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Reducing the risk of extinction of a globally threatened shorebird: translocations of the shore plover (*Thinornis novaeseelandiae*), 1990-2012

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Abstract The shore plover (*Thinornis novaeseelandiae*) is a highly threatened shorebird endemic to New Zealand. It is particularly susceptible to introduced mammalian predators, and has a very small total population and a very limited range. This paper lists the translocations that have formed the core of the shore plover recovery programme over the past 22 years, and summarises the outcomes. In the early 1990s, a captive population was established in mainland New Zealand using birds reared from eggs transferred from the last self-sustaining wild population on the Chatham Islands. Since 1994, captive-bred birds have been released on 5 offshore islands around the New Zealand mainland in attempts to found new populations. There have also been transfers of wild-bred birds from South East I to Mangere I in the Chatham Is. Between 1994 and April 2012, 404 juvenile and 28 adult shore plover have been released at a total of 6 sites. Birds bred at 4 of the 6 sites, and breeding populations established at 3 of them. However, recent mammalian predator incursions at 1 (and probably 2) of those, and habitat limitation at the 3rd, mean that the translocated populations are all currently small (6 pairs or less), and their long-term future is uncertain. Other challenges faced during the programme include avian predation of released birds, high rates of dispersal, and outbreaks of avian pox. In spite of recent setbacks, the risk of extinction for the species has gradually been reduced. Since 1990, a self-sustaining captive population has been set up, the number of breeding pairs has increased, and the number of breeding populations in the wild has risen from 2 to 4 (although 1 is currently facing extirpation). Features of the shore plover programme that have contributed to these outcomes are outlined. Aspects of shore plover ecology revealed by the translocations are noted. While progress has been made, existing populations will need to grow, and further populations will need to be established before the shore plover's threat ranking improves.

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INTRODUCTION

In the 19th century, the endemic shore plover (*Thinornis novaeseelandiae*) occurred on mainland New Zealand. Its previous distribution is uncertain, but it definitely bred around the coast of the South I (Davis 1994a). The species is highly susceptible to predation by introduced mammals (Dowding & Murphy 2001) and was apparently extirpated from mainland New Zealand by the 1870s (Davis 1994a). However, a population persisted on the Chatham Is, 800 km east of the South I. The species occurred on Chatham, Pitt, Mangere, and South East Is in the Chatham Is group, but was extirpated from the first 3 of these as invasive mammals spread (Dowding & Murphy 2001). For most of the 20th century, it was believed that the species survived only in a single population of 110-140 individuals on South East

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I. In 1999, a small, apparently isolated population of about 20 birds was discovered on Western Reef, off the north-west coast of Chatham I (Bell & Bell 2000), about 80 km north-west of South East I. Following its discovery, this population declined rapidly to effective extirpation; the reason for the decline is uncertain but it may have been caused by the presence of an expanding fur seal (*Arctocephalus forsteri*) rookery on the small (*c*. 8 ha) reef. The last surviving bird was taken into captivity in 2003 (Dowding *et al*. 2005).

The shore plover is currently classified internationally as Endangered (BirdLife International 2012). Under the New Zealand threat classification scheme, it is classified as Nationally Critical (Miskelly *et al*. 2008). Because of its very small population size and limited distribution, it has long been recognised that a predator irruption on South East I would put the species at serious risk of extinction, and so there have been regular calls for the establishment of insurance populations (Flack 1976; Davis 1987; Dowding & Kennedy 1993).

In the 1970s, birds were transferred from South East I to Mangere I, but a population did not establish. In the early 1980s, 2 attempts were made to establish a captive population in mainland New Zealand, but both were unsuccessful. The Department of Conservation (DOC) re-started the captive programme in 1990/91, with the first of several egg transfers from South East I to the National Wildlife Centre (NWC) at Pukaha/Mt Bruce. Since then, shore plovers have been bred in captivity at 2 institutions in New Zealand and captive-bred birds have been transferred to a number of offshore islands around the New Zealand mainland.

This paper summarises the translocations that have formed the core of DOC's shore plover recovery programme over the past 20+ years, and comments on the outcomes. At different times, the programme has involved wild to captive, wild to wild, and (predominantly) captive to wild transfers. The paper also notes features of the strategy employed by the recovery team, records some of the challenges faced during the programme, and notes some aspects of the ecology of the species revealed by the translocations.

METHODS

The recovery programme for shore plover presently centres around 2 main activities: (a) ensuring the security of the source population on South East I, and (b) founding new populations on suitable islands via captive breeding and translocations. The 2001-2011 recovery plan (Aikman *et al*. 2001) had a goal of maintaining and/or establishing shore plover populations at 5 or more locations, with a combined population of 250 birds or more, by 2011. The programme is advised by DOC's shore plover recovery group (SPRG), which comprises a representative from each of the 2 captive-breeding institutions, DOC staff involved with management and monitoring at each release site, external contractors with expertise in husbandry and release techniques, an external science advisor with 1st-hand research experience with the species, and a group leader from DOC.

Davis (1987) listed a number of potential management actions to assist recovery of the species, including the establishment of a captive population, and release of captive-bred birds at suitable release sites. These concepts were developed by Aikman (1995), who provided a detailed assessment of them and compiled a release strategy. The strategy favoured a soft-release technique in which the birds would be subject to a holding period in an aviary at the release site to allow them to become familiar with the location, recover from the stress of transfer, and re-gain condition before release. O'Connor (2000) noted that there would need to be 5 years of releases on Motuora I to evaluate the release design adequately. Later experience suggested this was also an appropriate release period at other sites (see General Discussion).

Captive populations

Two inter-dependent captive populations were established in the early 1990s at NWC and Isaac Wildlife Trust (IWT) at Peacock Springs, Christchurch (see below for details). Breeding birds that die in captivity are replaced by retaining captive-bred juveniles, and the combined NWC/IWT population has been self-sustaining for many years. Maintenance of this population has involved numerous transfers between the institutions to replace birds that have died, balance sex ratios, increase numbers of birds to encourage pairing, and coordinate releases. These internal transfers, while essential to the programme, are not documented here, nor are captive management protocols described.

Occasionally, adults surplus to the breeding programme's requirements have been released with captive-bred juveniles, and these are included in Table 1 and Appendix 1. The combined captive population has typically included 6-10 pairs in any season. In order to produce the 20-40 juveniles annually that are normally required for releases, captive pairs have usually had their first (and sometimes second) clutches removed and hand-reared, allowing the parents to re-nest. Final clutches have commonly been parent-reared.

Release-site selection

Aikman (1995) noted the need before releases are undertaken to be able to control factors that caused previous declines. In the case of shore plover, it appears almost certain that the primary agent of

Table 1. Summary of the dates and numbers of shore plover released at each site and outcomes, 1994-2012. J = juvenile (fledged bird up to 1 year of age), A = adult.

