CSIRO PUBLISHING
www.publish.csiro.au/journals/emu
Emu, 2004, **104**, 205–211

Establishment of a colony of Common Diving Petrels (*Pelecanoides urinatrix*) by chick transfers and acoustic attraction

Colin M. Miskelly[A] *and Graeme A. Taylor*[B,C]

[A]Wellington Conservancy, Department of Conservation, PO Box 5086, Wellington, New Zealand.
[B]Biodiversity Recovery Unit, Department of Conservation, PO Box 10420, Wellington, New Zealand.
[C]Corresponding author. Email: gtaylor@doc.govt.nz

Abstract. Burrow-nesting petrels have been extirpated from many traditional breeding sites by human-induced factors, especially the introduction of predatory mammals. Petrels have proven to be extraordinarily difficult to attract or restore to secure sites due to their strong philopatry, and low intrinsic rates of population growth. Translocation and/or attraction techniques are needed to establish additional populations of endangered petrels to restore species to part or all of their historic range and to restore the keystone role of petrels in terrestrial ecosystems. We attempted to restore a colony of Common Diving Petrels (*Pelecanoides urinatrix*) on Mana Island, New Zealand, by a combination of broadcasting vocalisations, and by transferring and hand-feeding nestlings until they fledged. Calls were broadcast at night almost continuously during 1993–2003, and 239 chicks were transferred during 1997–99. About half the chicks fledged, and 20 of these have returned to Mana Island, along with 51 unbanded birds. Fifteen of the returned chicks have bred on Mana Island, and at least 14 parent-reared chicks fledged in 2002.

Introduction

Translocation is widely used by conservation managers to restore and enhance populations of mammals, landbirds, reptiles, amphibians and invertebrates (Griffith *et al*. 1989; Dodd and Siegel 1991; New 1994; Fischer and Lindenmayer 2000). Translocations are most often successful when a large number of individuals are released into high-quality habitat with few or no predators (Wolf *et al*. 1996; Fischer and Lindenmayer 2000). However, few attempts have been made to transfer seabirds, as chicks of most species are typically extremely philopatric, returning to the near vicinity of their natal nest site (Marchant and Higgins 1990; Warham 1990), and, with the exception of terns (Sternidae), adults are also highly faithful to nest sites and colonies (Warham 1990; Kress 1997). Passive attraction techniques (mainly decoys and broadcasting vocalisations) have successfully been used to attract terns and Common Murres (*Uria aalge*) to new breeding sites (Kress 1983, 1997; Kress and Borzik 2002) but have had limited success with other seabirds unless they have been used (a) close to existing colonies (Podolsky and Kress 1992), or (b) in conjunction with the transfer of nestlings (Kress 1978, 1997; Kress and Nettleship 1988).

Burrow-nesting and surface-nesting seabirds of the families Procellariidae (petrels and shearwaters) and Oceanitidae (storm petrels) have been severely impacted at many colony sites by habitat modification, over-harvest and, especially, introduced predators (Feare 1984; Moors and Atkinson 1984; Vermeer and Rankin 1984). Local extinctions have led to range reductions for many species, about half of all species are threatened or endangered, and 11 species are critically endangered (Croxall *et al*. 1984; BirdLife International 2000). Methods for attracting petrels to new sites, or restoring them to historic breeding sites, are required to achieve threatened species recovery objectives (Taylor 2000*a*; Aikman *et al*. 2001; Veitch *et al*. 2004), and to restore the keystone role of petrels in terrestrial ecosystems (Miskelly 1999; Department of Conservation 2000; Markwell and Daugherty 2002). Petrels typically nest in dense colonies that may be of enormous size (Croxall *et al*. 1984; Marchant and Higgins 1990; Warham 1990; Furness 1991) and can dominate the ecology of islands free of mammalian predators through their burrowing activity, trampling and collection of ground-cover vegetation for nest linings, and especially by the importation of vast quantities of marine-sourced nutrients deposited at colonies as droppings, regurgitations, failed eggs and corpses (Smith 1976; Furness 1991; Warham 1996; Mulder and Keall 2001).

