Shipwrecks and mollymawks:
an account of Disappointment Island birds

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ABSTRACT: This paper describes the birds of Disappointment Island, a small pristine island in the subantarctic Auckland Islands archipelago, from an accumulation of observations made by ornithologists during 16 visits to the island during 1907–2019. The island supports large populations of both the Auckland Island rail (*Lewinia muelleri*) and the Auckland Island teal (*Anas aucklandica*), most of the global population of the New Zealand endemic white-capped mollymawk (*Thalassarche cauta steadi*) – an annual average of 63,856 breeding pairs during 2009–17, an estimated 155,500 pairs of the circumpolar white-chinned petrel (*Procellaria aequinoctialis*), and unquantified numbers of smaller petrels. The topography and vegetation communities of the island are described, the history of visits by ornithologists to the island is outlined, and a list of bird species and their breeding status is recorded.

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Introduction

Disappointment Island (50°36'S, 165°58'E, 284 ha) lies off the rugged west coast of Auckland Island, and is the fourth-largest of the islands in the Auckland Islands group, 480 km south of mainland New Zealand (Fig. 1). It is one of the least-known and least-modified islands in the New Zealand subantarctic region. Alien species are limited to a few self-introduced passerines, which occur in low numbers. Due to its exposure to persistent westerly gales, its position off the dangerous western cliffs of Auckland Island, and the fragility of its teeming burrowing-seabird communities to disturbance, Disappointment Island has received only brief and infrequent visits. This paper describes the physical nature of Disappointment Island, summarises island visits, lists the bird species present, and discusses the status of species of conservation concern, especially that of the white-capped mollymawk (*Thalassarche cauta steadi*).

Disappointment Island

The island comprises altered basaltic rocks cut by conspicuous white rhyolite dykes. It is a remnant of the central portion of the Ross volcano, which, along with the Carnley volcano, formed the present Auckland Islands (Speight & Finlayson 1909; Fleming 1975; Scott & Turnbull 2019). The coastline is extremely rugged and precipitous, with deeply fissured cliffs (Fig. 2). Landing is practical at only a few sites and is usually attempted only in Castaways Bay at the east end of the island (Fig. 1). The land rises steeply at the western end (Fig. 2) to Jabez Peak at 318 m, but rises more gently in the east from two main gullies.

The overwhelming feature of the island is its birdlife: hundreds of thousands of seabirds nest both above and below ground. The steep seaward slopes have been heavily fertilised by thousands of nesting white-capped mollymawks and are covered with bright green *Poa foliosa* (Fig. 2). On the margins of the mollymawk colonies, just above

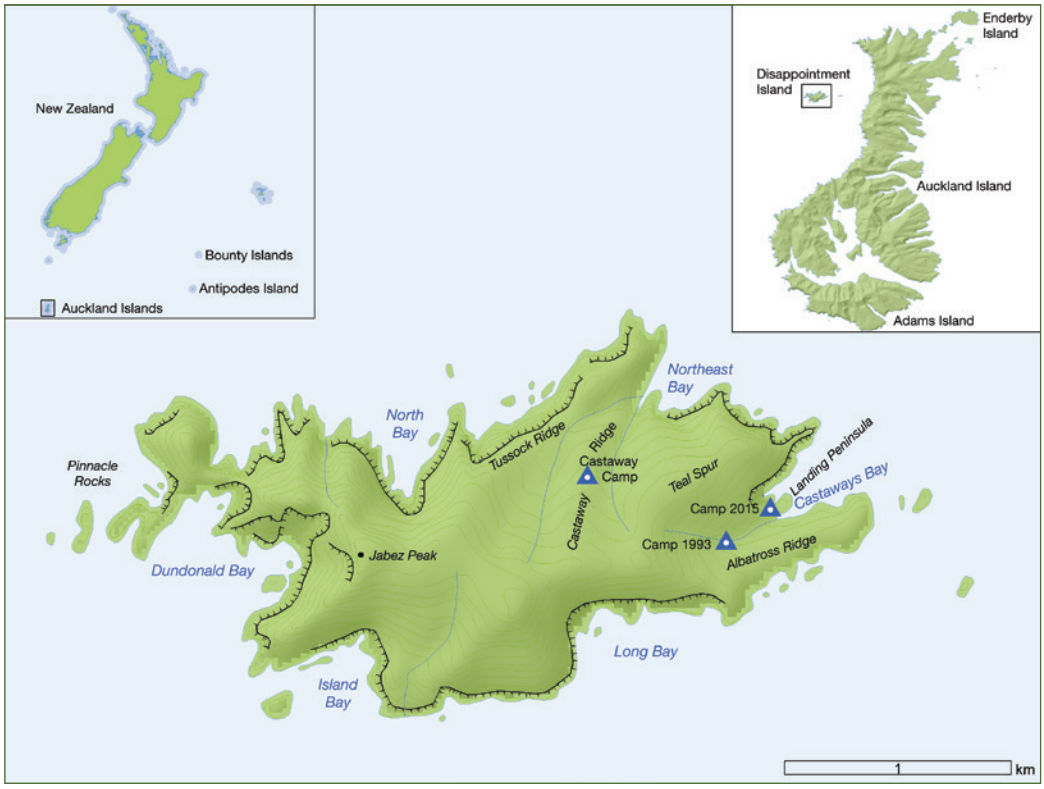

FIGURE 1. Disappointment Island (below) in the Auckland Island group (inset top right).

FIGURE 2. The high point above Dundonald Bay, north-west of Jabez Peak, in January 1993. Nesting white-capped mollymawks and white-chinned petrel burrows cover all the well-vegetated slopes, and light-mantled sooty albatross use the steepest sections. For scale, note Graeme Elliott and Pete McClelland visible at bottom right. *Image: Kath Walker.*

the cliffs, is a lush green blanket of *Leptinella plumosa* and *L. lanata*. In Castaways Bay valley, below the only mollymawk colony that does not end abruptly in sea-cliffs, a dense megaherb community grows where the soil has been enriched by guano run-off. This community is dominated by *Anisotome latifolia* and *Stilbocarpa polaris*, but around the fringes *Pleurophyllum criniferum* and *P. speciosum* also occur.

Although the island is entirely fringed by this bright green band, the gentler interior slopes are dominated by tawny *Poa litorosa* tussock. Except on the most exposed, dry slopes, this tussock vegetation is often infiltrated with other low-growing species; commonly ferns (*Asplenium obtusatum*, *Blechnum durum*, *Polystichum vestitum*), and occasional megaherbs (*Stilbocarpa polaris* and *Bulbinella rossii*) (background in Fig. 3). Along the island's ridges the *Poa litorosa* tussock gives way to a low (<1 m) woody shrub community of *Coprosma cuneata*, *C. foetidissima*, *Myrsine divaricata*, *Ozothamnus leptophyllus*, and *Dracophyllum longifolium*. Only in the lower reaches of Castaways Stream is there woody vegetation of any height: here a narrow band of *Veronica elliptica* sometimes reaches 4 m in height (Fig. 3).

In most areas the tussock is at least waist-high and intensively burrowed underneath by petrels, making it very difficult to walk through. The only areas not prone to collapse when walked on are the open areas of low sward along the ridge tops comprising bidibidi (*Acaena minor* var. *antarctica*), gentian (*Gentianella concinna*), *Bulbinella rossii*, and giant plantain (*Plantago aucklandica*).

The vegetation patterns appear to be greatly affected by landslides: there are a number of old slips in southern Castaways Valley now covered in low, yellowed *Poa foliosa*. During 1993, a large landslide of saturated peat occurred on gentle slopes east of Jabez Peak following prolonged heavy rain, and several slips occurred in northern Castaways Valley just prior to a visit in Jan 2016. There are no reliable meteorological records for the island, but like other parts of the Auckland Islands the climate

FIGURE 3. A patch of megaherbs and *Veronica elliptica* (foreground) abruptly changes to the deep tussock *Poa litorosa*, fern, and small woody shrub community (background), which covers the interior of Disappointment Island. Castaways Valley, January 2015. For scale, note Graham Parker on the valley floor. *Image: Kalinka Rexer-Huber.*

is changeable, windy, wet, and cold, with frequent mist. Due to its limited height, Disappointment Island does not receive quite as much rain as the highest parts of Auckland and Adams Islands, and its eastern tussock gullies are somewhat protected from the prevailing westerlies.

History of ornithological observation

Despite the importance of Disappointment Island for breeding seabirds, there has been remarkably little study of its fauna. No landings were recorded on the island before 1907, although sealers must have visited between 1806, when the Auckland Islands were discovered, and 1825, when seals were extirpated (McLaren 1948). Even the seven scientific expeditions that visited the Auckland Islands between 1840 and 1904 failed to land there (these were US, French, and British polar expeditions in 1840, a German expedition in 1874-75, and British Antarctic expeditions in 1900 and 1904; Dawson 1975; Miskelly & Taylor 2020 – Chapter 1 in this book). The handful of scientists who visited the subantarctic in the early 1900s on New Zealand government vessels in search of shipwreck survivors mostly also by-passed Disappointment Island.

