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RESEARCH ARTICLE

MUSEUM OF NEW ZEALAND TE PAPA TONGAREWA

From farm to forest – 50 years of ecological transformation on Mana Island, New Zealand

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Abstract

Ecological surveys of Mana Island, Wellington, in 1972 and 1975 confirmed that house mice (*Mus musculus*) were the only pest mammals present, and resulted in nationally significant populations of Cook Strait giant weta (*Deinacrida rugosa*) and of two threatened lizard species being confirmed or discovered. Photographs taken in June 1972 were re-taken in June 2022, and are used to document social and ecological change on the island over this 50-year interval. Mana Island was farmed until 1986, and has been a conservation reserve administered by the Department of Conservation (DOC) since 1987. Mice reached plague numbers after farm stock were removed, and caused a population crash of McGregor's skink (*Oligosoma macgregori*). Following mouse eradication in 1989–90, the island has been free of introduced mammals. A major revegetation effort since 1987 included planting of more than 443,000 trees and shrubs over about 36% of the 217 ha island. For the last two decades, conservation management of the island has largely followed a comprehensive ecological restoration plan that was published in 1999. The Friends of Mana Island was formed in 1998, and has taken the lead role in most conservation initiatives on the island since then, in partnership with Ngāti Toa Rangatira (mana whenua) and DOC. In addition to the revegetation programme, weed control, and recreation of a wetland, 22 animal species have been translocated to the island, and several bird species have colonised naturally. Conservation successes and failures are described, and research relevant to restoration ecology undertaken on the island is summarised.

Keywords

conservation management, ecological restoration, landscape ecology, translocation, unexpected outcomes, volunteer

Introduction

In 2019, the United Nations adopted a resolution to recognise the years 2021 to 2030 as the 'United Nations Decade on Ecosystem Restoration' (United Nations General Assembly 2019). The resolution aimed to prevent, halt and reverse the degradation of ecosystems worldwide, and (among other goals) encouraged Member States to promote the sharing of experiences and good practices in ecosystem conservation and restoration. New Zealand has a long history of ecological restoration programmes on islands (Towns et al. 1990; Veitch and Clout 2002; Towns and Broome 2003), and has identified ambitious goals for restoration of the three main islands (Russell et al. 2015; Parliamentary Commissioner for the Environment 2017). At most sites, effort has focussed on pest mammal eradication and exclusion (Innes et al. 2010; Burns et al. 2012; Butler et al. 2014); however, at a few severely degraded sites, more comprehensive ecological restoration has been undertaken, including extensive revegetation and species translocations (Miskelly 2009; Galbraith and Cooper 2013; Miskelly and Powlesland 2013).

Mana Island, near Wellington, is one of New Zealand's ecological restoration success stories (Galatowitsch 2012; Woodworth 2013; Butler et al. 2014; Miskelly 2022). Despite having been a farm for more than 150 years, the island is now home to an impressive variety of endemic wildlife, including many threatened species (Miskelly 2010; Miskelly and Powlesland 2013). This account summarises how this transformation occurred, including the unexpected sequence of events that led to management of the island changing from a production focus to a conservation one.

Since the turn of the century, the restoration of Mana Island has been guided by a comprehensive ecological restoration plan that has a primary goal of maintaining those threatened species and communities that survived on Mana Island within self-sustaining ecosystems similar to those likely to have existed on the island before human contact (Miskelly 1999). Secondary restoration goals (where compatible with the primary goal) include to: recreate coastal forest, shoreline, cliff and wetland plant communities typical of the Wellington coast; establish self-maintaining populations of threatened plants of the Wellington coast of Cook Strait appropriate to the habitats present on Mana Island; reintroduce or encourage colonisation by all native animal species known to have previously occurred on Mana Island; introduce (or reintroduce) threatened and locally extinct vertebrates of the southern North Island that are not able to exist in the presence of introduced mammals, and are likely to have occurred in coastal habitats in the Wellington region; introduce (or reintroduce) threatened macroinvertebrates appropriate for an island in eastern Cook Strait (Miskelly 1999).

The transformation of Mana Island is illustrated with a series of photographs taken on the island in June 1972, and retaken from the same sites exactly 50 years later. The 1972 photographs were taken by Anthony (Tony) Whitaker (1944–2014) while he was participating in an inventory of the biodiversity values of Mana Island, along with his colleagues Mike Meads and Mike Daniel from Ecology Division, Department of Scientific and Industrial Research (DSIR). At the time of Whitaker's 1972 visit, Mana Island was a crown-lease sheep (*Ovis aries*) farm, and had been since 1865. The island had been farmed since 1834, and was the source of the second known wool export from New Zealand, in 1835 (Day 1987; Maysmor 2009). Farm stock still had access to the coastal slopes and shoreline in 1972, mice (*Mus musculus*) were abundant, and native forest was confined to a 4 ha patch (largely of kānuka *Kunzea ericoides s.l.*) in a north-eastern valley (Fig. 1; Timmins et al. 1987b). By the time the second series of photographs was taken in 2022, stock had been absent from the entire island for 36 years, mice had been eradicated (in 1989–90), and about 38% of the island was forested (Fig. 2). In documenting the methods used and results achieved during the ecological restoration of Mana Island, this account aims to meet some of New Zealand's Member State obligations to the United Nations (United Nations General Assembly 2019).

Methods

Photography

Tony Whitaker's photographs, reports, and notebooks were donated to Te Papa by his wife Vivienne in 2020. I discovered Whitaker's Mana Island images while viewing his colour transparencies as part of this acquisition, and arranged to visit Mana Island in June 2022, to re-take the images from the same photo-points. Whitaker's field diaries for 1972 (Te Papa registration numbers CA001235/002/0011 & 0015) revealed that he visited Mana Island with Mike Meads on 5 June 1972, then returned on 28–30 June with Mike Meads and Mike Daniel (all three worked for Ecology Division, DSIR, at the time). Based on the time spent on the island, and the imprinted numbers on Whitaker's Kodachrome slide frames, it is likely that the 1972 images reproduced here were all taken during 28–30 June. I searched for and located most of the 13 photo-points on 18–19 June 2022 (Fig. 1), during overcast conditions with poor visibility. I returned to the island with Te Papa photographer Maarten Holl during 28–30 June 2022 to re-take the images presented here. Most images were re-taken from the ground; however, at three sites we used a drone to get above planted vegetation that would otherwise have blocked views comparable to those in the 1972 images.

Additional site visits

Much of the information summarised here was gathered during more than 120 personal visits to Mana Island between May 1992 and October 2022, initially as a Department of Conservation (DOC) staff member (1992–2010) then as a Te Papa staff member and Friends of Mana Island (FOMI) member during 2010–2022. The main reasons for these visits included preparation of the Mana Island Ecological Restoration Plan and its subsequent review (Miskelly 1999, 2010), accompanying researchers as a DOC representative, seabird restoration, translocations and monitoring (ongoing since 1993), lizard translocations and monitoring (1998–2010), flax weevil (*Anagotus fairburni*) research (ongoing since 2013), land bird monitoring (ongoing since 2020), and a survey of Hutton's speargrass weevils (*Lyperobius huttoni*) in February 2021. On two occasions I was privileged to assist Tony Whitaker with lizard surveys on Mana Island (February 1993 and January–February 2008), during his only visits to the island after April 1975.

Land bird counts

Twenty bird count stations were established on Mana Island in August 2016, and markers were installed at each site in early 2021. Sixteen of the sites were the same or near sites used for 5-minute bird counts between 1987 and 1993 (Miskelly et al. 2022a). Five-minute bird counts were undertaken by the author at these 16 shared sites on 22 October 2020, 25 October 2021, and 22 October 2022. Data from these counts are compared with published data on Mana Island land birds collected between 1944 and 1993 (Wodzicki and Oliver 1944; Appendix 1 in Department of Lands & Survey 1981; Miskelly et al. 2022a).

Bird and lizard records

Additional bird records were searched for in Classified Summarised Notes covering the years 1972 to 2002 (and published in *Notornis*), and in eBird (https://ebird.org/newzealand). While eBird has been widely adopted only in the last decade or so, several older Mana Island datasets have been retrospectively entered into eBird, including 1987–93 5-minute bird counts (Miskelly et al. 2022a), and Birds New Zealand (Ornithological Society of New Zealand) Wellington branch records dating back to at least 1997. Additional lizard records were searched for in the Amphibian & Reptile Distribution Scheme (ARDS), administered by DOC.

Literature review

Information on Mana Island history, and ecological restoration, was sourced mainly from publications gathered by the author over the past 30 years, including an archive of FOMI newsletters. Additional references were located using Google Scholar (search term 'Mana Island'). Unpublished reports or theses were also sourced from: Te Papa archives (A.H. Whitaker collection), DOC archives on Mana Island, Manaaki Whenua library, Lincoln, and Archives New Zealand, Wellington, and from personal reference collections held by Don Newman, Ross Pickard, and Susan Timmins.

GIS analysis of aerial images

The spatial extent of native forest and coastal slopes plus shoreline on Mana Island in 1972 and 2022 was estimated from aerial photographs taken in 1969 and 2021 (reproduced here as Figs 1, 2). The images were printed at A3 size, and polygons drawn by hand around the forest remnant in Forest Valley in 1969, around areas identified as planted native forest in the 2021 image, and along the top of steep coastal slopes or the edge of coastal vegetation (near Landing Bay). The spatial area of each polygon was estimated by geo-referencing the scanned documents into QGIS for polygon digitising. Using the same method, the spatial extent of the island was estimated at 218.7 ha from the A3 printouts, which is about 0.8% more than the official figure of 217 ha. This difference could be explained by differences in tide height in relation to the mean high water mark used for official land areas, and provides confidence in the accuracy of the forest and coastal margin area estimates.

Timeline of social, economic and ecological change

Information on social, organisational, and ecological change on Mana Island is presented in a series of themes in an approximately chronological sequence. While this review focusses on ecological changes between 1972 and 2022, relevant information on the island's earlier history, and on management regime changes after 1972, is summarised in order to provide context for the ecological changes during this 50-year period. As several of the themes cover extended time periods, there is considerable overlap in their chronology. A detailed timeline of ecologically significant events is presented in Appendix 1.

Nomenclature

The scientific and English names for many reptile, bird, and plant species have changed over the period covered by this account, and their Te Reo names have become more widely used. The current names presented here largely follow Hitchmough et al. (2021), Checklist Committee (2022), and the New Zealand Plant Conservation Network website respectively.

Results

Early history – 1400s to 1865

Based on remnant vegetation on Mana Island, and the forest cover on other Cook Strait islands, it is likely that Mana Island was originally cloaked in a coastal broadleaf forest of kohekohe (*Didymocheton spectabilis*), tūrepo (*Streblus banksii*), akiraho (*Olearia paniculata*), wharangi (*Melicope ternata*), kaikomako (*Pennantia corymbosa*), and tawa (*Beilschmedia tawa*), with emergent miro (*Prumnopitys ferruginea*), rimu (*Dacrydium cupressinum*), tōtara (*Podocarpus totara*), and northern rata (*Metrosideros robusta*) (Timmins et al. 1987b; Miskelly 1999, 2010). However, the island has a long history of human occupation, and the vegetation was heavily modified when the island was first described by European explorers (Dieffenbach 1843; Chester and Raine 1990; Chester 1991).

Archaeological investigations of the Landing Bay area on Mana Island revealed evidence of Māori occupation dating back to at least AD 1400 (Horwood 1991; Horwood et al. 1998). Palynological investigations were only able to find pollen deposits covering the previous 560 years, and revealed the presence of secondary forest (mānuka *Leptospermum scoparium* and kānuka) rather than the expected coastal broadleaf forest (Chester and Raine 1990; Chester 1991), indicating that the vegetation of Mana Island had probably been heavily modified for many hundreds of years.

Ernst Dieffenbach visited Mana Island in 1839, 5 years after 102 sheep and ten cattle (*Bos taurus*) had been landed there, and described the island as "covered by fern, native and artificial grasses, and clover" (Dieffenbach 1843, p.112; Maysmor 2009).

During early European contact, Mana Island was within the rohe of Ngāi Tara and Ngāti Ira, who were driven out by Ngāti Toa during the musket wars (Maysmor 2009). Soon after 1822, the Ngāti Toa chief Te Rangihaeata made the island his home, living there until 1843. Te Rangihaeata's

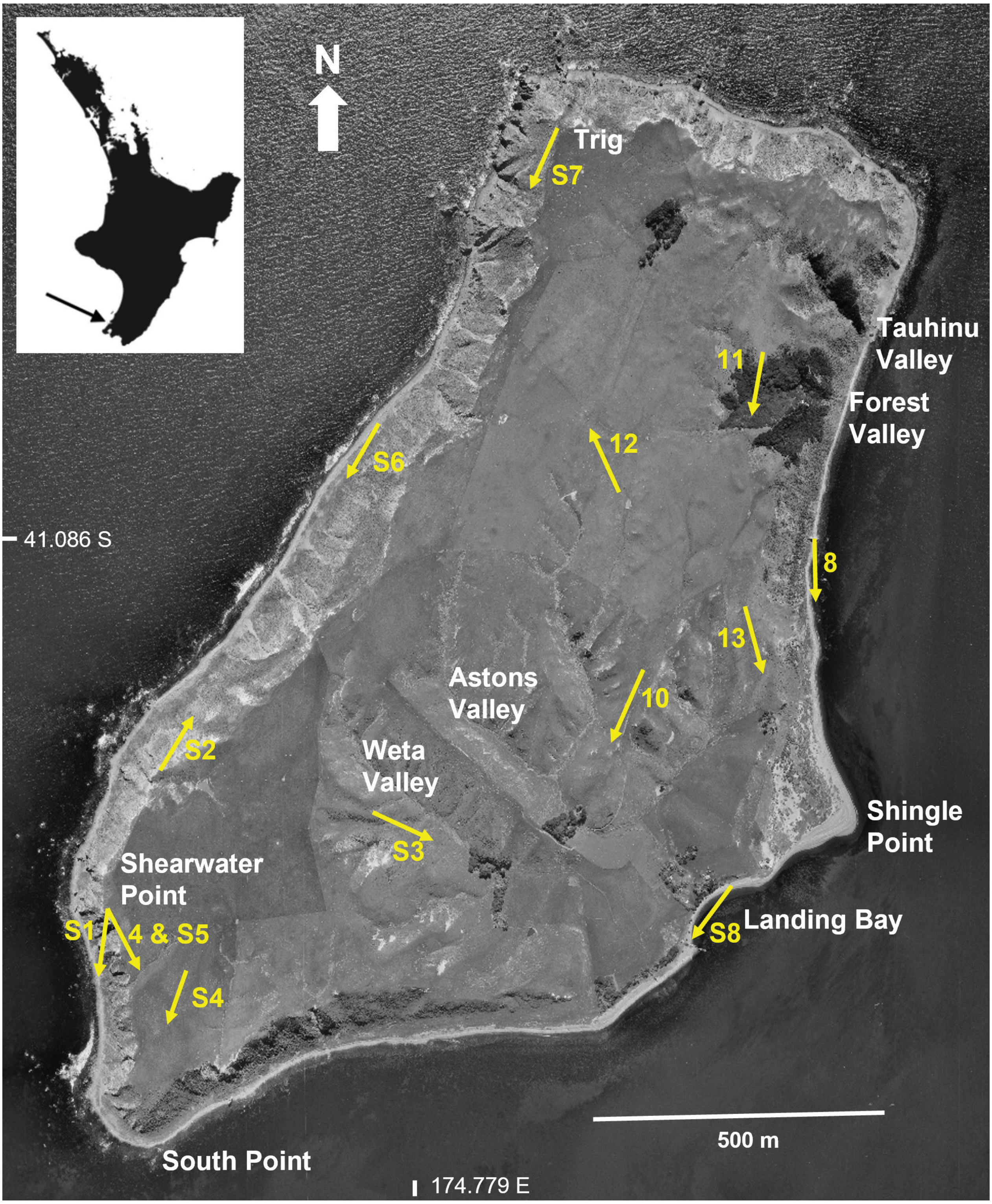

Figure 1. Aerial photograph of Mana Island taken in 1969, with locality names mentioned in the text. The yellow arrows show the location and direction of images taken by Tony Whitaker in June 1972; the yellow numbers relate to Figure numbers in this paper (S = supplementary materials). Base image from RetroLens.co.nz, reproduced under Creative Commons, LINZ CC-BY 3.0.

mother Waitohi (who was the older sister of the renown chief Te Rauparaha) lived on Mana Island until her death, and was buried there in 1839 (Maysmor 2009). Three Sydney merchants purchased the island as a farm and whaling station in 1832, although the terms of the agreement were later disputed by Te Rangihaeata and Te Rauparaha (Day 1987; Maysmor 2009). Shares in the island changed hands several times, with multiple parties claiming ownership. This was resolved through the government purchasing the island in 1865, and paying compensation of the same amount (£300) to Ngāti Toa (Maysmor 2009).

The whaling station (targeting southern right whales *Eubalaena australis*) was in the vicinity of Shingle Point, and was in use between about 1832 and 1845 (Maysmor 2009).

Figure 2. Aerial photograph of Mana Island taken in 2021, showing the extent of planted and regenerating forest. The yellow arrow shows the location and direction of the image taken by Don Newman in February 1986 (see Fig. 6). Base image from RetroLens.co.nz, reproduced under Creative Commons, LINZ CC-BY 3.0.

Crown-lease sheep farm – 1865 to 1973

Following purchase by the Crown in 1865, Mana Island was managed as a leasehold sheep farm, although the lease was not taken up until 1873 (Maysmor 2009). The main leaseholders were John Wright (during 1873–91), Mariano Vella (1893–1929), Andrew Vella (1929–51), and John Gault (1953–73) (Maysmor 2009).

Mice apparently colonised Mana Island during the crown-lease farming era. Daniel et al. (1972) reported: "Some information given by Miss M.E. [Mattea] Vella whose family farmed on Mana Island from 1880–1952 is of interest. Rats were never found on the island and mice were only observed after about 1910 when her brother ran the farm". It is noteworthy that one of the few shipwrecks recorded on the island (the 61 ton ketch *Emma Sims*) occurred only 3 years before this date, on 18 May 1907 (Ingram 1990; Maysmor 2009).

J.G. Myers ("Note on the host" in Cunningham 1922) published the earliest known reference to Cook Strait giant weta (*Deinacrida rugosa*) on Mana Island. After referring to its presence on Stephen Island [sic], Myers wrote: "The insect also occurs on Mana Island, and may possibly frequent other islets in Cook Strait."

Count Kazimierz Wodzicki (Polish consul general, and later director of Animal Ecology Division, DSIR) and Dr Reginald Oliver (Director, Dominion Museum) visited Mana Island during 1–2 January 1944, and published a summary of bird and plant life. They reported little penguin (kororā, *Eudyptula minor*) and mutton bird (sooty shearwater / tītī, *Ardenna grisea*) among the breeding bird species, and the presence of a few tūrepo (listed as large-leaved milk tree), wharangi (listed as koheriki) and kohekohe among the trees in what is now known as Forest Valley (Wodzicki and Oliver 1944).