Despite the urgent need for restoration techniques for petrels, there have been very few successful attempts to attract or move petrels to new sites. The only species known to have been attracted to new sites by passive means (acoustic attraction) is Leach's Storm Petrel (*Oceanodroma leucorhoa*) (Podolsky and Kress 1989; Kress 1997), and only one previous attempt to transfer petrel chicks (Fluttering Shearwater, *Puffinus gavia*) is believed to have led to the successful establishment of a breeding colony at a new site (Bell

10.1071/MU03062 0158-4197/04/030205

1995; Brian and Elizabeth Bell, personal communication). We chose to attempt acoustic attraction and chick transfers of Common Diving Petrels (*Pelecanoides urinatrix*) because they have an unusually quick life cycle for a petrel: birds return to colonies when only 1–2 years old, and first breed at 2–3 years old (Richdale 1965). In contrast, larger species such as the Southern Fulmar (*Fulmarus glacialoides*) do not return to colonies until 5–23 years old, and first breed at 6–22 years old (Jenouvrier *et al*. 2003). We hoped that lessons learnt from the diving petrels could be applied to more threatened species, and to species with much longer life cycles.

Methods

Biology of the Common Diving Petrel

Common Diving Petrels are small seabirds (110–150 g) that feed predominantly on crustaceans (Marchant and Higgins 1990). Within the New Zealand region they breed on many islands from the Three Kings Islands (34°10′S) south to Campbell Island (52°33′S) and east to the Chatham Islands. The breeding ecology of diving petrels has been studied in northern New Zealand (Thoresen 1967, 1969) and southern New Zealand (Richdale 1943, 1945, 1965; Miskelly *et al*. 2001), but their breeding ecology in the Cook Strait region (central New Zealand) is poorly known. A single egg is laid in a short burrow or under dense vegetation; incubation is shared and takes 53.5 days (n = 1) (Thoresen 1969); chicks fledge at 44–59 days old (Marchant and Higgins 1990; Miskelly *et al*. 2001). Laying in central New Zealand is thought to occur in late August to late September, hatching in mid-October to mid-November, and fledging in early December to early January (Gaston and Scofield 1995; authors' unpublished data). Chicks are fed nightly until fledging, and typically depart for the sea on the first night that they emerge from the burrow, although a few hide elsewhere on land for another day before fledging (Richdale 1943, 1965). The Cook Strait diving petrel population is thought to be stable in numbers and distribution, but data are limited (Taylor 2000*b*).

Study areas

Mana Island (217 ha; 41°06′S, 174°46′E) is situated in eastern Cook Strait, New Zealand, and is administered as a Scientific Reserve by the New Zealand Department of Conservation. The island was farmed for over 150 years until the last stock were removed in 1986. Following eradication of House Mice (*Mus musculus*) in 1989, Mana Island is free of all introduced mammals. Over 300 000 trees and shrubs have been planted since 1987 as part of a comprehensive restoration plan (Miskelly 1999), but much of the summit plateau remains covered in a rank sward of exotic grasses. Bones of diving petrels have been found in an archaeological deposit on Mana Island, and they are assumed to have been part of the original avifauna (Miskelly 1999). The site chosen for attracting and transferring petrels is on the south-western cliff-top (80 m above sea level), near a small colony of ~100 pairs of Sooty Shearwaters (*Puffinus griseus*). The soil at the site is a deep, friable, sandy loam and has a low grass cover with patches of herbs (including Iceplant, *Disphyma*, and Native Spinach, *Tetragonia*) and isolated shrubs of Tauhinu (*Ozothamnus leptophylla*), Porcupine Bush (*Melicytus crassifolius*) and the vine *Muehlenbeckia complexa*. The cliff-face below is shattered argillite with shallow soil and similar vegetation to the cliff-top.

The nearest known colony of Common Diving Petrels to Mana Island is on the Brothers Islands (41°06′S, 174°26′E), 28 km away on the western side of Cook Strait. Diving petrel chicks were sourced from North Brother Island (NBI; 4 ha), and also from Motumahanga (1.2 ha; 39°03′S, 174°01′E) in the Sugar Loaf Islands (SLI) off New Plymouth, 235 km north-north-west of Mana Island. There are ~600 pairs on NBI (Gaston and Scofield 1995) and 'several thousands' on Motumahanga (Merton 1961).