Release site	Release period	J	A	Total	Outcome
Motuora I	1994-1999	58	17	75	Two pairs bred but population not established
Waikawa/Portland I	1998-2006	103	7	110	Large population established, severely reduced in 2012 by probable predator incursion; future uncertain
Mangere I	2001-2003	40	0	40	Small population established; appears stable, currently self-sustaining
Release site 4	2005	15	0	15	Single release only; population did not establish
Mana I	2007-2012	158	4	162	Population establishing; reduced by rat incursion in 2011 but should persist
Motutapu I	2012	30	0	30	Unknown, first releases in 2012
Totals		404	28	432	

decline was predation by introduced mammals. Davis (1987) recommended that suitable release sites should have some of the characteristics of shore plover habitat found on South East I, such as suitable breeding habitat, suitable prey, and (preferably) no mammalian predators. They should obviously also be a sufficient distance from the mainland to reduce the chance of predator incursions. Potential sites listed by Aikman (1995) were Mana, Motuora and Tiritiri Matangi Is. Expanded lists of potential sites were included in Kennedy *et al*. (1997) and Aikman *et al*. (2001); those lists have periodically been updated and selection criteria refined by the SPRG. Two of the release sites are privately-owned islands. The owners of 1 of these sites have indicated that they do not wish the island to be publically identified, and it is referred to here as Release Site 4 (RS 4).

Release protocols

All but 1 release were soft releases, using portable holding aviaries set up on site. Holding periods varied considerably. On Waikawa/Portland I, birds were held for 10 days during the first release, but times were typically shorter (1-3 days) for later releases (Dowding *et al*. 2005). Holding periods on Mana I were typically between 7 and 14 days (R. Collen & H. Gummer, *unpubl. reports* to SPRG). The effect of holding time at the release site on retention rates has not been examined in detail, but it has been assumed that a longer holding period for first releases may increase the chances of birds becoming site-fixed. Once some birds are resident and breeding, it is assumed their presence will encourage retention of birds released subsequently.

Releases were undertaken in fine, settled weather, preferably with a similar forecast for several days ahead. Birds were released in the morning and on an ebbing or low tide; this protocol is designed to allow them time to find birds already resident at the site, and to forage naturally in the inter-tidal area (O'Connor 2000).

Post-release monitoring and reporting

The importance of post-release monitoring and reporting of translocation attempts has been repeated often (*e.g.,* Scott & Carpenter 1987; IUCN 1998; Fischer & Lindenmayer 2000). All shore plover released were individually colour-banded, and immediate post-release monitoring was normally intensive (*e.g.,* daily) for several weeks. Subsequent monitoring effort varied considerably between sites and at different times (commonly being more intensive during the breeding season); effort depended largely on the resources available and on ease of access to the site. Shore plover breed in the austral spring and summer, normally between Sep and Feb; references to breeding seasons are in the form 1981/82 (*i.e.,* from Sep 1981 to Feb 1982).

As noted by Bullock *et al*. (1996) and Fischer & Lindenmayer (2000), much of the translocation literature is not widely available. To some extent this is the case for shore plover translocations - much of the information presented below is derived from unpublished reports to annual meetings of the SPRG, and there is a need for better documentation of these data. Results from the first release site (Motuora I) and the early years at the second site (Waikawa/Portland I) have been published (Aikman 1999; O'Connor 2000; Dowding *et al*. 2005). Results from releases after 2003 are not widely available, and are included here.

RESULTS & DISCUSSION

Early transfers (1970s and 1980s)

South East I to Mangere I

Three unsuccessful attempts were made in the early 1970s to transfer wild birds from South East I to Mangere I, 12 km to the north-west (Bell 1974;

Flack 1976; Aikman 1995). In 1970, 15 adults were translocated (12 on 5 Nov and 3 on 11 Nov) and hard-released. A number of the birds from the first of these translocations had returned to South East I within 5 days. On 22 Mar 1972, 9 adults and 6 juveniles were translocated. To reduce dispersal ability, all these birds had the outer 2 primaries on each wing pulled. Six birds (including 1 juvenile) were still present on 31 Mar, but all had disappeared by the following summer. In Feb 1973, 4 birds (2 adult females and 2 juveniles) were translocated. Flight feathers were clipped to prevent sustained flight. One or 2 of the birds were present 3 months later, but a population did not establish.

South East I to captivity

During the 1981/82 breeding season, 13 freshly-laid eggs were transferred from South East I to NWC (8 eggs) and to Otorohanga Zoological Society (OZS, 5 eggs). Following a 6-day delay on Chatham I, apparently with no incubator (Crouchley 1982), only 1 egg hatched. The chick fledged and the bird survived for nearly 2 years (R. Collen, *pers. comm*.). In 1982/83, 22 partially incubated eggs were transferred (half to NWC and half to OZS), and 14 hatched. Some birds survived for 2 years and 1 pair formed; a nest was constructed but no eggs were laid. All the birds from these 2 transfers died in captivity without breeding (Aikman 1995).

Establishment of the present captive populations

The founding of the present captive-breeding population in the early 1990s was documented by Aikman (1995). In Nov 1990, 18 freshly-laid eggs were transferred to NWC; only 2 hatched, and both chicks died before fledging. In Nov 1991, 17 partially-incubated eggs were transferred to NWC; 14 hatched, and all were reared to fledging. Some of these birds paired and bred in their first year, producing 5 young. At the end of the 1992/93 season, the captive population consisted of 16 birds; in Aug 1993, 8 of these were transferred to IWT to found the second captive population (A. Richardson, *pers. comm*.). A further transfer of eggs from South East I was undertaken in 1993, when 18 eggs were transferred to NWC and 13 chicks fledged. The final transfer of eggs from South East I occurred in Dec 1996, when 21 eggs were taken to NWC and IWT; 20 chicks hatched and fledged (R. Collen, *pers. comm*.).

Releases at individual sites

Birds raised at NWC and IWT have been released at 5 sites since 1994, and there have been additional wild-to-wild translocations to a sixth site. A summary of the numbers and ages of birds released at each location from 1994-2012 is shown in Table 1; details of individual releases are given in Appendix 1.

Motuora I

Motuora I (85 ha) is located at 36°30′S, 174°47′E, in the Hauraki Gulf about 35 km north of Auckland. It is administered by DOC as a Recreation Reserve and is free of all mammalian predators (Aikman 1999). It lies 3.5 km from the mainland at the nearest point.

