Attempts to anchor pelagic fairy prions (*Pachyptila turtur*) to their release site on Mana Island

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Abstract New Zealand conservation managers have a distinguished history in translocating forest birds, shorebirds and waterfowl to achieve conservation gains. Although New Zealand is a centre of seabird diversity, and many species are threatened and/or have suffered human-induced range reductions, until recently there had been few attempts to translocate seabirds. Reluctance to attempt translocations was due largely to the perceived risk of dispersal, and the expectation that birds would return to their source colony. Translocations have now been attempted with 10 species of burrow-nesting petrels in New Zealand, with chicks moved before they were likely to have developed awareness of their natal colony location, and hand-fed until they fledged. The translocation of 240 fairy prion chicks from Takapourewa (Stephens I) to Mana I in 2002-04 was one of few petrel translocation studies where systematic searches for returning translocated chicks at both the release site and the source colony were undertaken, and where a sample of marked control chicks allowed comparison of natural return rates with those of translocated chicks. Twenty translocated chicks returned to Mana I during 2004-12, and 25 were recovered at the source colony during 2005-08. Nearly identical proportions (c.20%) of translocated and control chicks were recovered, with higher recovery rates at the release site for each successive cohort. Birds appeared to develop their homing ability at different ages, and there was no apparent maximum age after which chicks should not be translocated. Exposing chicks to the source colony surface in daylight did not increase the risk of them returning to the source colony.


Keywords ecological restoration; dispersal; petrel; prion; seabird; recruitment; survival; translocation

INTRODUCTION

History of seabird translocations in New Zealand

New Zealand has a long history of successful translocations of birds for conservation purposes, dating back to Richard Henry’s releases of South Island brown kiwi (*Apteryx australis australis*) on 3 islands in Dusky Sound in 1895-97 (Hill & Hill 1987; Miskelly & Powlesland 2013). More than a century later 49 taxa of New Zealand land birds, shorebirds and waterfowl have been translocated successfully as part of species recovery and site restoration programmes (Miskelly & Powlesland 2013).

New Zealand is the world centre of diversity for penguins, albatrosses, petrels and cormorants, and many of these species are threatened (Taylor 2000; Miskelly *et al.* 2008). Why then did no-one in New Zealand attempt to translocate a seabird species until 1986 (Imber *et al.* 2003; Miskelly *et al.* 2008)?
al. 2009), over 90 years after Richard Henry began his pioneering efforts with land birds? The major impediment to initiation of translocation trials with seabirds was their extreme philopatry and homing ability. Most seabirds are extremely faithful to their breeding sites, and most also recruit to the near vicinity of where they were reared (Warham 1990, 1996; Imber et al. 2003; Brooke 2004; Gaston 2004). Trials with breeding Manx shearwaters (Puffinus puffinus) released thousands of kilometres from their breeding burrows proved their extreme homing ability (Lockley 1952; Brooke 1990).

Burrow-nesting seabirds in the families Alcidae (auks), Spheniscidae (penguins) and the order Procellariiformes (petrels) were the obvious candidate seabird species for initial translocation trials, as burrows protect unattended chicks from aerial predators, and chicks cannot gain visual clues to aid homing until they emerge onto the colony surface (see Kress & Nettleship 1988; Miskelly & Taylor 2004; Priddel et al. 2006; Miskelly et al. 2009). Serventy (1967) had previously established that short-tailed shearwaters (Puffinus tenuirostris) reared from translocated and cross-fostered eggs returned to the site of hatching, not to where the eggs were laid, and so philopatry in petrels is presumed to develop during the nesting period.

Trials with petrel chick translocations in New Zealand began with black petrels (Procellaria parkinsoni) in 1986-90 (Imber et al. 2003), flapping shearwaters (Puffinus gavia) in 1991-96 (Bell et al. 2005) and common diving petrels (Pelecanoides urinatrix) in 1973-79 (Miskelly & Taylor 2004). By 2012, 10 species of burrow-nesting petrels had been translocated in New Zealand, and at least 5 other species elsewhere in the world (Miskelly et al. 2009; Miskelly & Powlesland 2013). We here report on the first attempt to translocate a species of prion (genus Pachyptila, family Procellariidae).