Acoustic attraction

An automated solar-powered sound system was first installed at the study site in April 1993. This was configured to switch on at dusk and off at dawn, to match the nocturnal colony-attendance patterns of the target species. The sound system played most nights of the year during 1993–2003, except for occasional periods when a fault developed and components needed replacing. Initially, we used a cassette tape containing calls obtained from colonies of Common Diving Petrels, Fairy Prions (*Pachyptila turtur*), Fluttering Shearwaters and White-faced Storm Petrels (*Pelagodroma marina*), and this was replaced with a compact disc system in June 2002. The sound recordings were mostly of birds calling on the ground or from breeding burrows, and included calls from both male and female diving petrels. Two 80-W weatherproof loudspeakers (TOA model SL-60W) were positioned 20 m apart, facing outwards to the open waters of Cook Strait, and into the prevailing north-westerly wind. In calm conditions, calls from the loudspeakers were audible to humans from over 1 km away. Fifty short burrows were manually excavated near the loudspeakers in 1993, but these became overgrown before any birds were found ashore.

Translocation of diving petrel chicks

During October 1997 artificial burrows were prepared on Mana Island on the upper shoulder of the cliff, around and between the loudspeakers. These were at least 60 cm long, with 10-cm-diameter PVC drainage pipe entrances leading to a 30 × 15 cm chamber covered with a length of wood used as an inspection hatch. A smaller 20 × 20 cm side chamber was excavated from the main chamber so that chicks could shelter away from the inspection hatch and away from the glare of light from the entrance tunnel. Dry nest material (mainly straw) was placed in each chamber.

Diving petrel chicks on NBI & SLI were located by hand-searching burrows by day and night. Precise ages of chicks were not known as observers were not present at the source colonies during hatching; however, aging criteria for diving petrel chicks were provided by Richdale (1945). Wing length was considered the best predictor of how far each chick was from fledging (authors' unpublished data). Chicks of a range of ages (~4–8 weeks) were sought, as we did not know at what age chicks developed a strong attraction to their natal site. Chicks were banded, measured and weighed when first encountered, and any burrow containing a chick suitable for transfer was tagged and mapped.

The chicks were collected from their burrows on the day of transfer and placed in ventilated cardboard boxes for transport (up to 16 birds per box, each in a separate compartment about twice the size of the chicks). Chicks were transferred on 24 November 1997 (39 ex NBI), 11 December 1997 (52 ex SLI), 21 November 1998 (63 ex SLI), 27 November 1998 (40 ex NBI), and 26 November 1999 (49 ex NBI).

Transport from NBI was a direct helicopter flight of about 10 min. Transport from SLI was more protracted. In 1997, the chicks were airlifted in a short helicopter flight to the adjacent mainland and held overnight before being flown the following day by commercial airliner to Wellington, then driven by car to Paremata and taken by boat for the 5 km to Mana Island, a total transit time of 22 h. In this transfer, one chick died when smothered by two chicks that climbed out of their adjacent transfer box compartments. In subsequent transfers each compartment was covered with plastic mesh to prevent chicks climbing out. In 1998, the chicks were flown by helicopter from SLI, transported by car for 5 h from New Plymouth to Paremata, and then taken by boat to Mana Island; total transit time was about 7 h. In this second transfer, three chicks died from presumed heat stress.

Each chick was placed into its own marked artificial burrow on arrival on Mana Island. Plastic mesh fences were placed over the burrow entrances to keep the chicks in the burrow for the first two nights after transfer to prevent early departure. After chicks were noted leaving the burrows during daylight in 1998, the mesh fences were kept in place until each chick reached a wing length of 110 mm.

Hand-feeding chicks

Chicks were fed once a day (1997) or twice a day (1998 and 1999) until fledging. A paste based on krill (*Euphausia superba*) was slowly injected directly into the crop from a 12-mL syringe via a crop needle (feeding tube). The paste was prepared by blending thawed krill (purchased as a frozen 24-kg block) with small quantities of calcium powder and vitamin supplements. The mixture was heated to body temperature before feeding. Meal sizes averaged 27.2 g (range 1–75 g; n = 4362). Care was taken to maintain high levels of hygiene. Following indications that some birds were suffering from candidiasis (*Candida albicans* yeast infection), crop needles were immersed in chlorhexidine solution after each bird was fed from 5 December 1999 on, in addition to standard rinsing in boiled water. Details on feeding technique for diving petrels and four other petrel species will be presented elsewhere. Chicks were weighed before and after each feed, and wing lengths were recorded every third day. The departure date was recorded for each chick.

