) and it is desirable to establish colonies on new offshore islands for the long-term conservation of the species (Taylor, 2000a). In March 2001, Taylor transferred 30 chicks from Red Mercury to Cuvier Islands in a trial translocation, and 100 birds are to be moved in both 2002 and 2003. If successful, these transfers will allow the establishment of a new Pycroft's petrel colony and will be used as a training to develop suitable techniques to safely transfer Chatham petrel chicks to create a new colony, as recommended by the Chatham petrel recovery programme (Taylor, 2000b).

To conduct trial transfer of Chatham petrels, information is needed on development and growth, feeding frequencies, meal sizes and behaviour of chicks of small *Pterodroma* species. Such data is currently available only for Gould's petrel (*P. leucoptera leucoptera*), on

Cabbage Tree Island, Australia (Priddel and Carlile, 2001). This species is the only species in the genus for which translocations have been conducted successfully (i.e. some translocated birds have been found in the new colony 3 years after being transferred). To know if this species is characteristic of the genus data from at least one other small *Pterodroma* was needed. In this paper we report on a study on chick growth and development in Pycroft's petrel and compare this data with a smaller dataset obtained from Chatham petrel.

3. SCOPE OF THE STUDY

3.1 General aim

The general aim of our study was to investigate feeding and growth patterns, and pre-fledging behaviour of Pycroft's petrel chicks to provide information about meal size and feeding frequency during the last few weeks of development, to determine how soon before fledging chicks first emerge from their burrows and how to age chicks using morphological measurements, and to compare these results with Chatham petrel data. Ultimately, such information could be used to make recommendations for the transfer of chicks of other *Pterodroma* species if it corresponds to what has been found in Gould's petrel.

3.2 Specific objectives

- To measure meal size and feeding frequency of Pycroft's petrel chicks and record how these change while chicks are developing.
- To measure the growth of morphological traits (wing length, bill length, tarsus length and tail length) to determine correlation between these and time to fledging.
- To determine how long before fledging chicks first emerge from their burrows.
- To compile the available information on the Chatham petrel, and through comparison with the better studied Pycroft's petrel make recommendations for the upcoming translocation of Chatham petrel from Rangatira island to Pitt Island.

4. STUDY SITE AND METHODS

4.1 Pycroft's petrel

We studied 50 Pycroft's petrel chicks, plus a control group of 30 chicks, from 17 January to 26 March on Red Mercury Island, off the Coromandel Peninsula, on which is found the main breeding colony for this species.

Chicks were weighed every day (30 chicks) or every second day (20 chicks) between 0900 hours and 1300 hours, from 18 January until the chicks fledged or until B. Gangloff left the island on 26 March, to determine if they had been fed the previous night. Tail, bill and tarsus lengths were measured at six- to eight-day intervals in January and February and at four- to six-day intervals in March. Wing length was measured at six- to eight-day intervals from mid-February to early March, then at two- to four-day intervals after the first week of March.

Towards the end of their development, observations of the chicks' behaviour outside their burrows were also carried out at night.

Bird's movements to and from the burrows were monitored with the help of toothpick fences built at the entrance of the burrows: toothpicks were stuck lightly into the ground just inside the entrance, so that birds could not enter or leave without displacing them. Displacement of the toothpicks indicated that a bird had entered or exited the burrow. From January until chicks first venture out of their burrow, in early March, a displaced fence indicated that at least one adult bird had visited the burrow overnight. In most cases, we assume that the visit would be by the chicks parents, but occasional visits by other birds might have occurred. From the second week of March, a broken fence indicated either the visit of an adult or that the chick had been outside the burrow. Each time a fence had been displaced, it was re-erected again at night or in the morning.

To assess the potential impact of daily manipulations on chicks, B. Gangloff weighed the 30 chicks of the control group on 29 January and weighed and measured them on 15 March. Some additional weights and measurements and observations of fledglings were made in 2000 by K-J. Wilson.

From 10 March, burrows were visited everyday to check for the presence or absence of chicks. Any chick no longer present in its burrow was considered to have fledged if it was previously fully feathered and in good health. The date of fledging was taken as the last day that the chick was found in the nest. Fledging weight and wing length were recorded as the weight and wing length found on the day of fledging.