The 1994 release at this site was the first in the programme; as such it was considered a trial of transport arrangements and logistics, a chance to assess the holding aviary, and to determine whether post-release supplementary feeding was required (Aikman 1995). This and subsequent releases at the site (Appendix 1) explored a range of holding periods, release ages, and release group sizes. Dispersal rates were high, and there were losses to predation, almost certainly by moreporks (*Ninox novaeseelandiae*, a native owl). It also appears that harassment by moreporks and other potential avian predators encouraged dispersal of shore plover (Aikman 1999). The results of the programme were assessed in detail by Aikman (1995, 1999), Davis & Aikman (1997), and O'Connor (2000). As noted by Aikman (1999), there was no difference in survival of parent-reared and hand-reared juveniles.

Breeding did occur on Motuora I, with 2 pairs attempting to breed in the 1998/99 season and 1 in 1999/2000. One chick fledged in each season, and these were probably the first wild-bred shore plovers around the New Zealand mainland for about 120 years. However, 1 young plover was probably taken by a swamp harrier (*Circus approximans*) and the other dispersed (Dowding *et al*. 2005). In the light of their unexpected impact, Aikman (1995) recommended that moreporks should be removed from the island to increase the chance of shore plover establishment. However, this proposal proved unacceptable on cultural grounds, and in 1999 the SPRG therefore recommended stopping further releases on the island, and selected a new release site (Waikawa/Portland I) free of moreporks (Aikman 1999; O'Connor 2000). A population did not establish on Motuora I and no shore plover remain at the site; 2 males were present on nearby Beehive I (6 km away) until 2005, when they were returned to the captive population. There are no plans to undertake further releases on Motuora I.

Waikawa/Portland I

Waikawa/Portland I (137 ha) is located at 39°17′S, 177°52′E, off the southern tip of Mahia Peninsula, northern Hawke's Bay. The island is privately owned and farmed. At the nearest point it is about 800 m from the mainland at low water. The house mouse (*Mus musculus*) is the only introduced mammalian predator.

In total, 110 shore plover were released on Waikawa/Portland I between 1998 and 2006 (Table 1,

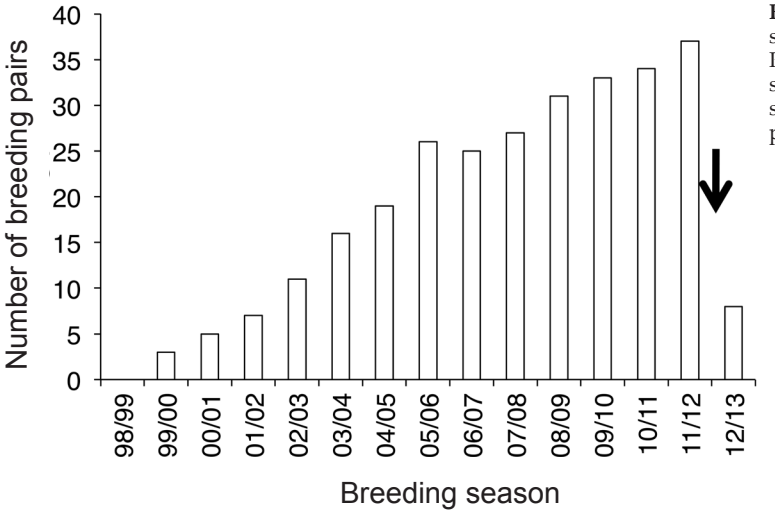

Fig. 1. Number of breeding pairs of shore plover present on Waikawa/Portland I at the start of each breeding season, 1998/99-2012/13. The arrow shows the approximate time of the probable predator incursion.

Appendix 1). Breeding first occurred in the 1999/2000 season, when birds from the first release were 2 years old, and the number of breeding pairs grew steadily until 2011/12 (Fig. 1). The final release at this site in May 2006 was of 18 juveniles that had been destined for release at RS4; this was the only hard release to date at any site in the current programme.

The Waikawa population was intensively managed and monitored during the breeding season in the early years, and productivity was very high; in the first 4 breeding seasons, annual productivity averaged 1.23 chicks fledged per pair (range 0.86-1.45)(Dowding *et al*. 2005). Since 2006/07, the intensity of management has been reduced, and in the 4 seasons from 2007/08-2010/11, productivity averaged 0.53 (range 0.44-0.70) chicks fledged per pair (JED, *unpubl. report* to SPRG). Egg survival was generally high, and most losses were at the chick stage. Among captive-bred juveniles released, there was no difference in first-year survival of parent-reared and hand-reared birds (Dowding *et al*. 2005). There was, however, significantly higher first-year survival of birds wild-bred on the island than of captive-bred birds released there (2-tailed Fisher's Exact test, $P = 0.028$)(JED, *unpubl. data*). In spite of the decline in productivity after 2007/08, the number of pairs continued to increase until 2011/12 (Fig. 1), although the total post-breeding population had stabilised at 85-95 individuals.

Even in the absence of management, annual adult survival of the Waikawa population has been much higher than that recorded on South East I (JED, *unpubl. data*). This is not surprising, as the adults on Waikawa are still younger on average, and the population has not yet reached a stable age structure.

Weights of adults on Waikawa/Portland I suggest that adequate food is available on the island. The average weight of 19 birds in Feb 2005 was 62.8 g, which is significantly higher than the mean weight of 59.6 g recorded from 32 adults on South East I in Jan-Feb 1998 ($t = 3.25$, df = 49, $P = 0.002$) (JED, *unpubl. data*).

In Dec 2011, 12 eggs were transferred from this population for captive-rearing and later release at another site. This was the first time any of the newly-established populations had been harvested in this way.

The translocations to Waikawa/Portland I appear to have been successful. With an estimated 37 pairs at the start of the 2011/12 season, the breeding population was approaching the size of the parent population on South East I (43-45 pairs). However, it is of note that the area occupied by the breeding birds had increased very little in recent years as the number of pairs increased; territories were therefore becoming noticeably smaller, perhaps suggesting that carrying capacity was being approached.

In Nov 2012, the first monitoring trip of the 2012/13 season revealed that the population had declined abruptly since the last visit in Dec 2011, with only 8 pairs and 7 unpaired adult males remaining. The cause of the decline was not apparent. Searches of the nearby mainland showed no evidence of mass dispersal from the island. Traps, tracking tunnels, and searches by trained predator-detecting dogs failed to catch or detect any mammalian predator (H. Jonas, *unpubl. report* to SPRG), and no shore plover remains were found. However, the big reduction in numbers over a relatively short time resembled the outcome of the rat incursion recorded on Mana I in 2011 (see below), and it seemed probable that a predator incursion was also responsible for the decline on Waikawa/Portland I. The population on Waikawa/Portland I remained stable at 23 birds between Nov 2012 and Jan 2013, suggesting that the