Searching for returning birds and immigrants

Only 3–4 nocturnal searches of the artificial colony site were undertaken per year during 1993–99, mainly during visits to the adjacent Sooty Shearwater colony. Search effort increased during 2000–03, with 3–7 visits per season during both the pre-breeding period (January–August) and the breeding season (September–December). Total visits per year were 14 (2000), 8 (2001), 7 (2002) and 9 (2003). Initially we searched for birds on the surface, and for droppings or feathers near the two loudspeakers, and also checked artificial burrows for signs of occupation. Burrow checks were facilitated by placing fences of small sticks across burrow entrances. From November 1999 we searched for diving petrels by turning off the sound system temporarily (to reduce background noise) and then inducing birds in burrows to call by mimicking their calls. Whenever calm weather provided good listening conditions, cliff areas north and south of known burrows were searched for peripheral birds. Most birds encountered were in natural burrows or under dense vegetation either on the lower shoulder of the cliff (about 5 m altitude lower than the artificial burrows) or on the cliff-face itself. All but one burrow had a nest chamber that was accessible to observers either via the entrance or via an excavated study hole. The exception was a rock-crevice nest site found down the cliff-face in 2002. All birds handled at the colony were checked for bands, and any unbanded birds were banded when first handled. Searches were initially focused near the loudspeakers (1993–99), but birds and burrows were found up to 50 m to the north and 100 m to the south in 2000, on the southern cliff-face in 2001, and on the cliff face below the loudspeakers in 2002. The ages of three banded birds recovered at the latter two sites indicated that some of these more isolated burrows had probably been used in previous breeding seasons.

Neither source colony (NBI and SLI) was searched for returning transferred chicks due to access constraints, cost, and the risk of burrow damage on these small, intensively burrowed islands.

Results

Survival and fledging of transferred chicks

Diving petrels proved to be more difficult to hand-feed than anticipated, and 42–60% of transferred chicks died before fledging each year (Table 1). The major causes of mortality were believed to be: food poisoning in 1997, candidiasis and food poisoning in 1998, and hypothermia during severe weather as well as candidiasis in 1999. Overall, 49% of the 239 chicks transferred were believed to have fledged from Mana Island (Table 1).

Table 1. Fledging success, return rates and recruitment of transferred diving petrel chicks

Figures do not include four chicks that died during transfer (see text)

Year of transfer	Transferred	Fledged	Returned	Bred
1997	90	52	6	6
1998	100	40	9	5
1999	49	26	5	4
Total	239	118	20	15

Those chicks that fledged from Mana Island were present at the release site for 0–44 days before fledging (mean 16 days) (Fig. 1). Fledging weights were 83–145 g (mean 117.6 g) (Fig. 2), which was about 7 g lighter than fledging weights on Whero Island (mean 124.6 g, range 96–148 g, n = 46: Richdale 1943, 1965). No comparable data were available for Cook Strait colonies. Fledging weights increased each year as the feeding methodology was refined; means were: 107.9 g in 1997, 122.7 g in 1998, and 129.1 g in 1999.

Recoveries of transferred chicks after fledging

The first transferred chicks (four) were recovered back on Mana Island on 3 November 1999 at 1, 1, 1 and 2 years old. Of the 20 returned chicks recovered on Mana Island, six were first recovered as 1-year-olds, nine as 2-year-olds, two as 3-year-olds, one as a 4-year-old, and two as 5-year-olds. As the three oldest birds (discovered in 2001 and 2002: Table 2) were found at cliff-face sites that had not previously been searched, it is likely that these birds had been present and breeding for several years before discovery. Even excluding these three birds, it is likely that the age of return has been over-estimated due to the low search effort, especially in

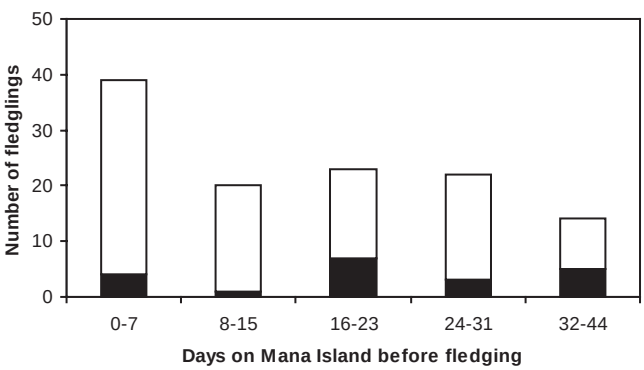

Fig. 1. The relationship between the length of time that transferred Common Diving Petrel chicks were on Mana Island before fledging, and the number of chicks of each age class that were recovered on Mana Island as adults. White = the 118 chicks that fledged; black = the 20 chicks that returned.