Tony Whitaker's visits to Mana Island – 1972 to 2008

Tony Whitaker visited Mana Island five times, with his first visit a day trip on 5 June 1972. Although on the island for only 2 hours, he made the notable discovery that McGregor's skinks (*Oligosoma macgregori*) were present along the north-east coast (Whitaker and Meads 1972 [cited in Whitaker and Thomas 1989]; Fig. 3). The species was undescribed at the time, and Whitaker used the tag name *Sphenomorphus* "Sail Rock" in his notebook, as he had previously discovered the same species on Sail Rock (south of Taranga/Hen Island, 565 km north of Mana Island) on 21 January 1968 and again on 22 March 1971 (Whitaker 1968, 1971, 1973; Atkinson 1972). He was apparently surprised to find the same spectacular skink on Mana Island, as his notebook entry for 5 June 1972 read "Saw & caught 7 S. "Sail Rock"!!! under driftwood & stones near shore". In addition to three other common lizard species (now known as Raukawa gecko *Woodworthia maculata*, copper skink *Oligosoma aeneum*, and northern grass skink *O. polychroma*), Whitaker noted "House mice very common – with no sign of other mammals".

All the 1972 & 1975 records of McGregor's skink on Mana Island were from the north-east shoreline, north of Shingle Point, apart from a single animal found by Whitaker on the south-west coast on 29 June 1972 (Suppl. material 1: fig. S1). Unbeknown to Whitaker, a specimen of the same large skink species had been collected by A.B. (Brett) Stephenson on the Cavalli Islands, Northland, in May 1967. Robb (1975) did not mention Whitaker's previous records from Sail Rock when she described and named *Leiolopisma macgregori* based on type specimens that she collected from the same locality in May 1974. Robb (1975) referred to the Cavalli Islands specimen in her type description, but was apparently unaware that the species had subsequently been discovered on Mana Island.

Figure 3. McGregor's skink, Mana Island. Image: Tony Whitaker. Gift of Vivienne Whitaker, 2020, Te Papa O.049935.

Whitaker discovered the goldstripe gecko (*Woodworthia chrysosiretica*) to be present on Mana Island during his second visit, later the same month. On the night of 29 June 1972, his notebook entry recorded "Out at 2000 & first to plantation up Gully – 2040 spot-lighted "Gold-Stripe" *pacificus* in *Muehlenbeckia*". Whitaker (1993) clarified that this was near the bottom of Weta Valley. He caught a second goldstripe gecko in low scrub below Forest Valley at night on 2 April 1975 during his third visit to Mana Island (1–3 April 1975; Atkinson et al. 1975; Whitaker 1993). Mike Meads subsequently found two goldstripe geckos during daytime searches in dense litter under tauhinu (*Ozothamnus leptophyllus*) bushes in Weta Valley, 12 November 1981 (Whitaker 1993; ARDS), and a fifth animal was found in 1984 (ARDS).

Robb (1980) described and named the goldstripe gecko (as *Hoplodactylus chrysosireticus*) based on type specimens from Taranaki, and noted the 1972 and 1975 specimens collected by A.H. Whitaker on Mana Island. Before 1972, the goldstripe gecko was known only from coastal Taranaki (Robb 1980). It was discovered on Kapiti Island in 2013 (Brown et al. 2016).

In addition to searching for lizards, the Ecology Division teams in 1972 and 1975 trapped for rodents (confirming that mice were the only pest mammals present), and produced annotated lists of plants, birds, and insects (Daniel et al. 1972; Atkinson et al. 1975; Appendix 1 in Department of Lands & Survey 1981; Miskelly et al. 2022a). The most notable bird record was confirmation of several small colonies (c. 50 burrows total) of sooty shearwaters at the south-west of the island in June 1972 (Fig. 4), and 15 burrows on a north-facing terrace below the trig in April 1975 (Daniel et al. 1972; Atkinson et al. 1975).

Whitaker returned to Mana Island 18–24 February 1993, to lead a survey for goldstripe geckos, which had not been reported since 1984. It was feared that the Mana Island population had been eaten to extinction by mice (Whitaker 1993). The geckos had not only survived, but were thriving only 3 years after mouse eradication – with a minimum of 112 goldstripe geckos found (Whitaker 1993; Fig. 5). Goldstripe geckos on Mana Island were found to have a strong association with flax (harakeke, *Phormium tenax*), with more than 80% of the animals found on flax (Whitaker 1993). Note that flax on the plateau of Mana Island are considered to be hybrids between planted *P. tenax* and naturally occurring wharariki (*P. cookianum*); the term 'flax' throughout this ms refers to both species and the hybrids between them.

Whitaker's final visit (28 January–3 February 2008) was to lead a general lizard survey, checking that the goldstripe gecko population continued to increase, and determining whether four lizard species released on the island during 1998–2004 had successfully established (see Lizard recovery and translocations). Three of the translocated species were recorded (Tohu's gecko *Hoplodactylus tohu*, northern spotted skink *Oligosoma korowai*, and Newman's speckled skink *O. newmani*); however, no barking geckos (= Wellington green geckos, *Naultinus punctatus*) were found.

Quarantine research station for exotic sheep breeds – 1973 to 1978

The DSIR team and the Mana Island leaseholder (John Gault) were unaware that the government was poised to buy back the Mana Island lease at the time of their June 1972 survey (Mike Daniel pers. comm., August 2022). From August 1973, the newly formed Ministry of Agriculture and Fisheries (MAF) leased the island from Department of Lands & Survey, and began to develop the island as a quarantine research station for exotic sheep breeds (Department of Lands & Survey 1981, 1986a; Maysmor 2009). Nearly all the buildings presently on Mana Island (with the notable exception of the historic woolshed) were constructed between 1973 and 1975, along with another large shed and a wharf that were demolished in 1988 and 1993–94 respectively (Fig. 6; Miskelly 2022).

Ecology Division staff were concerned that rats could reach the island via the numerous boat and barge movements during construction of the research station, and so they prepared biosecurity guidelines, and also recommended that the coastal slopes be fenced to prevent stock access (Department of Scientific and Industrial Research 1973a, b). The coastal slopes were subsequently managed as a "proposed flora and fauna reserve" (administered by the Department of Lands & Survey, which had underlying authority for the island; Atkinson et al. 1975). A ring fence along the top of the coastal slopes was completed in 1973, with the last sheep removed from the slopes in July 1974 (Timmins et al. 1987b).

Mike Meads (1938–2009) continued his surveys of Cook Strait giant weta on Mana Island between 1975 and 1981 (Fig. 7). He considered the Mana Island population to be the most abundant of the three known populations (the two other surviving natural populations are on Stephens Island / Takapourewa, and on Middle Trio Island / Kuru Pongi; Meads 1990). However, Meads considered the Mana Island population to be at high risk of extinction if rats (*Rattus* spp) colonised the island. In order to safeguard the population, he organised the first translocation of a threatened insect in New Zealand, and possibly the world, catching 43 giant weta on Mana Island 9–12 September 1977 and releasing them on Maud Island / Te Pākeka, Pelorus Sound, a week later (Meads and Moller 1977, 1978; Meads 1994; Sherley et al. 2010). Cook Strait giant weta are now abundant on Maud Island (Meads and Notman 1992; author, pers. obs.).

The MAF era on Mana Island ended abruptly after July–August 1978, when a third and final outbreak of scrapie disease was confirmed in the flock (Anonymous 1978). All 2,000 sheep were slaughtered and buried on the island, and the research station closed down (Timmins et al. 1987b; Maysmor 2009).

Figure 4. A. The area where the 1972 DSIR team found sooty shearwater burrows near Shearwater Point, June 1972 (Image: Tony Whitaker, gift of Vivienne Whitaker, 2020, Te Papa CT.067086). **B.** The same view in June 2022 (Image: Maarten Holl, Te Papa, 206576). Vegetation recovery at this site has been predominantly natural.

Lands & Survey cattle farm – 1979 to 1986

Control of the entire island reverted to the Department of Lands & Survey in April 1979, with access to the island strictly controlled for quarantine reasons for 5 years after the scrapie outbreak (Department of Lands & Survey 1981). A temporary beef cattle farming operation (bulls only, up to 400 animals) kept the grass short, in order to minimise fire risk, while Lands & Survey initiated a public consultation process to determine future management of the island (Department of Lands & Survey 1980, 1981). Wellington Botanical Society members visited in March 1984 and October 1986, gathering information to include in a detailed account of the island's vegetation and flora (Timmins et al. 1987b). Wellington Botanical Society (1984) also made detailed suggestions for the future management of the island.

Also in 1984, the Lands & Survey farm manager used a bulldozer to construct an unsanctioned farm road along the narrow shore platform north of Shingle Point, destroying about 70% of the known habitat for McGregor's skink

Figure 5. Goldstripe gecko, Mana Island. Image: Tony Whitaker. Gift of Vivienne Whitaker, 2020, Te Papa O.049774.

Figure 6. A. The flat behind Landing Bay in February 1986, showing infrastructure built during the MAF era (1973–75), plus Lands & Survey era stockyards at right (the cattle evident around the stockyards were removed 2 months later) (Image: Don Newman). **B.** The same view in June 2022 (Image: Maarten Holl, Te Papa, 206584).

Figure 7. Cook Strait giant weta, Mana Island. Image: Leon Berard.

Table 1. Mouse catch rates on Mana Island between 1972 and 1989. See Nelson and Clarke (1973) for the method used to calculate CTN = corrected trap nights. Pickard's (1984) data for 12 consecutive months are summarised in Fig. 10A, and May & June catch rates per 100 CTN are presented in Fig. 10B.

Date	Trap-nights	Mice caught	Catch/100 traps	Catch/100 CTN	Reference
Jun 1972	110	19	17.3	20.3	Meads and Moller 1977
Sep 1977	118	51	43.2	63.8	Efford et al. 1988
Nov-Dec 1977	278	70	25.2	32.6	Efford et al. 1988
Feb 1978	179	68	38.0	70.8	Efford et al. 1988
Jun 1978	179	86	48.0	81.1	Efford et al. 1988
Oct 1978	180	43	23.9	35.5	Efford et al. 1988
Mar 1981	145	56	38.6	74.7	Pickard 1984
Apr 1981	117	51	43.6	83.6	Pickard 1984
May 1981	116	63	54.3	96.9	Pickard 1984
Jun 1981	118	59	50.0	79.7	Pickard 1984
Jul 1981	120	52	43.3	65.0	Pickard 1984
Aug 1981	117	32	27.4	36.8	Pickard 1984
Sep 1981	119	29	24.4	30.1	Pickard 1984
Oct 1981	79	13	16.5	21.1	Pickard 1984
Nov 1981	120	25	20.8	26.6	Pickard 1984
Dec 1981	119	24	20.2	28.6	Pickard 1984
Jan 1982	120	27	22.5	34.0	Pickard 1984
Feb 1982	118	27	22.9	34.6	Pickard 1984
May 1989	95	56	58.9	114.3	Fitzgerald and Cong 1989

(Fig. 8; Towns 1984; Newman 1994). This damage was the trigger for Don Newman to establish a population survey and monitoring programme for McGregor's skink in February 1986 (Newman 1993, 1994).

Research on the ecology of Mana Island's mouse population began with the 1972 DSIR visit (Daniel et al. 1972) and continued during the MAF quarantine research farm era (Atkinson et al. 1975; Efford et al. 1988) and the Lands & Survey cattle-farm era (Pickard 1984), and also after stock were removed from the island (Fitzgerald and Cong 1989). Catch rates were consistently high throughout, with most traps either catching mice or being sprung (Table 1). The high interference rates made snap-trapping an insensitive index of changes in mouse abundance (Efford et al. 1988; Fitzgerald and Cong 1989); once a trap is sprung, it can't catch anything (or anything further) until it is reset, regardless of how many mice encounter the sprung trap. Mouse density peaked in autumn each year (Fig. 9A), and trapping over a 17-year period revealed that the annual peak in mouse numbers became higher each year as Mana Island land management changed from sheep grazing (1972 & 1978), to cattle grazing (1981), to the absence of any grazing (1989) (Fig. 9B).

In addition to reporting exceptionally high catch rates, two of the studies revealed that mouse diet changed after grazing ceased on Mana Island. The mice were

Figure 8. The view south from McGregor's Rock to Shingle Point, showing part of the shore platform damaged by the construction of an unauthorised farm track in 1984. **A.** June 1972 (Image: Tony Whitaker, gift of Vivienne Whitaker, 2020, Te Papa CT.066757). **B.** June 2022 (Image: Maarten Holl, Te Papa, 206599). The vegetation has recovered naturally from predominantly *Coprosma propinqua* to taupata (*C. repens*).

predominantly eating invertebrates when the island was grazed; however, their diet switched to mainly plant matter after cattle were removed (Pickard 1984; Fitzgerald and Cong 1989). This diet change may have been due to the extremely high density of mice in autumn 1989 consuming so many invertebrates that they depleted preferred invertebrate prey, with the mice then having to switch to a lower quality plant-based diet (Miskelly et al. 2022a).

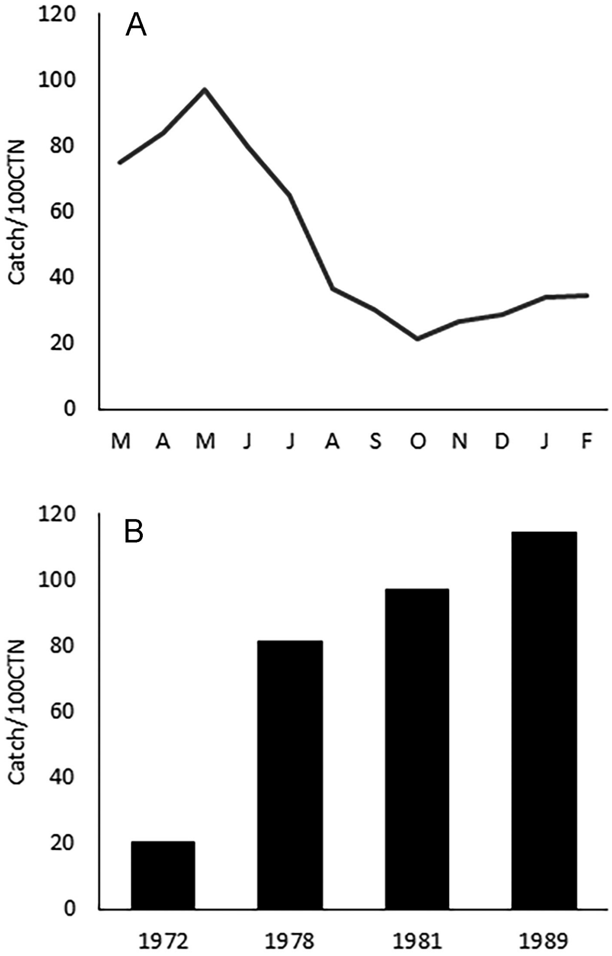

Figure 9. Mouse catch rates in snap traps on Mana Island, expressed as catch per 100 corrected trap nights (Nelson and Clarke 1973). **A.** Catch rates over 12 consecutive months in 1981–82, showing the annual peak in mouse density in late autumn and early winter (data from Pickard 1984). **B.** May–June catch rates over time, showing increasing mouse numbers after grazing by farm stock was reduced and then eliminated (see Table 1 for data sources).

The year 1986 was a pivotal one for the management of Mana Island. Following an analysis of public submissions on future uses for Mana Island, the Department of Lands & Survey decided to cease farming operations, and to manage the island solely for conservation purposes (Department of Lands & Survey 1986a). The last barge-load of bulls left the island in April 1986 (Newman 1994; Maysmor 2009). Later that year, Lands & Survey published a management plan for the island, followed by an implementation plan providing details on how to achieve the policies and objectives set out in the management plan (Department of Lands & Survey 1986a, b).

Department of Conservation formed, and scientific reserve status – 1987 & 1988

The Department of Conservation (DOC) was formed on 1 April 1987. Among other functions, DOC became responsible for managing reserves formerly managed by the Department of Lands and Survey (Conservation Act 1987). Mana Island was gazetted as a scientific reserve on 31 October 1988 (*NZ Gazette 190*: 4518, 10 November 1988; this date is often given incorrectly as 1987). This status ensured the "[protection and preservation] in perpetuity for scientific study, research, education, and the benefit of the country, ecological associations, plant or animal communities, types of soil, geomorphological phenomena, and like matters of special interest". Scientific reserve status requires that "the indigenous flora and fauna shall as far as possible be preserved and the exotic flora and fauna shall as far as possible be exterminated" (Reserves Act 1977).

The change in the island's status, and the new focus on conservation management (rather than farm production) precipitated a series of scientific papers with suggestions for the island's future biotic communities, and the opportunities that it presented for recovery of threatened fauna and flora (Timmins et al. 1987a; Atkinson 1988, 1990).

Mouse eradication – 1989 to 1992

DOC staff on Mana Island were very aware of how abundant mice had become after cattle were removed, and also the damage that they were doing to new plantings (Hook and Todd 1992). They famously caught 204 mice in a single bucket trap set for one night in autumn 1988, after which the bucket was so full that the mice could jump out (Hutton 1990; Phil Todd pers. comm., August 1997). The actual numbers of mice present on Mana Island at their peak is unknown, with estimates ranging as high as 5 million and 15 million (Anonymous 1989; Hutton 1990); these estimates equate to 2.3–6.9 mice per square metre over the entire island (Miskelly et al. 2022a).

Fortuitously, Newman (1993, 1994) had commenced monitoring of McGregor's skink just 2 months before cattle were removed in April 1986. In early 1989, he recorded an alarming drop in skink catch rates, and over three seasons recorded 21 instances of mice having eaten lizards inside pitfall traps (including two McGregor's skinks; Newman 1994). Concerned by this news, and inspired by the recent attempt to eradicate Norway rats (*Rattus norvegicus*) from Breaksea Island, Fiordland, Colin Ryder (from Wellington branch, Forest & Bird) lobbied for permission, funding, and human resources (via a Conservation Corps scheme) to attempt eradication of mice on Mana Island (Hutton 1990).

Mice were eradicated from Mana Island using a combination of aerial spread of baits containing anticoagulant toxin, and placement of similar baits in a 25 metre grid of 5,500 bait stations across the island (Hook and Todd 1992). Much of the labour was provided by Conservation Corps members and volunteers, both of which were organised by the Wellington branch of Forest & Bird. The Conservation Corp grant also covered bait costs. The first air drop of baits (4 g wax pellets containing 0.005% flocoumafen) was completed on coastal slopes on 24 July 1989. Two days later, the bait stations were all baited with ten × 16 g wax blocks containing the same concentration of flocoumafen. These were replenished on 8–10 August. Bait consumption had dropped to low levels by 4 September, when 2 tonnes of pellets containing 0.0002% brodifacoum were air-dropped over the whole island. A second brand of wax block bait (containing 0.0005% brodifacoum) was added to the bait stations from the end of October 1989 (details from Hook and Todd 1992; Newman 1994; Miskelly et al. 2022a). Baits were maintained in the stations until they were removed in February–March 1992. The last known mouse on Mana Island was caught on 5 February 1990, about 5 months after the previous last evidence of mouse presence (Newman 1994). The eradication was declared a success in November 1991 (Hook and Todd 1992).

Mouse eradication was followed by population increases of numerous species across several biotic groups. Newman (1994) reported increased catch rates of McGregor's skinks, Raukawa geckos, giant weta, and garden snails (*Cornu aspersum*) in pitfall traps over the following four years. He also considered that greater numbers and a wider variety of invertebrates were trapped after mice were eradicated, but did not keep detailed records of this (Newman 1994). Thirteen of 22 bird species monitored by 5-minute bird counts had significant increases after mouse eradication, and only three species decreased, with three further species increasing in one season and decreasing in the other (Table 2; Miskelly et al. 2022a). The overall pattern was for insectivorous bird species to increase after mouse eradication, with conflicted or nil responses for granivorous species. This suggests that competition for invertebrate prey was the main impact mice had on the birds of Mana Island (Miskelly et al. 2022a).