4.2 Chatham petrel

We analysed some data collected on Rangatira Island by F. Bancroft and H. Gummer in 1999 and 2001 respectively, for the Chatham Island Area Office of the Department of Conservation. Bancroft monitored the chicks daily between 16 February and 21 May 1999 by which time but three had disappeared. Gummer weighed chicks daily from 67 days old until they disappeared from their burrows. The wing length of the chicks was also recorded every seven days by Bancroft in 1999 and every five days by Gummer in 2001. Due to the small sample size, we merged the two sets of data for the analysis.

5. RESULTS

5.1 Feeding frequency

During the chicks' development, the mean probability of a chick being fed at various ages was (Fig. 1):

- From 60 to 24 days before fledging (DBF) : mean = 0.47, i.e a meal every second day;
- From 23 to 16 DBF: mean = 0.32, i.e a meal every third day;
- From 15 to 8 DBF: mean = 0.19, i.e a meal every fifth day;
- From 7 to 0 DBF: mean = 0.04, i.e no meal during this period.

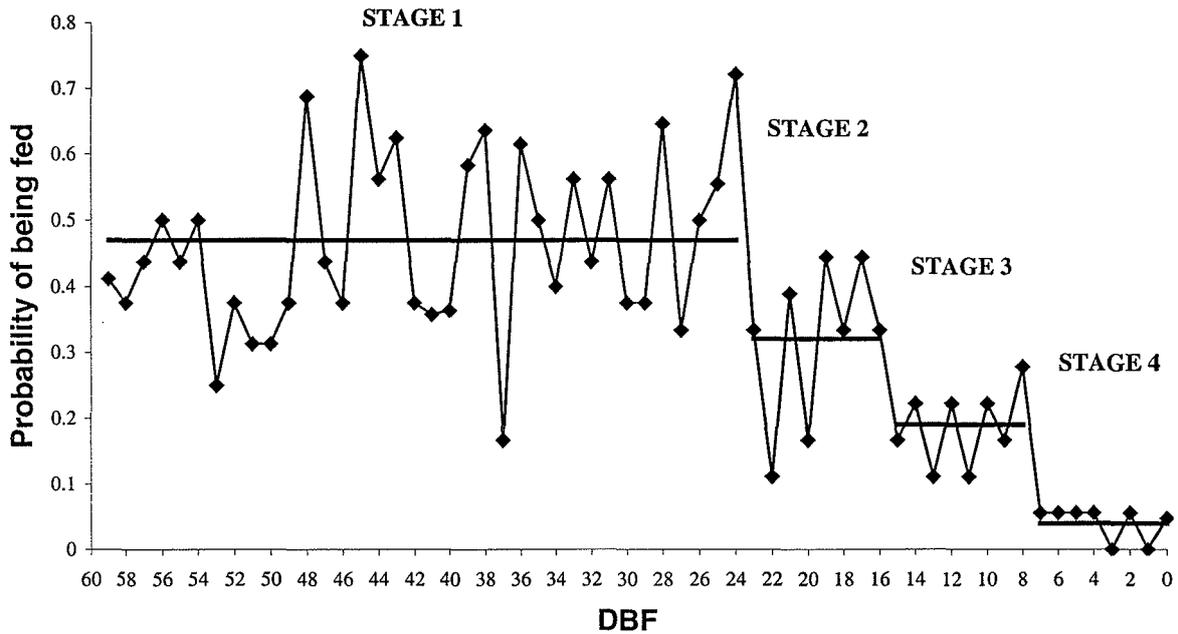


Figure 1: Probability of Pycroft's petrel chicks (n=18) being fed as a function of their age expressed in days before fledging (DBF) (Red Mercury Island, 2001). Lines show the mean probability of being fed for each stage.

5.2 Meal size

The mean overnight weight increase (OWI) observed was 22 ± 1 g. There was no correlation between the age of the chicks (expressed in DBF) and the OWI ($r^2 = 0.05$, $n = 338$ meals). After correction of the OWI, to allow for the weight loss between the time the chick was fed and the time it was weighed, the estimated meal size was 35-40g.