Prions as ecosystem engineers
Prions are among the most abundant seabirds in the Southern Ocean. The largest colonies of 5 of the 6 species number in the millions of pairs, with burrow densities often exceeding 1 m\(^{-2}\) (Marchant & Higgins 1990; Warham 1990; Brooke 2004; Gaston 2004). The vast size and high density of prion colonies result in these small seabirds having considerable impacts on the terrestrial ecology of their breeding sites due to their burrowing activity, trampling, harvesting of living and dead plant material for nest-lining, and deposition of enormous quantities of marine-derived nutrients via faeces, spilt regurgitations, lost feathers, failed eggs and corpses (Smith 1976; Furness 1991; Bancroft et al. 2004, 2005; Hawke & Newman 2004; McKechnie 2006; Grant-Hoffman et al. 2010; Ellis et al. 2011; Mulder et al. 2011; Smith et al. 2011). Ecosystem effects of dense prion colonies on islands in Cook Strait, New Zealand include changes in landform, soil fertility, vegetation structure, composition and productivity, and increased densities of invertebrates and reptiles (Mulder & Keall 2001; Markwell & Daugherty 2002; Jones 2010). The ecological benefits of the establishment of dense colonies of burrow-nesting seabirds were the primary motivation for translocations of fairy prions, common diving petrels and flapping shearwaters as part of the restoration of 217 ha Mana Island Scientific Reserve in eastern Cook Strait (Miskelly 1999; Miskelly & Taylor 2004; Miskelly et al. 2009; Gummer & Adams 2010).

Breeding ecology of fairy prions in Cook Strait
There is a long history of ecological research on Takapourewa (Stephens I) in western Cook Strait, mainly focussed on the large population of tuatara (Sphenodon punctatus) there (Brown 2001). Despite the enormous population of fairy prions on Takapourewa, and their multiple interactions with tuatara, several basic parameters of prion breeding ecology on the island were not known before this study, including the length of incubation and nestling periods, fledging weights and wing length, and the age of first breeding (but see Walls (1978) for a summary of the fairy prion breeding cycle on Takapourewa). Fairy prions have been studied at other sites in New Zealand (Richdale 1944 & 1965; Harper 1976; Miskelly et al. 2001); the following summary is based on those studies, plus Walls (1978), Marchant & Higgins (1990), Gaston & Scofield (1995) and Miskelly et al. (2009).

Fairy prions in Cook Strait weigh c.110-150 g. They breed as socially monogamous pairs, returning to colonies mainly from late Jun, and laying a single egg in late Oct to early Nov in a burrow 0.4-1.2 m long. Eggs hatch during Dec after 44-54 days of shared incubation. The chick is left unattended during daytime following a 2-3 day post-hatch guard period. Both adults feed the chick during nocturnal visits to the colony until the chick fledges from late Jan through to mid Feb, 43-56 days after hatching. Adults continue to feed chicks right through to fledging (there is no desertion period), and chicks spend an average of 1 night only on the colony surface before fledging (range 0-4 nights). They do not return to the colony until near breeding age (3+ years old; this study).

METHODS
Translocation of fairy prion chicks
Fairy prion chicks were translocated from Takapourewa to Mana I on 13 Jan 2002 (40 chicks), 14 Jan 2003 (100 chicks), and 17 Jan 2004 (100
chicks). Chicks were selected on the basis of weight and wing-length, to ensure that all birds moved were in good condition (> 117 g when first handled, > 93 g on the day of transfer 2-4 days later), and that a range of ages from 3-20 days before fledging was represented in the sample. Wing-length was used as a proxy age measure: the 240 translocated fairy prions fledged at wing-lengths of 168.6 ± s.e. 0.3 mm (range 154-182 mm), and wing-length grew at a mean rate of 3.3 mm d⁻¹ (data from Miskelly & Williams 2002; Miskelly & Gummer 2003 & 2004).

Most of the birds translocated (194 of 240) were sourced from a 0.3 ha area of the ‘dam paddock’ on Takapourewa, facilitating subsequent searches for birds that might return as adults near their natal burrows. Takapourewa (150 ha) has a fairy prion breeding population estimated at 1.83 million pairs (Craig 2010), and so it was necessary to confine searches to a small portion of the colony.

In 2002 & 2003, all chicks were briefly removed from their burrows in daylight when first handled for measuring and the fitting of a uniquely-numbered leg-band, as well as being exposed to daylight when placed in translocation boxes on the day of transfer. In 2004, 49 of the chicks translocated were treated as in 2002 & 2003, while the remaining 51 chicks were kept under dark towels and in dark bags during handling, so that they did not see the source colony surface in daylight. Sixty-three of the 2004 chicks were sourced from the dam paddock; 28 of these were exposed to the light, and 35 kept in the dark.

Chicks were placed in cardboard pet boxes (2 birds per box, separated by a diagonal divider) and flown the 80 km between islands by helicopter (further details in Miskelly et al. 2009).