Planting, and volunteer involvement – 1987 to 2022

Propagation and planting of eco-sourced trees, shrubs and other plants became a major focus of the Mana Island ecological restoration programme after DOC took over management of the island in 1987 (Hutton 1990; Miskelly 1999, 2010). The earliest recommendation for a revegetation programme was made by the Wellington Botanical Society (1984). These ideas were developed further in a 'pre-DOC' implementation plan (Department of Lands & Survey 1986b). This included prescribing how to re-establish plant communities representative of the Sounds-Wellington Ecological Region, by collecting seed within 5 km of the island, and planting the resulting seedlings in the sheltered valleys. The report advocated for most germination to be done offsite, with seedlings returned to the island for pricking out and growing-on in a nursery area (Department of Lands & Survey 1986b). These ideas were expanded by Timmins et al. (1987a) and Nicholls (1989). Timmins et al. (1988) recommended planting trials to compare the outcomes of various methodologies, including comparing plant species, various site preparation techniques (including use of herbicide, mowing, and grubbing), use of plants raised by different plant propagation methods, planting densities, and contrasting after-care methods. Detailed planning of

Table 2. Significant changes in bird populations on Mana Island following mouse eradication, based on 5-minute bird counts (Miskelly et al. 2022a). Species are listed in decreasing order of abundance (= frequency of records during counts), with shading used to show the predominant diet for each species. Insectivorous species showed the strongest positive response following mouse eradication.

Species	Diet	Autumn	Spring
Southern black-backed gull *Larus dominicanus*	Marine	No change	No change
Starling *Sturnus vulgaris*	Insectivore	No change	Increase
Red-billed gull *Chroicocephalus novaehollandiae*	Marine	Decrease	No change
Goldfinch *Carduelis carduelis*	Granivore	Decrease	Increase
Skylark *Alauda arvensis*	Insectivore	Increase	Increase
Silvereye *Zosterops lateralis*	Insectivore/frugivore	Increase	Increase
Greenfinch *Chloris chloris*	Granivore	Decrease	Increase
New Zealand fantail *Rhipidura fuliginosa*	Insectivore	Increase	Increase
White-fronted tern *Sterna striata*	Marine	No change	Increase
Yellowhammer *Emberiza citrinella*	Granivore	No change	No change
Swamp harrier *Circus approximans*	Carnivore	Increase	Decrease
House sparrow *Passer domesticus*	Granivore	Decrease	No change
Rock pigeon *Columba livea*	Granivore	No change	No change
Chaffinch *Fringilla coelebs*	Insectivore/granivore	Increase	No change
Dunnock *Prunella modularis*	Insectivore	No change	No change
Blackbird *Turdus merula*	Insectivore/frugivore	Increase	No change
Pūkeko *Porphyrio melanotus*	Herbivore	Increase	Increase
Paradise shelduck *Tadorna variegata*	Herbivore	Increase	No change
New Zealand pipit *Anthus novaeseelandiae*	Insectivore	Increase	Increase
Grey warbler *Gerygone igata*	Insectivore	Increase	No change
Song thrush *Turdus philomelos*	Insectivore/frugivore	Increase	Increase
Welcome swallow *Hirundo neoxena*	Insectivore	Increase	No change

the revegetation programme included comparisons with plant communities growing on similar soils and landforms on the adjacent mainland coast (Gabites 1994; Gay 1999; Miskelly 1999).

Planting began in 1987, and peaked at 29,800 plants in 1996. Bulk planting ceased in 2011, by which time close to 443,000 trees and shrubs had been planted (Table 3). Since then, plantings have focussed on threatened species and small numbers of eventual canopy species, at an average of about 200 plants per annum, giving a total close to 444,000 plants. Planting began in the sheltered valleys (Fig. 10), followed by efforts to link the valley plantings to the forest remnant in Forest Valley (Fig. 11). The windswept and more drought-prone summit plateau was the final area to receive bulk plantings (Fig. 12).

Much of the labour during the intensive planting programme was undertaken by volunteers (Hutton 1990; Gay 1999). The two resident DOC staff co-ordinated the work and were involved in all stages, with volunteers assisting with seed collection on the mainland, nursery work, and much of the actual planting. Many community groups participated, particularly local Forest & Bird branches, Tararua Tramping Club, and Wellington Botanical Society. The Friends of Mana Island became heavily involved with the revegetation programme (and also fauna introductions) following their formation in 1998 (Hansford 2005).

Pūkeko (*Porphyrio melanotus*) colonised Mana Island in 1989: a pair was first seen on 4 October 1989, and they were seen mating 6 days later (Trevor Hook pers. comm., October 2022). Pūkeko damage to fresh plantings was recognised as a major problem in the 1990s, with numerous new plantings pulled out but not eaten (Miskelly 1999). This was overcome by using 30 cm lengths of 11 cm diameter Novacoil pipe as cloches around the plants, burying 2–3 rings in the soil. While effective at minimising pūkeko damage, this required a lot more time and care during planting, and a follow-up visit 1–2 years later to remove the tubes. This was not achieved for all plants, and there are many large plants on Mana Island that remain encircled by Novacoil tubes.

At least 75 species were used in the planting programme (Appendix 2), and at least 70 of these planted species were still present on the island in 2015 (Ward 2016). Planted forest covered about 79 ha in 2021 (Fig. 2). When combined with the 4 ha of original forest, this meant that about 38% of the island had forest cover by 2021, leaving 74 ha of the plateau and valleys unplanted (34%). The remaining 60 ha (28%) are coastal slopes and shoreline, which have been left to regenerate naturally (Fig. 13).

Table 3. Number of trees, shrubs, and other plants planted on Mana Island between 1987 and 2021. FOMI records from author, pers. obs. and Linda Kerkmeester (pers. comm., August 2022).

Year	Plants	Reference
1987	11500	Miskelly 1999
1988	27000	Miskelly 1999
1989	15000	Miskelly 1999
1990	20000	Miskelly 1999
1991	22000	Miskelly 1999
1992	23900	Miskelly 1999
1993	17000	Miskelly 1999
1994	13500	Miskelly 1999
1995	27800	Miskelly 1999
1996	29800	Miskelly 1999
1997	26000	Ward 2016
1998	24000	Ward 2016
1999	25965	Ward 2016
2000	21257	Ward 2016
2001	11890	Ward 2016
2002	25475	Ward 2016
2003	26340	Ward 2016
2004	12355	Ward 2016
2005	14000	Ward 2016
2006	11365	Ward 2016
2007	7000	Ward 2016
2008	8000	Ward 2016
2009	10773	Ward 2016
2010	6000	Ward 2016
2011	5000	Ward 2016
2012	-	
2013	-	
2014	-	
2015	60	FOMI records
2016	60	FOMI records
2017	690	FOMI records
2018	110	FOMI records
2019	90	FOMI records
2020	-	
2021	-	
Total	443930	

Natural vegetation recovery – 1975 to 2022

Regeneration of taupata (*Coprosma repens*) and ngaio (*Myoporum laetum*) was evident along the western shore within a year of sheep being fenced out (Atkinson et al. 1975, and Suppl. material 1: figs S2, S6, S7). Shortly after this, the Department of Lands and Survey (1980) reported regeneration of kohekohe, wharangi, kawakawa (*Piper excelsum*), māhoe (*Melicytus ramiflorus*), and rangiora (*Brachyglottis repanda*) in areas where stock were excluded.

Parts of three catchments were identified in the ecological restoration plan as sites where plant communities would be left to recover naturally (Miskelly 1999). Ward (2016) reported that one of these (Tauhinu Valley) was "thriving with *Arthropodium cirratum* – Rengarenga in full flower…This area has re-generated significantly since the farming has ceased…". Ward (2016) also reported extensive natural recovery of mingimingi (*Coprosma propinqua*) on the northern edge of the plateau (Fig. 14, and discussed further under 'Lizard recovery and translocations').

At the other end of the island a dense sward of flax spread unaided across the plateau inland from Shearwater Point before 2004 (Miskelly 2017), and more recently has formed an extensive sward for several hundred metres south of the trig (Fig. 15). Wind-dispersed flax remains a dominant component of the shrub community at the

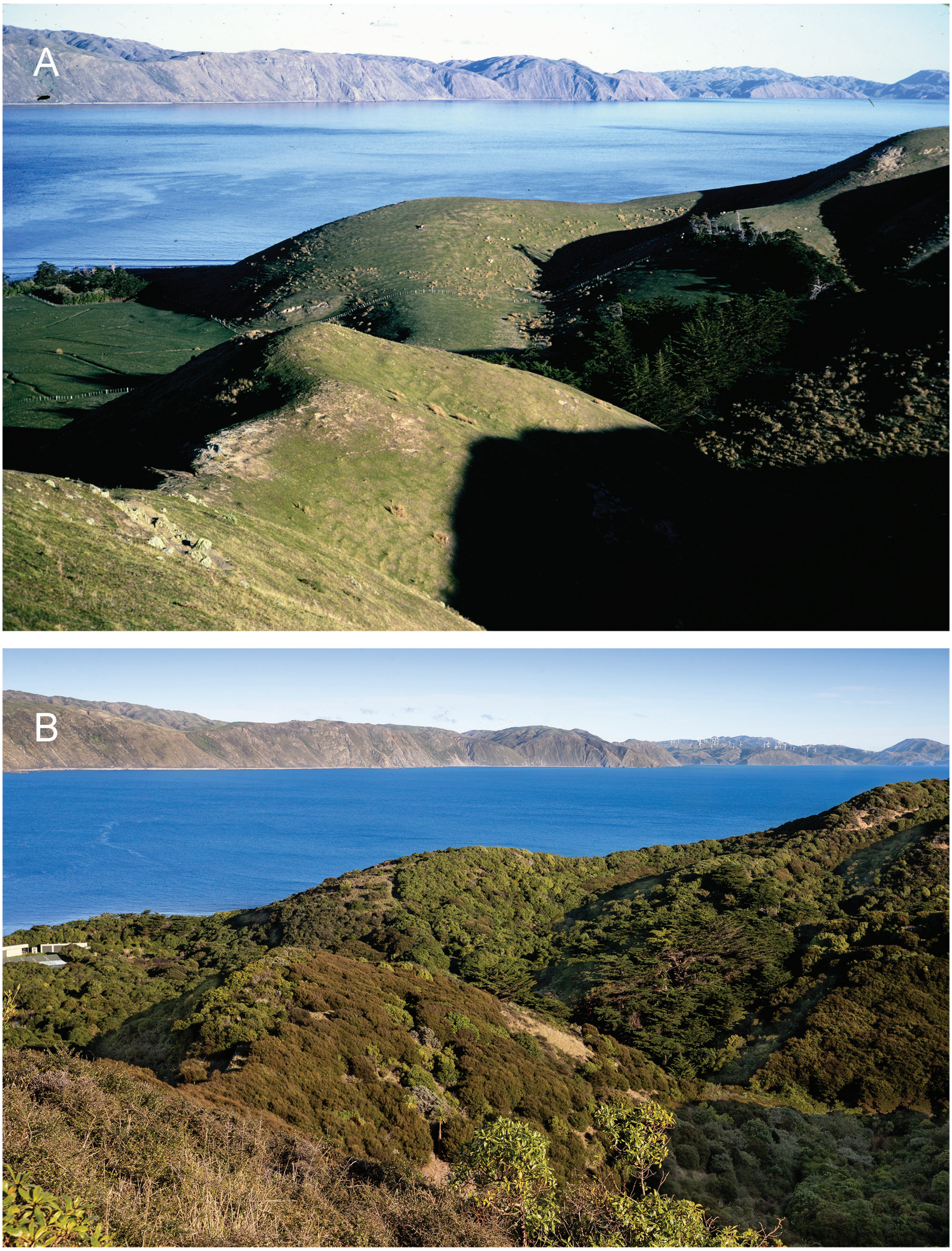

Figure 10. The view south across lower Astons Valley and Weta Valley, showing sheltered sites that were planted early in the revegetation programme. **A.** June 1972 (Image: Tony Whitaker, gift of Vivienne Whitaker, 2020, Te Papa CT.067087). **B.** June 2022 (Image: Maarten Holl, Te Papa, 206588).

north end of the plateau; however, healthy flaxes are now scarce in the southern half of the island due to the impacts of flax weevils (*Anagotus fairburni*), discussed further below.

Weed control – 1994 to 2022

Concerns about the proliferation of weed species on Mana Island were raised soon after stock were excluded from

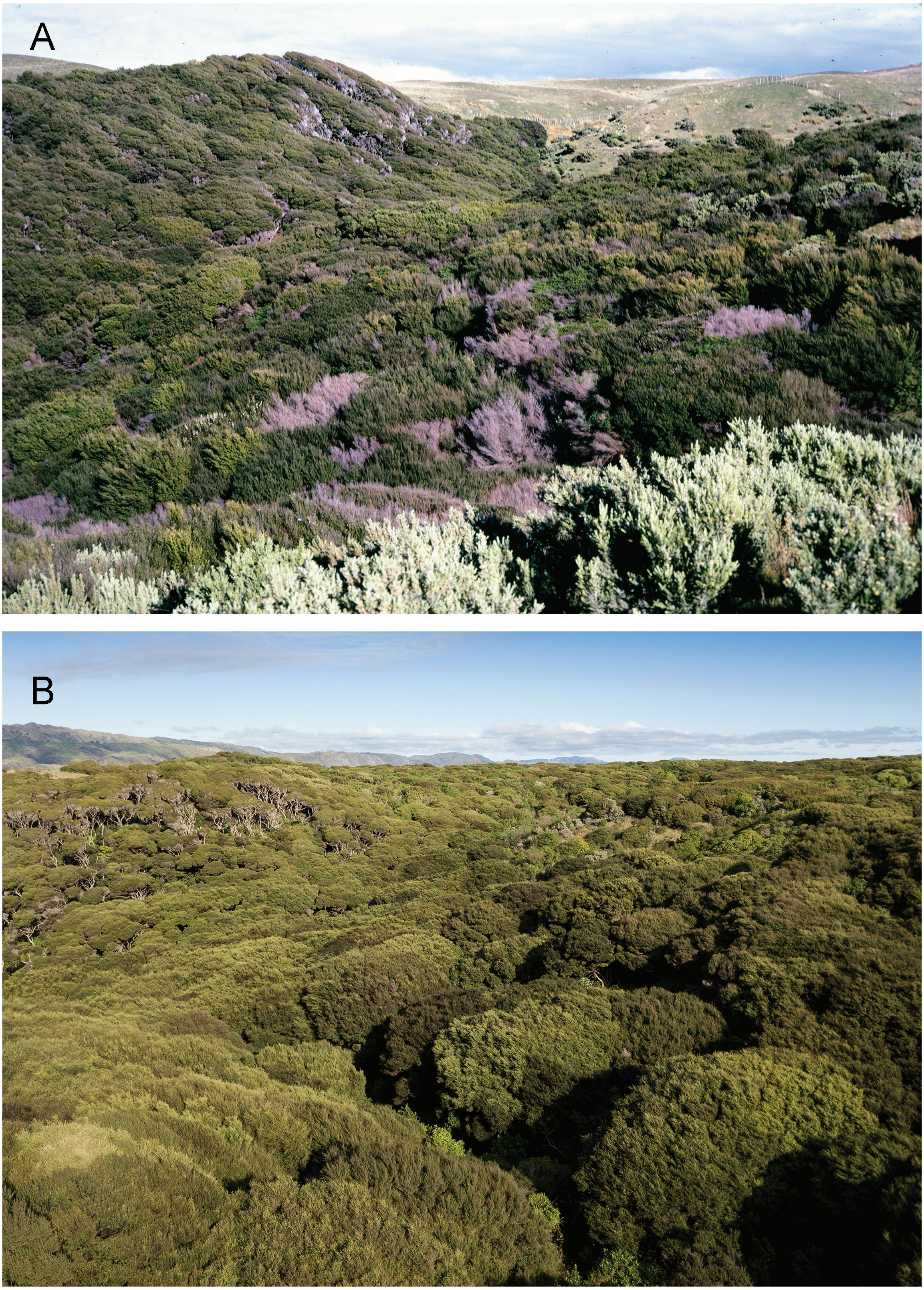

Figure 11. The view south across the head of Forest Valley, showing the original forest remnant and subsequent planting on the plateau to the south-west. **A.** June 1972 (Image: Tony Whitaker, gift of Vivienne Whitaker, 2020, Te Papa CT.067096). **B.** June 2022 (Image: Maarten Holl, Te Papa, 206607). A drone was used for the 2022 image (to get above surrounding trees), creating a different perspective as evident from the distant Wellington skyline.

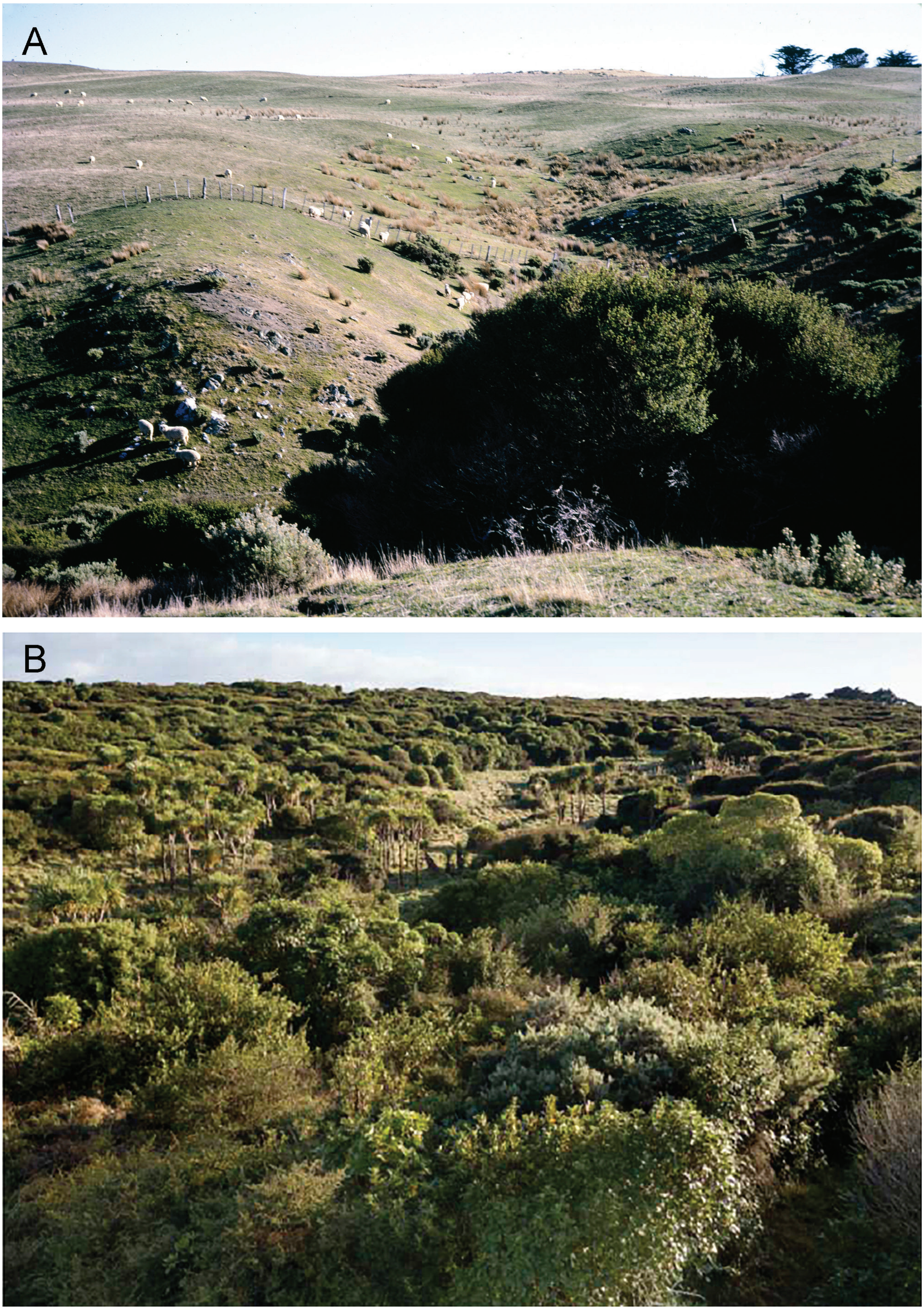

Figure 12. Part of the Mana Island plateau, showing sheep grazing in 1972, and planted vegetation in 2022. **A.** June 1972 (Image: Tony Whitaker, gift of Vivienne Whitaker, 2020, Te Papa CT.067098). **B.** June 2022 (Image: Maarten Holl, Te Papa, 206612). A drone was used for the 2022 image (to get above surrounding trees).