5.3 Weight changes

The maximum weight (mean = 286.5 ± 4.6 g, range = 253-337g) was attained at 26 ± 1 DBF. Mean fledging weight was 162g and was on average 99.4% of adult weight (range: 81-117.2%).

Mean weight loss averaged 2.7 ± 1.8 g between 24 and 15 DBF; 5 ± 1.4 g between 14 and 10 DBF; and 5.4 ± 0.4 g between 9 and 0 DBF.

The weight loss appeared to be correlated with age; the equation: $\text{weight} = -0.159 \times \text{DBF}^2 + 7.867 \text{ DBF} + 155.633$ fitted the data relatively well ($r^2 = 0.63$) (Fig. 2).

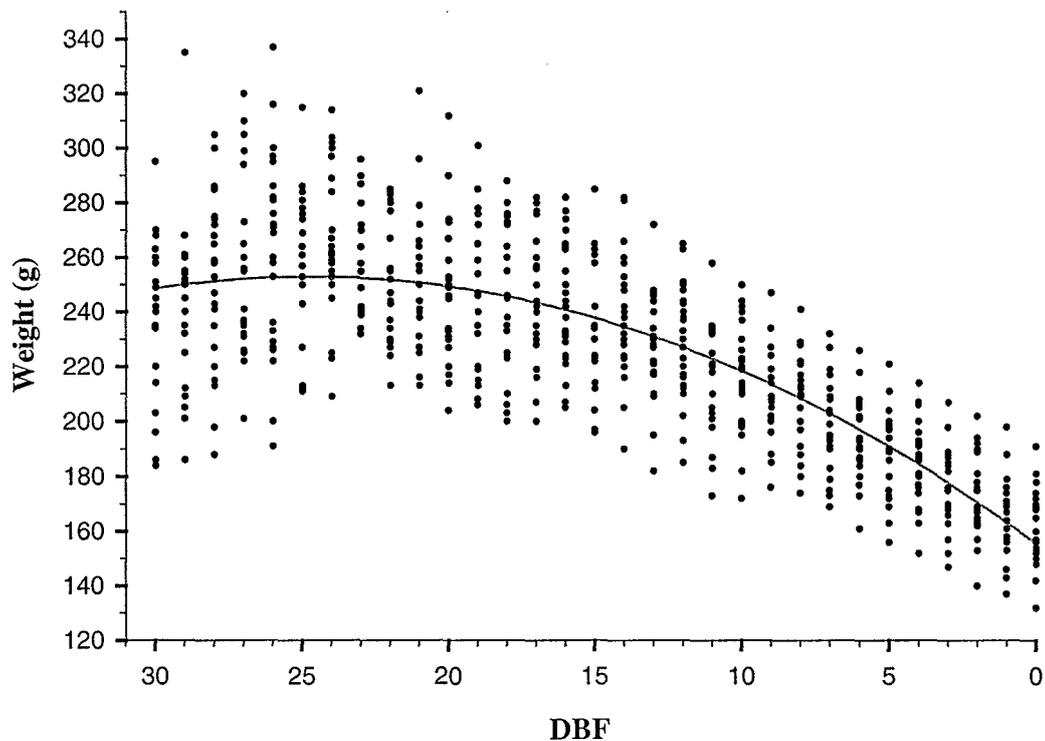


Figure 2: Weight of Pycroft's petrel chicks ($n = 26$) as a function of age expressed in days before fledging (DBF) (Red Mercury Island, 2001). Regression line (equation: $\text{weight} = -0.159 \times \text{DBF}^2 + 7.867 \times \text{DBF} + 155.633$; $r^2 = 0.63$) is shown

5.4 Wing length

On the day of first emergence (7-8 DBF), the wing length of the nestlings averaged $89.7 \pm 0.7\%$ of adult wing length (range 81.6% - 95.3%; $n = 17$), and was on average 98.1% of adult wing length, at fledging. The wing length was strongly correlated with the age of the chicks (expressed in DBF); the equation: $\text{wing length} = -3.474 \times \text{DBF} + 218.616$ fitted the data extremely well ($r^2 = 0.95$) (Fig. 3).