Care of translocated fairy prion chicks at the release site

On arrival on Mana I, chicks were given up to 5 ml of fresh water and individually placed in artificial burrows previously used for diving petrels (Miskelly & Taylor 2004). They were hand-fed daily from the day after arrival until they fledged. Three different artificial diets were used (Miskelly et al. 2009): 20 chicks were fed a krill-based diet in 2002, 16 chicks were fed a diet based on Ocean Catch™ tinned sardines in 2003, and the remaining 204 chicks were fed a diet based on Brunswick™ tinned sardines in soy oil. All meals were delivered as a blended slurry via a syringe and crop needle, with meal sizes averaging 26.6 g (Brunswick™ sardines, n = 1914 meals), 28.4 g (krill, n = 127) and 33.4 g (Ocean Catch™ sardines, n = 160). Details of artificial diets, feeding methodology and husbandry practices were given by Miskelly & Williams (2002), Miskelly & Gummer (2003 & 2004) and Miskelly et al. (2009).

Chicks were weighed daily before they were fed, and their wing lengths were also measured daily as they approached fledging. They fledged during the hours of darkness, and so fledging weights and wing measurements were taken approximately 8-16 hours before the birds departed the release site. Stick fences were placed at burrow entrances in 2003 & 2004 to allow detection of whether chicks exited their burrow for one or more nights before fledging.

Control chicks

Thirty parent-reared fairy prion chicks were weighed daily for the last 2-11 days of the nestling period on Takapourewa in Jan 2004, providing a sample of natural fledging weights. Some of these chicks were part of a larger sample of 149 control chicks of similar size to the translocated chicks that were banded and left to fledge naturally within the dam paddock chick collection and search area (42 in 2002, 20 in 2003, 87 in 2004).

Acoustic attraction at the release site

A solar-powered loud-speaker system has broadcast calls of fairy prions and other petrel species during the hours of darkness at the release site almost continuously since 1993 (Miskelly & Taylor 2004; Miskelly et al. 2009).

Surveys for birds that survived to adulthood

Fairy prions do not return to breeding colonies until at least 2.5 years after they fledge (data presented here). Both the 0.3 ha portion of the Takapourewa colony where the majority of chicks were sourced from and the Mana I release site were searched regularly between Aug 2004 and Dec 2008, 2.5-7 years after the first chicks were translocated. Searches continued at lower frequency on Mana I during 2009-12 (Table 1). Searches started about an hour after dark and continued for 30-180 minutes, depending on the number of birds present on the colony surface (typical duration 90 mins). Prions located on the surface of the search areas were captured where possible to check for the presence of uniquely-numbered leg bands that had been applied to study chicks. Few prions were present on Mana I, and so we attempted to catch all birds seen. Up to 550 prions were handled per night on Takapourewa, with a total of 9313 birds located on the surface of the dam paddock chick collection and search area there. Breeding by translocated and control chicks on Takapourewa was not monitored.

From Nov 2007, feather samples from returned birds were collected for sexing using DNA techniques.

Measurements

Unless stated otherwise, measurements are presented as mean ± standard error (minimum - maximum, n = sample size).
RESULTS
Survival rate and condition of fairy prion chicks after translocation
All 240 chicks fledged in good condition 2-21 days after translocation (median 10 days). The effects of 3 different artificial diets on fledging weights were reported by Miskelly et al. (2009). In summary, birds fed on a krill-based diet or on a diet based on Ocean Catch™ sardines fledged at weights close to those of parent-fed chicks, while those fed on a diet based on Brunswick™ sardines fledged at significantly higher body-weights (Table 2). The very high fledging weights reached by chicks fed on Brunswick™ sardines in 2003 were due partly to the chicks being in very good condition before transfer. Body-weights for these 84 chicks on the day of transfer were $152 \pm 1.8$ g ($111-184$ g); comparative transfer weights for chicks fed on Brunswick™ sardines in 2002 were $134 \pm 2.1$ g ($118-154$ g, $n = 20$), and in 2004 were $131.2 \pm 1.7$ g ($93-165$ g, $n = 100$).

Recoveries of translocated fairy prions and control chicks as adults
Forty-five (18.8%) of the 240 translocated birds were recovered as adults, 20 on Mana I and 25 within the dam paddock on Takapourewa (i.e., within metres of their natal burrows). Twenty-nine of the 149 control (non-translocated) chicks (19.5%) were also recovered in the dam paddock. No new recoveries of translocated or control birds were made during the last 7 nights of searching on Takapourewa (Nov-Dec 2008), during which 1151 birds were handled (cf. Table 1).