The first recorded landing is by the shipwrecked sailors of the *Dundonald* in 1907. From a crew of 28, only 16 men reached shore. Although the second mate Jabez Peters died almost immediately, the rest survived on the island for 7 months. They built small huts of tussock and *Veronica* branches to shelter from the atrocious weather and sustained themselves by eating *c.* 12,000 white-capped mollymawk chicks between March and mid-Aug 1907 (Escott-Inman 1911). When the remaining chicks began to fledge, starvation forced the men to take the desperate risk of three of them rowing a sailcloth-covered coracle, framed with the branches of *Veronica*, 6 km to the main Auckland Island (Figs 1, 4). However, they failed to reach the

FIGURE 4. A. One of the coracles built by survivors of the *Dundonald* shipwreck, at the landing spot on Disappointment Island in 1907 (Chilton 1909). **B.** Graeme Elliott above the same landing spot in 1993, near a white post at far right, the only remnant of the collapsed boat and boatshed placed there after the *Dundonald* shipwreck. Low *Veronica* 'forest' sheltering the rockhopper penguin colony is just visible in the gully where Castaways Stream tumbles into the sea. *Image: Kath Walker.*

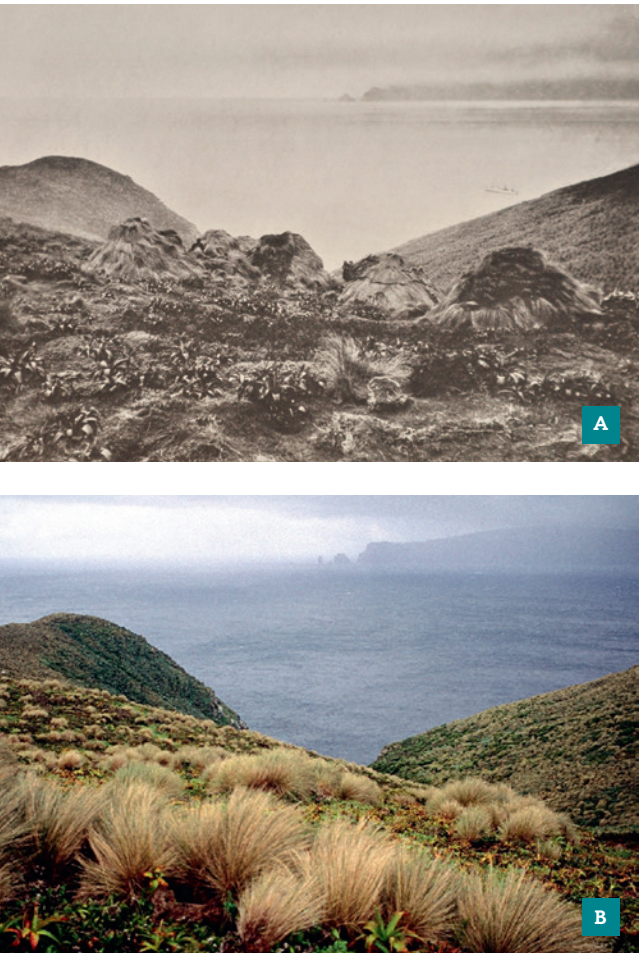

FIGURE 5. A. Tussock huts built by the *Dundonald* castaways in 1907. Four men standing by the huts show the scale, and the government steamer *Hinemoa*, which rescued the men, is visible in the middle right (from Chilton 1909). **B.** Approximately the same place in 1993. A low sward of herbs on humpy ground in front of the shelters in the 1907 photo indicates where tussock to make the shelters was harvested, but tussock had recovered much of the site by 1993. *Image: Kath Walker.*

castaway depot and, still starving after finding the mainland bereft of birdlife, paddled the coracle back to the *'fat mollyhawks'* of Disappointment Island, now viewed in comparison *'as a very Eden'* (Escott-Inman 1911). After making several more coracles, on a third attempt they managed to reach the mainland again. Despite capsizing on arrival and losing both the coracle and the fire they had brought with them in a wodge of peat, four men survived on raw seal long enough to discover the castaway depot at Port Ross. They sailed back to Disappointment Island in the small boat found in the depot, and ferried their crewmates to Erebus Cove, where the government steamer *Hinemoa* found them 2 months later (Escott-Inman 1911; Egerton *et al.* 2009).

Although their tale is remarkable, the sailors' contribution to biological knowledge of the island was meagre. They recorded *'hundreds and hundreds of night birds or mutton birds'* from whose bones they made coarse sewing needles, and noted *'the whole of Disappointment Island was honeycombed with their burrows'*. They described *'a lot of whale birds* [prion species] *on the island; but these are only little fellows . . . of no use to us at all'* (Escott-Inman 1911). They also saw *'some birds about the size of a chicken, which we sailors call skewer gulls'* which unlike *'the mollyhawks, were always on the wing, and without guns or nets, impossible to catch'* (Escott-Inman 1911). Their effect on the island, however, was substantial: as well as their damage to the mollymawk population, they burned most of the island's woody vegetation on their cooking and signal fires, which they kept alight continuously.

The ship that rescued the *Dundonald* sailors, the government steamer *Hinemoa*, was also carrying the Philosophical Institute of Canterbury's subantarctic expedition (Chilton 1909). After picking up the *Dundonald* sailors at Port Ross on 28 Nov 1907, the *Hinemoa* visited Disappointment Island to collect Jabez Peter's body for reburial at Port Ross. About 20 of the expedition's 26 members landed on Disappointment Island that day, and probably spent about 4–6 hours ashore (Table 1). Among these were the first naturalists on the island: Dr L. Cockayne made notes on the vegetation, Dr Marshall on the physiography and geology, and a Mr Browne collected a beetle *'probably the only entomological specimen extant from the island'*

TABLE 1. Visits to Disappointment Island for which there are ornithological records.

When	Who	Main purpose	Length of visit	Source
7 Mar–Sep 1907	15 sailors from the wreck of the ship *Dundonald*	Survival after being shipwrecked	7 months	Escott-Inman 1911
28 Nov 1907	Philosophical Institute of Canterbury's subantarctic expedition	Recovering the body of a shipwrecked sailor; and scientific observations	4–6 h	Waite 1909; Godley 1979
9 Dec 1944	Graham Turbott, George Easton, Les Clifton	Surveying	1.5 h	Eden 1955; Turbott 2002
6 Jan 1973	Rodney Russ, Ron Nilsson, Graham Wilson, Brian Bell, Mike Rudge, Gerry van Tets, Peter Johns, Gordon Williams	Wildlife survey	4.5 hours	Wilson 1975; Rodney Russ, *pers. comm.*
15 Feb 1973	Brian Bell, Rodney Russ, Ben Thorpe, Christopher Robertson, Rowley Taylor, Karl Johnson, Don Horning, Shirley Rolston, Hugh Best	Wildlife survey	A few hours	Rowley Taylor and Rodney Russ, *pers. comms*
11 Dec 1976	Sandy Bartle, Chris Paulin	Wildlife survey	4 h	Bartle & Paulin 1986
31 Dec 1980	Maggie Wassilieff	Botanical survey	3 h	Wassilieff 1986
8 Dec 1983	Pauline Mayhill, Jim Goulstone	Land snail survey	4 h	Mayhill & Goulstone 1986
Mar 1985	Christopher Robertson, Murray Williams	Wildlife survey	1 day and night	Christopher Robertson, *pers. comm.*
8 Feb 1988	Graeme Taylor, Greg Lind, Sue Pollock	Wildlife survey	4 h	G.A. Taylor 1988
16–27 Jan 1993	Kath Walker, Graeme Elliott, Pete McClelland, Christopher Robertson	White-capped mollymawk, rail, teal, Gibson's wandering albatross study and wildlife survey	10 days	logbook
2 Mar 2001	Ian Flux	Collecting blood from white-capped mollymawk	a few hours	Flux 2002
9 Dec 2008	Paul Sagar, David Thompson, Leigh Torres	Deploying satellite tags on white-capped mollymawk	4 h	Thompson *et al.* 2009
31 Dec 2014–11 Jan 2015	Paul Sagar, Graham Parker, Kalinka Rexer-Huber	White-capped mollymawk and white-chinned petrel research	11 days	Thompson *et al.* 2015; Rexer-Huber *et al.* 2017; logbook
11–13 Jan 2016	Graham Parker, Kalinka Rexer-Huber	White-capped mollymawk study and northern giant petrel census	3 days	Parker *et al.* 2016, 2017
13–16 Feb 2017	Graham Parker, Kalinka Rexer-Huber	White-capped mollymawk study	4 days	Parker *et al.* 2017
16–19 Jan 2018	Graham Parker, Kalinka Rexer-Huber, Kevin Parker, Colin Miskelly,	White-capped mollymawk study, snipe blood-sampling, and wildlife survey	4 days	Rexer-Huber *et al.* 2018; Shepherd *et al.* 2020*
5–7 Feb 2019	Graham Parker, Kalinka Rexer-Huber	White-capped mollymawk study	3 days	Rexer-Huber *et al.* 2019

* Chapter 16 in this book.