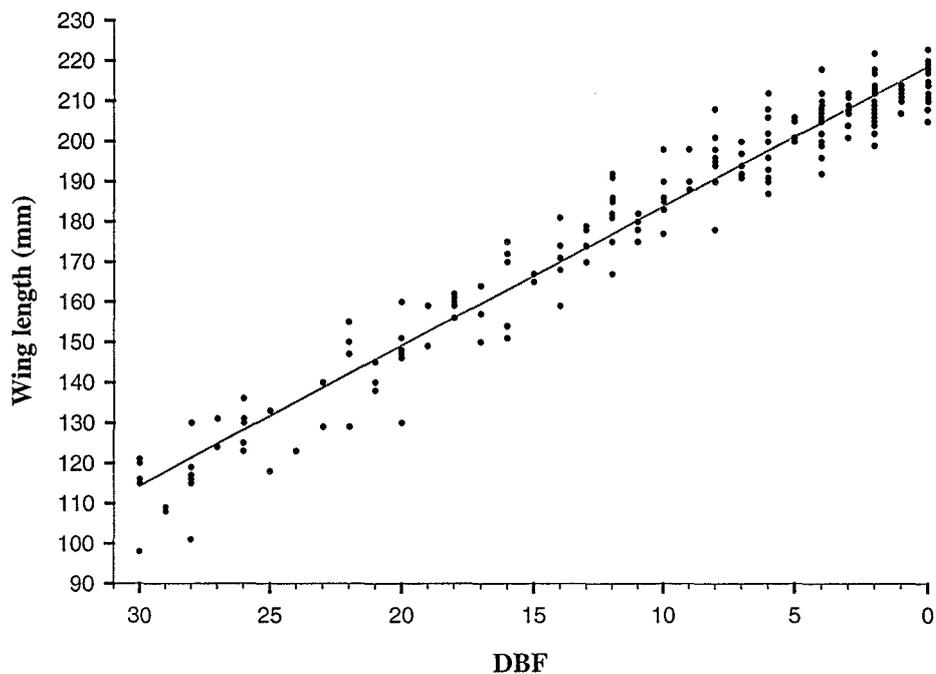


Figure 3: Wing length of Pycroft's petrel chicks ($n = 18$) as a function of age between 30 and 0 days before fledging (DBF) (Red Mercury Island, 2001). Regression line (wing length = $-3.474 \times \text{DBF} + 218.616$; $r^2 = 0.95$) is shown

5.5 Other measurements

- Tail length appeared to be correlated quite well with age ($r^2 = 0.86$).
- Bill length reached an asymptote approximately two weeks before fledging and was not correlated with age ($r^2 = 0.17$).
- Tarsus length: as the bill it was not correlated with age ($r^2 = 0.16$) and it reached an asymptote approximately 2 weeks before fledging.

5.6 Emergence of nestlings from their burrows

Data from the fences erected at the entrance of the burrows indicated that chicks first emerge from their burrows at 8 days before fledging.

Data from direct observation of chicks' behaviour at night indicated that chicks first emerge at 7 ± 1 DBF, with an observed range of 1 to 15 days.

These two values correspond quite well and it is likely that they are an accurate estimate of age of first emergence in Pycroft's petrels.

5.7 Fledging

In 2000, K-J. Wilson observed 8 chicks that fledged, between 15 and 22 March. In 2001, 26 chicks fledged before B. Gangloff left the island on 26 March, with the first one leaving the island on 14 March.

Table 1 shows the characteristics of these 26 chicks at last measurement before fledging.

Table 1: Morphological parameters of Pycroft's petrel chicks (n = 26) at last measurement before fledging (Red Mercury Island, 2001). Adult weight (in brackets in row 4) from Warham, 1990; other adult measurements (in brackets in row 4) from Marchant & Higgins, 1990

	Weight (g)	Wing length (mm)	Bill length (mm)	Tarsus length (mm)	Tail length (mm)
Mean \pm s.e.	162 \pm 2.6	214 \pm 1	24.9 \pm 0.2	29.2 \pm 0.1	92 \pm 1
Range	132-191	205-223	21.6-26.2	27.7-30.9	80-99
Mean % of adult measurement \pm s.e.	99.4 \pm 1.6 (163)	98.1 \pm 0.5 (218.2)	102.6 \pm 0.7 (24.3)	99.9 \pm 0.5 (29.2)	94.0 \pm 2.4 (94.7)

Figure 4 shows the number of fledging events recorded at different dates in March 2000 and 2001.