Ages of the 74 birds when first recaptured as adults were 3 years (24 birds), 4 years (31 birds), 5 years (13 birds), 6 years (5 birds), and 9 years (1 bird). Most birds were recovered as adults between Aug and Dec; as they hatched from eggs in Dec, ages were rounded up as if the birds were recovered in Dec of the year they were caught. The youngest bird recovered was 2.5 years old (a 2003

Table 1. Search effort for returned translocated chicks at the source colony and release site. Capture rates for control chicks on Takapourewa are not shown, but they comprised part of the total number of birds handled there.

<table>
<thead>
<tr>
<th></th>
<th>Source colony (Takapourewa)</th>
<th>Release site (Mana I)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of nights of searching</td>
<td>Birds handled¹</td>
</tr>
<tr>
<td>Jul-Dec 2004</td>
<td>8</td>
<td>877</td>
</tr>
<tr>
<td>May-Nov 2005</td>
<td>5</td>
<td>1012</td>
</tr>
<tr>
<td>Jun-Nov 2006</td>
<td>10</td>
<td>2564</td>
</tr>
<tr>
<td>Aug-Nov 2007</td>
<td>10</td>
<td>3122</td>
</tr>
<tr>
<td>Aug-Dec 2008</td>
<td>10</td>
<td>1738</td>
</tr>
<tr>
<td>Jul-Nov 2009</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nov 2010</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sep &amp; Nov 2011</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Jul &amp; Oct 2012</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>43</td>
<td>9313</td>
</tr>
</tbody>
</table>

¹ May include the same individuals handled on multiple nights or (due to the number of unbanded birds handled on Takapourewa) on the same night.

Table 2. Fledging weights (g) of fairy prion chicks fed on 4 different diets at Cook Strait sites during 2002-04. Note that artificial diets were used (on Mana I) for only the last 2-21 days before chicks fledged, with all birds being fed by their parents on Takapourewa for c.3-6 weeks before then. Natural fledging weights were obtained on Takapourewa.

<table>
<thead>
<tr>
<th>Diet</th>
<th>Year</th>
<th>n</th>
<th>Mean ± s.e.</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural (parent-reared)</td>
<td>2004</td>
<td>30</td>
<td>106 ± 2.1</td>
<td>86</td>
<td>132</td>
</tr>
<tr>
<td>Krill-based</td>
<td>2002</td>
<td>18¹</td>
<td>104 ± 2.4</td>
<td>88</td>
<td>126</td>
</tr>
<tr>
<td>Ocean Catch™ sardines</td>
<td>2003</td>
<td>16</td>
<td>105 ± 1.5</td>
<td>94</td>
<td>118</td>
</tr>
<tr>
<td>Brunswick™ sardines</td>
<td>2002</td>
<td>20</td>
<td>115 ± 1.5</td>
<td>105</td>
<td>135</td>
</tr>
<tr>
<td>Brunswick™ sardines</td>
<td>2003</td>
<td>84</td>
<td>123 ± 1.2</td>
<td>100</td>
<td>149</td>
</tr>
<tr>
<td>Brunswick™ sardines</td>
<td>2004</td>
<td>100</td>
<td>115 ± 0.9</td>
<td>96</td>
<td>139</td>
</tr>
</tbody>
</table>

¹ Two chicks fed a sardine-based diet for the last 3 days they were on Mana I excluded from data.
Because 46 of the translocated chicks came from parts of Takapourewa that were not searched subsequently, these birds (which included 3 that returned to Mana I) were excluded from analyses of recovery rates. Of the 194 chicks translocated from the search area in the dam paddock, 39 (20.1%) were recovered on either island. There was no significant difference in recovery rates of parent-reared versus translocated chicks ($\chi^2 = 0.045$, 1 d.f., n.s.).

There were marked differences in recovery rates of chicks between years (Table 3), with 2 only of the 2002 cohort recovered (6%), compared to 19 & 29% respectively for the 2003 & 2004 cohorts. The proportion of birds recovered at the release site differed greatly between the 2003 & 2004 cohorts, with 26% of the recovered birds from the 2003 cohort found on Mana I (5 out of 19) compared to 61% of the returned birds in the 2004 cohort (11 out of 18).

Sex was determined for 24 of the 45 recovered birds. The 17 sexed birds on Mana I comprised 9 males and 8 females; the 7 sexed birds on Takapourewa comprised 5 males and 2 females. The combined total of 14 males and 10 females did not differ significantly from an equal sex ratio ($\chi^2 = 0.414$, 1 d.f., $p = 0.52$). Few studies have reported the sex ratio of petrels recovered after translocation, however 13 of 14 sexed Gould’s petrels (Pterodroma leucoptera) that returned to their release site were male (N. Carlile, pers. comm. 27 Jan 2012), as were 9 of 17 sexed common diving petrels that returned to Mana I (CMM, unpbl.).