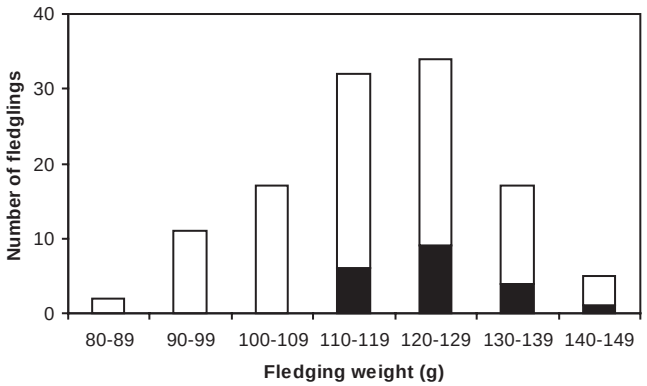

Fig. 2. The relationship between fledging weights of transferred Common Diving Petrel chicks, and the number of chicks of each size class that were recovered on Mana Island as adults. White = the 118 chicks that fledged; black = the 20 chicks that returned.

1998 and 1999. The five locally bred chicks recovered at the colony to date were first found as 1-year-olds (4 birds), plus a 2-year-old recovered in 2003 (Table 2).

The only transferred chick recovered away from Mana Island was found beach-wrecked at Te Horo, 40 km to the north-east, on 8 July 1999, 19 months after fledging. This bird was found during the second year (1999) of the largest mortality event for diving petrels on New Zealand coasts since records of beach-wrecked birds began in 1940 (G. Taylor, unpublished).

The 20 transferred chicks that returned to Mana Island had been present at the release site for 2–35 days before fledging (Fig. 1), and it was apparent that not all chicks that were close to fledging at the time of transfer had formed an unbreakable attachment to their source colonies. Four of the transferred chicks that returned to Mana Island had been present at the release site for only 2, 3, 3 and 3 days before fledging. In contrast to the age at transfer, fledging weight had a major effect on the likelihood of transferred chicks being recovered as adults on Mana Island (Fig. 2). The 20 chicks that returned to Mana Island were significantly heavier at fledging (mean 124 g, s.e. 1.9; range 110–142 g) than the 98 fledglings that did not return (mean 116 g, s.e. 1.4; range 83–145 g; *t*-test, $P = 0.002$).

The overall return rate for transferred chicks was 17% (20 of 118) compared with 31% (4 of 13) for the first three cohorts of parent-reared chicks known to have fledged from Mana Island. This is likely to be an under-estimate for both groups due to low search effort. It is unlikely that the three returned chicks found on cliff-faces in 2001 and 2002 were the only chicks to visit these cliff sites, given that birds could have been landing there undetected during the 4 years 1998–2001.

Table 2. Provenance of adult diving petrels handled on Mana Island

Records are based on the first occasion that each bird was captured as an adult (age 1+ years). The rapid increase in the colony during 2000–02 was partly an artefact of extensions to the colony being discovered; the known spatial extent of the colony was stable during 2002–03

Year	Transferred chicks	Locally bred chicks	Unbanded immigrants	Total
1997	0	0	2	2
1998	0	0	1	1
1999	5	0	4	9
2000	10	0	10	20
2001	3[A]	2	12	17
2002	2[A]	1	16	19
2003	0	2	6	8
Total	20	5	51	76

[A]One of the transferred chicks recovered in 2001, and both those recovered in 2002, had probably returned to Mana Island in previous years as they were 4–5 years old and were found at sites not searched previously.