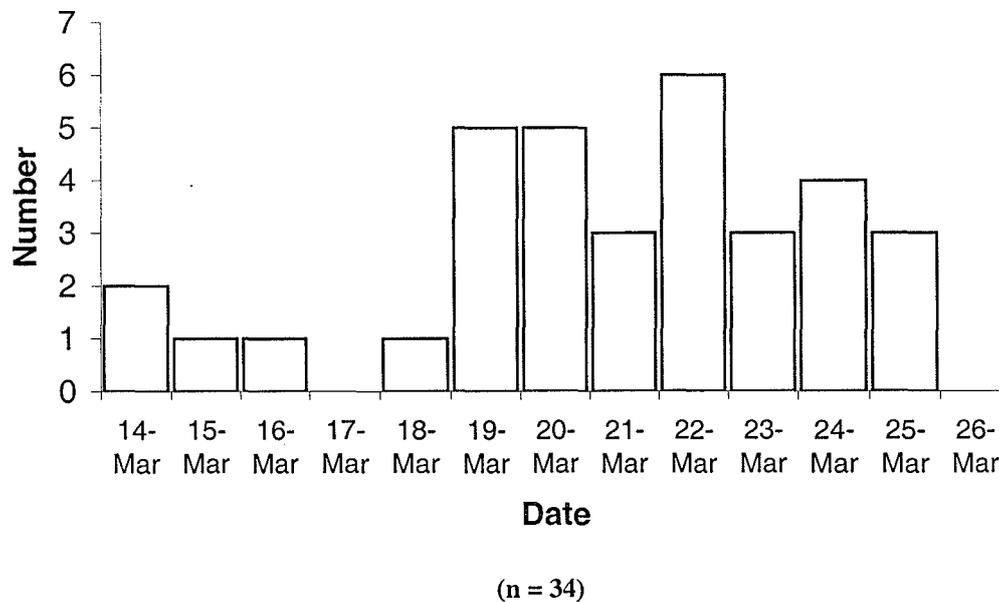


Figure 4: Number of fledging events between 14 and 26 March 2000 and 2001 on Red Mercury Island

5.8 Control group

Mean weights and wing length of control and study groups on 29 January and 15 March are presented in Table 2. On 29 January, these groups did not have significantly different mean weights (155 ± 7 g for study group and 161 ± 6 g for control group; Table 2) (Mann-Whitney U-test; $U = 960$; $p = 0.41$; $n = 62$). However, on 15 March, the mean weights of the control group (237 ± 7 g; Table 2) and of the study group (215 ± 5 g; Table 2) were significantly different (Mann-Whitney U-test; $U = 630$; $p = 0.02$; $n = 51$). On 15 March, chicks of the study group had longer wings (192 ± 2 mm; Table 2) than chicks of the control group (185 ± 5 mm; Table 2), but the difference was not significant (Mann-Whitney U-test; $U = 968$; $p = 0.37$; $n = 66$).

Table 2: Mean weight and mean wing length of Pycroft's petrel chicks of the study and control groups (Red Mercury Island, 2001)

	Mean weight (g)		Mean wing length (mm)
	29/01/2001	15/03/2001	15/03/2001
Study group	155 ± 7 (n = 32)	215 ± 5 (n = 30)	192 ± 2 (n = 44)
Control group	161 ± 6 (n = 30)	237 ± 7 (n = 21)	185 ± 5 (n = 21)

It is not clear what caused the weight difference between control and study chicks towards the end of their development. It is possible that stress due to daily handling affected the experimental chicks. However, human disturbance is not necessarily the only, or the main reason. The weight difference between the two groups might be due to a difference in the average age of chicks in the two groups. If the experimental chicks were older than the control ones, then on 15 March they would be closer to fledging, and therefore lighter than the control nestlings. This is partly confirmed by the wing length of the chicks of both groups. Although the difference was not significant, on 15 March experimental chicks had longer wings than control ones, indicating that they were in a more advanced stage of development than birds of the control group.