**Table 3.** Recovery rates of translocated fairy prion chicks fed different artificial diets, plus combined annual cohort recovery rates at both the source colony (Takapourewa) and the release site (Mana I). Data from birds sourced beyond the dam paddock search area excluded.

<table>
<thead>
<tr>
<th>Artificial diet used and/or year of translocation</th>
<th>No. of chicks translocated</th>
<th>No. recovered as adults at the source colony</th>
<th>No. recovered as adults at the release site</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Krill 2002</td>
<td>17</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Ocean Catch™ sardines 2003</td>
<td>16</td>
<td>0</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Brunswick™ sardines 2002</td>
<td>14</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Brunswick™ sardines 2003</td>
<td>84</td>
<td>13</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>Brunswick™ sardines 2004</td>
<td>63</td>
<td>7</td>
<td>11</td>
<td>18</td>
</tr>
<tr>
<td>Brunswick™ sardines total</td>
<td>161</td>
<td>21</td>
<td>14</td>
<td>35</td>
</tr>
<tr>
<td>2002 total</td>
<td>31</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2003 total</td>
<td>100</td>
<td>14</td>
<td>5</td>
<td>19</td>
</tr>
<tr>
<td>2004 total</td>
<td>63</td>
<td>7</td>
<td>11</td>
<td>18</td>
</tr>
<tr>
<td>Combined total</td>
<td>194</td>
<td>22</td>
<td>17</td>
<td>39</td>
</tr>
</tbody>
</table>

**Relationship between fledge weight and recovery rate**

There was no apparent relationship between fledge weight and the subsequent recovery of chicks as adults, nor on where the birds recruited to (Fig. 1). The mean fledge weight of 45 translocated chicks recovered as adults was $118.4 \pm 1.6$ g (97 - 141 g), compared to $118.2 \pm 1.0$ g (88 - 151 g) for 155 translocated chicks not recovered as adults ($t = 0.102$, $P = 0.92$). The mean fledge weight of the 20 translocated chicks recovered as adults on Mana I was $117.0 \pm 2.2$ g (102 - 134 g), compared to $119.6 \pm 2.3$ g (97 - 141 g) for the 25 translocated chicks recovered as adults on Takapourewa ($t = 0.841$, $P = 0.41$).

**Relationship between the length of time birds were at the release site before fledging and recovery rates at the source site and release site**

The length of time that translocated fairy prion chicks spent in artificial burrows on Mana I had no apparent affect on which island they were recovered on as adults (Fig. 2). One chick that was on Mana I for 18 days still returned to Takapourewa, whereas a chick that was on Mana I for 3 days only before fledging was recovered on Mana I as an adult. The median length of stay on Mana I for chicks that returned there was 10 days ($n = 20$, range 3 - 19 days), compared to 9 days ($n = 25$, range 5 - 18 days) for chicks that returned to the source colony. The median length of stay on Mana I for chicks sourced from the dam paddock that were not recovered was 11 days ($n = 155$, range 2 - 21 days).

The length of time that translocated chicks spent on the surface of the release site at night...
Effect of chicks being exposed to the source colony surface in daylight on their subsequent recovery rate at the source colony

Exposing fairy prion chicks to the surface of their natal colony in daylight before translocation did not increase the likelihood that they returned to their natal colony as adults. Eighteen of the 63 chicks translocated from the dam paddock in 2004 were recovered as adults, 11 on Mana I and 7 on Takapourewa. A higher proportion of the birds exposed to their natal colony in daylight were subsequently recovered as adults at the release site compared to the natal colony (Table 5).

Recovery rates of translocated petrels of 7 species compared to control chicks

This was one of few petrel translocation studies where comprehensive searches for translocated chicks were undertaken at both the release site and the source colony. Six previous studies reported recovery (recapture) rates of translocated petrel chicks at their release site (Table 6). Three only of these studies (of black petrel *Procellaria parkinsoni*, Gould’s petrel, and Bermuda petrel *Pterodroma cahow*) included comprehensive searches for translocated chicks returning to the source colony (Imber et al. 2003; Priddel et al. 2006; Carlile et al. 2012). However, Imber et al. (2003) were unable to search the release site (Hauturu) thoroughly due to its rugged topography and the scattered distribution of burrows there.