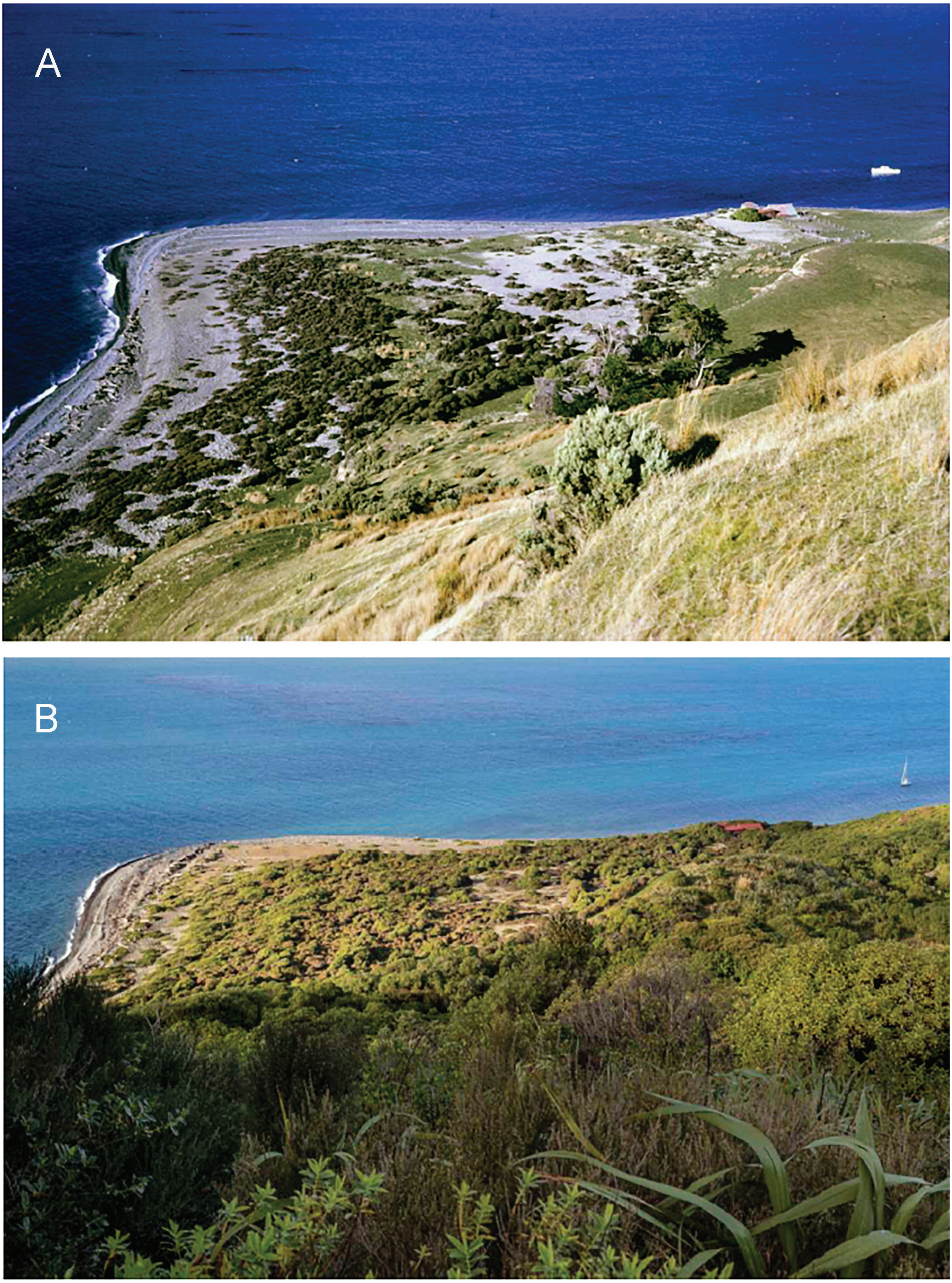

Figure 13. Natural recovery of vegetation on Shingle Point after farm stock were excluded then removed (the slopes in the foreground have been planted). Note the historic woolshed at top right in both images. **A.** June 1972 (Image: Tony Whitaker, gift of Vivienne Whitaker, 2020, Te Papa CT.067097). **B.** June 2022 (Image: Maarten Holl, Te Papa, 206595).

Figure 14. Natural regeneration of *Coprosma propinqua* shrubland on the northern plateau of Mana Island, October 2022. Image: Colin Miskelly.

Figure 15. Natural regeneration of flax on the plateau *c*. 200 m south of the trig, January 2019. Image: Colin Miskelly.

the coastal slopes, when boxthorn (*Lycium ferocissimum*) was noted to be spreading rapidly along coastal slopes and the shoreline, covering an estimated 3.3 ha in 1984 (Wellington Botanical Society 1984; Timmins et al. 1987b). Other species of concern included gorse (*Ulex europaeus*), brush wattle (*Paraserianthes lophantha*), and wild broom (*Cytisus scoparius*) (Wellington Botanical Society 1984).

Concerted effort to control boxthorn began in 1994, with a team employed each summer to cut and mulch the shrubs, and to paint the fresh stumps with herbicide. By 2005 it was estimated that $5 million had been invested in the boxthorn control programme (Hansford 2005). Five years later, boxthorn had been reduced to a negligible component of the shoreline vegetation community (Miskelly 2010), where taupata and mingimingi rapidly reclaimed the areas cleared. Weed control continues to be a focus of the Mana Island ecological restoration programme, with 32 target species identified in 2008 (listed in Appendix 2 in Miskelly 2010).

Mana Island is a major nocturnal roosting site for starlings (*Sturnus vulgaris*), which fly across from the mainland each evening (Brockie 1983; Miskelly 2010). This was considered a likely way for boxthorn seeds and other weed seeds to be introduced or reintroduced to the island (Timmins et al. 1987b; Miskelly 1999). However, Ferguson and Drake (1999) found little evidence of weed seeds being spread by starlings, with native species dominating the seedfall collected in trays set under starling roosts. Inkweed (*Phytolacca octandra*) comprised 22.8% of the seed rain, with the only other weed species detected (nightshade *Solanum* spp. and blackberry *Rubus fruticosus* agg.) making up another 2.8% (Ferguson and Drake 1999). The same species were also the only weed species detected in the soil (= seed bank) below the roosts. All these species were present on Mana Island at the time of the study, with blackberry the only one of them targeted for eradication (Miskelly 2010; Ward 2016).

Wetland restoration – 1998

Most ecological restoration on Mana Island has been undertaken by hand, including with hand-held power tools. The notable exception was restoration of Waikōkō wetland on the flat behind Landing Bay. This area was likely a sedge-dominated swamp before it was drained for farming (Chester and Raine 1990). A wetland was recreated at the site in March–April 1998 by Ducks Unlimited volunteers Jim Campbell and Gary Thompson using a D2 bulldozer, an 8-ton digger, and a truck that were barged to the island (Campbell 1998). The system of ponds and weirs was designed by DOC landscape architect Robin Gay (1939–2008), and was intended to create habitat for a range of wetland plants and animals, including brown teal (pāteke, *Anas chlorotis*) and fernbird (mātātā, *Poodytes punctatus*), which were released on Mana Island in 2000–01 and 2019 respectively (see below).

Within 18 years, most of the ponds had become filled with silt, and few held water throughout the year (Ward 2016). However, wetland plants and birds remain present, and the ponds slow the rate that water is lost from the catchment.

Ecological restoration plan, and formation of Friends of Mana Island – 1998 & 1999

The Mana Island Ecological Restoration Plan (Miskelly 1999) was developed following a series of workshops hosted by the Department of Conservation, beginning in June 1992. An early draft of the plan (1997) contained recommendations on wetland development and lizard translocations that were initiated before the plan was finalised (see above and below). The final plan was published in January 1999, in the month following the formation of Friends of Mana Island Incorporated Society on 14 December 1998 (Paget 2007).

The FOMI concept was raised in 1998 by Jason Christensen (then the island manager), and sponsored though to fruition by Brian Paget (1936–2018), then president of the Kapi-Mana Chapter of Rotary Club (Ryder 2018). The Mana branch of Forest & Bird merged with the Kapiti branch in 1998 to form the Kapiti-Mana branch. The Mana branch had been one of the main sources of volunteers during the first decade of the revegetation programme on Mana Island; the formation of FOMI ensured that former branch members could continue their involvement with the island (Ryder 2018).

Colin Ryder (1946–2021) was the founding president of FOMI, and an enthusiastic champion of the Mana Island Ecological Restoration Plan. Over the following two decades, FOMI worked with DOC and Ngāti Toa to implement many of the plan's recommendations, including raising funds and contributing personnel for most of the species translocations and monitoring projects summarised below.

Translocations of land birds, waterfowl and coastal birds – 1987 to 2022

Sixteen bird taxa have been translocated to Mana Island since the first translocation of takahē in 1988 (Table 4, which provides scientific names), with the species selected largely following the recommendations of Miskelly (1999). Takahē on Mana Island are managed as part of a national meta-population, with birds moved on and off the island in order to manipulate the genetic relatedness of pairs, and to maximise national productivity (Greaves et al. 2020). The Mana Island population peaked at 38 adults and 4 juveniles in 2007 (Fig. 16), and until recently was the largest population outside Fiordland (Ryan and Jamieson 1998; Ward 2016; Greaves et al. 2020). Mana Island has been one of the most productive sites for takahē, with 91 birds translocated off Mana Island

Table 4. Summary of bird translocations to Mana Island.

Species	Year	No.	Source	Outcome	Data sources and references
South Island takahe *Porphyrio hochstetteri*	1988–2022	48	Fiordland (originally)	Managed population	Takahē Recovery Database, DOC (Glen Greaves, pers. comm., September 2022)
Kākāpō *Strigops habroptila*	1992	2	Rakiura / Stewart Island	Failed	Miskelly 1999; Ballance 2018
Potts' kiwi *Apteryx rowi* X *owenii*	1992	1	Franz Josef	Removed 2006	Shepherd et al. 2021; Miskelly et al. 2022b
Little spotted kiwi *A. owenii*	1994	1	Kapiti Island	Failed	Miskelly 1999
North Island robin *Petroica longipes*	1995–96	66	Kapiti Island	Successful	Wiles 2000; Miskelly and Powlesland 2013
Common diving petrel *Pelecanoides urinatrix*	1997–99	239	North Brother + Sugarloaf Islands	Successful	Miskelly and Taylor 2004
Brown teal *Anas chlorotis*	2000–01	16	Captive	Successful	Miskelly and Powlesland 2013
Fairy prion *Pachyptila turtur*	2002–04	240	Takapourewa / Stephens Island	Successful	Miskelly and Gummer 2013
Yellow-crowned parakeet *Cyanoramphus auriceps*	2004	27	Te Kakaho Island, Marlborough	Successful	Adams and Cash 2010
Fluttering shearwater *Puffinus gavia*	2006–08	225	Long Island, Marlborough	Successful	Miskelly et al. 2009; Gummer and Adams 2010
Shore plover *Thinornis novaeseelandiae*	2007–13	171	Captive	Failed	Collen 2007, 2008; Collen and Gummer 2009, 2010, 2011; Gummer and Caldwell 2012; Hall 2013
Whitehead *Mohoua albicilla*	2010	37	Kapiti Island	Successful	Adams and Caldwell 2012
Bellbird *Anthornis melanura*	2010 & 12	102	Kapiti Island	Successful	Adams and Caldwell 2012
Rowi *Apteryx rowi*	2012	20	Okarito	Successful	Miskelly and Powlesland 2013
Fairy prion	2015–16	200	Takapourewa / Stephens Island	Successful	Gummer et al. 2015, 2016
Fernbird *Poodytes punctatus*	2019	40	Lake Rotokare, Taranaki	Successful	Harrison 2019, 2021
White-faced storm petrel *Pelagodroma marina*	2019–21	246	Rangatira Island, Chatham Islands	Unknown	Mitchell and McKoy 2021
Shore plover	2020	34	Captive	Failed	Collen et al. 2022

Figure 16. The number of adult takahē on Mana Island since the first translocation in 1988. Data are from between breeding seasons, with juveniles from the previous breeding season not included. Changes in numbers are due to translocations on and off the island, as well as local productivity and mortality. The founding birds were removed from the island during the mouse eradication; all had been returned by 1992. Data from the Takahē Recovery Database, and DOC annual breeding season reports (Glen Greaves and Alison Ballance, pers. comms) and Mana Island takahē file NHS-03-14-07-08, WNMI-1.

between 1989 and 2022 (Table 5). The population has declined as the area of open habitat has decreased, and is currently stable at 7–8 pairs (Fig. 16; Greaves et al. 2020; Ballance in press).

Two male kākāpō from Rakiura / Stewart Island were released on Mana Island in May 1992 (Miskelly 1999). One was not seen again, and the other was found dead 15 months later (Miskelly 1999; Ballance 2018). Since then, the kākāpō recovery programme has focussed effort on larger, forested islands, with no further releases on Mana Island (Ballance 2018).

For a few years in the 1990s, Mana Island was used in an attempt to salvage genes of mainland little spotted kiwi (kiwi pukupuku), after a male 'little spotted kiwi' was caught near Franz Josef and moved to Mana Island in October 1992. After surveys failed to locate any further mainland birds, a female little spotted kiwi from Kapiti Island was moved to Mana Island as a potential mate in June 1994 (Miskelly 2010). They are not known to have bred, and the female was last heard about 4 years later. By then, genetic tests had revealed that the Franz Josef bird was a hybrid little spotted kiwi × rowi, which is a recurring hybrid now known as Potts' kiwi (Shepherd et al. 2021; Miskelly et al. 2022b). A second (female) Potts' kiwi

Table 5. Summary of fauna translocations off Mana Island.

Species	Year	No.	Release site	Outcome	Comments
Cook Strait giant weta	1977	43	Maud Island / Te Pākeka	Successful	Subsequently to Titi Island (2001), Long Island (2002), Blumine Island (2011)
South Island takahe	1989–2022	91	15+ sites	Ongoing	Managed as a national metapopulation; data from Takahē Recovery Database, DOC (Glen Greaves, pers. comm., September 2022)
Cook Strait giant weta	1996	62	Matiu/Somes Island	Successful	Subsequently to Zealandia (2007, 2008, 2010), Cape Sanctuary (2013)
Wellington tree weta	1996–97	59	Matiu/Somes Island	Successful	
Potts' kiwi	2006	1	Allports Island	Unknown	Plus one bird from Okarito (at least 2 chicks produced; Shepherd et al. 2021)
Yellow-crowned parakeet	2012	29	Boundary Stream	Failed	
Rowi	2012	8	Omoeroa Ranges	Successful	Plus birds sourced from Okarito (including via captive-rearing)
Cook Strait giant weta	2013	89	Cape Sanctuary	Successful	Plus a further 41 from Matiu/Somes Island

was confirmed near Okarito in 2005, and both it and the 'Franz Josef' bird were moved to Allports Island in Queen Charlotte Sound in 2006, where they have raised at least two chicks (Shepherd et al. 2021). This cleared the way for another kiwi taxon to be translocated to Mana Island, and in July 2012, 20 juvenile rowi from Okarito were released. The population grew, and in July 2019, eight rowi (including seven locally-bred birds) were translocated from Mana Island to the Omoeroa Ranges in South Westland.

North Island robins (toutouwai) from Kapiti Island were translocated to Mana Island in 1995 & 1996 to mitigate the risk of the Kapiti Island population being impacted by the 1996 rat eradication operation (Empson and Miskelly 1999). Despite the limited forest cover on Mana Island in 1995–96, the robins thrived (Wiles 2000), and expanded their distribution on Mana Island as the plantings matured. However, as robins generally stay under closed forest canopy, and the public tracks on Mana Island mainly skirt around the edges of the planted forest, few visitors to Mana Island manage to see North Island robins. Robins were notably scarce on the island in late 2022 (de Lisle and Bishop 2022; author, pers. obs.). As the birds mainly occur away from the tracks, are not vocal, and have not been monitored for many years, the cause and timing of this apparent decline in numbers are unknown.

Brown teal (pāteke) were one of the target species when Waikōkō wetland was developed (Miskelly 1999). They were introduced 2–3 years later, with ducklings seen within the first year (Miskelly 2010, and pers. obs.). The Mana Island population remains centred on Waikōkō, although pairs and singles are occasionally seen on ponds on the island's plateau. Bowker-Wright et al. (2012) concluded that most of the Mana Island birds were descended from a single pair. The largest flock reported was 21 on 21 February 2019 (Shane Cotter, in eBird).

Yellow-crowned parakeets (kākāriki) are common on the Chetwode Islands in outer Pelorus Sound, on both Nukuwaiata (forested) and Te Kākāho (which has regenerating shrubland). As Mana Island had a mosaic of forest, shrubland and open country in the early 2000s, Te Kākāho (Outer Chetwode Island) was selected as the source population for Mana Island (Adams and Cash 2010). Twenty-seven yellow-crowned parakeets from Te Kākāho were released on Mana Island on 12 May 2004. The population established rapidly, with unbanded birds seen within 2 months of release (Adams and Cash 2010). Parakeets were abundant and widespread on Mana Island within 5 years (Adams and Cash 2010; Miskelly 2010).

Shore plover (tūturuatu) are one of New Zealand's most endangered birds, with a single natural population of 110–140 birds (Davis 1994; Dowding & O'Connor 2013). The main method attempted to improve the security of the species is captive-breeding, with releases of captive-reared juveniles onto islands lacking mammalian predators (Collen 2007, 2008; Dowding & O'Connor 2013). In order to reduce the risk of immediate dispersal off the islands, the birds are typically kept in temporary aviaries at the release sites for several weeks before being released (Dowding and O'Connor 2013). There have been two attempts to establish shore plover on Mana Island, in 2007–13, and in 2020. Shore plover bred within a year of their initial release, and 16 nests were reported during the 2010–11 season (Collen 2007; Collen and Gummer 2011). Unfortunately, the birds began to spend increasing amounts of time off the island, particularly at Plimmerton, with 30 birds regularly visiting there in August 2011 (Gummer and Caldwell 2012). The likely cause of their departure from Mana Island was identified in November 2011, when a single Norway rat was detected on the island, and it was estimated that it had killed at least 10 shore plover (Gummer and Caldwell 2012). Although the rat was poisoned within a month of detection, the remaining shore plovers continued to spend most of their time off the island, and (as a consequence) also enticed newly-released birds away. The last four birds were recaptured and returned to captivity in October 2014 (Anonymous 2014).