6. CHATHAM PETREL RESULTS

6.1 Weight changes

Mean fledging weight of Chatham petrel chicks in 1999 and 2001 was $217 \pm 4\text{g}$ (range 181-306g). The weight of fledglings averaged $108.5 \pm 1.9\%$ of adult weight (200g; Marchant and Higgins, 1990), ranging from 90.5% to 153.0%.

It was possible to fit a regression line (equation: $\text{weight} = -0.208 \times \text{DBF}^2 + 9.697 \times \text{DBF} + 209.806$) to the data (Fig. 5). Although this curve does not fit the data as well as the curve generated for Pycroft's petrel chicks the r^2 is still relatively high ($r^2 = 0.61$)

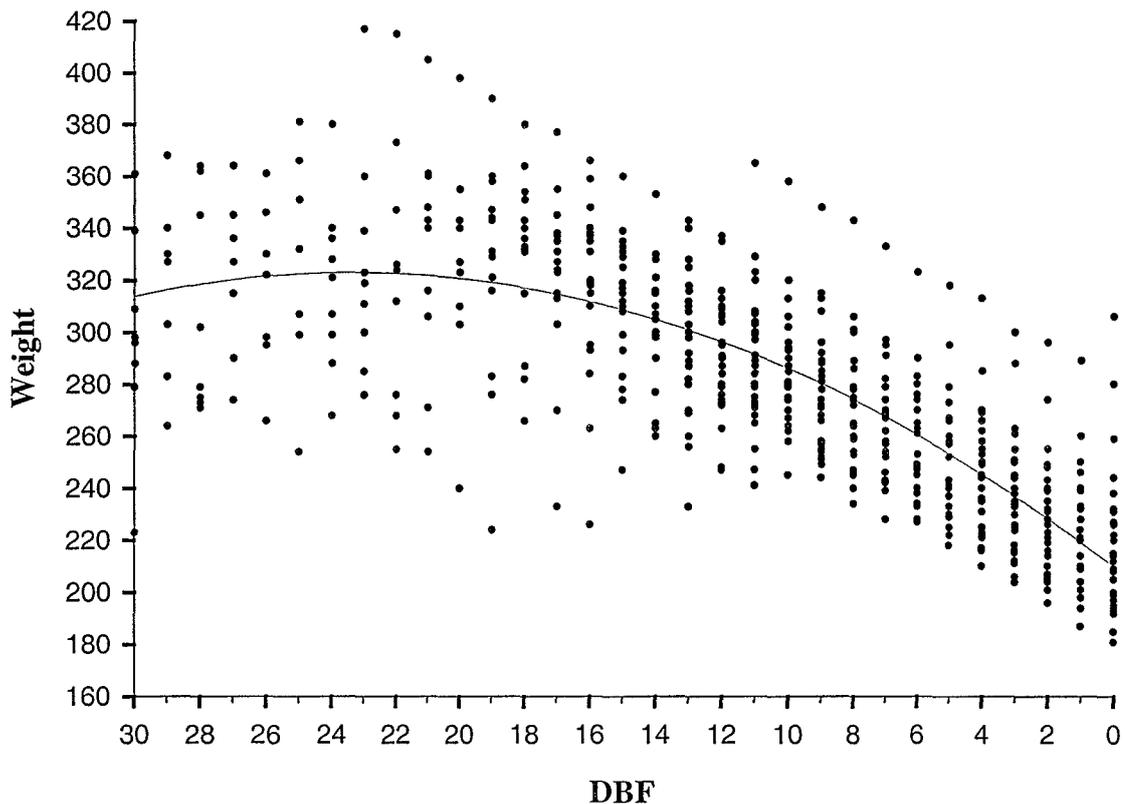


Figure 5: Weight of Chatham petrel chicks (combined sample of Bancroft (1999) and Gummer (2001); $n = 31$) as a function of age expressed in days before fledging (DBF) (South East Island, 1999 and 2001). Regression line (equation: $\text{weight} = -0.208 \times \text{DBF}^2 + 9.697 \times \text{DBF} + 209.806$; $r^2 = 0.61$) is shown

6.2 Wing length

Wing length at fledging of Chatham petrel chicks in 1999 and 2001 averaged $220 \pm 1\text{mm}$ (range: 213-227). On the day of first emergence, the nestlings' wing length averaged $92.3 \pm 1.6\%$ of adult wing length (range 83.0% - 99.5%; $n = 11$).