The Bermuda petrel study had the highest recovery rate of translocated chicks (24.2%, Carlile et al. 2012), followed by fairy prions (19.6%).
However, only 8.2% of fairy prions were recovered at their release site, compared to 17.2% for Bermuda petrel, 16.9% for common diving petrel, and 11.7% for fluttering shearwater (Miskelly & Taylor 2004; Bell et al. 2005; Carlile et al. 2012).

Three previous studies included data on recovery rates of non-translocated chicks at natal colonies, with recovery rates of up to 58.6% per cohort for Bermuda petrel (Carlile et al. 2012), 41.4% for short-tailed shearwater Puffinus tenuirostris (see Serventy & Curry 1984), and 6.5% for black petrel (Imber et al. 2003), compared to 19.5% for fairy prion.

### Role of resident birds as anchors for subsequent cohorts

Nearly all petrel translocation studies where more than 10 chicks returned had low recovery rates of the first cohort translocated, with higher (and typically increasing) recovery rates of second and subsequent cohorts (Table 7). The one exception was Gould’s petrels on Boondelbah I, where almost identical proportions of both cohorts were recovered at the release site. Boondelbah I was the only site among the 5 release sites where conspecifics were already present and breeding (Priddel et al. 2006).

The pattern of increased recruitment of the second and subsequent cohorts of petrels translocated to new sites is probably due to the presence of increasing numbers of adult conspecifics at the release site attracting more returning birds to land and to remain long enough at the site to be detected during occasional surveys. This implies that a proportion of the birds from early cohorts that returned to the release sites were not detected, and presumably recruited elsewhere. An estimate of the number of fairy prions from early cohorts that failed to recruit at the release site can be obtained from comparison with return rates to the source colony, where the level of social attraction was constant between seasons.

The proportion of translocated birds detected in the dam paddock on Takapourewa varied from 3.2 to 14.0% each year (Table 8), and was strongly correlated with recovery rates of control chicks from the same cohort (Table 8; \( r = 0.962 \)). Based on the ratio of translocated chicks recovered at each site from the 2004 cohort (Mana I = 1.58 x Takapourewa) when those birds returning to Mana I would have encountered other adult fairy prions at the release site, we estimate that c.17% of the 2003 cohort probably returned to Mana I but did not recruit there, and were not detected in either search area (Table 9). Similarly, assuming equal sex ratios and survival among translocated chicks, we estimate that c.9 females recruited outside the search areas (Table 9).

### Breeding by fairy prions on Mana I

Twenty-five adult fairy prions were handled on Mana I during 2004-2012: 20 translocated birds that returned as adults, 4 unbanded birds, and
one locally-reared chick (first recovered when nearly 5 years old). An unbanded pair reared a chick in 2005/06, but one of the adults was not seen subsequently. At least 6 other pairs of prions bred on the island between 2007/08 and 2011/12, with 9 chicks reared to fledging in known, accessible burrows during these 5 breeding seasons. Identities of all the breeding birds each year were not known, but they included at least 7 translocated birds (and possibly all but one of the remaining breeding adults had been translocated). Several pairs bred in long natural burrows where the nesting chambers were inaccessible, and it is estimated that up to 8 additional chicks were reared during these 5 breeding seasons (based on evidence of burrow visits late in the nesting period). In 2011/12, 5-6 pairs of prions were believed to be occupying burrows at the release site, and 4 chicks fledged.

The minimum age of first breeding by translocated fairy prion males and females on Mana I was 3 years 10 months after hatching.

**DISCUSSION**

This first translocation of a species of prion achieved an unprecedented 100% fledging success for a petrel chick translocation, with all 240 birds fledging in good condition. Heaviest fledging weights were achieved by the 204 chicks fed a diet based on Brunswick TM sardines in soy oil blended with fresh water, delivered daily into the proventriculus via a syringe fitted with a crop needle. This is an
easy, practical diet and method to use for petrel translocations at remote field sites (Miskelly et al. 2009).