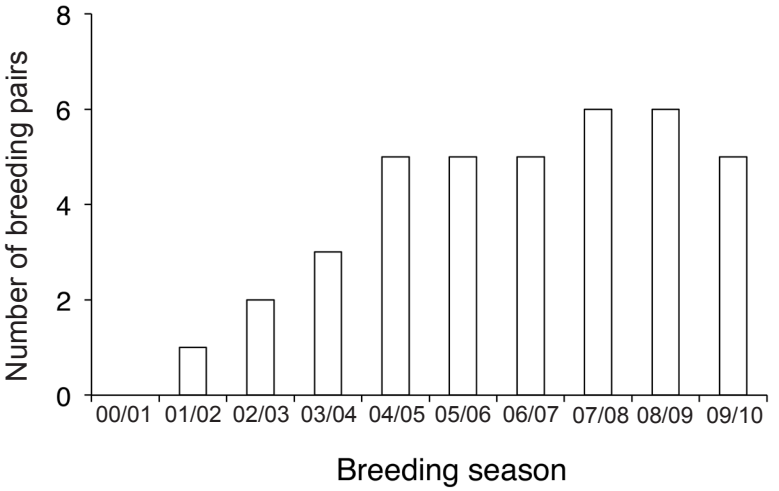

Fig. 2. Number of breeding pairs of shore plover present on Mangere I at the start of each breeding season, 2000/01-2009/10. Assessment of the number of pairs has been less precise since Feb 2010 when all colour bands were removed.

agent of decline was no longer present. However, a visit in late Feb 2013 showed a further decline, with 16 birds remaining (including only 4 adult females). Again, no remains were found, and no predators were trapped or detected. The SPRG has proposed capturing the remaining birds and transferring them to captivity until the cause of the decline is identified and removed. If the cause cannot be removed, it seems very likely that the Waikawa/Portland I population will become extirpated.

Mangere I

Mangere I (113 ha) is a Nature Reserve administered by DOC and located at 44°16′S, 176°18′W in the Chatham Is. At the nearest point it is 2.2 km from Pitt I, which has house mice and cats (*Felis catus*). The coastal habitat is generally similar to that on South East I, but the inter-tidal rock platforms are much less extensive.

Three soft releases totalling 40 wild-bred juveniles from South East I were undertaken between 2000/01-2002/03 (Appendix 1). Shore plover were previously present on Mangere I and these translocations therefore constituted a re-introduction *sensu* IUCN (1998). Breeding was first recorded in 2001/02, and the number of pairs and the total population subsequently increased (Fig. 2). The breeding population has stabilised at 5-6 pairs since 2005/06, and this probably represents carrying capacity, as most of the island's shoreline is steep and unsuitable for shore plover breeding or feeding. Since 2006, the total autumn population has varied from 15-19 birds and, while small, the population appears so far to be self-sustaining. The 16 birds present in Feb 2010 consisted of 10 breeding adults (5 pairs), 3 unpaired adults, a one-year-old, and 2 juveniles. Of these, 3 were adults translocated from South East I and the other 13 were locally-bred (JED, *unpubl. data*).

Although there were occasional records of shore plover on Mangere I between 1895 and 2001, no definite cases of immigration from South East I were detected during the re-introduction programme and subsequent monitoring (2001-2012). The Mangere I population therefore probably cannot rely on immigration from South East I to sustain it. While it has apparently remained stable since 2004/05, such a small population will always be vulnerable to stochastic events, and its long-term future is obviously uncertain. Flack (1976) considered that the shore plover population on Mangere I in the 19th century was probably too small to be self-sustaining and was probably maintained by dispersal from Pitt I.

Although small, the Mangere I population does provide some insurance against a predator incursion on South East I. Transfers of shore plover from mainland New Zealand to the Chatham Is are currently not recommended because of the possibility of disease transfer (Aikman *et al*. 2001). Given that restriction, and the extirpation of the Western Reef population (Dowding *et al*. 2005), the successful reintroduction to Mangere I provides some security against extirpation of the shore plover on the Chatham Is.

Release site 4

A single release of 15 captive-bred juveniles was undertaken at RS4 in Mar 2006. A second group of 18 juveniles was to have been transferred immediately after that release, but an outbreak of avian pox occurred at NWC and the 13 birds there destined for release were held back. Five birds from IWT appeared disease-free, and were transferred to RS4; while in the pre-release aviary, however, 1 of these birds developed a pox-like lesion. The owners of the island requested that none of the 5 birds be released until it had been determined that the lesion was not

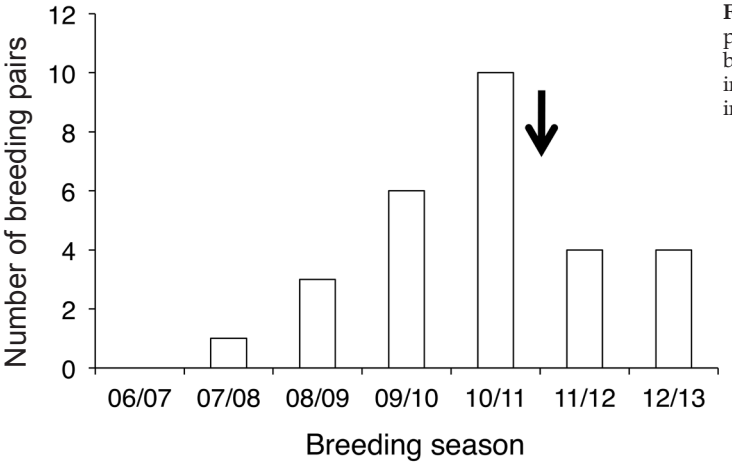

Fig. 3. Number of breeding pairs of shore plover present on Mana I at the start of each breeding season, 2006/07-2012/13. The arrow indicates the approximate timing of the rat incursion.

caused by avian pox virus. In the circumstances, this would have been difficult and time-consuming, and a decision was taken to return the birds to IWT. The owners also indicated that they did not wish any of the second group of 18 birds to be released on the island even after they had recovered from avian pox (R. Collen, *unpubl. report* to SPRG). The 15 birds from the first release gradually dispersed from the island, and some were seen on the mainland about 10 km from the release site over a period of several months before disappearing. A population did not establish on the island and there are not thought to be any survivors of the 2006 release. There are currently no plans to undertake further releases at RS4, but they remain a possibility.

Mana I

Mana I (217 ha) is located at 41°05'S, 174°47'E, 2.5 km off the west coast of the North I about 20 km north of Wellington City. It is a Recreation Reserve administered by DOC, and is free of mammalian predators.

In total, 162 birds were released on Mana I in 19 separate releases (Appendix 1). The first releases in autumn 2007 totalled 41 juveniles, by far the largest initial release group in the translocation programme to date. One pair bred in their first year, and the number of breeding pairs grew rapidly, reaching a peak of 10 at the start of the 2010/11 season (Fig. 3).