It seems that wing length can be a reasonably good indicator of age expressed in days before fledging for Chatham petrel chicks, the coefficient of regression found when fitting a regression line to the data being $r^2 = 0.62$ (Fig. 6). However, this regression line is not as good

as the regression line generated to fit the data for Pycroft's petrel chicks ($r^2 = 0.95$). This might be due to variation between the two different persons.

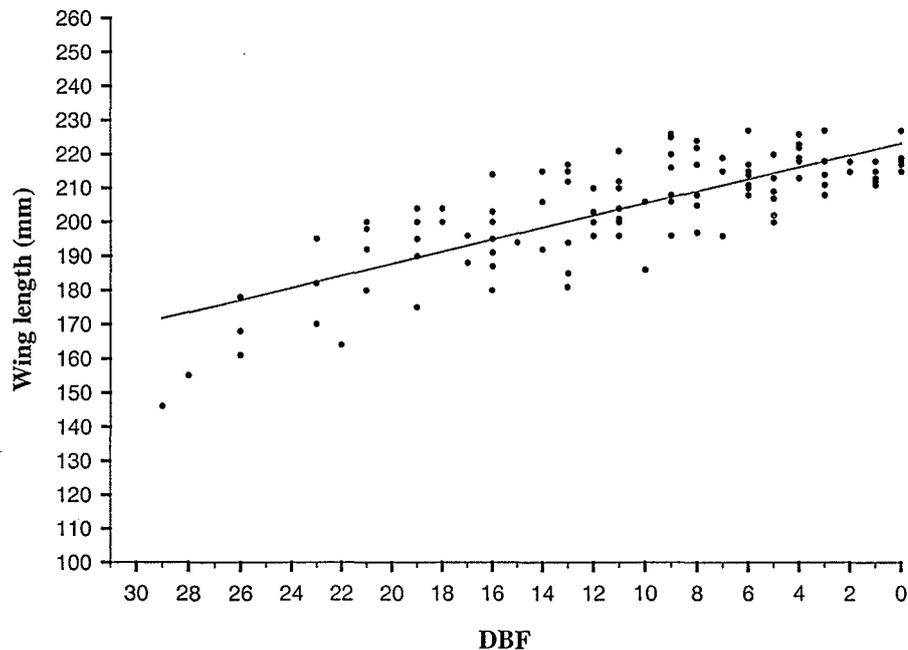


Figure 6: Wing length of Chatham petrel chicks (combined samples of Bancroft (1999) and Gummer (2001); $n = 31$) as a function of age expressed in days before fledging (DBF) (South East Island, 1999 and 2001). Regression line (equation: wing length = $-1.781 \times \text{DBF} + 223.381$; $r^2 = 0.62$) is shown

7. DISCUSSION AND RECOMMENDATIONS FOR CHICK TRANSFER

On average, Pycroft's petrel chicks reached their maximum weight at 24 DBF. In order to reduce the number of feeding events after the transfer, it is better to transfer Pycroft's petrel chicks that are not younger than 20 DBF. However, Pycroft's petrel nestlings should not be transferred to a new site when less than 12 days before fledging, as chicks apparently first venture out of their burrow at about 7-8 DBF.

From this study, it appears that the wing length is the best criteria to use in order to age an unknown chick. Our results indicate that the wing lengths at 20 DBF and 12 DBF are 149mm and 177mm respectively. Hence, the wing length of transferable chicks should be between 150mm and 180mm. This corresponds, to the lower limit (150mm) of wing length for the chicks that were transferred by Taylor (2001). However, our data suggest that the maximum wing length of those birds that were transferred (190mm) was too high and it is likely that some of these birds had already been outside their burrows and may already be imprinted on their natal colony on Red Mercury Island.

Furthermore, to be sure that a chick will not fledge too early (i.e. within 6-7 days after being transferred), it should not be underweight when transferred. Our data suggest that the weight

of a chick is about 250g at 20 DBF and about 227g at 12 DBF. However, to take into account the variation in chicks' weight, the translocated chicks should weigh between 220g and 260g. Therefore, we recommend that the translocation criteria for Pycroft's petrel chicks should be:

- wing length between 150 and 180mm;
- weight between 220 and 260g.