(Chilton 1909) during their brief visit. No detailed bird records were made. Photographs were also taken of the castaways' huts (Fig. 5A).

After the 1907 Philosophical Institute expedition and a sealing expedition in 1916 (Wilson 1975), 27 years passed before Disappointment Island was next visited briefly in 1944 by some of the Auckland Island coastwatchers (Turbott 2002; Table 1). In 1972–73, members of the largest scientific expedition to the Auckland Islands made two short visits to Disappointment Island, and subsequently there were visits every few years although almost always of only a few hours' duration (Table 1). The exceptions were 10- and 11-day visits (1993 and 2015) and, in recent years, annual 2- or 3-day visits (2016–19) (Table 1).

Species list

Thirty-two bird species have been recorded from Disappointment Island (Table 2), ten of which are land birds. Twenty-six species have been recorded breeding or are probably breeding there, while four have been seen only over the sea adjacent to the island.

Species accounts

Auckland Island teal *Anas aucklandica*

Teal are very common in every habitat, from near the coast to the summit of Disappointment Island and on both northern and southern slopes. Most teal seen are well away from the few streams and ponds, and the density of birds and their territorial behaviour probably means that most birds have little to do with freshwater for at least part of the year. Teal are most commonly seen in tussock- and fern-dominated communities, where they use the runways made by seabirds burrowing beneath the tussock clumps. Teal are also common in the megaherb communities associated with nesting mollymawks, and in a megaherb-dominated wetland in the valley bottom near the Castaways Stream waterfall (Fig. 3).

On 21 Jan 1993 an adult and a chick were caught in a cage trap by the Castaways Stream waterfall, and on 22 Jan 1993 four teal were captured when they responded to broadcast taped calls in tussock on Teal Spur ridge. Only males were attracted to the taped calls, and a new male teal was encountered at least every 100 m along Teal Spur. Teal were as common on Albatross Ridge, but harder to catch because of thicker undergrowth covering many runways there. If it is assumed that each male had a mate and that there was a similar density of teal over the whole island, then about 700 teal live on the island. The number is probably a little lower than this, perhaps more in the order of 500–600, given that densities are likely to be lower on the steep cliffs at the western end of the island where fresh water is scarce. This is not, of course, an accurate estimate of the island's teal population, but it suggests that the island supports many more than the 30 birds suggested by Williams (1986), and that the total teal population of the Auckland Islands group is more than the 600 birds suggested by Moore & Walker (1991). In 2015–19, teal encounter rates and call rates remained very high but there was no further attempt to estimate the teal population size.

Auckland Island teal were first reported from Disappointment Island by Waite (1909), who even then noted that *'they frequent the kelp but were also found high up the hillsides in watercourses'*. Ducklings were seen on 6 Jan 1973 (Rodney Russ, *pers. comm.*), 21 Jan 1993, and 17–18 Jan 2018 (this study).

Yellow-eyed penguin *Megadyptes antipodes*

Yellow-eyed penguins were first recorded on Disappointment Island in 1993. Since then they have been regularly seen in the lower reaches of Castaways Valley, moving ashore from the boat landing area. A pair nested near the big sinkhole near the Castaways Bay landing in both 2017 and 2018. It is likely that 5–10 pairs nest on the island.

Eastern rockhopper penguin *Eudyptes filholi*

A small breeding colony of rockhopper penguins is located at the mouth of Castaways Stream (Figs 4, 6), with adult penguins regularly seen arriving at and departing from the Castaways Bay landing and en route to the colony. The main creche area is on the south-east side of the stream, under *Veronica elliptica* and a stand of deep

TABLE 2. Breeding status of bird species recorded on Disappointment Island.

Species	Status
Auckland Island teal (*Anas aucklandica*)	breeding
Eastern rockhopper penguin (*Eudyptes filholi*)	breeding
Yellow-eyed penguin (*Megadyptes antipodes*)	breeding
Erect-crested penguin (*Eudyptes sclateri*)	possibly breeding
Gibson's wandering albatross (*Diomedea antipodensis gibsoni*)	breeding
White-capped mollymawk (*Thalassarche cauta steadi*)	breeding
Light-mantled sooty albatross (*Phoebetria palpebrata*)	breeding
Northern giant petrel (*Macronectes halli*)	breeding
White-headed petrel (*Pterodroma lessonii*)	breeding
Antarctic prion (*Pachyptila desolata*)	probably breeding
Lesser fulmar prion (*Pachyptila crassirostris flemingi*)	breeding
White-chinned petrel (*Procellaria aequinoctialis*)	breeding
Sooty shearwater (*Ardenna grisea*)	breeding
Grey-backed storm petrel (*Garrodia nereis*)	probably breeding
Black-bellied storm petrel (*Fregetta tropica*)	probably breeding
Subantarctic diving petrel (*Pelecanoides urinatrix exsul*)	breeding
Auckland Island shag (*Leucocarbo colensoi*)	breeding
Auckland Island rail (*Lewinia muelleri*)	breeding
Auckland Island snipe (*Coenocorypha aucklandica aucklandica*)	breeding
Subantarctic skua (*Catharacta antarctica lonnbergi*)	breeding
Southern black-backed gull (*Larus dominicanus*)	seen at sea near island
Red-billed gull (*Chroicocephalus novaehollandiae scopulinus*)	seen at sea near island
White-fronted tern (*Sterna striata*)	seen at sea and roosting on island
Antarctic tern (*Sterna vittata*)	seen at sea near island
Auckland Island pipit (*Anthus novaeseelandiae aucklandicus*)	breeding
Dunnock (*Prunella modularis*)	breeding
Eurasian blackbird (*Turdus merula*)	breeding
Silvereye (*Zosterops lateralis*)	breeding
Common redpoll (*Carduelis flammea*)	breeding
Common starling (*Sturnus vulgaris*)	breeding
Vagrants	
Song thrush (*Turdus philomelos*)	recorded once
Goldfinch (*Carduelis carduelis*)	recorded once

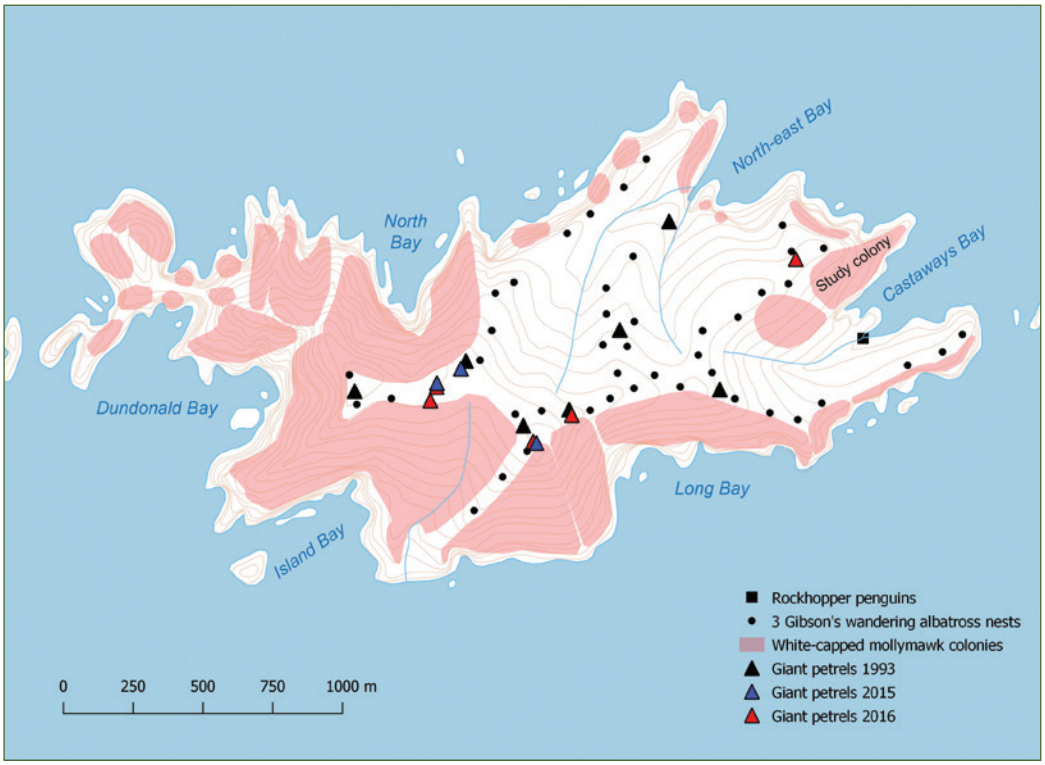

FIGURE 6. Location of rockhopper penguin colony and Gibson's wandering albatross nesting areas in 1993, giant petrel nest clusters in 1993 and 2015–16, and white-capped mollymawk colonies and study area on Disappointment Island.