In Jun 2011, however, the entire population of about 35 birds was noted to be dispersing from Mana I en masse to Plimmerton on the nearby mainland. Over the following months, the flock moved regularly back and forth, and numbers fell. Subsequent monitoring revealed that a rat (probably a single *Rattus norvegicus*) had arrived on the island. By the start of the 2011/12 breeding season, only 12 birds (including 4 pairs) of shore plover remained, and in Nov 2011, the male of 1 pair was found dead and scavenged on the nest. Two other clutches of eggs were removed to IWT to protect them and the incubating adults from potential predation. The rat was poisoned in Dec 2011 (H. Gummer & S. Caldwell, *unpubl. report* to SPRG). The impacts of this incursion on the establishment of shore plover on Mana I will be reported in detail elsewhere (Dowding *et al*., in prep.). No further releases had been planned for this site, but following the 2011 losses, a supplementary release of 8 juveniles was undertaken in Apr 2012. Given that some breeding birds are still present, and that the initial increase in breeding pairs on Mana I was rapid, there is reason to hope that the population will recover.

Motutapu I

Motutapu I (1560 ha) is a Recreation Reserve administered by DOC, and located at 36°46'S, 174°55'E in the inner Hauraki Gulf, 15 km from Auckland City. It is connected by a causeway to Rangitoto I, which is 3 km from the mainland at the closest point. Following a multi-species eradication programme started in 2009, Motutapu I is now free of all mammalian predators.

Up to Jan 2013, there had been only 1 season of releases. Seventeen birds were released in Feb 2012 and a further 13 in Mar 2012. Three birds have been found dead, 1 on the island and 2 on the mainland 9 km from the release site. Dispersal rates have been relatively high; 7 of the 30 birds remained on Motutapu in Jun 2012, and 4 in Jan 2013. One has been seen at Pakiri River, 61 km to the north of the release site, and another at Miranda, 58 km to the south-east. Up to 5 years of releases are planned for the site.

Overall population outcomes

In spite of the recent setbacks on Mana and Waikawa/Portland Is, the outlook for the shore plover population has improved gradually over the past 20 years. The total number of breeding pairs in

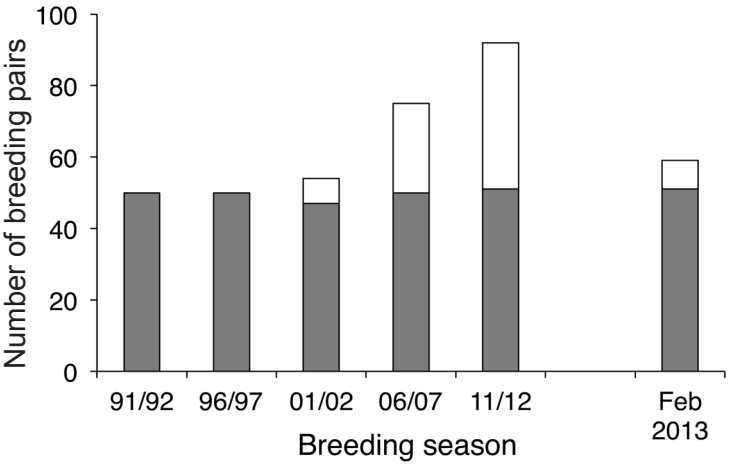

Fig. 4. Numbers of breeding pairs in the wild in the global shore plover population at 5-yearly intervals, 1991/92-2011/12. Filled columns show the number of pairs in the Chatham Is; open columns show the combined number of pairs on offshore islands around mainland New Zealand. The column on the right shows the situation in late Feb 2013 after the decline on Waikawa/Portland I.

the wild increased from about 50 to a peak of about 95 in 2010/11, before declining to about 63 in 2012/13 (Fig. 4). Total post-breeding population size in the wild varies annually as a result of variable survival and productivity at each location, but increased from about 150 in the early 1990s to a peak of about 275 individuals in early 2011, before falling again. However, assuming the Mana I and Waikawa/Portland I populations persist, the number of sites with established breeding birds has increased from 2 to 4, which has clearly reduced the risk of extinction. There is the added security of a small but self-sustaining captive population.

It is notable that the Chatham Is population has remained largely static, with the gains made by re-introduction to Mangere I almost exactly offset by the loss of the similar-sized Western Reef population. The overall increase in the total number of breeding pairs has thus been a result of the establishment of new populations on offshore islands around mainland New Zealand.

Challenges encountered during the translocation programme

The definite and probable predator incursions on Mana and Waikawa/Portland Is respectively have had an obvious and highly-negative impact on the programme, but other challenges have also arisen.

Avian predators

The major role played by avian predators in the failure of the Motuora I programme was largely unexpected, and has affected subsequent site selection and management actions (Aikman 1999; O'Connor 2000). The second release site (Waikawa/Portland I) had no moreporks, and a colony of southern black-backed gulls (*Larus dominicanus*) was controlled to very low levels as a precaution. Occasional predation of shore plover chicks by red-billed gulls (*L. novaehollandiae*) has been recorded there (M.H. Smith & H. Jonas, *pers. comm*.), but currently does not appear to be at a level that threatens the survival of the population. Black-backed gulls are controlled annually on Mana I.

Control of avian predators may be particularly important during the early (establishment) phase of an introduction programme. It seems likely that captive-bred juvenile shore plover will be more naïve than wild-reared birds, and thus more vulnerable. It is also possible that before birds become site-fixed through breeding they will be more likely to disperse in response to harassment by avian predators (Aikman 1999).

There will obviously be very few (if any) potential release sites for shore plover that are free of all avian predators, and avian predation (at varying levels) is likely to be an ongoing issue. In addition to control during the establishment phase, it is possible that periodic control of some avian predators may be necessary to ensure long-term shore plover persistence at some sites. The alternative is to accept that avian predation is a natural cause of loss, that occasional population reductions (or even extirpations) may occur, and to compensate by spreading the risk of overall extinction through establishing more populations. Decisions on whether to intervene are likely to be made on a case-by-case basis, and will be affected by a range of factors, including the number of extant populations at the time, the number of available release sites, the size (importance) of the population in question, and the resources already invested and likely to be required.

Black-backed and red-billed gulls and swamp harriers are known predators of shore plover; other species that may have an impact include New Zealand falcon (*Falco novaeseelandiae*), variable oystercatcher (*Haematopus unicolor*), spur-winged plover (*Vanellus miles*), and pukeko (*Porphyrio melanotus*). The last 3 of these are known to break

eggs and/or kill chicks of another (larger) endemic coastal-breeding plover, the northern New Zealand dotterel (*Charadrius obscurus aquilonius*) (Dowding & Murphy 2001, Dowding 2006, Neate *et al*. 2011). As on Motuora I, control of predatory avian species to protect shore plover may be contentious in some circumstances.