Colonisation of Mana Island by unbanded diving petrels and other petrels

At least 51 unbanded 'immigrant' Common Diving Petrels have visited or colonised the release site on Mana Island, outnumbering returned transferred chicks by more than 2:1 (Table 2). The first two adult diving petrels were found on the surface near the loudspeakers on 1 October 1997, 4.5 years after the sound system was installed, but only 8 weeks before the first transferred chicks were due to arrive. The numbers of immigrants captured at the colony has increased each year since 1998, and 73% of the 30 identified breeding birds in 2002 were immigrants. All diving petrels were found within 150 m of the loudspeakers, and there was no evidence of diving petrels colonising other parts of Mana Island.

During the 11 years 1993–2003, only two White-faced Storm Petrels and no Fairy Prions or Fluttering Shearwaters were known to be attracted to the sound system. Transfers of Fairy Prion chicks commenced in 2002, but these birds are not expected to return until at least 2004.

Table 3. Colony size and breeding output of diving petrels on Mana Island

Year	Adults	Pairs	Eggs	Chicks	Fledglings
1999	10[A]	2	2	2	1
2000	26	9	8	6	5
2001	35	15	12	8	7
2002	40	19	15[B]	14[B]	14[B]
2003	42	19	16[B]	11[B]	7[B]
Total	76	–	53	41	34

[A]One pair not handled or identified, but assumed to have failed at chick stage in 1999 (based on the dried corpse of a small chick found in 2000).

[B]Does not include the breeding output of one pair that probably had a chick in an inaccessible crevice.

Breeding by Common Diving Petrels on Mana Island

Breeding was first detected on 3 November 1999, when two immigrants were found caring for a small chick in a natural burrow about 7 m below, and upwind from, the artificial burrows (which received the final cohort of transferred chicks 23 days later). The first of the transferred chicks were found breeding in 2000, when eight birds aged 2 years (n = 5) and 3 years (n = 3) were found in six different pairs that laid. The colony has since continued to grow annually due to both immigration and recruitment (Table 3). Most breeding birds kept the same mate (81% of 21 pairs where both birds known to be alive in Year N + 1) and same burrow (81% of 27 breeding males; 81% of 26 breeding females) in subsequent seasons.

All but three of the 53 confirmed breeding attempts recorded up to 2003 were in natural burrows 17–150 m from the loudspeakers. The three exceptions were a pair of returned fledglings (one from NBI, one from SLI) that bred in an artificial burrow in 2000, and a pair of immigrants that bred in a different artificial burrow in both 2002 and 2003. Both artificial burrows were within 6 m of a loudspeaker. We suspect that diving petrels chose not to use the artificial burrows due to their large tunnel diameters (10 cm, cf. 6–7 cm for natural burrows). Natural burrows were all downslope, and typically upwind, from the two loudspeakers.

As parent-reared chicks were handled infrequently, we were unable to compare fledging weights of parent-reared versus hand-fed chicks.

Discussion

The successful establishment of a colony of diving petrels on Mana Island has demonstrated that a combination of chick transfers and acoustic attraction is a viable method for establishing petrels at new sites. Key lessons learnt from the project include: determination of the developmental stage at which chicks become fixed on their natal colony, techniques for maintaining good health of hand-fed petrel chicks, and the importance of high fledging weights for increased post-fledging survival rates.

Common Diving Petrel chicks apparently do not become fixed to their natal site until they emerge from their burrow for the first time on the night that they fledge, as demonstrated by four fledglings that returned to Mana Island after spending only the last 2–3 days of their nestling period there. While this discovery should simplify chick transfers for petrel species that exhibit little or no pre-fledging emergence from burrows (e.g. diving petrels, *Pelecanoides* spp., and prions, *Pachyptila* spp.), most gadfly petrels (*Pterodroma* spp.) and shearwaters (*Puffinus* spp.) typically emerge from their burrows every night for up to 2 weeks before fledging (Marchant and Higgins 1990; authors' observations). For these latter genera, we suggest that chick transfers should occur before pre-fledging emergence commences.

The husbandry techniques developed during this study, particularly the use of crop needles for feeding, and ways to reduce cross-infection of *Candida*, are already being applied successfully to other petrel transfers. Nine transfers of a total of 617 Pycroft's Petrel (*Pterodroma pycrofti*), Chatham Petrel (*P. axillaris*) and Fairy Prion chicks undertaken in 2001–04 have all achieved fledging rates of 97–100% (C. M. Miskelly and G. A. Taylor, unpublished data).