Chionochloa snow tussock and *Poa litorosa*. Up to 100 birds were estimated to be in the colony in 1944 (Turbott 2002) and 1973 (Rodney Russ, *pers. comm.*). Graeme Taylor (1988) recorded *c.* 30 rockhopper chicks on 8 Feb 1988, and noted that the birds on Disappointment Island were about 7–10 days behind in development compared with rockhopper penguin chicks at Campbell Island at the same date. In 2015 at least 36 adults, most with chicks, were present. The colony on the south-east side of Castaways Stream is on particularly fragile ground and close to the cliff, and so some penguins will have gone undetected in the 2015 count, judging by calls from areas that were difficult to access.

Since the colony is so close to the boat landing site (Figs. 4, 6) it has been recorded by many observers (Miskelly *et al.* 2020 – Chapter 2 in this book). Perhaps the most interesting record is that made on 9 Dec 1944, when on entering '*the waist-high mega-herbs round the nesting molly-mawks* [at the bottom of the Castaways Bay colony, there were] ... *many nesting rockhopper penguins*' (Turbott 2002). Rockhoppers were also heard '*among the mega-herbs further up*' and '*it seemed likely* [the colony] *extended throughout the mega-herb zone*' (Turbott 2002). In 1993 the rockhopper colony no longer reached the bottom of the molly-mawk colony (*c.* 80 m above sea level [a.s.l.]) but only extended to the big sea-hole *c.* 40 m a.s.l. Today the rockhopper penguin colony occurs just to the south of, and immediately beside, Castaways Stream. While it is possible that the mollymawk colony has shrunk or shifted since the 1940s, it is more likely that the penguin colony has shifted or shrunk. In 1891 '*vast rookeries*' were present on the west coast of the main Auckland Island (Chapman 1891), but a century later only 886 adult penguins were counted in eight colonies on the main Auckland Island and one on Adams Island (Cooper 1992), reflecting the global decline in rockhopper penguin populations.

Erect-crested penguin
Eudyptes sclateri

Erect-crested penguins were seen close to the rockhopper penguin colony on Disappointment Island on five occasions between 1973 and 1993, but none has been seen since.

There are two records of erect-crested penguins nesting on Disappointment Island, but these should be treated with caution. Four adults and two chicks were reported on the edge of the rockhopper penguin colony on 15 Feb 1973 (Christopher Robertson, *pers. comm.*). However, chicks have mostly fledged by 15 Feb at the erect-crested penguin's main breeding grounds on Antipodes Island (Miskelly 2013), although eastern rockhopper penguin chicks are still on the island (Morrison 2017). On 11 Dec 1976, Bartle & Paulin (1986) saw at least one erect-crested penguin on eggs under *Anisotome latifolia* behind Castaways Bay. However, on Antipodes Island erect-crested penguin eggs have all hatched by 11 Dec (Miskelly 2013), although eastern rockhopper penguins are still on eggs (Morrison 2017). It is possible that the birds seen on Disappointment Island were brooding abandoned eastern rockhopper eggs. Regardless of whether erect-crested penguins have ever bred on the island, they have not been reported breeding since 1976. Records of non-breeding birds include five moulting birds on the landing rocks on 8 Feb 1988 (G.A. Taylor 1988), and two immature penguins at the landing rocks and an adult under dense *A. latifolia* on the fringes of the rockhopper penguin colony on the north-east side of Castaways Stream mouth on 20 Jan 1993.

Erect-crested penguins predominately breed on Antipodes and Bounty Islands. Apart from the two records above, they have not been recorded breeding at the Auckland Islands (Miskelly 2013; Miskelly *et al*. 2020 – Chapter 2).

Gibson's wandering albatross
Diomedea antipodensis gibsoni

Gibson's wandering albatross, endemic to the Auckland Islands, nests sparsely but evenly distributed along all the main ridges of Disappointment Island, where exposure to wind keeps the vegetation short and where the birds can easily take off (Figs 6, 7).

The albatrosses nesting on Disappointment Island appear indistinguishable in plumage pattern and breeding timetable to the main population on nearby Adams Island. An estimated 200 pairs nested on Disappointment Island in 1973 (Robertson 1975). On 17–18 Jan 1993 a count of breeding pairs of Gibson's wandering albatross was made. On Albatross Ridge (Fig. 1) all birds on nests were closely checked for eggs, and in the rest of the island about 25% of nesting birds were checked for eggs. About 10% were only viewed through binoculars. After adjusting for the proportion of non-breeding birds, as measured on Albatross Ridge (8.9%), an estimated 226 birds were incubating eggs on Disappointment Island on 17–18 Jan 1993. The Disappointment Island population thus comprised about 4% of the total Gibson's wandering albatross breeding population (Walker & Elliott 1999).

The number of wandering albatrosses on the ground at 1400 h on 20 Jan 2014 was counted from aerial photographs of the upper slopes and plateau of Disappointment Island, taken from a helicopter (Baker & Jensz 2014). In all, 463 birds were counted, of which 452 were presumed to be incubating birds and 11 the partner of a bird on an egg (Baker & Jensz 2014). However, it is likely that a much

FIGURE 7. Gibson's wandering albatross nesting at the top of Tussock Ridge, Disappointment Island in 1993. The seaward slopes to the left of the ridge are occupied by white-capped albatrosses, and the slopes to the right are fragile with burrows of white-headed petrels and sooty shearwaters. Column Rocks, where the *Invercauld* wrecked in 1864 off the North West Cape of the main Auckland Island, are visible in the background. *Image: Kath Walker.*

smaller number of the sitting birds were on eggs. The same day in a study area on nearby Adams Island, 44% of Gibson's wandering albatrosses on the ground were not breeding but 'none of these birds were displaying, just hunkered down in the tussock everywhere', due to very strong westerly winds after a southerly gale (Graham Parker, *pers. obs*). The same strong winds – recorded by Baker & Jensz (2014) as 40 knots – were affecting Disappointment Island when the aerial photos were taken. Southerlies are known to greatly increase the numbers of non-breeders on land on Adams Island (Elliott *et al.* 2020 – Chapter 3 in this book), and potentially also on Disappointment Island. If 44% of the 463 birds counted in the aerial photos were, as on Adams Island at the same time, sitting but not incubating an egg, 56% or around 257 birds may have been on eggs; a similar number to that counted on Disappointment Island in 1973 and 1993.

White-capped mollymawk *Thalassarche cauta steadi*

The overwhelming feature of Disappointment Island is the immense numbers of white-capped mollymawks. Their pedestal nests densely cover the steep seaward-facing slopes all around the island (Figs 2, 6, 8). The guano-enriched run-off from their nests turns the luxuriant vegetation a rich dark green. In favourable weather, rafts of many hundreds of mollymawks are present on the sea around the island. Large numbers of mollymawks circle the nesting grounds throughout the day, and their braying calls fill the air. The noise rises to a crescendo just on dark as white-chinned petrels ('shoemakers') arrive and add their repetitive clacking to the cacophony.

Robertson (1975) photographed the colonies from a boat circumnavigating the island from 0900 h 1300 h on 15 Feb 1973 (Black 1975). Approximately 60,000 pairs were estimated to be present. Bartle

FIGURE 8. The enormous white-capped mollymawk colony above Long Bay on the southern slopes of Disappointment Island in January 1993, where the *'white dots'* of birds, *'which from the sea look like innumerable great white flowers amongst the tussock'* (Cockayne 1909), speckle the slopes as far as the eye can see. *Image: Kath Walker.*

& Paulin (1986) suggested that in 1976 '*it seemed all colonies were slowly expanding, for birds nesting on the edges of major colonies had nest sites in relatively unmodified vegetation, and there were no areas of "mollymawk-induced" vegetation without birds*'. Between 1981 and 2003, aerial photographs of the main breeding colonies of white-capped albatrosses on Disappointment Island were taken irregularly and opportunistically, with the most complete sets of images taken on 18 Feb 1985 (Rebergen 1991) and 21 Feb 2002 (this study), and a partial series, which includes the Castaways Bay colonies, taken on 22 Feb 1993 (Rebergen 1995). Since 2006, aerial photographs have been taken annually, initially in early- to mid-Dec (2006–10) and later in mid-Jan (2012–17) (Baker *et al.* 2015, 2018).

Counting the number of breeding pairs in aerial photographs is problematic due to the variable number of birds at the colonies that are not incubating but cannot necessarily be distinguished from those birds that are. Checks on the ground of the proportion of birds that were incubating eggs were made, and a ground-correction index applied to all available aerial photograph counts to estimate the size and trend of the white-capped mollymawk population on Disappointment Island (see Appendix for details).

From a low count of 50,259 pairs breeding annually in 1985, there are signs of recovery over the following two decades (Table A.3, Fig. A.2 in Appendix). A comparatively high number of breeding pairs of white-capped mollymawk recorded in 2006 (Baker *et al.* 2009) had been thought to be an anomaly (Francis 2012), but the addition here of a relatively high count in 2002 tends to support its validity. The inclusion of an extra count in the Castaways Bay colonies in 1993 further smooths the apparent trend of an increasing population in 1985–2006 and a decreasing trend thereafter.