Dispersal

As noted above, there were high levels of dispersal (particularly of juveniles) from Motuora I. It was not clear whether this reflected a lack of site-fidelity by young birds or was related to harassment by avian predators, or both (Aikman 1999). However, dispersal was also common on Mana I, and on Waikawa/Portland I where moreporks do not occur and other avian predators were initially controlled to low levels. Many of the birds released on Mangere I dispersed. One was found dead on Pitt I in 2001, and 13 of the 40 birds released were seen back on South East I; 1 of these was recorded back on Mangere I.

Dispersal has normally occurred gradually, with a slow fall-off in numbers of recently-released birds over several weeks to months. Some birds, notably on Mana I, have been recorded on the mainland nearby and later returned to the island; repeated trips off the island and back are not uncommon at this site, and have also been recorded to a lesser extent on Waikawa/Portland I. This behaviour is not believed to be related to the captive origin of the birds - similar movements of juveniles between South East and Pitt Is have also been recorded in the natural Chatham Is population. Dispersal by a proportion of the juveniles released at each site is currently accepted as inevitable, and it seems likely that repeated releases of shore plover are required to ensure that enough individuals remain at a site until some breed and exhibit site tenacity. Dispersal rates have varied temporally and spatially, and no obvious patterns are apparent yet that might assist in a release design that reduces dispersal.

Disease

The main disease affecting translocations has been avian pox. In the 'dry' form, this virus causes large wart-like lesions, particularly on the joints of the legs and feet, and occasionally around the gape. Lesions dry and drop off after about a month; most birds recover fully and are immune. Pox is often transferred by biting insects, or by virus from the substrate entering through breaks in the skin. Infection rates often vary seasonally and are higher when insect densities are higher (Friend & Franson 1999). Juveniles appear more susceptible to infection than adults.

Outbreaks of avian pox have affected shore plover translocations in a number of ways. They have resulted in mortality; for example, 5 of 17 juveniles died at NWC following a pox outbreak in Mar 2006. As noted above, that outbreak also resulted in the cessation of releases at RS4. Birds showing symptoms of avian pox are held back until they recover, and this has resulted in delays to some releases and increased expense. In Mar 2009, 12 juveniles in the pre-release aviary on Mana I developed pox lesions and were returned to NWC to recover.

The problem of avian pox outbreaks has been overcome to some extent by (a) attempting to release as many birds as possible early in the season (before pox outbreaks normally occur), and (b) at NWC by housing late-season cohorts of juveniles in aviaries lined with insect-proof mesh. A vaccine is also being developed, and will be trialled in 2013/14 (B. Gartrell, Massey University, *pers. comm*.)

Social and cultural issues

Non-ecological factors may also affect translocation programmes (Fischer & Lindenmayer 2000). The importance of public relations, education, and consideration of social values in the planning of translocations (and the need for appropriate public reporting of outcomes) have been emphasised often (*e.g.,* Reading & Kellert 1993; Reading *et al*. 1997; IUCN 1998; McLean 2003). As noted above in the case of Motuora I, the cultural values associated with moreporks resulted in that release site being abandoned, in spite of its apparent suitability for shore plover in other respects (Aikman 1999). At RS4, the land-owners did not want birds that had been infected with avian pox to be released, even after the birds had recovered and were immune. This decision was made in spite of the fact that veterinary advice and experience at other release sites suggested there was very little risk to other avian species on the island.

Notes on shore plover ecology

The shore plover on South East I have been studied in considerable detail (Fleming 1939; Flack 1976; Davis 1987; Dowding & Kennedy 1993). However, that population has long been at carrying capacity and has a stable age structure (Dowding & Kennedy 1993; Davis 1994a). The translocations described above have resulted in the founding of small, new populations that are not at carrying capacity. That, and habitat differences between South East I and the New Zealand release sites, have provided additional information on the ecology of the species.

Habitat type/substrate

On South East I there are no sandy beaches, and most shore plover territories are on rock platforms, with nests among vegetation along the landward margins of the platforms. A few also breed on The Clears (an elevated salt-meadow) and some previously bred on short pasture in the centre of

the island (Fleming 1939). Motuora I was chosen as the first release site in part because of the presence of rock platforms (Aikman 1995). However, it has become clear that shore plover will readily use a wide variety of other substrates for foraging and breeding.

On Motuora I, shore plover foraged most frequently on sand (Davis & Aikman 1997), and the 2 pairs that bred had nests among vegetation 3-4 m landward of a sandy beach (JED, *pers. obs.*). Dispersing birds sighted on the mainland nearby were also predominantly found on sandy beaches (Davis & Aikman 1997). These observations, and the fact that the species has previously been called 'sand plover' (*e.g.,* Hutton & Drummond 1904; Oliver 1930), suggest that sandy beaches may have been a primary substrate for shore plover on the New Zealand mainland before extirpation in the 1870s. On Waikawa/Portland I, a variety of habitat types have been used, including gravel beach, papa platform, sand, and short-cropped pasture. On Mana I, shore plover have predominantly used gravel beaches.

Nesting under cover

The shore plover on South East I nearly always nest under cover (Fleming 1939; Davis 1994b). It was suggested by Young (2002) that concealed nesting by shore plovers (as well as by red-billed gulls and Chatham Island oystercatchers, *H. chathamensis*) on the island was probably a response to the presence of the predatory subantarctic skua (*Catharacta antarctica lonnbergi*).We can find no records showing whether pre-1870s nests on mainland New Zealand were open or concealed. However, observations in both captive populations and at all release sites demonstrate clearly that nesting under cover is now the norm and is innate. The captive populations were founded from eggs transferred from South East I to mainland New Zealand, so there can have been no cultural transmission of the behaviour. However, it remains possible that mainland nests were open, and concealed nesting evolved on the Chatham Is in response to predation of open nests by skuas. The shore plover's only congener, the hooded plover (*T. rubricollis*), nests in the open (Marchant & Higgins 1993).

Age at first breeding

The youngest age at first breeding on South East I was 2 years, but many birds first bred at 3 or 4 years (Davis 1994b). Breeding at 1 year by some birds has been recorded in captivity since early in the programme (Aikman 1995). It has also occurred in the wild on Motuora, Waikawa/Portland, Mangere, and Mana Is, but by a relatively small proportion of individuals. Males and females of captive-bred and wild-bred birds are capable of breeding successfully at 1 year.

Double-brooding

Double-brooding (successful fledging of 1 or more chicks followed by another breeding attempt within the same season by the same pair) was not detected on South East I (Davis 1994b). It was, however, recorded on Waikawa/Portland I; the proportion of pairs double-brooding there varied considerably. For example, 1 of 7 pairs in 2001/02, none of 19 in 2004/05, and 8 of 26 in 2005/06 double-brooded in this population (M.H Smith, *unpubl. reports* to SPRG). Double-brooding was also recorded on Mana I, where 2 of 10 pairs in 2010/11 produced further clutches after fledging chicks (H. Gummer, *unpubl. report* to SPRG).