Many similarities are observed between chick development in Pycroft's and Gould's petrel (Table 3) (Priddel and Carlile, 2001). It is, therefore, very likely that these recommendations are also appropriate for other gadfly petrel species of similar size, such as Cook's petrel (*P. cookii*) or Stejneger's petrel (*P. longirostris*).

Table 3: Comparison of Pycroft's and Gould's petrel chicks

	Pycroft's petrel chick	Gould's petrel chick
Feeding frequency	- 60 to 24 DBF: every 2 nd day - 23 to 16 DBF: every 3 rd day - 15 to 8 DBF: every 5 th day - no feeding afterwards	- 42 to 18 DBF: every 2 nd day - 17 to 11 DBF: every 3 rd day - no feeding afterwards
Overnight weight increase	22 ± 1g	17.2 ± 0.6g
Correlation between meal size and age	No correlation, $r^2 = 0.05$	No correlation, $r^2 = 0.048$
Weight:		
- age at peak weight	26 DBF;	29 DBF;
- daily weight loss	5.4g in the last 9 DBF	5.6g in the last 10 DBF
Age at first emergence	8 DBF	10 DBF

For Chatham petrels, given the fact that chicks start to emerge from their burrow at about 11-13 days before fledging, no nestling should be transferred when less than 15 DBF. A reasonable period for possible transfer would therefore be between 25 and 15 DBF. This corresponds to Gummer's recommendation (2001) to transfer Chatham petrel chicks when they are about 70 days old, i.e. about 15 DBF. Hence, using the curves generated by the data used in this study, we recommend that the transferable chicks should have the following measurements:

- wing length of 180-200mm;
- weight of 300-330g.

It is very likely that those values would also be appropriate for gadfly petrels of similar size to the Chatham petrel belonging to the same sub-genera and to the *Cookilaria* sub-genera.

Once translocated, it is not necessary to feed the Pycroft's petrel chicks more than once every third or fourth day, until they reach 7 DBF (i.e. a wing length of 194mm). Once chicks reach that stage, they should not be fed, unless they weigh less than the mean adult weight, about 160g for Pycroft's petrel and 200g for Chatham petrel. The size of the meals delivered by Taylor (2001) to translocated chicks on Cuvier Island (27g average) seems appropriate

although our study suggests that the average meal size in Pycroft's petrel is between 35 and 40g, as is the mean meal size calculated for Chatham petrels (Gardner, 1999). In order to reduce the number of feeds after translocation, it seems best to give feeds of about 35g to the translocated chicks every three or four days, instead of giving them smaller feeds more often. The objective of feeding must be to maintain chicks at a weight close to adult weight and to avoid chicks fledging underweight.

Chatham petrel chicks should not be fed when older than 15 DBF in order to let them loose enough weight to fledge around the same age as other chicks. Given the similarities between Pycroft's, Gould's and Chatham petrels in terms of feeding frequency and meal size, it is very likely that these recommendations about the feeding of translocated chicks could be adapted for chicks of other *Pterodroma* species of similar size.

8. ACKNOWLEDGEMENTS

Funding for this study was provided by the Pacific Development and Conservation Trust, Department of Conservation (investigation 2352) and Lincoln University. The research on Pycroft's petrel was carried out under a permit from the Waikato Conservancy of Department of Conservation and animal ethic approval was granted by Lincoln University.

This study would not have been possible without support from Graeme Taylor, Biodiversity Recovery Unit, Department of Conservation. Graeme provided logistical support plus advice and encouragement at all stages of the research. Our study would not have proceeded without the support of the Chatham Petrel Recovery Group and we are especially grateful to the Group for allowing us to utilise the Chatham Petrel data collected by Fiona Bancroft, Helen Gummer and other staff on Rangatira Island. We are particularly grateful to Jason Roxburgh from the Hauraki Area Office for his support of our trips to Red Mercury Island.

Jim Hope provided transport to Red Mercury Island and accommodation in Tairua. The data collection would not have been possible without assistance from the following volunteers, Kirsten Basse, Mark Fraser, Paul Cuming and Dai Morgan. Thanks to you all.

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