The mean number of breeding pairs annually nesting on Disappointment Island in 2009–17, corrected by ground checks, is estimated to be 63,856 (Appendix). This is 21% less than the 80,969 pairs estimated over the same period when corrected for non-breeders by close-up aerial photography (Baker *et al.* 2018) rather than ground checks. Ground-corrected aerial count totals indicate a significant decline of 4.1% per annum in the population since 2006 (Appendix).

During the Jan 1993 and 2015 visits, white-capped mollymawks were incubating. In 1993 eggs began hatching on 20 Jan, and subsequent visits recorded first hatching on 16–19 Jan (2018). The brood-guard stage peaked early- to mid-Feb, with no chicks unguarded during 5–7 Feb (2019) and very small numbers unguarded 13–16 Feb (2017). Chicks fledged *c.* 27 Jul (range 12 Jul–23 Aug), and adults returned to the colony from around 30 Sep (Rexer-Huber *et al.* 2019).

Light-mantled sooty albatross *Phoebetria palpebrata*

Light-mantled sooty albatross are regularly seen flying along all parts of Disappointment Island's coastline. Most nests are on the steeper cliffs on the western side of the island between North Bay, Dundonald Bay, and Island Bay (Fig. 1). Seventy-nine pairs were detected in aerial photographs taken of the island in Jan 2014 (Baker & Jensz 2014). The breeding timetable on Disappointment Island appears to be similar to that on nearby Adams Island, with a small downy chick and attendant parent seen at a nest on 19 Jan 1993, and unattended small chicks visible at three of 79 nests on 20 Jan 2014 (Baker & Jensz 2014).

Northern giant petrel *Macronectes halli*

Giant petrels breed in loose clusters along the ridge crests and on the island's summit (Fig. 6), with chicks reported by most visitors since 1973 (Miskelly *et al.* 2020 – Chapter 2). Giant petrel breeding locations vary between years. In 1993 eight clusters were found (Fig. 6), each with 1–15 chicks, with an island total of 44 chicks. In 2015 there were 53 chicks in six nest clusters, and in 2016 there were 38 chicks in five clusters (Fig. 6). Every year 5–10 adult giant petrels of unknown breeding status attend each nesting cluster as the chicks near fledging. In early-Jan chick plumage ranges from 50% down to fully feathered, and by mid-Jan most of the chicks have little or no down remaining, making it likely that January counts miss some chicks that have already fledged. By early- to mid-Feb in 2017 and 2019 all remaining chicks were large, shiny, and at the point of fledging. Parker *et al.* (2020 – Chapter 13 in this book) provide more detail on a recent (2015–16) Auckland Islands-wide census.

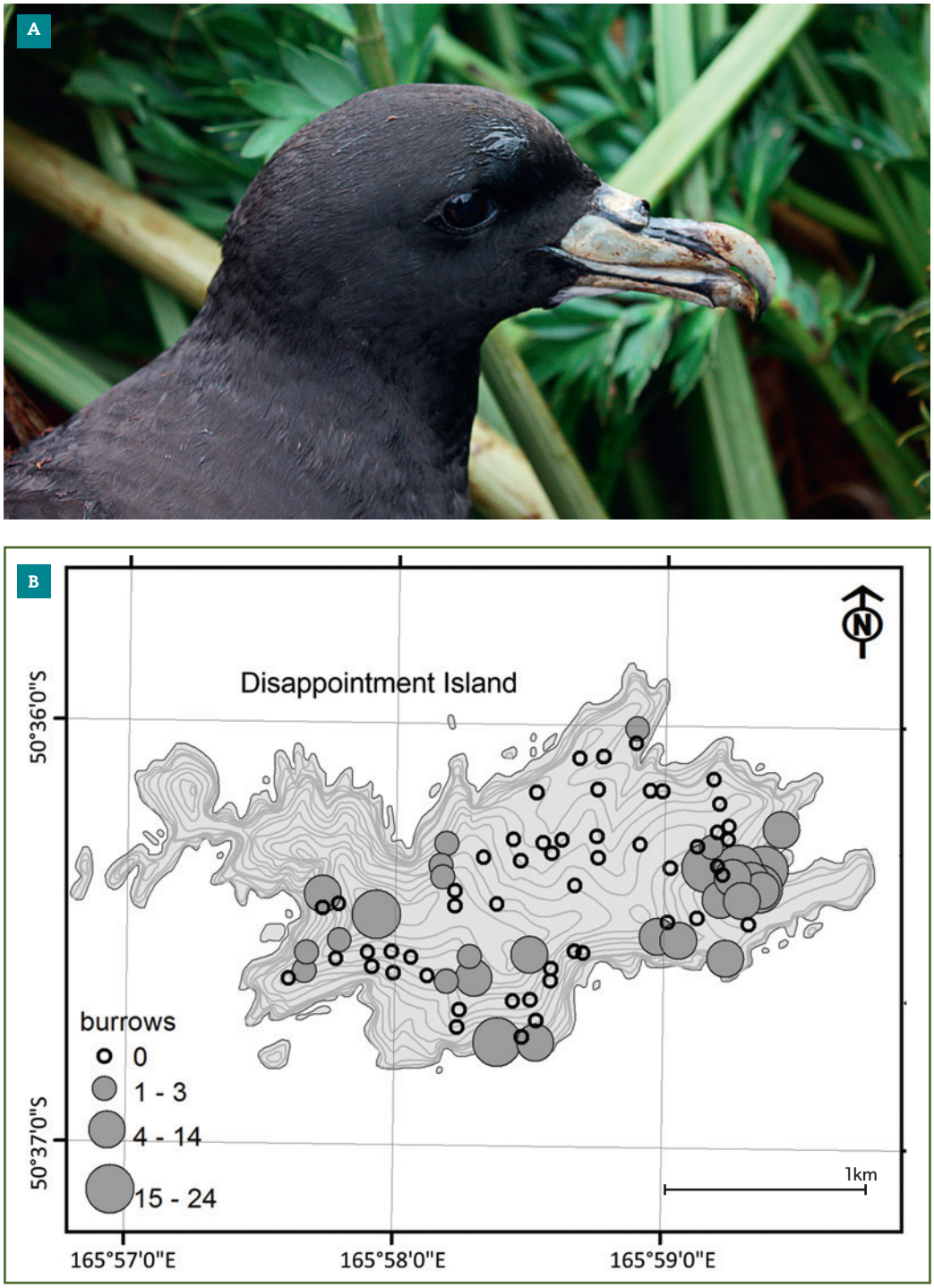

FIGURE 9. A. White-chinned petrel near burrow entrance under *Anisotome*, Castaways Bay (*image: Kalinka Rexer-Huber*). **B.** Burrow distribution of white-chinned petrels on Disappointment Island using distance sampling from 20 m line transects (n = 81). Burrow numbers are indicated by the size of the point. *Figure modified from Rexer-Huber* et al. *(2017).*

White-chinned petrel *Procellaria aequinoctialis*

White-chinned petrels (Fig. 9A) are a noisy and conspicuous component of the island ecosystem. A dribble of birds arrive at the island throughout the day, but the peak of activity occurs from 1900 h to 2200 h, when clouds of white-chinned petrels and white-capped mollymawks swirl above the megaherb slopes. A deafening clatter arises just on dark as the petrels call in the air, from the tops of tussock and megaherbs, and from inside their burrows.

The distribution of white-chinned petrels on Disappointment Island resembles that of white-capped mollymawks (Figs 6, 9). They appear to be the main petrel able to handle (and contribute to) the wet, muddy conditions created by the mollymawks on the megaherb slopes, with burrows of white-headed petrel and sooty shearwater less commonly encountered there. Their burrows typically have large entrances, and a 'moat' of pooled water often extends well into the tunnel. Tunnels are usually 0.6–1.2 m long, leading to a chamber with a raised nesting mound, but white-chinned petrels sometimes tunnel as much as 2.4 m before excavating a chamber (KRH, *unpubl. data*).

In 1993, 58 petrel burrows within 15 randomly located 10 × 1 m plots were inspected and measured. Four plots were within vegetation dominated by *Poa foliosa* and megaherbs characteristic of the mollymawk colonies, while 11 plots were in *Poa litorosa*-dominated vegetation, which covers most of the rest of the island. On the basis of the white-chinned petrel's large size and the presence of water in the entrance to five large burrows, 12 burrows with entrances larger than 200 × 200 mm were assumed to belong to this species. White-chinned petrel burrows occurred at 3,900 burrows/ha in megaherb-dominated communities and 1,750 burrows/ha in *Poa litorosa*-dominated communities. The planar area of the two vegetation types was estimated from satellite imagery and corrected for slope using randomised slope measurements from within the two vegetation types. Using these slope-corrected surface areas, there were an estimated 402,000 white-chinned petrel burrows on the island in 1993. The total numbers of breeding pairs would have been lower than this, as 25% of the 12 burrows checked appeared not to be in use.