A second attempt to establish shore plover on Mana Island was initiated in February 2020, then abandoned within 9 months after a New Zealand falcon (kārearea, *Falco novaeseelandiae*) was observed killing a newly-released shore plover (Collen et al. 2022). It was later found that the falcon had consumed at least two shore plover (DOC media release, 16 September 2020). Falcons have been seen with increasing frequency on Mana Island in recent years (Fig. 17), reflecting their increasing abundance in the Wellington region. At least two different falcons (an adult and a juvenile) were on

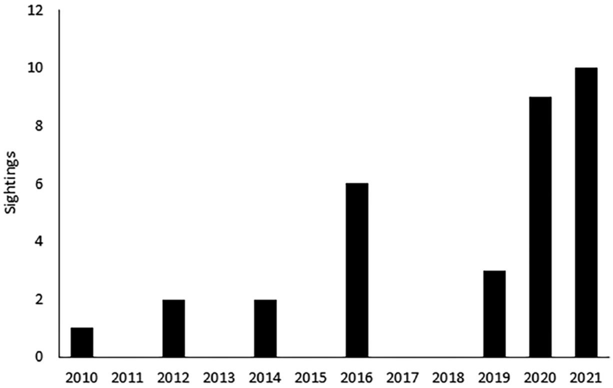

Figure 17. New Zealand falcon sightings on Mana Island, 2010–2021. Data from eBird (most sightings contributed by Dallas Bishop, Geoff de Lisle, and Colin Miskelly).

Mana Island in October 2020 (author, pers. obs.), which contributed to the decision to halt shore plover releases (Collen et al. 2022).

Whiteheads (pōpokotea) and bellbirds (korimako) were translocated simultaneously from Kapiti Island in July 2010, with a supplementary translocation of 61 further bellbirds in July 2012. Both species bred in the first year, and rapidly established throughout the planted forest. They are now among the most abundant birds on Mana Island (see below).

Fernbirds (mātātā) were one of the target species for Waikōkō wetland (Miskelly 1999); however, their translocation was delayed due to the preferred source population (Manawatu estuary) being unsuitable. FOMI commissioned a survey of the Manawatu estuary fernbird population, which concluded that there were too few birds to harvest for translocation (Tobón 2005). Birds were eventually sourced from Lake Rotokare, Taranaki, with a single release of 40 birds in April 2019. Although released in the wetland, the birds rapidly spread across the island, showing a strong preference for toetoe (*Austroderia toetoe*) and densely tangled *Coprosma propinqua* shrubland on the plateau (Fig. 18).

Figure 18. Fernbird in *Coprosma propinqua* on Mana Island. Image: Dallas Bishop.

Seabird attraction and translocations – 1993 to 2022

Mana Island is the site of one of the most complex and successful seabird restoration projects in the world (Miskelly et al. 2009; Galatowitsch 2012; Woodworth 2013). The main focus of seabird restoration on Mana Island is to restore their role as ecosystem engineers, delivering marine nutrients to the island, and creating stable subterranean habitat (burrows) that improves habitat quality for reptiles and invertebrates (Miskelly 1999, 2010; Mulder and Keall 2001; Markwell and Daugherty 2002; Jones 2010). Mana Island has also had a role in the development of seabird translocation techniques that have been applied to rarer petrel (Procellariidae) species elsewhere (Miskelly and Taylor 2004; Miskelly et al. 2009; Gummer 2013; Gummer et al. 2014).

Seabird restoration efforts began with the installation of a solar-powered call-broadcasting system at Shearwater Point in April 1993, along with 50 short 'starter' burrows dug around the two loud speakers. The sound system was designed to broadcast calls through the hours of darkness, and played calls of fluttering shearwaters (pakahā), common diving petrel (kuaka), fairy prion (tītī wainui) and white-faced storm petrel (takahikare) (Miskelly 1999; Miskelly and Taylor 2004). After 4 years with no evidence of petrels visiting the site, approval was granted for translocations of diving petrel chicks to Mana Island. Chicks from Ngā Motu / Sugar Loaf Islands (Taranaki) and North Brother Island (Marlborough Sounds) were placed in artificial burrows and hand-fed until they fledged, in the hope that their homing mechanism could be reset from their source colonies to Mana Island (Miskelly and Taylor 2004; Miskelly et al. 2009). Diving petrels were chosen as the initial species to translocate, as they have a quicker life-cycle than other petrels, and so would provide more rapid feedback on whether the translocation technique worked (Miskelly and Taylor 2004; Miskelly et al. 2009). Subsequent monitoring of the Mana Island colony has revealed that some diving petrels breed when only a year old (Miskelly and Taylor 2007, 2023), although most birds breed when 2 or 3 years old.

Ironically, two adult diving petrels were caught at the restoration site shortly before the first chick translocation in November 1997 (Miskelly and Taylor 2004), revealing that call attraction alone may have been sufficient to attract diving petrels to Mana Island. By 2003, 51 unbanded 'immigrants' had been recorded at the site, along with 20 of the translocated chicks that had returned as adults, and five locally-reared birds (Miskelly and Taylor 2004). By 2022, 141 unbanded adults (and 43 locally-reared birds) had been handled at the colony, although some of the unbanded birds are likely to have been locally-reared chicks from unmonitored burrows on Mana Island (Miskelly and Taylor accepted ms; Fig. 19A). Diving petrels breed at multiple sites on Mana Island, many of which are on steep slopes and are difficult to access (Miskelly and Taylor 2004; Miskelly et al. 2004). Fifteen to 20 breeding pairs near Shearwater

Point are monitored each year, with 202 chicks fledging from monitored burrows between 1999 and 2021 (Table 6).

The initial fairy prion translocation to Mana Island (2002–04) was one of the few seabird translocation projects where effort was made to search for birds that returned to the source colony (Takapourewa / Stephens Island, 80 km away). Fifty nights of searching over 5 years revealed 25 chicks at the source colony, compared to 20 that recruited to Mana Island (Miskelly and Gummer 2013). Unlike the diving petrels, relatively few unbanded prions have been detected on Mana Island (17 unbanded birds between 2004 and 2022; author, unpubl. data). As there were at least two burrows with inaccessible nest chambers for much of this time, it is likely that some of these unbanded birds were reared on Mana Island.

Although translocated fairy prions returned to Mana Island and bred (Table 6), there were only 5–6 pairs at the colony before a supplementary translocation of 200 further chicks in 2015 & 2016 (Table 4). At least 13 of the 2015–16 translocated chicks had returned to Mana Island by 2022, and at least 13 eggs were laid in both October 2021 and October 2022 (Fig. 19B). Unfortunately, extreme rain events around the time that eggs hatched in 2020, 2021, and 2022 drowned several young fairy prion chicks in their burrows, and reduced the colony's output (Table 6).

The most successful petrel translocation to Mana Island was fluttering shearwaters from Long Island, Queen Charlotte Sound, in 2006–08 (Gummer and Adams 2010). At least 63 of the 211 chicks that fledged in good condition returned to the colony as adults (Gummer and Adams 2010; Helen Gummer pers. comm., October 2022; Fig. 19C), and at least 255 locally-reared chicks had fledged from Mana Island by 2022 (Table 6).

The first three of the 246 white-faced storm petrel chicks translocated from Rangatira Island, Chatham Islands, to Mana Island in 2019–21 (Mitchell and McKoy 2021) were recorded back on Mana Island in October 2022 (author, pers. obs.).

Although less successful than the petrel chick translocations, efforts to attract Australasian gannets (tākapu, *Morus serrator*) to Mana Island using concrete decoys and broadcast calls have attracted far more media attention (Cottle 1998; Hansford 2005; Joseph 2018; Fallon 2022). A potential colony site on the western cliff-top was cleared of vegetation in 1997, painted white to simulate guano, and 100 concrete gannet decoys deployed (Cottle 1998; Miskelly 2010). Two birds landed among the decoys on the day they were installed in December 1997 (Cottle 1998), and one bird was seen there at night in March 1998 (Miskelly 2010). An acoustic attraction system was installed in 1999; however, there were no subsequent sightings of live birds until 62 decoys and the acoustic attraction system were moved to the north-eastern headland of Mana Island in November 2012. Gannets have visited this second site sporadically since then, including one male regularly present for about 2 years before he was found dead among the decoys in January 2018 (Joseph 2018; Fallon 2022). The most recent report

Figure 19. The three translocated petrel species that have returned and bred on Mana Island. **A.** Common diving petrel (11 year-old, Mana Island reared). **B.** Fairy prion (7 year-old, translocated as a chick). **C.** Fluttering shearwater (first banded as adult on Mana Island, October 2021). All images are of breeding birds in artificial burrows and were taken on Mana Island in October 2022 by Annemieke Hendriks.

Table 6. Fledgling output for three translocated petrel species on Mana Island. Figures are incomplete for the first two species as many diving petrel breeding burrows and 1–2 fairy prion breeding burrows were not able to be monitored. * = chick translocations also occurred in the same year (see Table 4). Most of the fluttering shearwater monitoring was undertaken by Helen Gummer (pers. comm., October 2022).

Year	Diving petrel	Fairy prion	Fluttering shearwater
1997–98	Translocated	-	-
1998–99	Translocated	-	-
1999–00	*1	-	-
2000–01	5	-	-
2001–02	7	Translocated	-
2002–03	14	Translocated	-
2003–04	7	Translocated	-
2004–05	11	-	-
2005–06	4	1	Translocated
2006–07	7	0	Translocated
2007–08	9	1	Translocated
2008–09	7	2	-
2009–10	5	0	-
2010–11	5	2	1
2011–12	8	4	7
2012–13	9	1	14
2013–14	9	1	13
2014–15	8	*5	20
2015–16	13	*4	25
2016–17	7	2	13
2017–18	12	3	25
2018–19	12	4	28
2019–20	14	4	36
2020–21	14	6	33
2021–22	14	9	40
Total	202	49	255

was two birds at night on 27 November 2020 (Shirtliff 2021). While gannets have gathered nesting material, and up to four have been seen among the decoys at a time (Joseph 2018), no pairs have occupied nest sites or laid.

Natural colonisations of seabirds and land birds – 1994 to 2021

Several native bird species have colonised Mana Island naturally in the last 30 years, although not all the colonisations can be attributed to habitat changes resulting from mouse eradication and the revegetation programme.

Pied shags (kāruhiruhi, *Phalacrocorax varius*) were rare in the Wellington region before they started breeding at Makara Beach in 1996 (Reese et al. 1996). Single birds were seen on Mana Island on 21 April 1994 and 28 September 2000 (author, pers. obs.) before they started roosting on the island regularly in 2005, with up to 14 at a time in macrocarpas (*Cupressus macrocarpa*) just north of the boatshed (Colin Miskelly in Powlesland et al. 2008). Breeding was first reported at this site in April 2010 (Sue Caldwell in Miskelly 2010). The original breeding trees were blown over by strong southerly winds in 2013, and the colony shifted to a stand of macrocarpas south of Landing Bay in 2014, where they continue to breed.

Diving petrels colonised Mana Island naturally around the time that they were translocated to the island. Thirteen burrows were discovered about 0.6 km south-west of the trig (and 1.1 km north-east of the artificial colony) in 2004 (Miskelly et al. 2004). All 22 adults handled at the northern colony were unbanded, indicating that this population had established independently of the translocation of diving petrel chicks to Mana Island 5–7 years earlier (Miskelly and Taylor 2004; Miskelly et al. 2004).

Single white-faced storm petrels were found at night at Shearwater Point on 2 November 2000 and 20 September 2001, and an unbanded pair were found on an egg in an artificial burrow there on 4 November 2013 (author, pers. obs.). This pair successfully fledged a chick; however, the burrow was taken over by fairy prions the following year. An unbanded white-faced storm petrel was calling from a natural burrow on 20 September 2019; it was in the same burrow by itself on 29 October 2019 and 22 October 2020, but was not seen subsequently (author, pers. obs.).

Tūī occasionally visited Mana Island to feed on flax nectar in the early 1990s. The first records were a single bird seen on 10 & 20 January 1990, and two birds on 25 January 1990 (Trevor Hook and Phil Todd pers. comms, October 2022). Sightings became more frequent in the early 2000s, and breeding was confirmed in 2009–10 (fledglings being fed; Frank Higgott in Miskelly 2010). Tūī are now abundant on Mana Island (see below).

Kererū (New Zealand pigeon, *Hemiphaga novaeseelandiae*) and New Zealand falcon have visited Mana Island occasionally since at least 1994 (Miskelly 1999 and pers. obs.), with both species seen more frequently in recent years (Figs 17, 20). While there is no evidence that either has bred successfully on Mana Island, a pair of kereru were seen display diving (a courtship display) c. October 2022 (Patrick Elliott, pers. comm.). Other notable records included six kererū on 10 April 2016 (Grant Timlin, pers. comm.) and four on 20 February 2020 (Cathy Mitchell in eBird).

Ruru (morepork, *Ninox novaeseelandiae*) are reported most years and may be resident, although there are no records of more than one bird being present at a time. The first record was one in June 1990 (Trevor Hook pers. comm., October 2022). Other notable endemic land bird records include a long-tailed cuckoo (koekoea, *Eudynamis taitensis*) in March 1998 and December 2008 (Grant Timlin in Miskelly 1999; eBird), three reports of a red-crowned parakeet (kākāriki, *Cyanoramphus novaezelandiae*) in October–November 2018 (eBird), and a kākā (*Nestor meridionalis*) on 25 & 26 October 2021 (author, pers. obs.). A *Cyanoramphus* parakeet seen on Mana Island in November 2003 (6 months before yellow-crowned parakeets were released there) was most likely a red-crowned parakeet from Kapiti Island (see Miskelly et al. 2005). A hybrid parakeet (morphologically closest to red-crowned) was consorting with a yellow-crowned parakeet at Shearwater Point on 25 October 2022 (Fig. 21; Annemieke Hendriks pers. comm.).

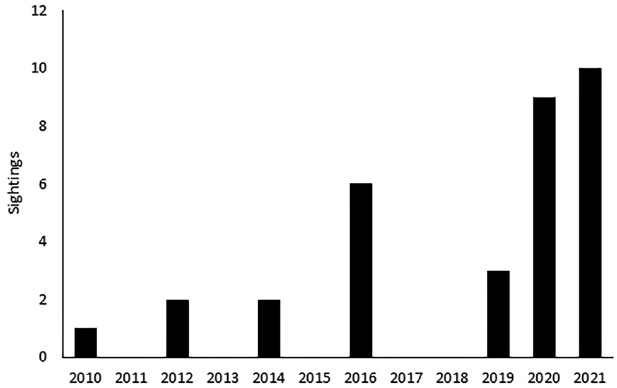

Figure 20. Kererū sightings on Mana Island, 2010–2021. Data from eBird (most sightings contributed by Dallas Bishop and Geoff de Lisle).

Changes in the land bird community 1972–2022

The Mana Island land bird community has changed considerably since the DSIR survey team visited the island in 1972 and 1975 (Table 7). Introduced passerines characteristic of open grassland dominated the community until at least 1993 (Miskelly et al. 2022a). In the three decades since then, sufficient forest has established for five endemic forest bird species to be successfully translocated to Mana Island (Table 4), and for tūī to colonise and become abundant. The four bird species recorded most often on Mana Island during 2020–22 were all absent from Mana Island as breeding species before 2009 (Fig. 22; Table 7; Miskelly 2010; Miskelly et al. 2022a).

The establishment of forest has occurred over the same time period as the decline and loss of some open country bird species on Mana Island. New Zealand pipits (pihoihoi, *Anthus novaeseelandiae*) were commonly recorded on Mana Island up to 1993 (Miskelly et al. 2022a); there have been only three records of pipits recorded in eBird since then. However, the disappearance of Australian magpies (*Gymnorhina tibicen*) from Mana Island can be attributed to resident and colonising birds being shot (Miskelly 1999). Some forest-dwelling bird species have also declined. Grey warblers (riroriro, *Gerygone igata*) have become very rare on Mana Island since whiteheads and bellbirds were introduced (author, unpublished data). Shining cuckoos (pīpīwharauroa, *Chrysococcyx lucidus*) are dependent on grey warblers as brood-hosts, and are also much scarcer on Mana Island than they were in the 1990s (author, pers. obs.).

Lizard recovery and translocations – 1993 to 2021

Recovery of lizard populations was detected and reported within 4 years of the 1989–90 mouse eradication. Five lizard species were known from the island before mice were eradicated, with three of them widespread and easily found before and after mouse eradication (Raukawa gecko, copper skink, and northern grass skink; see

Figure 21. Hybrid parakeet (predominantly red-crowned, but with a trace of yellow on hind crown), Mana Island, October 2022. Image: Annemieke Hendriks.

Table 7. Changes in the rankings of the seven most abundant land birds on Mana Island over nearly 80 years. The top seven species for each count period are listed, as this was the number of land bird species listed as 'Abundant' in 1972 & 1975 (without any rankings being given). The most frequently recorded species is listed first for each time period, apart from 1972 & 1975 (all species marked *), where no ranking or count results are available. Data from Wodzicki and Oliver (1944), Appendix 1 in Department of Lands & Survey (1981), Miskelly et al. (2022a), and author pers. obs. for 2020–22 data. Shading is used to emphasise native (lighter) and endemic (darker) species; introduced bird species have no shading. The 1972 & 1975 list was based on surveys in June 1972 and April 1975, and was published as a single combined dataset.