Scale of movements

Shore plover movements recorded on the Chatham Is have been between South East, Pitt, and Mangere Is; all are less than 15 km (straight-line), with water barriers of 2-3 km. The translocations around mainland New Zealand have revealed that shore plover can travel much greater distances. Birds have returned from release sites to the institutions where they were bred, *e.g.*, from Waikawa/Portland I to NWC (250 km straight-line), and from Mana I to IWT (325 km straight-line). Between Nov 2012 and Jan 2013, a female released on Mana I in 2009 was seen (in order) at Plimmerton, Lake Ellesmere, Manawatu Estuary, and back at Plimmerton, a minimum round-trip of 850 km. Three birds are known to have crossed Cook Strait (one of them twice), a minimum water crossing of 22 km.

Costs of the programme

In a review of the outcomes of animal translocations, Fischer & Lindenmayer (2000) noted that very few studies reported their costs; they also pointed out that because resources for conservation are scarce, information on costs is useful in planning and fund-raising for future programmes. During the Motuora I releases in the late 1990s, the cost of rearing shore plover juveniles and releasing them was conservatively estimated at NZ$ 2500-3000 per released bird (SOC, *unpubl. data*). Allowing for inflation and multiplying by the numbers of juveniles released at different times suggests a total cost of NZ$ 1.3-1.6 million. This is clearly an underestimate; it does not include infrastructure costs at the captive facilities, assistance provided by local DOC staff at release sites, or time donated by volunteers during monitoring.

GENERAL DISCUSSION

With strongly-flighted birds such as shorebirds, there are obvious difficulties in getting translocated individuals to remain at the release site. Juvenile shore plover commonly disperse from their natal territories after fledging (although they may later

return and show high natal site fidelity) (Davis 1987) and, as demonstrated during the transfers in the 1970s, breeding adults are highly site-faithful and will quickly attempt to return to their territories if transferred. In addition, reviews of translocation programmes (Griffith *et al*. 1989; Fischer & Lindenmayer 2000) suggest that transfers of captive-reared birds are less successful than those of wild-caught birds (but see Wolf *et al*. 1996), as are translocations of threatened or rare species.

Assessing whether a translocation has been successful is complex. There are no generally agreed criteria, although the establishment of a self-sustaining population (Griffith *et al*. 1989) is widely used as an indicator of success. By this measure, success may take a long time to demonstrate, with the result that a high proportion of projects have unknown success at the time of reporting (Fischer & Lindenmayer 2000). Nevertheless, the translocations outlined here have succeeded in establishing new breeding populations of shore plovers at 3 sites. They have also demonstrated that even with the same species, and using the same basic methodology, outcomes have varied. This highlights the fact that each release site presents a different set of ecological and socio-cultural circumstances and challenges, and emphasises the need for an adaptive management approach in planning translocations.

Inevitably, it is not yet clear whether the 3 new populations will be self-sustaining in the long term; many of the release sites are relatively small, and their carrying capacity will be limited. In addition, the release sites around mainland New Zealand are widely separated, and there is little or no interchange between them. Nevertheless, the population on Waikawa/Portland I established and continued to grow over 14 years (about 2 generations), until the probable predator incursion. The population on Mangere I, although small, has persisted for 9 years without supplementation or management, and with no detectable immigration.

It is also clear that at all 3 sites at which birds have established, locally-bred birds have entered the breeding population quickly. Although some translocated birds have survived for many years, successful outcomes have therefore not had to rely on long-term survival of those founding individuals once breeding began. Translocations of shore plover have not been designed to test how many years of releases or how many birds are required to establish a population; rather there is a general plan to undertake 5 years of releases at a site initially, with annual re-assessment of progress by the SPRG and flexibility to alter the release design and period. The re-introduction to Mangere I showed that 3 years of releases, with a modest total of 40 birds, was sufficient to establish a population there. At least 5 years of releases were undertaken at both Waikawa/Portland I and Mana I, although in hindsight the relatively rapid increases in the numbers of breeding pairs suggested that populations might have established in both cases with fewer releases. However, establishing populations are obviously at greater risk of failing as a result of stochastic events, as was clearly demonstrated on Mana I in 2011. Given the conservation status of the species and the resources being expended, a precautionary approach appears appropriate, and in our view 5 years remains a suitable 'rule of thumb' release period, at least during planning.

Monitoring

It is widely accepted that monitoring of translocation outcomes is essential (*e.g.*, Scott & Carpenter 1987; IUCN 1998; Fischer & Lindenmayer 2000). It must also continue for an appropriate time; McLean (2003) noted that "monitoring will need to be continued for a sufficiently long period (in relation to the lifespan of the species involved) so as to be able to measure the population performance over several generations". Where species are long-lived, this may be difficult to achieve in practice. In the case of shore plover, at least 20 years of monitoring is required to include 3 generations, and resources are not available for such extended follow-up. Unfortunately, without long-term monitoring of such long-lived species, demographic data collected over a short period are likely to be unrepresentative, and predicted population trends derived from them may be unreliable as a result.

The information on establishment and growth of the shore plover populations described here was possible in large part because birds were individually colour-banded. However, the plastic colour bands fitted to shore plover wear rapidly in the wild, and are usually replaced every 3-4 years to minimise foot injuries. At the 2 release sites where populations were considered well-established (Waikawa/Portland and Mangere Is), colour bands were removed. This was partly because resources for the repeated (and essential) re-banding exercises are lacking, and partly because resources for monitoring are fewer (and colour-bands are not required in populations that will not be monitored). Future monitoring at these sites will primarily involve total counts and territory mapping, and there will inevitably be a loss of demographic information. With the global population still very small, and the future of recently established populations uncertain, this situation is highly undesirable but appears to be unavoidable. Given the number of threatened species requiring conservation action in New Zealand, resource constraints of this type are inevitable.

Features of the shore plover reintroduction effort

While each translocation programme provides a unique set of challenges, there are often common threads that can provide guidelines for future programmes (Clark & Westrum 1989). We note here some general comments about the features of the shore plover programme that we believe have contributed to the outcomes described above.

Recovery team

Clark &Westrum (1989) highlighted the importance of appropriate personnel in rare species recovery teams. We believe that the successes to date in the shore plover programme have in part been due to the composition of the SPRG; members provide a balance between practical skills for managing and monitoring birds in the wild, captive-management expertise, organisational ability, and science input. The ability to cooperate and be flexible as circumstances change has also been important. The fact that some members of the group have been involved for many years has also been beneficial, improving continuity and reducing loss of institutional knowledge.