Heavy fledglings are known to have higher post-fledging survival rates in those petrel species for which this relationship has been investigated (Perrins *et al*. 1973; Sagar and Horning 1998). We had difficulty attaining good fledging weights for diving petrels using a single daily feed of a krill-based diet in 1997, and adjusted the feeding regime to provide two feeds a day in 1998 and 1999, thereby raising mean fledging weights by 14–20%. It is likely that low fledging weights contributed to the low return rate of the 1997 cohort, but this was undoubtedly compounded by a severe mortality event that affected diving petrels around New Zealand during the first two winters that these chicks were at sea.

The return rates that we recorded for both transferred chicks (12–23% per cohort) and for 13 parent-reared chicks (31%) are probably underestimates of the true return rates for diving petrels. Observers made very few visits to the colony in 1998 and 1999, when it is likely that chicks from the first two transfers would have started to return. Even in 2000–03, visits were too infrequent to locate birds that visited the colony irregularly, but should have allowed detection of all breeding birds within the areas searched. Unfortunately, we did not realise the extent to which diving petrels were utilising the cliff-faces below and to the south of the artificial burrows and loudspeakers until late in the 2002 breeding season, and it is likely that other banded birds had visited these sites in the four preceding years.

It is unlikely that the 1997–99 chick transfers alone would have led to the establishment of a viable diving petrel colony on Mana Island, as only 15 of the 239 chicks transferred were recruited into the breeding population, and only seven of these birds were known to be present at the colony by 2003. The arrival of at least 42 unbanded diving petrels during the period that transferred chicks were returning was a surprise, and undoubtedly was the main factor that allowed the Mana Island colony to establish and grow. These birds were assumed to have been attracted by the sound system, but as this had been in place for the previous 6 years (with only three diving petrels known to have been attracted before the transferred chicks started returning), we suspect that the presence of returned transferred chicks in addition to the sound system was a key factor in both attracting unbanded birds and encouraging them to stay. This conclusion is reinforced by the observation that acoustic attraction alone has failed to attract any Fairy Prions and Fluttering Shearwaters, and has attracted only two White-faced Storm Petrels (once each) after 10.5 years of broadcast calls.

We were unable to determine whether chick translocations in the absence of broadcast calls can result in colony establishment, as the site chosen for chick transfers had already had a sound system in place for 4.5 years. Limited resources, plus our imperative to develop translocation and attraction techniques rapidly for use on endangered petrel species, did not allow duplication of the trial in the absence of broadcast calls.

On the basis of the results of this trial, we recommend that both chick transfers and acoustic attraction be used simultaneously to restore petrels to sites where they have been extirpated, and to establish additional populations of endangered species at sites safe from introduced predators.

Acknowledgments

This project was funded by the Department of Conservation, which also granted permission to access the islands and to translocate diving petrels. We are grateful for the support and participation of Ngati Te Whiti, Te Atiawa ki Waikawa and Ngati Toa (tangata whenua for Sugar Loaf Islands, Brothers Islands, and Mana Island respectively) during the transfers. The difficult and, at times, demoralising task of feeding the chicks was undertaken by contractors Rex Williams, Rachael Coumbe, Heidi Baillie, Vaughn Bell, Enfys Graham, Jason Leppens, Amanda McKenzie, Kate McNabb, David Pike, Sian Robinson, and over 26 volunteers from the Ornithological Society of New Zealand, and the Department of Conservation; we thank them all, and particularly acknowledge the efforts of Rex Williams in 1997 and 1998 and Rachel Coumbe in 1999. Logistic support was provided by local Department of Conservation staff, especially Mike Aviss, Bill Cash, Jason Christensen, Tony Henry, Nio Mana, Grant Timlin and Bryan Williams. We thank Brian Gartrell for advice on managing candidiasis, and Maurice Alley and Caroline Twentyman (Massey University) for completing necropsies. David Pike searched for returning chicks in 2000. This manuscript was improved by comments from Barry Baker, Nicholas Carlile, John Craig, Stephen Kress, Paul Scofield, Alan Tennyson and an anonymous referee.

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Manuscript received 31 December 2003, accepted 9 March 2004