Jan 1944	1972 & 1975	Spring 1987–88	Spring 1991–93	Spring 2020–22
Starling	Starling*	Starling	Starling	Bellbird
Chaffinch	House sparrow*	Goldfinch	Skylark	Yellow-crowned parakeet
House sparrow	Blackbird*	Greenfinch	Goldfinch	Whitehead
Blackbird	Song thrush*	Skylark	Silvereye	Tūī
Australian magpie	Greenfinch*	Yellowhammer	Greenfinch	Starling
Skylark	NZ fantail*	Silvereye	NZ fantail	Swamp harrier
Song thrush	NZ pipit*	Dunnock	Chaffinch	Goldfinch

Fig. 23, and Table 8 for scientific names). Following the very successful survey for goldstripe geckos in February 1993, when a minimum of 112 individuals were found, Whitaker (1993) wrote "[it is likely] that they survived on Mana Island at very low densities, held at these levels by the combined effects of limited habitat during the years when the island was intensively farmed and predation pressure from house mice". Whitaker (1993) also reported that copper skinks had disappeared from inland areas on Mana Island since 1972, and attributed this to mouse

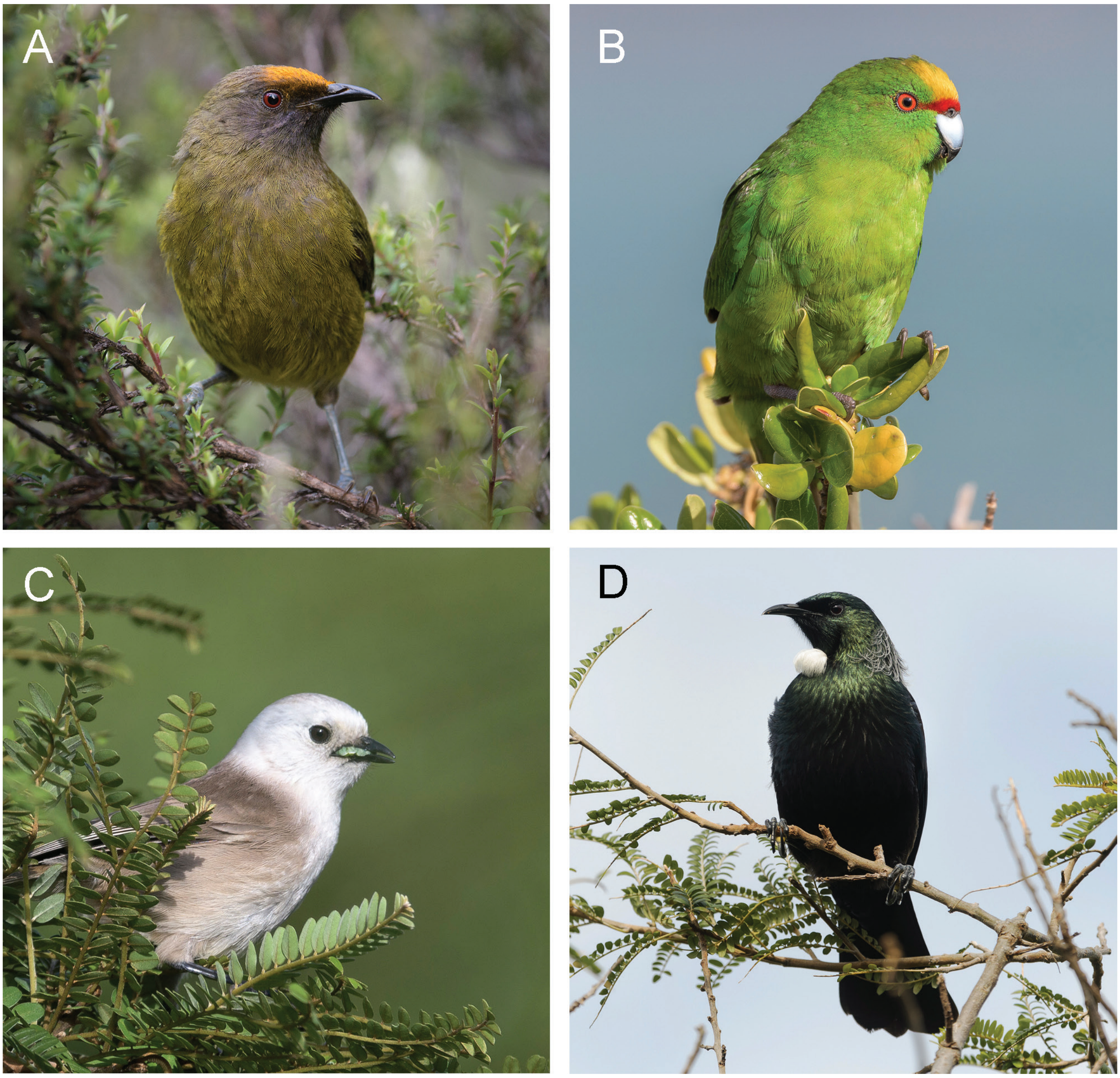

Figure 22. The four most commonly recorded bird species on Mana Island in 2020–22. **A.** Male bellbird with flax pollen on its forehead. **B.** Yellow-crowned parakeet. **C.** Whitehead. **D.** Tūī. All images taken on Mana Island, by Leon Berard.

predation. By 2018–22, copper skinks had recovered at inland sites and were very abundant (see below).

Catch rates for McGregor's skinks and Raukawa geckos increased significantly within 1–2 years of mouse eradication (Newman 1994). McGregor's skinks have expanded both their habitat use and range since then. Single animals were found under planted forest 150 m inland from the core population (and 85 m a.s.l.) on 10 July 2012 (author, pers. obs.), on the beach ridge south of Landing Bay on 10 April 2015 (Lynn Adams, pers. comm., September 2022), on the edge of planted forest 340 m inland from the core population (and 98 m a.s.l.) on 18 August 2017 (Jess Richardson, pers. comm., August 2022), and in the stream bed in upper Forest Valley (80 m a.s.l.) on 9 December 2017 (author, pers. obs.; Fig. 24). A population of McGregor's skinks was confirmed to have survived on the south-west coast in 2010, 38 years after Tony Whitaker had caught a single animal there (Adams and Caldwell 2012).

The most unexpected lizard response to mouse eradication was the discovery of a sixth 'natural' lizard species on Mana Island. It is assumed that glossy brown skinks (Fig. 25) were present on Mana Island at undetectably low levels when mice were present, and that they have recovered naturally since mice were eradicated (Miskelly 1999). The first glossy brown skink was caught by Alan Tennyson at the mouth of Astons Valley on 17 April 1996 (author, pers. obs.). Within a year of discovery, there had been at least ten records at several sites spread over a large area of the island's interior (Miskelly 1999; ARDS). Glossy brown skinks comprised 8.7% of 1,711 skink captures in pitfall traps set underneath 80 flax bushes in the central plateau during 2018–22, with the remainder comprised of copper skinks (60.5%) and northern grass

Figure 23. The three widespread and abundant lizard species on Mana Island. **A.** Raukawa gecko. **B.** Copper skink. **C.** Northern grass skink (striped morph). **D.** Northern grass skink (dark morph). All images taken on Mana Island by Tony Whitaker (gifted by Vivienne Whitaker, 2020, Te Papa O.050048, O.049858, O.049960 & O.049853).

Table 8. Name changes affecting Mana Island lizards since 1993 (as used in Mana Island publications).

Current names	Previous names	Status on Mana Island
Raukawa gecko *Woodworthia maculata*	Common gecko *Hoplodactylus maculatus*	Natural, abundant
Goldstripe gecko *Woodworthia chrysosiretica*	*Hoplodactylus chrysosireticus*	Natural, formerly scarce
Copper skink *Oligosoma aeneum*	*Cyclodina aenea*	Natural, abundant
McGregor's skink *Oligosoma macgregori*	*Cyclodina macgregori*	Natural, formerly scarce
Northern grass skink *Oligosoma polychroma*	Common skink *Leiolopisma nigriplantare polychroma*	Natural, abundant
Glossy brown skink *Oligosoma zelandicum*	Brown skink	Natural (discovered 1996)
Tohu's gecko *Hoplodactylus tohu*	Duvaucel's gecko *Hoplodactylus duvaucelii*	Translocated 1998
Northern spotted skink *Oligosoma kokowai*	Spotted skink *Oligosoma lineoocellatum*	Translocated 1998
Barking gecko *Naultinus punctatus*	Wellington green gecko *Naultinus elegans punctatus*	Translocated 1998–2021
Newman's speckled skink *Oligosoma newmani*	Speckled skink *Oligosoma infrapunctatum*	Translocated 2004
Ngāhere gecko *Mokopirirakau* sp.	Southern North Island forest gecko, forest gecko *Hoplodactylus granulatus*	Translocated 2015–18

skinks (30.8%) (data from Will Brockelsby pers. comm., August 2022, and author, pers. obs.).

The successful mouse eradication on Mana Island created 217 ha of diverse habitat that was free of mammalian predators, and therefore suitable for restoration of a diverse reptile community (Miskelly 1999, 2010; Flannagan et al. 1999; Bell and Herbert 2017; Flynn-Plummer and Monks 2021; Yee et al. 2022). Five lizard species have been translocated to Mana Island since 1998, with variable outcomes (Table 9). Most of the species released are highly cryptic, and have low reproductive rates (Cree and Hare 2016; van Winkel et al. 2018). Low detection rates after release may be due to crypsis, low survival, low productivity, dispersal to contiguous habitat that is difficult to access and search (and with initial low density of the target species), or a combination of these factors. It is therefore difficult to determine whether a lizard translocation has failed until many years after translocation. In contrast, a species that stays near the release site with good survival rates of released animals and their offspring, and that can be readily detected by searching or trapping, can be confidently assessed as having been successfully translocated.

Two of the lizard species released on Mana Island are considered to be well-established (Table 9). Tohu's geckos (Fig. 26A) mainly stayed near the release site, and had good survivorship, weight gain, and productivity (Bell and Herbert 2017). Although they remained

Table 9. Summary of reptile and insect translocations to Mana Island.

Species	Year	No.	Source	Outcome	References
Tohu's gecko	1998	40	North Brother Island	Successful	Flannagan 2000; Jones 2000; Bell and Herbert 2017
Northern spotted skink	1998	50	Matiu / Somes Island	Successful	Griffiths 1999; Miskelly 2010
Barking gecko	1998–2005	48	Wellington (salvage + captive)	Failed?	Miskelly 1999, 2010; Flynn-Plummer and Monks 2021
Newman's speckled skink	2004	49	Takapourewa / Stephens Island	Unknown	Miskelly 2010; Adams and Caldwell 2012
Flax weevil	2004 & 2006	150	Maud Island / Te Pākeka	Successful	Miskelly 2010; Brockelsby 2022
Hutton's speargrass weevil	2006–07	40	Wellington south coast	Successful	Miskelly and Hamilton 2022
Barking gecko	2014–21	63	Wellington (captive + salvage)	Unknown	Flynn-Plummer and Monks 2021; Hendriks and Florence-Bennett 2021
Ngahere gecko	2015–18	49	Belmont (salvage)	Unknown	Yee et al. 2022

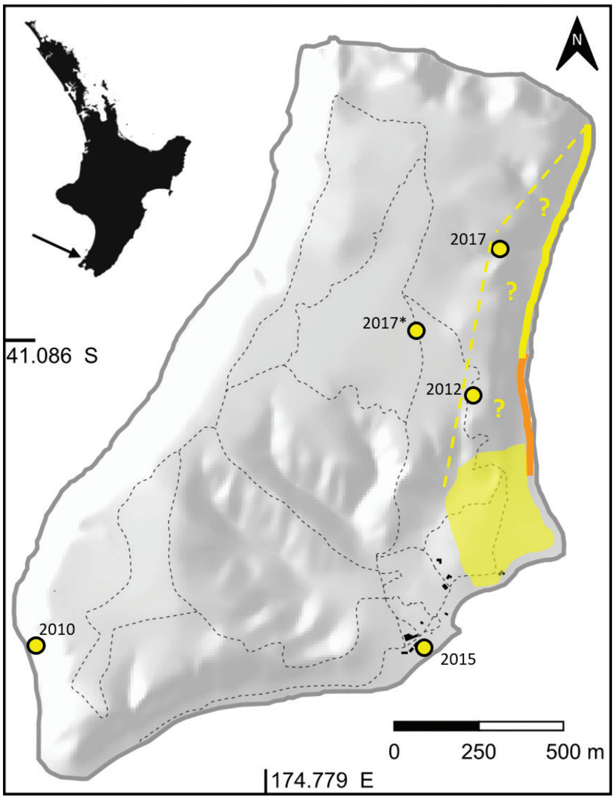

Figure 24. McGregor's skink distribution on Mana Island. Dated records author pers. obs., apart from '2010' (Adams and Caldwell 2012), '2015' (Adams 2015), and '2017*' (Jess Richardson, pers. comm., August 2022). Orange = core distribution 1990, yellow = core distribution 2020. Question marks show unsurveyed coastal slopes, and the dashed line shows the presumed extent of the current core distribution.

Figure 25. Glossy brown skink, Mana Island. Image: Annemieke Hendriks.

confined to a small part of the island, they were readily detected near the release site more than 20 years later. Northern spotted skinks (Fig. 26B) were the focus of an MSc study during and soon after their release (Griffiths 1999). Since then, I have conducted brief searches for them most years, and have found them along 750 m of shoreline south of Landing Bay, centred on their release site. They have become more difficult to find over time, as the shoreline vegetation has become dense and tangled with vines. There is no evidence of spotted skinks moving away from the shore platform; however, the scarp above the southeast shoreline is difficult to access and search.

Newman's speckled skinks (Fig. 26C) were regularly detected at their release site in lower Weta Valley for about 7 years after their release in 2004, with locally bred juveniles found in September 2005 and February 2008 (the latter on Tony Whitaker's final visit to Mana Island; Miskelly 2010, and pers. obs.). Trapping at the release site since 2019 has failed to detect any speckled skinks. However, one was photographed by Richard Grasse 200 m further up Weta Valley on 6 October 2019, revealing that some animals have moved away from the release site.

The January–February 2008 lizard survey led by Tony Whitaker failed to find any of the barking geckos (or their offspring) released during 1998–2005. A second series of releases beginning in 2014 included use of temporary pens around the release sites (in 2019 & 2020), to discourage the animals from dispersing ('soft-release' *sensu* Flynn-Plummer and Monks 2021). Geckos were monitored for 2 weeks after the first pen was removed on 2 February 2019, with 16 of 19 animals detected (Flynn-Plummer and Monks 2021). The last sighting from this release was on 18 August 2019 (Hendriks and Florence-Bennett 2021; Fig. 26D). A second pen (containing 20 geckos) was removed on 11 April 2020. The last sighting from this release was on 22 October 2020 (Cooper French and Colin Miskelly in Hendriks and Florence-Bennett 2021). A further 17 barking geckos were hard-released nearby in November 2021 (Dale Shirtliff pers. comm., November 2022).

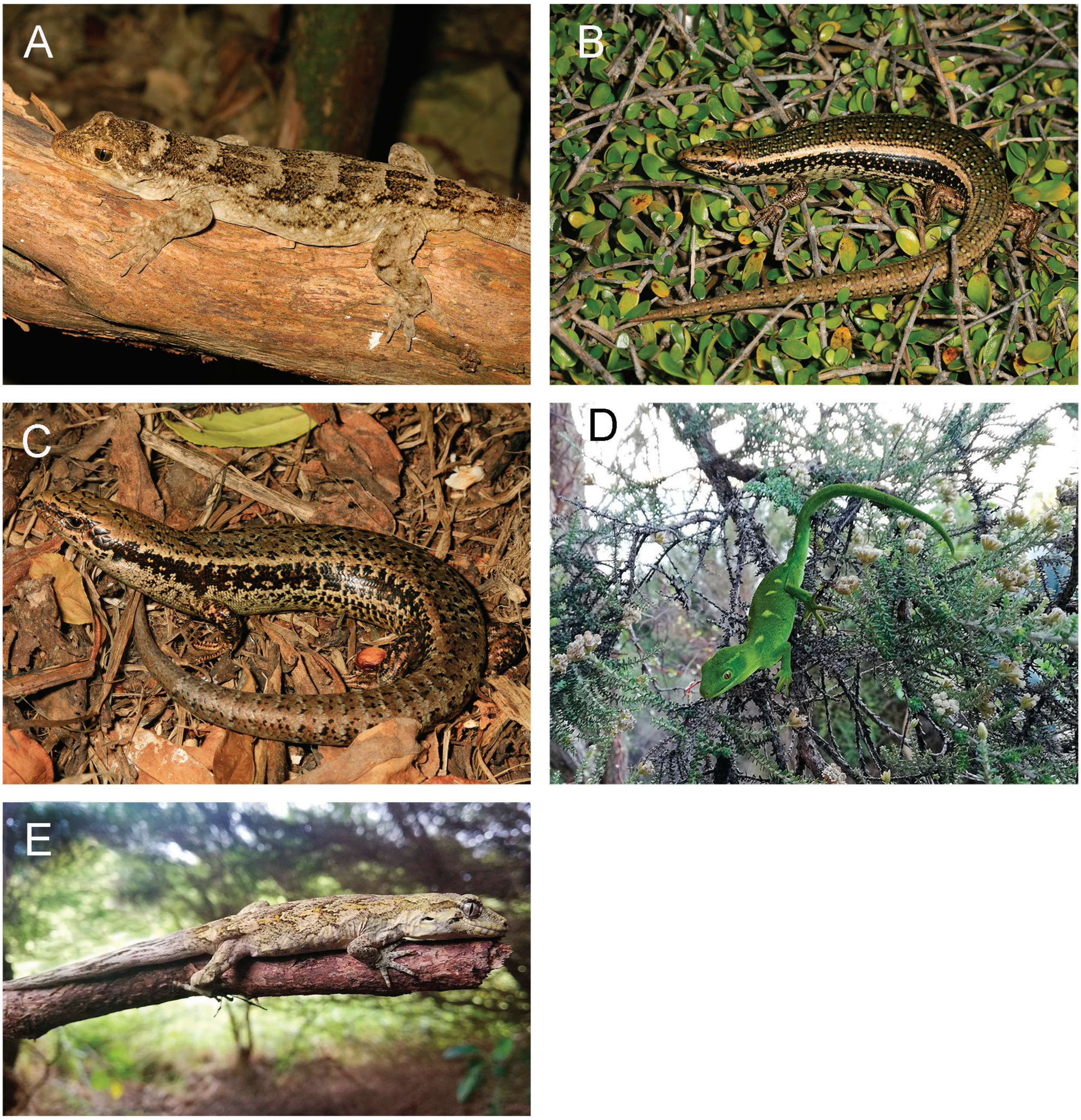

Figure 26. The five lizard species translocated to Mana Island (all images taken on Mana Island). **A.** Tohu's gecko. **B.** Northern spotted skink. **C.** Newman's speckled skink. **D.** Barking gecko. E. Ngāhere gecko. Images **A–C**: Tony Whitaker (gifted by Vivienne Whitaker, 2020, Te Papa O.050049, O.050050 & O.050051); images **D** & **E**: Annemieke Hendriks.

A similar soft-release methodology was used for 36 of 49 ngāhere geckos (Fig. 26E) salvaged from a quarry expansion site at Belmont, Hutt Valley, and translocated to Mana Island 2015–18, with the remaining 13 animals released directly (Yee et al. 2022). The penned animals were constrained for 10–31 months before the pen was removed in January 2018. During the first 4–52 days after release (or pen removal), the animals that were released directly travelled further and had larger home ranges than the penned geckos (Yee et al. 2022). Long-term persistence and population growth of ngāhere geckos on Mana Island has not yet been demonstrated, but initial signs are encouraging, including sightings of locally-bred animals (Yee et al. 2022; Annemieke Hendriks pers. comm., October 2022).

Lizards in general, and Raukawa geckos in particular, are hugely abundant on Mana Island (Hare and Hoare 2005; Fig. 27). Little is known about the role of lizards in Mana Island foodwebs and ecosystem processes, with the exception of a study of frugivory and seed dispersal by Raukawa geckos (Wotton 2000, 2002). Geckos were found to be the major dispersers of *Coprosma propinqua* fruit; 40% of gecko droppings contained seeds, more than 95% of which were from *C. propinqua* (Wotton 2002). Other species (seeds) identified in the droppings were *Muehlenbeckia complexa* and inkweed (*Phytolacca octandra*). Lizards were estimated to consume 47–93% of *C. propinqua* fruit (it was not possible to separate the roles of geckos and skinks in fruit consumption). Raukawa

Figure 27. An aggregation of Raukawa geckos on Mana Island, October 2018. Image: Colin Miskelly.

geckos transported *C. propinqua* seeds up to at least 9.3 m from source plants, and typically deposited seeds in suitable germination sites under rocks. Wotton (2002) concluded that fruit was an important component of Raukawa gecko diet, and that they provided effective seed dispersal for *C. propinqua* (Fig. 14).

Weevil translocations – 2004 to 2007

Two large, flightless weevil species were translocated to Mana Island as part of the ecological restoration programme: flax weevil (*Anagotus fairburni*) in 2004 & 2006, and Hutton's speargrass weevil (*Lyperobius huttoni*) in 2006–07 (Table 9). Both species are fully protected under the Wildlife Act 1953, and both are essentially monophagous, feeding only on *Phormium* spp and *Aciphylla squarrosa* respectively, with adults browsing on foliage and stems, and larvae tunnelling into the roots (Meads 1990; Miskelly 2014). Both weevil species are considered to be threatened or locally extirpated by rodent predation on the mainland (Meads 1990; Miskelly et al. 2018).

The two weevil species have followed very different population trajectories since their releases on Mana Island.