The recovery rate of translocated fairy prion chicks as adults (20.1%) was the second highest recorded for a translocated petrel species (after Bermuda petrel, see Carlile et al. 2012), although higher recovery totals might have been reached by translocated common diving petrels (minimum 16.9%) and fluttering shearwaters (minimum 12.1%) if the source colonies had been adequately searched for returning chicks (data from Miskelly & Taylor 2004; Bell et al. 2005). The similarity between the recovery rates of translocated prions (20.1%) and control (non-translocated) chicks (19.5%) was surprising given several factors expected to reduce recovery rates of translocated chicks. Firstly, the process of translocating chicks 80 km, handling them daily for up to 3 weeks, and feeding them an unfamiliar diet, would all be expected to impact on post-fledging survival rates. Secondly, we expected that translocated chicks would be at greater risk than control chicks of recruiting to fairy prion colonies located between the release site and source colony, including the Brothers Is (28 km from Mana I, 62 km from Takapourewa) and the Trio Is (71 km from Mana I, 19 km from Takapourewa). It is also unlikely that none of the translocated birds recruited among the estimated 1.83 million pairs of prions (Craig 2010) in the 99.8% of Takapourewa that was not searched for returning chicks. The most likely explanation for the similar recovery rates of translocated and control chicks is that the high fledging weights achieved using the sardine diet increased the survival to adulthood of translocated prions compared to control chicks, and that coincidentally this increased survival exactly offset any ‘leakage’ of translocated birds recruiting to sites other than the release site and the immediate vicinity of natal burrows.

Unlike several previous petrel translocation studies (Imber et al. 2003; Miskelly & Taylor 2004; Bell et al. 2005), we found no tendency for higher recovery rates of heavier fledglings. A likely explanation for this is that most of the translocated chicks fledged with above-average weight: 207 (86%) of fledglings exceeded the mean fledging weight of parent-reared chicks on Takapourewa (105.9 g). Similarly, there was no relationship between fledging weight and whether chicks recruited to the release site or source colony.

The large number of chicks that returned to Takapourewa, and the absence of any relationship between the time that chicks spent at the release site and where they were recovered as adults were both unexpected. Fairy prion chicks do not emerge from their burrows until the night of fledging or the night before (exceptionally up to 4 nights before) their burrows at night before translocation, unless this is part of the experimental design.

Several studies have revealed that male

| Table 8. Recovery rates (%) of fairy prion control chicks and translocated chicks at the source site and release site, separated by cohort. |
|---|---|---|---|---|
| | Cohort | 2002 | 2003 | 2004 | Total |
| Control chicks recovered at source site | | 4.8 | 25.0 | 25.3 | 19.5 |
| Translocated chicks recovered at source site | | 3.2 | 14.0 | 11.1 | 11.3 |
| Translocated chicks recovered at release site | | 3.2 | 5.0 | 17.5 | 8.8 |

(Richdale 1965; Harper 1976; Table 4). It is therefore unlikely that any of the translocated chicks had ventured onto the source colony surface before translocation. Although burrows were short, almost all were curved, and it is unlikely that more than a handful of chicks could have viewed the burrow entrance from the nest chamber. However, we had no way to determine whether chicks had moved up towards the burrow entrance at night sufficiently to see some of their surroundings, even if they did not fully emerge from the burrow. Alternatively, the birds could be using non-visual cues to allow recognition of the vicinity of their natal burrows as adults. Odour is known to be a close-range cue for prions locating their burrows (Bonadonna & Bretagnolle 2002; Bonadonna et al. 2003), but is unlikely to aid birds choosing between 2 potential recruitment sites situated 80 km apart. Regardless of the mechanism used, the recovery of so many ‘pre-emerged’ chicks within metres of their natal burrows demonstrates that this philopatric ability can develop more than 2 weeks before fledging in prions, and that it is extraordinarily accurate even when chicks have had little or no opportunity to see the night sky or view the silhouette of the landscape surrounding their burrow.

Our discovery that allowing chicks to see their natal colony surface in daylight did not increase the likelihood of them returning to the colony greatly simplifies the selection and collection of petrel chicks for transfer, when it is typically necessary to extract hundreds of chicks from burrows 2 or more times before they are translocated. This variable has not been mentioned in previous petrel translocation studies, and we assume that chicks in all other studies had the opportunity to see their natal colony surface during either day or night during handling. Chicks may be more sensitive to visual cues at night, as both adults and fledglings avoid the colony surface in daylight. We recommend that care be taken if petrel chicks are extracted from burrows at night before translocation, unless this is part of the experimental design.
procellariiforms are more likely to recruit close to natal burrows than females, with females more likely to disperse to other colonies or other parts of the same colony (Fisher 1976; Brooke 1978, 1990; Rabouam et al. 1998). Our results indicated a similar trend (58% of recovered birds were male), but this sex ratio was not significantly different from 1:1. Assuming that sex ratios were equal in the sample of chicks fledged, and that similar proportions survived to adulthood, it is possible that up to 24% of fledglings survived (cf. 20.1% recorded), with c.36% of females recruiting outside the 2 search areas.