Distance sampling from 80 island-wide sampling transects in 2015 (Fig. 9B), stratified by vegetation, gave an estimated burrow density of 654/ha (Rexer-Huber *et al.* 2017). Of 158 burrows inspected by burrowscope, 115 (73%) were occupied. Corrected for occupancy and using the slope-corrected surface area of the island, an estimated 155,500 (95% CI: 125,600–192,500) breeding pairs were present during mid-incubation in 2015 (see Rexer-Huber *et al.* 2017 for a detailed account). Assuming the same burrow occupancy in 1993 and 2015, the number of active burrows decreased from about 294,000 to 155,500 in 22 years. The methodologies used to make the 1993 and 2015 estimates are different, and the 1993 estimate is based on a very small sample size, and so conclusions about white-chinned petrel density and trend should be treated with caution.

On 11 Dec 1976 eggs were being incubated in all the burrows examined (Bartle & Paulin 1986), and in 2015 all pairs were still incubating in early- to mid-Jan (of 96 nests inspected; Rexer-Huber *et al.* 2017). In 1993 birds in two burrows were incubating on 19 Jan, and by 24 & 26 Jan a chick was just hatching in one burrow, with a big fluffy chick in another burrow. The breeding chronology is similar to that on Adams Island: in early- to mid-Dec eggs were being incubated in all the active burrows examined (184 burrows; Rexer-Huber 2017), and by 8 Feb four active burrows contained eggs and six contained chicks (2014; KRH, *unpubl. data*).

White-headed petrel *Pterodroma lessonii*

The distinctive yapping cries of white-headed petrels provide the main nocturnal soundscape of Disappointment Island from about 2330 h. Their burrows are so common that they effectively undermine the extensive *Poa litorosa* tussock and *Asplenium obtusatum* fern communities.

In early-Jan 1973, numbers were described as '*almost into millions, with burrows everywhere, mixed with sooties*' (Rodney Russ, *pers. comm.*, although no count would have been possible in the time available), and in early-Dec 1976 as '*abundant, especially on the lower and better drained slopes; very many skua-eaten remains*' (Bartle & Paulin 1986). The difficulty in quantifying the size of the population lies in the overlap

in dimensions of white-headed petrel and sooty shearwater burrows, particularly as both nest in similar habitat.

In 1993, when 58 petrel burrows within fifteen 10 × 1 m plots were inspected (see white-chinned petrel section above), 46 medium-sized burrows were found, which were presumed to belong to either white-headed petrels or sooty shearwaters. Medium-sized petrel burrows occurred at a density of 1,750 burrows/ha in the megaherb fields and 3,909 burrows/ha in *Poa litorosa* tussock-land. Using the slope-corrected surface areas, there were an estimated 1,107,521 medium-sized petrel burrows in 1993 that could contain white-headed petrels or sooty shearwaters.

In 2015, sampling along 81 transects (Fig. 10) suggested that medium-sized burrows occurred at a density of 1,105 burrows/ha. Using the slope-corrected surface area of the island (see white-chinned petrel section), there were an estimated 443,000 medium-sized burrows that could contain white-headed petrels or sooty shearwaters in 2015.

White-headed petrels were more conspicuous than sooty shearwaters at night in both 1993 and 2015, although this may be a result of their differing courting behaviours, with the petrels aerially based and the shearwaters ground based. However, in both 1993 and 2015 white-headed petrel were also more abundant in skua middens throughout the island. If it is assumed that around 80% of medium-sized burrows could belong to white-headed petrels, following Miskelly *et al.* (2019), then up to *c.* 350,000 burrows in 2015 belonged to white-headed petrels, although this ratio remains an educated guess. For a reliable estimate of white-headed petrels, inspection of many burrows with a burrowscope is needed in transects across different habitats, both to identify species and provide certainty as to occupancy rate.

White-headed petrels at the Auckland Islands do not breed every year (G.A. Taylor *et. al.* 2020 – Chapter 14 in this book), with burrow occupancy around 50% (Graeme Taylor, *pers. comm.*). When this occupancy rate is applied, an estimated 175,000 breeding pairs of white-headed petrel nested on Disappointment Island in 2015, down from an estimated 443,000 pairs in 1993. The methodologies used to make the 1993 and 2015 burrow counts are different, and the 1993 estimate

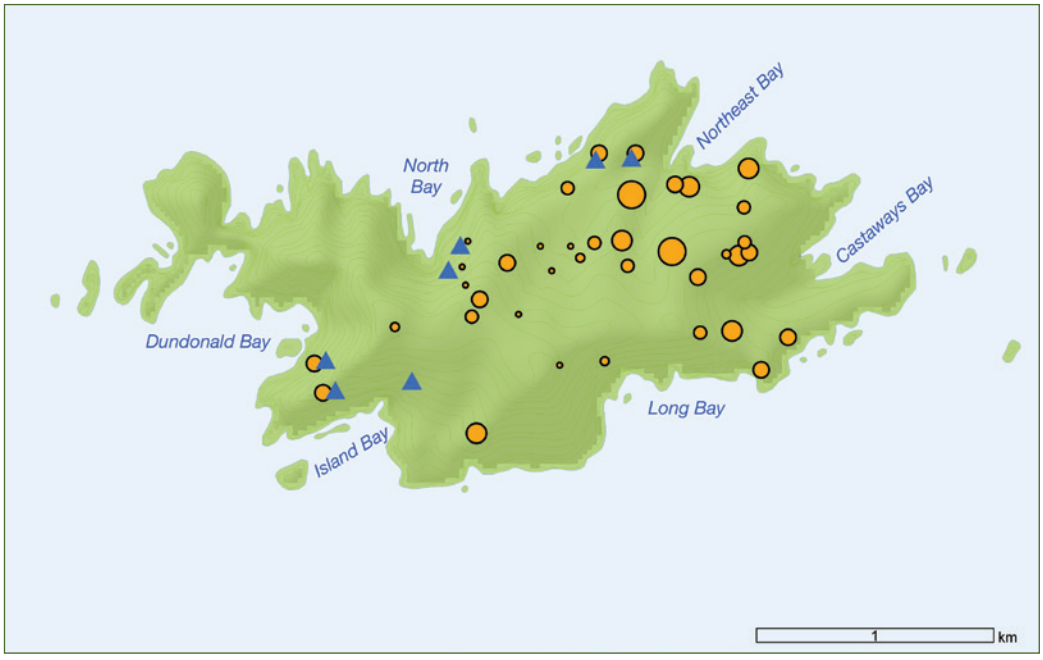

FIGURE 10. Distribution of medium-sized burrows (orange points) and small burrows (blue triangles) in 20 m transects on Disappointment Island, Jan 2015. The size of medium-burrow points indicates the number of burrows, from 1 to 38 per transect. Triangles for small burrows are not scaled (up to 8 small burrows found per triangle). *n* = 81 transects.

is based on a very small sample size, and so conclusions as to white-headed petrel density and trends on the island should be treated with caution.

Despite their abundance, only limited information is available on the breeding chronology of white-headed petrel. On 6 Jan 1973 a bird was seen incubating (Rodney Russ, *pers. comm*.) and during 1–10 Jan 2015 four of five white-headed petrel burrows inspected contained a bird on an egg. A chick was hatching in a burrow checked on 23 Jan 1993, and a recently hatched chick was found on 17 Jan 2018 (Miskelly *et al*. 2020 – Chapter 2).

Antarctic prion *Pachyptila desolata*

Antarctic prions were not recorded from Disappointment Island until 1993, and both Bartle & Paulin (1986) and Graeme Taylor (1988) noted their failure to find them there. Four Antarctic prions were attracted to spotlights in 1993 at the head of Castaways Stream, at Albatross Ridge, and at Landing Peninsula (Fig. 1). They were one of the least common seabirds seen by spotlight and came ashore after about 2300 h. On Albatross Ridge birds landed among *Poa litorosa* and fern (*Asplenium obtusatum*) near the top of the ridge, and at Landing Peninsula birds were apparently landing above the cliffs. Small 'prion-sized' burrows were found on the slopes of Albatross Ridge, and Northeast, North, and Dundonald Bays (Fig. 10) in 1993 and 2015. Remains of one prion were found in a skua midden in 1993 and again in 2015.

Lesser fulmar prion *Pachyptila crassirostris flemingi*

The distribution and size of the fulmar prion population on Disappointment Island is unknown, as they were not discovered there until 16 Jan 2018, when Colin Miskelly found a fledgling in a burrow, and a day later attracted another fledgling with a spotlight (Miskelly *et al*. 2020 – Chapter 2 in this book).

Sooty shearwater *Ardenna grisea*

Remains of sooty shearwaters were found in skua middens by the earliest observers (Waite 1909; Turbott 2002). In early-Jan 1973 the birds were reported in '*large numbers, mixed with white-headed petrels*' (Rodney Russ, *pers. comm*), and on 15 Feb 1973 there were '*many, with the taller tussock areas riddled with the burrows of this species*' (Rowley Taylor, *pers. comm*.). In early-Dec 1976 they were described as '*easily the most common breeding bird; very large numbers of burrows everywhere; c.1000 skua-killed corpses*' (Bartle & Paulin 1986). However, few skua-eaten sooty shearwater remains were seen in 1993 and 2015. Spotlighting at Landing Peninsula and around the head of Castaways Stream in mid-Jan 1993 produced only a few birds, and none on the top of Albatross Ridge, although more intensive spotlighting in mid-Jan 2018 produced 40 birds (Miskelly *et al*. 2020 – Chapter 2). Sooty shearwaters appear to be much less common than white-headed petrels nowadays.