Flax weevils (Fig. 28) were released near Shearwater Point, with the nocturnally-active adult weevils readily detectable from the outset (author, pers. obs.). Flax weevils were first noted to be causing deaths of "some"

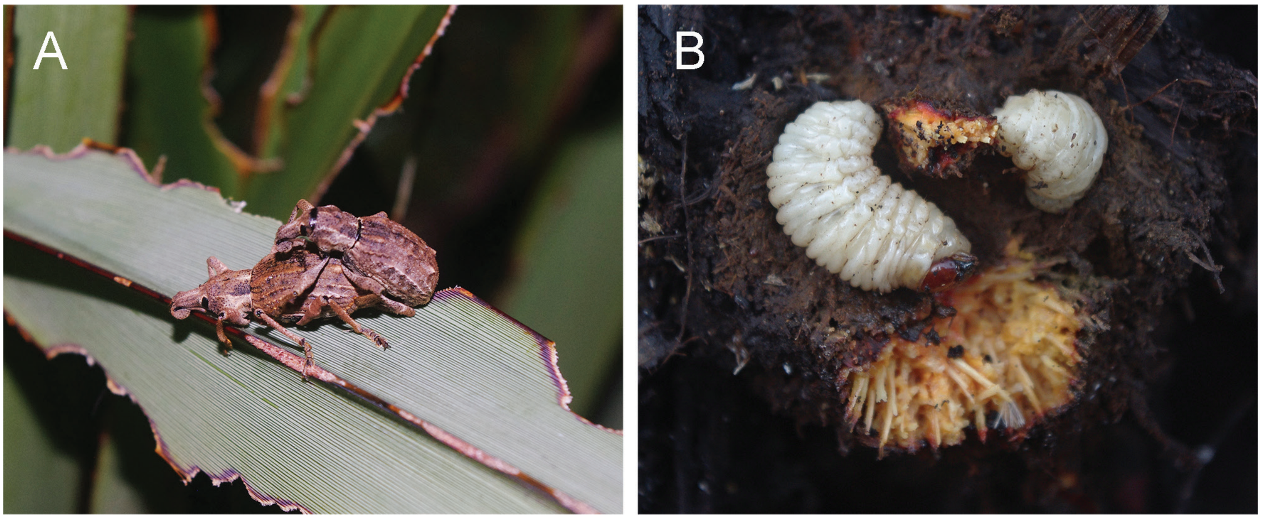

Figure 28. Flax weevils on Mana Island. **A.** Mating adults (note browsed leaves). **B.** Larvae in their tunnels inside a flax rhizome. Images: Colin Miskelly.

Figure 29. Flax weevils on an unopened flax flower stalk on Mana Island. Image: Colin Miskelly.

host plants in 2012 (Adams and Caldwell 2012), and Miskelly (2013) raised concerns about the super-abundance of flax weevils near the release site in a Te Papa blog "A plague of flax weevils – a conservation hyper-success story" (Fig. 29). Flax weevils have spread across Mana Island's plateau at a rate of about 50 m per annum (Miskelly 2017, and pers. obs.). At well-drained sites, nearly all adult flaxes (*P. tenax*, *P. cookianum*, and hybrids between them) have typically collapsed and died within 2 years of weevil browse being evident (Fig. 30). As most plants still have substantial foliage when they collapse, their death is presumed to be due to root damage caused by flax weevil larvae tunnelling through and eating the rhizomes (Miskelly 2017; Brockelsby 2022).

These observations led to two parallel investigations of the cause of flax weevil over-abundance on Mana Island.

Flax seeds were collected on Maud Island / Te Pākeka (where the flax weevils were sourced from) in January 2015, and raised on Mana for planting out in paired trials with Mana-sourced flaxes, to determine whether flax resistance to weevil damage differed in relation to whether the parent plants had been exposed to flax weevil presence. The plots were established in June 2017, with a total of 200 flax plants (100 plants from each source; Miskelly 2017). Young flax plants from Maud and Mana Islands proved to be equally (highly) susceptible to weevil damage; by October 2022 only a single healthy (Mana-sourced) plant survived (author, unpublished data).

The second line of investigation was whether a natural control agent had inadvertently been left behind on Maud Island when the 150 adult weevils were translocated to Mana Island. Many large weevil species globally are controlled in their natural environments by entomopathogenic fungi, and such fungi are widely used in control of weevil crop pests (Richard Bull pers. comm., January 2014; Glare and Brookes 2017). Based on this information (and with DOC permission), I visited Maud Island in August 2017 to search for dead or dying flax weevil larvae. One moribund larva was found and sent to the Bio-Protection Research Centre, Lincoln. It subsequently died of a fungal infection, with the causative agent identified as a novel strain of *Beauveria pseudobassiana* (Glare and Brookes 2017). Members of the genus *Beauveria* (family Cordycipiaceae) are obligate entomopathogenic fungi related to vegetable caterpillar fungi.

Soil samples and flax weevil larvae collected from Mana Island in October 2017 revealed *Beauveria* spores to already be present on Mana Island. Spores were abundant near where the flax weevils had been released (and where most flax plants had died); however, spores were scarce or absent in parts of the island not yet reached by the weevils (Glare and Brookes 2017). Laboratory exposure of both adult and larval flax weevils to the strain

Figure 30. Flax plants at the experimental study plot on Mana Island before and after 20 adult weevils were released on each plant in March 2020 (both views from the same photo-point). **A.** October 2018. **B.** October 2022. Images: Colin Miskelly.

Figure 31. Deceased adult flax weevil infected with *Beauveria pseudobassiana*, Mana Island. Image: Will Brockelsby.

of *B. pseudobassiana* discovered on Maud and Mana Islands caused high mortality rates in both life stages (Fig. 31; Glare and Brookes 2017).

The distribution of *B. pseudobassiana* on Mana Island indicated that the spores had been unknowingly introduced with the weevils, and were spread by the flightless weevils as they radiated out from the release site. It is hypothesised that spore densities were too low at newly-invaded plants (at the edge of the flax weevil distribution) to protect their roots from the initial cohort of larvae (Brockelsby 2022). In August 2018, an experimental plot of 80 mature flax plants was established in the centre of the island (ahead of the dispersing flax weevils), and invertebrate and reptile communities at the site were monitored through pitfall trapping and nocturnal spotlighting surveys (Brockelsby 2022). In March 2020, half the plants were treated with a solution containing *Beauveria* spores, and 20 adult weevils were introduced to each plant (1600 weevils in total). Unfortunately, the *Beauveria* treatment was insufficient to prevent high mortality of treated flaxes, with Brockelsby (2022) suggesting that the spore concentration used may not have been high enough. Partial recovery of flaxes near the flax weevil release site since 2020 (author, pers. obs.) fits the hypothesis that the presence of *B. pseudobassiana* spores at high density reduces mortality of *Phormium* species, presumably by causing high mortality of flax weevil larvae.

Figure 32. Hutton's speargrass weevil on Mana Island. Image: Colin Miskelly.

In contrast to the flax weevils, few speargrass weevils have been seen since they were released on Mana Island in 2006–07. Although their characteristic feeding sign is occasionally noticed, only ten adult speargrass weevils were reported from Mana Island between 2012 and 2020 (Fig. 32; Miskelly and Hamilton 2022). A targeted survey in February 2021 found three speargrass weevils, with feeding sign evident on 130 speargrass plants spread over 1 km, and centred on the release site (Fig. 33; Miskelly and Hamilton 2022). As speargrass weevils may be impacted by the 'flax weevil' strain of *B. pseudobassiana*, survey participants also measured the distance between browsed speargrass plants and the nearest flax plant, so that any future changes in speargrass weevil distribution can be assessed in relation to their potential exposure to *Beauveria* (Miskelly and Hamilton 2022).

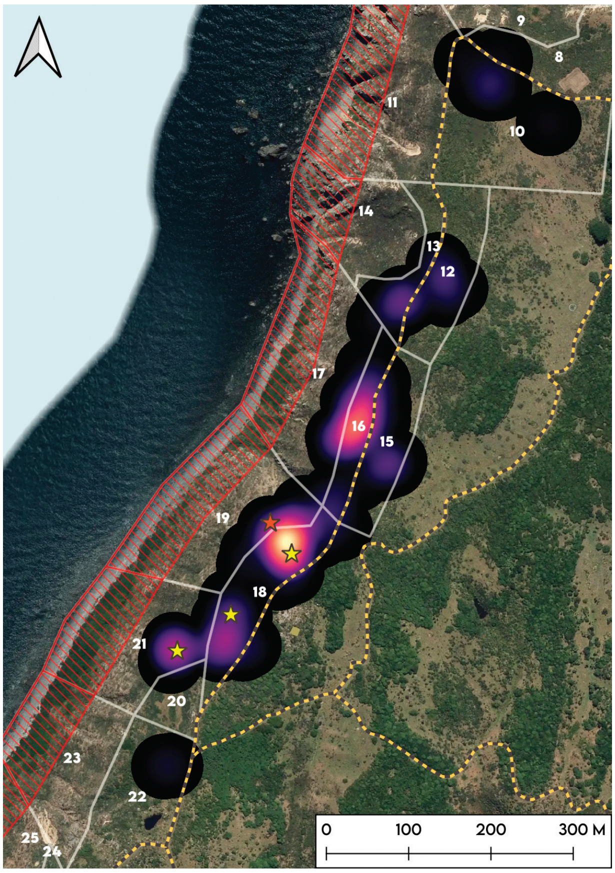

Figure 33. Heat map of speargrass weevil browse sign on Mana Island in February 2021. Brighter colours show areas with high densities of speargrass weevil browsing sign, with black showing low density of browse sign (areas outside the black areas had no browse sign detected). Red star = speargrass weevil release site, yellow stars = sites where adult speargrass weevils were found in February 2021. Red hatched areas (lower slopes) had low speargrass densities and were not surveyed. Image reproduced from Miskelly and Hamilton (2022).

Fauna translocations off Mana – 1977 to 2012

Four bird species and two insect species have been translocated off Mana Island since the initial giant weta translocation in 1977 (Table 5). The weta translocations have proven to be the most successful, with Cook Strait giant weta originally sourced from Mana Island now present at seven other sites (Table 5).

Ngāti Toa Rangatira claims settlement – 2014 to 2024

The Ngati Toa Rangatira Claims Settlement Act 2014 came into force on 23 April 2014. As part of the settlement of historical claims, the Act prescribed a series of land transactions required to be completed by 31 December 2024. These include revocation of Mana Island Scientific Reserve status with regard to 4.33 ha at Landing Bay, vesting of this portion of the island as fee simple estate in the trustee of the Toa Rangatira Trust, and re-classification of this area as Te Mana a Kupe Scientific Reserve, to be administered, controlled, and managed by the Crown. The Act further requires that the balance of Mana Island (212.46 ha) be vested in the trustee of the Toa Rangatira Trust for a period of 10 days before being gifted back to the Crown for the people of New Zealand. When completed, these transactions will result in Mana Island being managed by DOC in its entirety as two complementary scientific reserves, with the 4.33 ha Te Mana a Kupe Scientific Reserve owned by Ngāti Toa Rangatira. As part of the settlement, the Crown will offer Statutory Acknowledgements and Deeds of Recognition to Ngāti Toa Rangatira in relation to the balance of Mana Island.

Discussion

Tony Whitaker's contribution to the ecological restoration of Mana Island

Whitaker spent a total of 21 days on Mana Island. Despite his limited time on the island, he had a profound influence on the island's history and management, and also our knowledge of lizard presence and status on the island and how they have changed over time. Whitaker's discovery of McGregor's skinks and goldstripe geckos on Mana Island in 1972 greatly increased conservationists' awareness of the conservation values of the island, as this tripled the number of threatened animal species known from the island (Cook Strait giant weta were already known to be present; Salmon 1950). The 1972 DSIR team also confirmed that mice were the only introduced mammals present, which greatly increased the restoration potential of the island compared to if rats or stoats (*Mustela erminea*) were present (Wellington Botanical Society 1984; Department of Lands & Survey 1986a). The presence of these three threatened fauna species, and the absence of rats, were among the strongest arguments for the island to be managed for conservation purposes, as opposed to the island continuing to be farmed (Department of Lands & Survey 1981, 1986a; Timmins et al. 1987a; Atkinson 1991).

Whitaker's documentation of McGregor's skinks being predominantly confined to the shore platform north of Shingle Point meant that conservationists were immediately aware of the likely impacts of a bulldozer being used to create a farm track along this section of coast in 1984 (Towns 1984; Newman 1994). This act of vandalism, and awareness of the skink's limited distribution, were the catalyst for Newman's (1993, 1994) 8-year study of McGregor's skink population dynamics on Mana Island. If Newman had not been monitoring the skink population during and following the removal of cattle, conservationists would have been unaware of the impacts of the burgeoning mouse population on McGregor's skinks (Hutton 1990). While it is likely that mouse eradication would eventually have been attempted on Mana Island, the sequence of events following Whitaker's lizard surveys in 1972 and 1975 led to lobbying for mouse eradication by Colin Ryder in 1989 (Hutton 1990; Newman 1994). The timely eradication of mice within 4 years of cattle being removed from Mana Island may have prevented local extinction of McGregor's skink, goldstripe gecko and Cook Strait giant weta, and undoubtedly contributed to their rapid recovery following mouse eradication (Whitaker 1993; Newman 1994). The goldstripe gecko survey led by Whitaker in February 1993 was the first study to document faunal recovery on Mana Island after mice were eradicated (see also Newman 1993, 1994).

Photographs taken by Whitaker in June 1972 fortuitously captured Mana Island at the very end of a century of stasis, as a crown-leased sheep farm. Donation of these images to Te Papa made the images accessible, and provided a framework to illustrate the dramatic social, economic and ecological changes on the island in the 50 years since Whitaker's first two visits.

Highlights of the Mana Island ecological restoration programme

At a macro level, the objectives of the Mana Island Ecological Restoration Plan have all been achieved (Miskelly 1999, 2010). The three flagship threatened animal species that naturally persisted on the island (Cook Strait giant weta, McGregor's skink and goldstripe gecko) have all become much more abundant (Whitaker 1993; Newman 1994; this review), more than half of Mana Island is covered in native forest or shrubland where it was grazed pasture 36 years ago, and the four land bird species that are seen or heard most often are all endemic forest-dwelling species that were absent from the island when the restoration plan was published 24 years ago.

There have been numerous highlights since the Mana Island ecological restoration programme commenced with the first tree plantings in 1987. The following list is a summary of nine significant highlights and successes, listed in roughly chronological sequence.

1. Community involvement

The ecological restoration programme on Mana Island has been a three-way partnership between the government (DOC), mana whenua (Ngāti Toa Rangatira), and the wider community, with thousands of individuals contributing their time and effort (Hansford 2005; Maysmor 2009: Galatowitsch 2012; Butler et al. 2014). Volunteer involvement began with vegetation and bird surveys, tree planting and mouse eradication, and evolved into species translocation effort (particularly hand-feeding of seabirds) and a diversity of ecological management and monitoring projects, as well as assisting DOC with management of infrastructure and recreational assets. In addition to providing labour, several community groups have organised projects, raised funds, and obtained statutory approvals, most notably Wellington Botanical Society, Forest & Bird, the Ornithological Society of New Zealand (now Birds New Zealand), and the Friends of Mana Island.

Beyond providing the human and financial resources to ensure that projects were adequately planned, approved and completed, the high level of community involvement over four decades has created an extensive network of people with a personal connection to Mana Island, and who are invested in the island's future.

2. Mouse eradication

The Mana Island mouse eradication was world-leading at the time, as the previous largest island to be cleared of mice anywhere in the world was only 50 ha (Ruscoe and Murphy 2005; Butler et al. 2014). It is likely that mouse eradication prevented at least two lizard species from becoming locally extinct, and five of the six resident lizard species plus Cook Strait giant weta have become more abundant since mice were eradicated (Whitaker 1993; Newman 1994; this review). In addition to allowing remnant fauna populations to recover, mouse eradication greatly increased the restoration potential of Mana Island, particularly for other lizard species and large invertebrates (Miskelly 1999, 2010).

3. Revegetation and natural vegetation recovery

The revegetation programme was an enormous undertaking, involving planning for, propagating, and planting close to half a million trees and shrubs over 30 years, by a huge team of people. The effort has transformed the landscape, with 79 ha of planted forest merging seamlessly with about 64 ha of remnant forest and naturally recovering shrubland (Ward 2016; Miskelly 2022), as illustrated by the paired 1972 and 2022 images presented in this review. The seral forest established is already providing habitat for bird and lizard species that were not present 30 years ago, as well as microhabitats where future canopy species can be planted or establish (Miskelly 2010; Ward 2016).

4. Takahē conservation

Mana Island is one of the most important sites outside Fiordland for takahē conservation (Ballance in press). Takahē were first introduced to Mana Island in September 1988, and by 2007 Mana Island held about 20% of the global population of the species, which had a threat ranking of Nationally Critical at the time (Miskelly et al. 2008; Miskelly 2010; Galatowitsch 2012). The Mana Island population is managed as part of a national metapopulation, and takahē raised on Mana Island have been translocated to at least fifteen other sites (Table 5). The number of takahē on Mana Island has declined from a high of 42 birds to about 8 pairs as the extent of grassland on Mana Island has reduced (Fig. 16; Ballance in press).

5. Natural recovery of lizard populations

Lizards occur at enormous densities on Mana Island (Whitaker 1993; Newman 1994; Hare and Hoare 2005; Fig. 27), providing an insight into what mainland ecosystems may have been like before the introduction of kiore (*Rattus exulans*) followed by other mammalian predators. All but one of the resident lizard species on Mana Island increased spectacularly after farm stock were removed and mice were eradicated, with the two most threatened species (goldstripe gecko and McGregor's skink) becoming much more abundant and readily detected (Whitaker 1993; Newman 1994). The discovery of a sixth naturally-occurring species (glossy brown skink) within 7 years of mouse eradication was an unexpected exemplar of how the Mana Island lizard community responded positively to removal of grazing and eradication of mice.

6. Seabird translocations

Mana Island was one of the pioneering sites for translocation of burrow-nesting petrels globally (Miskelly et al. 2009; Galatowitsch 2012; Butler et al. 2014). Although projects had commenced earlier at a few other sites, the young first-breeding age of common diving petrels meant that a successful outcome was apparent on Mana Island before results had been published from projects involving fluttering shearwaters and Gould's petrels (*Pterodroma leucoptera*) elsewhere (Miskelly and Taylor 2004; Bell et al. 2005; Priddel et al. 2006). Mana Island was also the first site where successful breeding by three species of translocated petrel species at a single locality was documented (Miskelly and Gummer 2013; Butler et al. 2014), and lessons learned on Mana Island were successfully applied to other, more threatened, petrel species (Miskelly et al. 2009; Gummer 2013).

7. Weed control

Boxthorn control has transformed Mana Island. Before control started, boxthorn was the predominant woody vegetation along much of the eastern and northern shorelines, forming an impenetrable thicket at sites now dominated by taupata, *Coprosma propinqua*, and kaikomako (Miskelly 2010). The weed control programme has also suppressed boneseed (*Chrysanthemoides monilifera*) and pink ragwort (*Senecio glastifolius*) to low levels. These two species dominate coastal shrublands and roadsides on the adjacent mainland. Due to this sustained effort over three decades, the shrublands and forests of Mana Island are almost entirely comprised of indigenous species, apart from a few large macrocarpas and Monterey pines (*Pinus radiata*) that are more than 70 years old (Timmins et al. 1987b).