Recognition that petrels translocated to new sites have low recruitment rates until some adults have recruited to the site has important consequences for future translocations. We suggest that the presence of adult birds greatly increases the perceived suitability of release sites to pre-breeders compared to aural stimuli alone. This realisation lends support to multi-year translocations (cf. single releases), with increasing sample sizes for later cohorts when there is a higher likelihood of returning chicks encountering adult conspecifics at the release site. Further, supplementary translocations (e.g. to sites with remnant populations, or where translocations have had limited success) are likely to result in higher recruitment than translocations to sites where the target species is absent.

We recorded a high survival rate of translocated birds to adulthood, but only 8% (20 birds) were recovered as adults at the release site, along with 4 unbanded colonists. Ten years after the first translocation, there were fewer than 6 pairs of fairy prions known to be present on Mana I. The low level of recruitment of non-translocated birds at the release site contrasts with common diving petrel (80 non-translocated birds recorded within 11 years of the first chick translocation; Miskelly & Taylor 2004; Miskelly et al. 2009) and Gould’s petrel (31 birds recorded within 5 years; Priddel et al. 2006), and has greatly impacted the establishment of a viable colony of fairy prions on Mana I. Variability in colonisation rates is apparently a species-specific trait, as both fairy prions and common diving petrels have their nearest breeding colony on the Brothers Is, 28 km from Mana I, and the calls of both species have been broadcast from loud speakers at their release site on Mana I since 1993. The fairy prion population on Mana I remains extremely vulnerable to stochastic events, and is unlikely to persist without further chick translocations.

**Recommendations**

This first attempt to establish a colony of fairy prions by chick translocations yielded several key pieces of information that could aid future attempts. The diet based on blended Brunswick™ sardines in soy oil and freshwater was practical and effective in ensuring hand-fed birds fledged in good condition (see also Miskelly et al. 2009). As only 8% of translocated chicks were recovered at the release site, we recommend that 200 additional chicks be translocated to Mana I to ensure that the colony there continues to grow. With the enhanced social attraction provided by the small fairy prion colony now on Mana I, at least 14% of the additional birds are predicted to recruit there.

To minimise hand-feeding costs and effort (and recognising that there was no age threshold at which chicks became fixed to their natal colony), chicks selected for translocation should exceed 115 g and have wing lengths of 142-162 mm (i.e.,
targeting birds 2-8 days before fledging). It is not necessary to prevent chicks from seeing the surface of the source colony in daylight.

We also recommend that petrel translocations to new sites be undertaken over at least 3 years, with the greatest numbers of chicks translocated in the final cohort. These birds are more likely to encounter conspecifics at the release site when they return as pre-breeders, and are predicted to have higher recruitment rates than birds translocated in earlier cohorts.

ACKNOWLEDGEMENTS

The translocation was approved and supported by the Department of Conservation (DOC), Ngati Koata and Ngati Toa, and funded by the Friends of Mana Island Incorporated Society (FOMI). Ngati Koata and Ngati Toa representatives and DOC staff assisted with locating and selecting chicks for translocation; we particularly thank Anaru Paul, Clint Purches, Mike Aviss, Lynn Adams, Jason Christensen and Bill Cash for their assistance over several seasons on Takapourewa. The volunteer bird-feeding teams on Mana I were organised by FOMI, particularly Colin Ryder, and the teams were ably led by Rex Williams (in 2002) and HG (2003 & 2004). Over 35 people helped with feeding the birds, with Reg Cotter, Kelvin Hunt, Allan Correy, Barry Dent, Andy Rawnsley, Sue Freitag, Annette Harvey, Shelley Meehan, Lance Mundy and Luke Rawnsley all assisting for 2 or more seasons. Thanks also to Gerald & Margaret Freeman (DOC staff on Takapourewa) for their persistence in the daily weighing of 30 parent-reared prion chicks until they fledged. Searching for returned birds on Takapourewa was undertaken by resident DOC staff and volunteers, particularly Clare Allen, Jon de Vries, Karen Ismay, John McKeown, Emma Craig and Jason Butt; we are extremely grateful for their herculean efforts. Logistic support for access to Mana I to monitor returning birds was provided by resident DOC staff Grant Timlin, Jason Christensen, Sue Caldwell and Frank Higgott. Many people assisted with searches for returning prions there, and we particularly acknowledge the assistance of Nio Mana and Graeme Taylor. DNA sexing of feather samples was undertaken by the Equine Parentage & Animal Genetic Services Centre, Massey University. We thank Nicholas Carlile, David Priddel, Graeme Taylor and Alan Tennison for their helpful comments on the manuscript.

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