However, the burrows of both species are of medium size, and both nest in the *Poa litorosa* tussock, which covers much of the interior of the island. In 1993 the density of petrel burrows in 15 random plots was assessed (see white-chinned petrel section above), and in 2015 the density along 81 transects covering most parts of the island was assessed (Fig. 10). If approximately 20% of the medium-sized burrows found belong to sooty shearwaters (see white-headed petrel section), then approximately 222,000 in 1993 and 88,000 in 2015 may have been sooty shearwater burrows. Considering that an unknown proportion will be unoccupied and assuming that this proportion is 50%, perhaps 44,000 breeding pairs might have been nesting in 2015, a substantial reduction from the 111,000 pairs estimated to be there two decades earlier.

Breeding chronology is poorly known on the island: on 11 Dec 1976 '*sooty shearwaters were incubating eggs*' (Bartle & Paulin 1986); on 8 Feb 1988 a 2–3-week-old chick was found in a burrow (G.A. Taylor 1988); on 2–7 Jan 2015 four sooty shearwater burrows examined contained two birds on eggs and two birds without an egg.

Subantarctic diving petrel *Pelecanoides urinatrix exsul*

Subantarctic diving petrels were first detected on Disappointment Island on 8 Feb 1988, when their feathers were found in a small, very narrow tunnel among ten such burrows on the summit ridge (G.A. Taylor 1988). Subantarctic diving petrels

seemed the most common of the small petrels in 1993, when their presence was confirmed. Most records were from spotlighting, with birds seen and several caught at Landing Peninsula, the head of Castaways Stream, and Albatross Ridge (Fig. 1) in mid-Jan 1993. Many came into land near the waterfall at the head of Castaways Stream in 1993, and a dozen were attracted to spotlights at 2325 h in mid-Jan 2018 (Miskelly *et al*. 2020 – Chapter 2).

As the last seabird to start coming ashore in the evening, they are presumably very sensitive to skua predation. Eleven of 33 birds identified from skua middens in Jan 2018 were diving petrels (cf. 12 white-headed petrels and six sooty shearwaters; Miskelly *et. al*. 2020 – Chapter 2). One of 17 small burrows seen on the ridge between Island and Dundonald Bays in 2015 (Fig. 10) had a diving petrel corpse in near proximity, and diving petrel calls were heard on the face above Island Bay.

Grey-backed storm petrel *Garrodia nereis*

The first record of a grey-backed storm petrel on Disappointment Island was on 28 Nov 1907 when one was caught after it 'darted out of a burrow in *Anisotome* dotted with incubating mollymawks' (Waite 1909). This sighting was repeated 50 years later, when it was further embellished 'burrows, like "rat-holes" have been found in a belt of *Anisotome* among sitting mollymawks on Disappointment Island' by Falla *et al*. (1966). However, *Garrodia* species never nest in soil burrows, with all known nests under vegetation on the surface (Graeme Taylor, *pers. comm*). Presumably the dense ground cover of megaherbs on Disappointment Island made it appear as if the petrel arose from below the ground. Their nests are usually well concealed in dense vegetation, which might be the reason no burrows definitely attributable to grey-backed storm petrel have so far been found on Disappointment Island. Six birds were caught after midnight during spotlighting on Albatross Ridge and at the head of Castaways Stream in mid-Jan 1993, and 46 were seen in mid-Jan 2018 (Miskelly *et al*. 2020 – Chapter 2). Remains of one grey-backed storm petrel were found in a skua midden in 1993.

Black-bellied storm petrel *Fregetta tropica*

Spotlighting on Albatross Ridge attracted four black-bellied storm petrels, one at Castaways Stream, and quite a few at Landing Peninsula 2300–2400 h on 17–24 Jan 1993. The remains of a black-bellied storm petrel were found in a skua pellet in 2015, and another in 2018 (Miskelly *et al*. 2020 – Chapter 2). Spotlighting at Landing Peninsula on 16 Jan 2018 attracted 20 black-bellied storm petrels (Miskelly *et al*. 2020 – Chapter 2).

Auckland Island shag *Leucocarbo colensoi*

Single birds were regularly seen feeding and flying around the coast, with shags visible in Castaways Bay on most days during visits 2015 and 2019. A pair of half-grown chicks with two adults were seen on the north-east end of Teal Spur on 19 Jan 1993, and at least five nests and 20 birds were seen on the islets east of Albatross Ridge on 19 Jan 2018 (Miskelly *et al*. 2020 – Chapter 2; Colin Miskelly, *pers. comm*.).

Auckland Island rail *Lewinia muelleri*

Rails occur everywhere on Disappointment Island, from vegetation just above the level of the tide to the highest point on the island. Although they appear to be more common in wet sites, particularly in megaherb fields around mollymawk colonies, they have been recorded in every vegetation type on the island.

Rails are quite vocal, and most of the 1993 records were of birds that called spontaneously. Taped calls played in mid-Jan 1993 at the head of Castaways Stream attracted birds to within a few metres of the tape recorder and elicited vocal responses from them. Rails are seen more readily on Disappointment Island than on Adams Island, probably because the ground is much more intensively burrowed on Disappointment Island and more open beneath the dense, waist-high tussock and megaherb vegetation.

In 1993 two birds, an adult and a downy chick, were caught in a megaherb wetland near the head of Castaways Stream. The adult was weighed and measured (bill length 34.1 mm, bill width 7.2 mm, bill depth 8.7 mm, tarsus 29.8 mm, wing 80.5 mm, tail 35.5, weight 81 g). The chick was

completely covered in black down with just a few proper feathers showing, and was estimated to be less than 2 weeks old. A downy chick sighted 7 Jan 2015 on the south-coast slopes under low *Anisotome latifolia* had no feathers visible. A chick seen on 5 Feb 2019 in deep *A. latifolia* was still developing tail feathers. The presence of chicks on Disappointment Island in January, combined with earlier observations from Adams Island (Elliott *et. al.* 1991) suggests that the Auckland Island rail breeds Nov to late-Feb.

Rails appear to be at higher densities on Disappointment Island than on Adams Island; while Disappointment Island is only 284 ha, it may have well over 500 rails. The finding of rails on Disappointment Island in 1993 changed the conservation status of the species. Until 1993 they were known only from Adams Island, where it was thought there were several hundred birds (Elliott *et al.* 1991), although subsequent observations suggest that this was a substantial underestimate (Elliott *et al.* 2020 – Chapter 3). With two populations and a combined total count of perhaps several thousand birds, they are under less threat than previously thought.

Auckland Island snipe *Coenocorypha aucklandica aucklandica*

Snipe are common on the island and are found from sea level to the top of Jabez Peak. They are perhaps more often seen on the ridge crests where the tussock clumps are interspersed with areas of low-growing herbs, but they also flush readily from megaherb fields and hill-slopes of dense tussock. Almost all visits to the island have been in early-Jan, when snipe have either been incubating or are with downy chicks (Miskelly *et al.* 2020 – Chapter 2), although adults with chicks were seen on 8 Dec 1983 (Mayhill & Goulstone 1986), indicating an extended breeding season. Most of the four nests found on Disappointment Island have been deep within tall tussock (*Poa foliosa*, *P. litorosa*) and fern (*Polystichum vestitum*) (Miskelly *et al.* 2006, 2020 – Chapter 2; authors, *pers. obs*).

Subantarctic skua *Catharacta antarctica*

Skuas are dispersed widely over Disappointment Island, with an estimated 20+ pairs present in 1976 (Bartle & Paulin 1986). '*Skewers*' were first recorded on Disappointment Island by the shipwrecked sailors of the *Dundonald* in 1907 (Escott-Inman 1911) and by their rescuers (Waite 1909), and have been noted by every visitor thereafter.

Their most frequent prey, judging from their middens, are white-headed petrels and sooty shearwaters, although most of Disappointment Island's bird species are eaten at least occasionally, with Auckland Island teal, white-chinned petrel, Antarctic prion, fulmar prion, diving petrel, grey-backed storm petrel, and black-bellied storm petrel carcasses having been found in skua middens (Waite 1909; Turbott 2002; Rodney Russ, *unpubl. diary*; G.A Taylor 1988; Miskelly *et al.* 2020 – Chapter 2; this study).

Other less obvious food consumed by skuas on Disappointment Island is regurgitated from white-chinned petrels harassed by skuas, and white-capped mollymawk eggs and small chicks, which we observed in 1993 and 2015–19, respectively. In Castaways Bay, skuas follow New Zealand sea lions (*Phocarctos hookeri*) climbing through the white-capped mollymawk colony, taking an egg if a bird is disturbed off the nest.