8. Restoration of forest birds

Most of the forest bird species introduced to Mana Island have now become abundant there (particularly yellow-crowned parakeet, bellbird, and whitehead), and the self-colonised tūī is also abundant. These species are all dependent on the restored forest, and could not have established if this habitat had not been created. The bellbird translocation is particularly noteworthy, as they are one of the most difficult New Zealand bird species to translocate successfully (Miskelly and Powlesland 2013). Mana Island remains the only site where translocated bellbirds have established without supplementary feeding. Competition with tūī has been suggested as one of the reasons why bellbirds are difficult to establish at new sites (Miskelly and Powlesland 2013), and so it is perhaps fortuitous that tūī colonisation of Mana Island occurred around the same time that bellbirds were introduced, meaning that both species were at low densities initially.

9. Fernbird translocation

The fernbird population on Mana Island is derived from a single release of 40 birds. Within 3 years, fernbirds spread and bred rapidly, and unbanded (= locally-reared) birds are now numerous throughout *Coprosma propinqua* dominated shrublands in the island's interior.

Unanticipated outcomes, and projects that didn't deliver intended outcomes

In contrast to the numerous successes in the Mana Island ecological restoration programme, the following five projects failed to achieve their objectives, have yet to deliver intended outcomes, or have had unintended impacts on other species.

1. Attempts to attract Australasian gannets

Gannet decoys have been deployed at two consecutive sites on Mana Island for 25 years, with acoustic attraction used at the sites for 23 years (Miskelly 2010; Fallon 2022). Despite occasional gannets landing among the decoys, breeding has not yet occurred. However, the same methodology produced rapid results at two other sites in New Zealand (Young Nicks Head and Motuora Island: Sawyer and Fogle 2013; Butler et al. 2014). At Young Nicks Head, an estimated 200 gannets roosted among the decoys within 4 months, eggs were recorded after 16 months, and 11 chicks fledged the following breeding season, about 2.5 years after the decoys were deployed (Sawyer and Fogle 2013). This points to the importance of the location of the attraction site in relation to the extent that the immediate vicinity is used by gannets (and particularly subadults not yet attached to a breeding site). Gannet behaviour may change over time, and the costs of leaving the decoys and solar-powered sound system in place on Mana Island are minimal.

2. Waikōkō wetland

Construction of Waikōkō wetland was necessary to create habitat for the successful translocation of brown teal

(Bowker-Wright et al. 2012; Miskelly and Powlesland 2013). Gradual filling of the ponds with silt in the 24 years since the wetland was constructed has reduced the number of ponds that hold water year-round. While the impact of this on the brown teal population has not been assessed, ongoing management of the wetland will be required if open water is to be retained (Ward 2016).

3. Lizard translocations

While at least two of the lizard species translocated to Mana Island appear to have established successfully (Miskelly 2010; Bell and Herbert 2017), none of the five species translocated has yet become either widespread or conspicuous, and the original barking gecko translocation is considered to have failed (Romijn and Hartley 2016). The slow rate of establishment of the three gecko and two skink species introduced to Mana Island can partially be attributed to the low reproductive output of New Zealand lizards (Cree and Hare 2016). It is possible that competition from the extremely abundant Raukawa geckos, northern grass skinks, and copper skinks on Mana Island has restricted the rate that other lizard species have been able to establish and spread; however, this has not been investigated.

4. Shore plover releases

The two attempts to establish shore plover on Mana Island demonstrate how bad luck, or bad timing, can have a big influence in conservation outcomes when translocated or colonising populations are establishing. Shore plover appeared to be well-established on Mana Island by mid-2011, with 11 pairs present, and 11 chicks fledging during the 2010–11 breeding season (Collen and Gummer 2011). The only live rat ever reported from Mana Island was confirmed to be present in November 2011, although shore plover behaviour indicated that it may have been present since at least June 2011 (Gummer and Caldwell 2012). This single rat may have been present on Mana Island for less than 6 months before it was killed, yet it is considered the causal factor for shore plover abandoning the island for the adjacent mainland (Gummer and Caldwell 2012; Butler et al. 2014). Were it not for this unfortunate event, it is likely that there would have been a substantial population of locally-reared shore plover on Mana Island before falcons started visiting regularly from 2016 on (Fig. 17). Falcon predation of recently-released shore plover in August 2020 led to the second series of shore plover releases being abandoned (Collen et al. 2022).

5. Flax weevil translocation

The extreme impact of translocated flax weevils on their host plant on Mana Island was both unexpected and unprecedented. I have observed or reported flax weevils or their feeding sign on 93 islands between the Poor Knights Islands, Northland, and Preservation Inlet, Fiordland (Miskelly et al. 2018; pers. obs.). At all sites other than Mana Island, flax weevils had minimal impact on the host plants, and were typically difficult to detect. Flax weevils have been translocated to three islands other than Mana Island (Thomas et al. 1992; Brockelsby 2022), without any reports of excessive host-plant mortality at other sites.

High mortality of flaxes on Mana was likely due to the sheer abundance of flax (Figs 15, 30A), combined with the initial absence of the ‘flax weevil’ *Beauveria* strain. Dispersing flax weevils on Mana Island readily encountered new host plants. At other sites, the greater distance between host plant patches likely causes high mortality of dispersing weevils, with lower numbers of weevils colonising each host plant (see Schöps 2000, who documented flightless *Hadramphus spinipennis* weevils moving up to 600 m to find new *Aciphylla dieffenbachii* host plants).

Widespread mortality of flax plants on Mana Island is of particular concern due to the high utilisation of flax by goldstripe geckos; about 80% of goldstripe gecko records were from flax (Whitaker 1993). Other valued species utilise flax as a seasonal food source on Mana Island: bellbirds and tūī frequently feed on flax nectar (Fig. 22A), and yellow-crowned parakeets feed on flax seeds (author, pers. obs.). The impacts of flax collapse and death on lizard and invertebrate communities on Mana Island are the focus of an ongoing study (author and Will Brockelsby, unpubl. data).

There was no awareness of the role of *Beauveria* fungus in controlling flax weevil populations before the situation on Mana Island triggered an investigation of potential limiting factors for the weevil (Glare and Brookes 2017; Brockelsby 2022). Unfortunately, a trial at using *Beauveria* to prevent flax mortality was unsuccessful (Brockelsby 2022). The current distribution and rate of spread of flax weevils on Mana Island leaves too little time to establish another trial before the entire island is colonised (author, pers. obs.). While there are encouraging signs of flax regrowth near where flax weevils were first released 18 years ago (and where *Beauveria* spore counts are known to be high; Glare and Brookes 2017), it is likely to be several years before we know if flax will recover sufficiently to again be a dominant component of shrubland communities on the Mana Island plateau.

Benign, passive management of a dynamic landscape

There is an ironic twist in the flax weevil story on Mana Island, as the death and collapse of mature flaxes caused by flax weevils may benefit takahē, which prefer open habitats (Miskelly 1999, 2010; Phil Marsh in Ward 2016). Since the planting programme ceased, the four main processes affecting the extent of open habitat on Mana Island have been: gecko-assisted dispersal of *Coprosma propinqua* (Wotton 2002), wind-dispersal of flax seed, re-sprouting of collapsed flax bushes, and flax weevil-induced mortality of flax plants. The first three of these processes collectively reduce the area of open grassland, while the fourth (flax weevil impacts) increases the area of grassland, potentially benefiting takahē.

Takahē has long been recognised as the one species that has habitat requirements that conflict with other restoration goals on Mana Island (Miskelly 1999, 2010). Maintaining habitat for takahē would likely require removal of naturally regenerating woody plants (Ward 2016). In addition to labour costs, large-scale removal of vegetation would be a philosophical departure from the ecological restoration plan, which advocated for restoration of natural processes: "Over time the natural processes of pollination, seed dispersal, germination and seedling survival will gradually create a more natural forest, with local community structure suited to the microclimate at each site" (Miskelly 2010).

The ecological restoration plan did not consider the role that herbivory might play in vegetation community structure on Mana Island. It is expected that flax weevils, *Beauveria* and flax will eventually reach a more 'normal' equilibrium on Mana Island, where weevils cause minimal damage to individual host plants (Miskelly et al. 2018; Brockelsby 2022). However, the current trajectory of flax weevil impacts, and the slow rate of flax recovery, will likely allow takahē to persist at their current density on Mana Island for at least two decades longer than if flax weevils were absent, without requiring any deliberate removal of vegetation. The takahē population on Mana Island has apparently stabilised at 7–8 pairs since about 2014 (Fig. 16; Takahē Database per Glen Greaves pers. comm., September 2022). This may be due to the rate of natural vegetation regeneration on Mana Island being approximately offset by the rate of flax mortality due to flax weevils over the past 8 years, although this has not been analysed in detail.

Flax weevil impacts on Mana Island are a reminder that restoration ecology is an imprecise science that may deliver unexpected outcomes (Towns 2002; Lindig-Cisneros 2007; Terborgh and Estes 2010; Ripple et al. 2014). There is much that we don't know about species interactions in New Zealand ecosystems, and much to learn before the next set of Mana Island photographs are taken in 2072.

Acknowledgements

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Appendix 1

Timeline of significant ecological events on Mana Island

1834	Sheep introduced to Mana Island (103 animals)
1910	Approximate date that mice were noticed on Mana Island (possibly linked with the wreck of the ketch *Emma Sims* in 1907)
1922	Earliest known reference to Cook Strait giant weta on Mana Island
1944	Visit by Count Kazimierz Wodzicki and Dr Reginald Oliver (bird and plant life described)
1972	Mice confirmed to be the only rodents present on Mana Island; McGregor's skink and goldstripe gecko discovered on the island (although they were not named until 1975 and 1980 respectively)

1973	Crown lease terminated; most of the island becomes managed by Ministry of Agriculture & Fisheries as a quarantine research station for exotic sheep breeds, with the coastal slopes and foreshore managed as a reserve by Department of Lands & Survey
1977	43 giant weta translocated to Maud Island / Te Pākeka
1978	Scrapie detected for the third and final time, all 2000 sheep slaughtered
1979	Management of the entire island reverts to Department of Lands & Survey; beef cattle (bull) farming commenced
1984	Unsanctioned farm road constructed along north-east shore, destroying 70% of McGregor's skink habitat; detailed botanical survey by members of Wellington Botanical Society
1986	Monitoring of McGregor's skink commenced; last farm stock (bulls) removed; Mana Island management plan published
1987	Management of the island passed to the newly created Department of Conservation; tree planting initiated; 5-minute bird count surveys commenced
1988	Mana Island gazetted as a scientific reserve; takahē introduced (the first of many releases of this species)
1989	Pūkeko colonised
1989–90	Mice eradicated, freeing the island of introduced mammals
1990	First sightings of tūī and ruru
1991	Mouse eradication declared successful
1992	Two male kākāpō from Stewart Island introduced; hybrid little spotted kiwi × rowi introduced (from Franz Josef)
1993	Goldstripe geckos rediscovered on Mana Island (112 found); first seabird attraction sound system installed; boxthorn control programme initiated; second (= last) kākāpō found dead; 5-minute bird count surveys completed
1994	First reported sighting of a pied shag on the island; female little spotted kiwi from Kapiti Island released as a mate for the Franz Josef bird
1995	27 North Island robins re-introduced from Kapiti Island
1996	39 further robins released; Cook Strait giant weta and Wellington tree weta translocated from Mana Island to Matiu/Somes Island; glossy brown skinks discovered on Mana Island
1997	First diving petrel chick translocation (90 chicks); two adult diving petrels found ashore; gannet decoys installed near top of Central Track; 250,000th tree planted
1998	50 northern spotted skinks, 9 barking geckos and 40 Tohu's geckos released; Waikōkō wetland restored; long-tailed cuckoo sighted; second diving petrel chick translocation (100 chicks); Friends of Mana Island Incorporated Society formed
1999	Mana Island ecological restoration plan published; diving petrel chick translocations completed (49 chicks; 118 chicks fledged over 3 years); first breeding by diving petrels
2000	10 captive-reared brown teal released on Waikōkō wetland; first white-faced storm petrel found ashore; second record of pied shag roosting
2001	6 more brown teal released; second white-faced storm petrel found ashore
2002	First fairy prion chick translocation (40 chicks); underplanting with future canopy species begins
2003	Second fairy prion chick translocation (100 chicks)
2004	48 Newman's speckled skinks, 27 yellow-crowned parakeets and 80 flax weevils released; fairy prion chick translocations completed (240 chicks fledged over 3 years); second diving petrel colony discovered; first adult fairy prions confirmed (3), including one returned chick
2005	First breeding by yellow-crowned parakeets and fairy prions; pied shags began roosting on the island regularly; further barking geckos released (47 total)
2006	First fluttering shearwater chick translocation (40 chicks); first releases of Hutton's speargrass weevils (31); the hybrid little spotted kiwi × rowi was translocated to Allports Island; 70 more flax weevils released
2007	Second fluttering shearwater chick translocation (91 chicks); first release of shore plover (41 captive-reared birds); first breeding by shore plovers; *Notoreas* moths identified on natural and planted *Pimelea*; takahē population peaked at 42 birds; a few tūī visited to feed on flax; 9 more Hutton's speargrass weevils released (40 in total over 2 years)
2008	Fluttering shearwater chick translocations completed (94 chicks; 211 chicks fledged over 3 years); an unbanded fluttering shearwater confirmed at South Point artificial colony; 2 kererū regularly seen, and one bellbird and one long-tailed cuckoo seen
2009	Five shore plover chicks fledged; Mana Island recognised as one of the "Top 25" ecological restoration projects in Australasia by the journal Ecological Management & Restoration and the Ecological Society of Australia

2010 Tūī bred and produced fledglings; nine shore plover chicks fledged; 41 bellbirds and 37 whiteheads introduced; pied shags confirmed to be breeding; new sound system installed targeting white-faced storm petrels; McGregor's skinks rediscovered on southwest coast

2011 Unbanded whiteheads and bellbirds seen; fluttering shearwaters bred for first time (one chick); a single Norway rat detected then poisoned (after it had killed several shore plover); last shore plover release before 2020; final year of bulk planting (c. 5000 plants)

2012 20 rowi juveniles released; 61 more bellbirds released; gannet decoys moved to north-east corner of island; few shore plover remaining on island; McGregor's skink confirmed to be above the coastal scarp; flax weevil impacts noticed

2013 Strong winds toppled macrocarpas where pied shags bred; white-faced storm petrel found on an egg

2014 Last four shore plover re-captured and returned to captivity; 12 barking geckos released; pied shags confirmed breeding at new site south of buildings; Ngati Toa Rangatira Claims Settlement Act 2014 finalised and gazetted

2015 Supplementary translocation of 100 fairy prion chicks (all fledged); 28 ngahere geckos released; McGregor's skink caught south of wharf; live gannet regularly visiting decoys

2016 Another 100 fairy prion chicks translocated (all fledged); two live gannets regularly visiting decoys

2017 Eight more ngahere geckos released; flax weevil fungus (*Beauveria pseudobassiana* strain) confirmed to be present

2018 The lone gannet (Nigel) found dead; last of 49 ngahere geckos released

2019 First white-faced storm petrel translocation (48 chicks); 19 barking geckos released; 40 fernbirds released; record 100 sooty shearwater chicks banded

2020 98 translocated white-faced storm petrel chicks fledged; 20 barking geckos released; a new round of shore plover releases attempted (34 birds) and then abandoned due to falcon predation; two live gannets reported in November

2021 Speargrass weevil survey (3 found, plus much sign); third and final white-faced storm petrel chick translocation (97 fledged = total of 243); single kākā seen over 2 days in October; many unbanded fernbirds seen; 12 barking geckos released. Commercial transport to the island ceased in March, effectively ending FOMI guided trips and working weekends (this situation was unresolved as of late 2022)

2022 Tony Whitaker 1972 images retaken from the same photo-points; first (3) translocated white-faced storm petrels recorded back

Appendix 2

Plant species planted on Mana Island 1987–2021 (data from Miskelly 1999, 2010; Ward 2016; Linda Kerkmeester, pers. comm., August 2022).

A. Bulk plantings

Akiraho *Olearia paniculata*, coastal tree daisy *Olearia solandri*, common broom *Carmichaelia australis*, *Coprosma rhamnoides*, harakeke (flax) *Phormium tenax*, horoeka (lancewood) *Pseudopanax crassifolius*, hīnau *Elaeocarpus dentatus*, huruhuruwhenua (shining spleenwort) *Asplenium oblongifolium*, kaikōmako *Pennantia corymbosa*, kakaho *Austroderia fulvida*, kānuka *Kunzea ericoides s.l.*, karaka *Corynocarpus laevigatus*, karamū *Coprosma robusta*, karamū (shining karamu) *C. lucida*, kohekohe *Didymocheton spectabilis*, kohukohu *Pittosporum tenuifolium*, koromiko *Veronica stricta* var. *stricta*, kowhai *Sophora chathamica*, *S. microphylla* & *S. molloyi*, māhoe *Melicytus ramiflorus*, mānuka *Leptospermum scoparium*, mingimingi *Coprosma propinqua* var. *propinqua*, ngaio *Myoporum laetum*, pikopiko (hen & chicken fern) *Asplenium bulbiferum*, puka *Griselinia lucida*, northern rātā *Metrosideros robusta*, red mapou (red matipo) *Myrsine australis*, rewarewa *Knightia excelsa*, tarata *Pittosporum eugenioides*, taupata *Coprosma repens*, tī kōuka (cabbage tree) *Cordyline australis*, tītoki *Alectryon excelsus* subsp. *excelsus*, toetoe *Austroderia toetoe*, toetoe upokotangata (giant umbrella sedge) *Cyperus ustulatus*, tūrepo (large-leaved milk tree) *Streblus banksii*, wharangi *Melicope ternata*, whau *Entelea arborescens*, whauwhaupaku (fivefinger) *Pseudopanax arboreus*.

B. Small scale plantings (at least one plant known to survive)

Akeake *Dodonaea viscosa*, *Blechnum zeelandicum* (= *Doodia squarrosa*), *Carex flagellifera*, *C. geminata*, *C. litorosa*, *C. secta*, *C. testacea* & *C. virgata*, *Gahnia rigida*, Cook's scurvy grass *Lepidium oleraceum*, hangehange *Geniostoma ligustrifolium* var. *ligustrifolium*, kahikatea *Dacrycarpus dacrydioides*, kōkōmuka *Veronica elliptica*, leafless lawyer *Rubus squarrosus*, mākaka (saltmarsh ribbonwood) *Plagianthus divaricatus*, mataī *Prumnopitys taxifolia*, *Melicytus obovatus*, miro *Prumnopitys ferruginea*, nīkau *Rhopalostylis sapida*, *Pimelea* aff. *aridula* ‘Pipinui Point’, porokaiwhiri (pigeonwood) *Hedycarya arborea*, pukatea *Laurelia novae-zelandiae*, pygmy button daisy *Leptinella nana*, rengarenga *Arthropodium cirratum*, rimu *Dacrydium cupressinum*, shrubby tororaro *Muehlenbeckia astonii*, tawa *Beilschmiedia tawa*, thin-leaved coprosma *Coprosma areolata*, tōtara *Podocarpus totara*, *Trisetum antarcticum*, waiū-atua (shore spurge) *Euphorbia glauca*, wharariki (mountain flax) *Phormium cookianum*.

C. Planted but not known to have survived

Matagouri *Discaria toumatou*, rōhutu *Lophomyrtus obcordata*, sand coprosma *Coprosma acerosa*, scrambling fuchsia *Fuchsia perscandens*.

Supplementary material 1

Additional paired photographs

Authors: Colin M. Miskelly
Data type: Adobe PDF file
Explanation note: Additional paired photographs taken in June 1972 and June 2022.

Link: https://doi.org/10.3897/tuhinga.34.98136.suppl1