Balanced approach to risk

There is always a risk of failure in translocation programmes, with the possibility that scarce conservation resources will be wasted and the future of the programme may be questioned. Experience during the shore plover programme suggests that an important factor in managing that risk is striking a balance between the desire for greater scientific certainty before proceeding, and urgency - the need to proceed more rapidly to reduce extinction risk. Given the very small size of the shore plover population (*c.* 200 adults globally), the relatively small number of animals available for translocations, and limited resources for research and monitoring, knowledge has inevitably been gained slowly. While known ecological and demographic factors have always been taken into account, some translocations have therefore knowingly been undertaken with less information (and hence less certainty of success) than was ideal. For example, it was not clear whether shore plover would be able to breed successfully in the presence of house mice on Waikawa/Portland I before translocations began. In addition, other than on Motuora I (Davis & Aikman 1997), there have not been pre-release assessments of the availability of suitable types or densities of prey at release sites.

Release strategy

Throughout the programme there has been a deliberate focus on releasing at 1 site at a time, and trying to establish a population there before moving attention to another site. While this has required a long-term commitment (by both the recovery team and the funding agencies), we believe it has been an appropriate approach in the circumstances. One constraint has been the limited number of juveniles that could be bred annually for release. With so few populations globally, it therefore seemed prudent to put all available resources into increasing the chance of establishing 1 new population, rather than risking failure at 2 or more sites by spreading the birds and other resources more thinly. Before stopping releases at a site, we wished to have evidence that the number of pairs breeding was increasing, and was large enough to give some assurance that the population was likely to persist (*e.g.*, Dowding *et al*. 2005).

Learning from experience

It is obviously essential to apply the experience accumulated at previous sites to subsequent translocations. In the case of shore plover, birds dispersing from Motuora I to the mainland nearby were captured and returned. They invariably dispersed again (Aikman 1999), and the re-capture effort was wasted. At later release sites, birds that dispersed were considered lost to the programme, and resources were concentrated on improving breeding success of birds that had not dispersed.

Site-selection criteria and the suitability of potential release sites have also been reappraised on a regular basis as experience has been gained from existing sites (and as new sites became available through eradication programmes). As noted earlier, selection criteria have changed as a result of (a) the unanticipated impacts of moreporks on Motuora I, and (b) the knowledge gained on Waikawa that shore plover can breed successfully in the presence of house mice. Site selection has also been affected by practical issues. For example, conditions on the subantarctic Auckland Is appear suitable for shore plover, but regular access for releases and monitoring is difficult and very expensive.

Where threatened species are confined to single locations, there may be a temptation to assume the particular habitat type found at those sites is required or optimal, and to restrict site-selection criteria for translocations accordingly. For example, the sub-alpine tussock grassland that constituted the last refuge of the South Island takahe (*Porphyrio hochstetteri*) is now known to be atypical habitat for the species (Beauchamp & Worthy 1988), which has been successfully established on a number of low-altitude offshore islands (Ryan & Jamieson 1998). Similarly, Laysan teal (*Anas laysanensis*) translocated to Midway Atoll did not require the hyper-saline ecosystem present on Laysan I, and used a wide variety of vegetation types for nesting and foraging that are absent on Laysan (Reynolds *et al*. 2008). During the shore plover programme, it became clear that the species is not dependent on the rock-

platform habitat primarily used on South East I, and can use a wide variety of substrates (see *Habitat type/substrate* above). These examples (from a range of taxonomic orders) suggest that many species may be plastic in their habitat requirements, and that where small, relict populations are concerned, site-selection for translocations should not necessarily be overly constrained by habitat type.

Conclusions

The shore plover's range has declined dramatically in historic times. The recovery programme described above has relied on captive breeding and translocations to found new populations in an effort to secure the species from extinction. There have been undoubted successes in the programme; a self-sustaining captive population has existed for nearly 20 years, and new populations have been established in the wild. Maintaining these populations has been challenging however, and in particular, the potential loss of the large Waikawa/Portland I population after so many years is a major setback.

While the risk of extinction has been reduced, the shore plover is still automatically classified as Nationally Critical under the New Zealand threat-ranking scheme because there are fewer than 250 mature individuals (see Townsend *et al*. 2008). It will require persistence of the South East and Mangere Is populations, sustained recoveries of the populations on Waikawa/Portland and Mana Is,and the successful establishment of at least 1 (and probably 2) further populations before the species regularly exceeds the threshold of 250 mature individuals and can be down-listed.

Because it is so highly sensitive to introduced mammalian predators, the shore plover will probably be confined in the medium-term to islands free of them, or to mainland sanctuaries with highly effective predator exclusion. In either situation, the recent incidents on Mana I and (probably) Waikawa/Portland I show that individual populations will always be extremely vulnerable to predator incursions, and strict quarantine and biosecurity protocols are necessary at all shore plover sites.

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Appendix 1. Dates, locations, and numbers of individual shore plover releases, 1994-2012. J = juvenile (fledged bird up to 1 year of age), A = adult, RS4 = Release Site 4.

Date	Release site	Numbers released		Notes
		J	A	
Sep 1994	Motuora I	5	0	
Sep 1995	Motuora I	15	0	
Feb 1996	Motuora I	8	8	
Feb 1997	Motuora I	11	6	
Dec 1997	Motuora I	18	0	Released in 3 groups Dec 97-Feb 98
Jun 1999	Motuora I	1	3	
Aug 1998	Waikawa	15	0	
Jul 1999	Waikawa	11	0	
May 2000	Waikawa	13	0	

Appendix 1. Continued.

May 2001	Waikawa	13	0	
May 2002	Waikawa	9	0	
Oct 2002	Waikawa	4	0	
Mar 2003	Waikawa	10	1	
Nov 2004	Waikawa	2	0	
Feb 2005	Waikawa	6	2	
Jul 2005	Waikawa	2	4	
May 2006	Waikawa	18	0	Hard release of birds destined for RS4
Feb 2001	Mangere I	14	0	Wild-bred on South East I
Jan 2002	Mangere I	11	0	Wild-bred on South East I
Jan 2003	Mangere I	15	0	Wild-bred on South East I
Mar 2006	RS4	15	0	No further releases (avian pox)
Mar 2007	Mana I	21	0	
Apr 2007	Mana I	9	0	
May 2007	Mana I	11	0	
Jun 2007	Mana I	0	3	
Feb 2008	Mana I	20	0	
Apr 2008	Mana I	4	0	
Oct 2008	Mana I	2	1	
Jan 2009	Mana I	16	0	
May 2009	Mana I	3	0	
Jul 2009	Mana I	7	0	
Sep 2009	Mana I	2	0	
Oct 2009	Mana I	5	0	
Dec 2009	Mana I	3	0	
Feb 2010	Mana I	9	0	
Mar 2010	Mana I	11	0	
Apr 2010	Mana I	4	0	
Jan 2011	Mana I	8	0	
Mar 2011	Mana I	15	0	
Apr 2012	Mana I	8	0	Supplementary release after rat incursion
Feb 2012	Motutapu I	17	0	
Mar 2012	Motutapu I	13	0	
TOTALS		**404**	**28**	