Evidence of natal fidelity was obtained from a banded adult observed on 21 Jan 1993 that was breeding at the same location near the top of Castaway Ridge where it had been banded as a chick 20 years earlier.

Southern black-backed gull *Larus dominicanus*

One or two black-backed gulls are seen at sea around the island during most visits.

Red-billed gull *Chroicocephalus novaehollandiae scopulinus*

A few red-billed gulls are occasionally seen flying near cliffs on both the northern and southern coasts of Disappointment Island.

White-fronted tern *Sterna striata*

White-fronted terns are commonly seen feeding in Castaways Bay and elsewhere around the coast, usually in small numbers; but in 2018 a flock of 32 birds was seen roosting and feeding off the south-east coast (Miskelly *et al.* 2020 – Chapter 2).

Antarctic tern *Sterna vittata*

In 2015 and 2018 a few Antarctic tern were noted feeding in mixed flocks with white-fronted terns at sea off the coast of Disappointment Island.

Auckland Island pipit *Anthus novaeseelandiae aucklandicus*

Pipits are common everywhere on the island. Waite (1909) reported that '[pipits] *frequented the deserted camps of the survivors of the "Dundonald" at Disappointment Island in large numbers, being attracted by the insect-life which gathered around the remains of dead birds, etc. left by the sailors*'. In 1976, Bartle & Paulin (1986) described them as '*the most abundant terrestrial bird species*'. Given that pipits are '*widespread and common throughout, particularly on ridges*' (G.A. Taylor 1988), surprisingly few observers commented on pipit nests, with breeding confirmed only on 7–8 Jan 2015, when two nests with eggs were found: one on the summit of the island and the other near sea level. An adult with a fledged chick was seen on 10 Jan 2015, and four recently fledged young were caught and blood-sampled on the summit ridges on 17 Jan 2018 (Colin Miskelly, *pers. comm*.)

Silvereye *Zosterops lateralis*

Silvereyes on Disappointment Island are common only in Castaways Valley, which is the only place with tall vegetation. They inhabit the *Veronica elliptica* scrub by the small stream in Castaways Valley, as well as the tall megaherb and dense tussock on its fringes. A fledgling was seen being fed by an adult on caterpillars gathered from *Veronica elliptica* on 21 Jan 1993.

Dunnock *Prunella modularis*

Dunnocks are almost certainly resident and breeding on the island, albeit in small numbers. Their presence has been noted by many visitors (Miskelly *et. al*. 2020 – Chapter 2) and they have been seen in all habitats on the island, albeit only rarely.

Eurasian blackbird *Turdus merula*

Although seen and heard infrequently, blackbirds are present in every habitat from sea level to the summit. In 1944, Turbott (2002) considered them to have a '*well established population*'. On 31 Dec 1980 a nest with eggs was found in *Veronica elliptica* scrub (Wassilieff 1986), and blackbird chicks were heard on 18 Jan 2018 (Kevin Parker, *pers. comm*.).

Common redpoll *Carduelis flammea*

Redpolls were first recorded from Disappointment Island in Dec 1944, when a flock was seen (Turbott 2002), and small numbers have been reported by most visitors since then (Miskelly *et. al*. 2020 – Chapter 2). Redpolls were encountered in low to moderate density all over the island, with highest numbers in the scrubby vegetation in Castaways Valley, where three nests were found in 1993 (for details see Miskelly *et al*. 2020 – Chapter 2).

Common starling *Sturnus vulgaris*

Starlings were first recorded on Disappointment Island in 1993, when a flock of ten was seen over the sea near Northeast Bay on 18 Jan, 17 were seen flying over the sea at Dundonald Bay on 19 Jan, and a single bird was seen flying over land above bluffs near Castaways Bay on 21 Jan. In 2015, 1–2 starlings were recorded almost daily flying across Castaways Bay and around the sinkhole near the campsite.

European goldfinch *Carduelis carduelis*

The only record of goldfinch on Disappointment Island is a small flock seen in 1976 (Bartle & Paulin 1986).

Song thrush *Turdus philomelos*

A single song thrush was recorded on Disappointment Island on 17 Jan 2018 (Miskelly *et. al*. 2020 – Chapter 2).

Discussion

Biogeography of Disappointment Island birds

While it is not surprising that shipwrecked sailors would view with 'disappointment' the lack of a land connection between the shores they had washed up on and a much larger and more promising island nearby, an island as full of (edible) birds as described in this paper belies that description. Indeed, the survivors of the wreck of

the *Dundonald* recalled Disappointment Island as '*a very Eden*' when they eventually reached Auckland Island and found it to be a land devoid of birds they could eat (Escott-Inman 1911). Due to the introduction of pigs, mice, and cats, there was no longer on Auckland Island the '*fowls of many kinds … and snipes, teals … in such plenty … two or three dozen could be gathered in an afternoon*', as described by Abraham Bristow in an 1810 letter to Lord Auckland (R.H. Taylor 2006). It was in fact Bristow – the first European to discover the Auckland Islands – and not the *Dundonald* castaways who named Disappointment Island (Jones & Dingwall 2009) a century before the *Dundonald* was wrecked there. Bristow had made a survey of the archipelego in the ship *Sarah* while hunting fur seals (*Arctocephalus forsteri*), whose breeding colonies were predominantly at the base of the formidable cliffs on the western coast of Auckland Island (Wilson 1975). As described by Bristow, '*the western side produces neither wood or anchoring birth* [sic]*, an up and down iron bound shore*' (R.H. Taylor 2006). He probably hoped that the small island to the west of those cliffs would provide a large and more accessible fur seal rookery, or at least a close and convenient base to reach those rookeries below Auckland Island's western cliffs, but was apparently disappointed on all counts.

The location of Disappointment Island on the exposed western side of Auckland Island, where few ships deliberately venture and separated from it by a rough stretch of water (Fig. 11), has so far kept it free of introduced mammals. Its exposure to the prevailing westerlies means that its vegetation cover is low, so ground-dwelling birds dominate the terrestrial avifauna. Notably absent are those forest-dwelling land birds that are abundant in other parts of the Auckland Island archipelago, and that could easily reach Disappointment Island. The lack of forest on Disappointment Island and its small size is almost certainly the reason that bellbird (*Anthornis melanura*), tui (*Prosthemadera novaeseelandiae*), red-crowned parakeet (*Cyanoramphus novaezelandiae*), and New Zealand falcon (*Falco novaeseelandiae*) are absent. It is less obvious why tomtits (*Petroica macrocephala*) are absent, as on Adams Island they seem able to live their whole lives in similar megaherb communities to those on the coastal slopes of Disappointment Island.

FIGURE 11. So near, yet so far: the western cliffs of Auckland Island in the distance behind a white-capped mollymawk on Teal Ridge, Disappointment Island, January 1993. *Image: Kath Walker.*

However, despite similarities, there are also differences between the islands in the nature of the understorey in the tussock and megaherb communities. On Disappointment Island, but not Adams Island, the ground in many places is bare under its dense canopy of tussock and herbs, due to the immense number of burrowing petrels.

The birdlife of Disappointment Island is dominated by marine species. They occur in such abundance that nutrients from the sea have a visible effect on the vegetation. The guano-enriched soils result in a lush green vegetation under which ground-dwelling insectivorous species such as snipe, rail, and teal can forage while hiding from predatory skua and giant petrels. White-capped mollymawk, white-chinned petrel, white-headed petrel, and sooty shearwater together appear to provide the greatest biomass and are presumably key species in terms of ecosystem functioning on the island. The Disappointment Island population of all four species is important, although sooty shearwater, white-chinned petrel, and white-headed petrel have wide global distributions and large total populations (Table 3). A reasonably accurate baseline estimate of the size of their Disappointment Island populations is useful given that conservation concern has been expressed about each of these four species (Birdlife International 2019).

TABLE 3. Estimated number over time of breeding pairs of key seabird species on Disappointment Island, and how important those populations are in a global context.

	Disappointment Island breeding pairs in 1993	Disappointment Island breeding pairs in 2015	Proportion of global population	Birdlife status
White-capped mollymawk	87,833*	63,856**	95%	Near Threatened
White-chinned petrel	294,000	155,500	*c.* 17%	Vulnerable
White-headed petrel	443,000	176,000	*c.* 25%	Least Concern
Sooty shearwater	111,000	44,000	*c.* 0.5%	Near Threatened

* in 2002; ** mean number in 2009–17.

Estimating the population size and trend in key Disappointment Island seabirds

The main threat to Disappointment Island seabirds comes not while ashore, but during their life at sea. Measuring the size of their breeding populations is difficult, due primarily to the variability in their attendance at the remote breeding grounds. The island is not only difficult to reach, but there are also so many burrowing seabirds present that the ground is very fragile: this means that only monitoring that is essential and cannot be carried out elsewhere has occurred. Strenuous efforts have been made to count the most endemic and most threatened species, white-capped mollymawk, without setting foot on the island. Likewise, assessment of one of Disappointment Island's most important and threatened burrowing species, white-chinned petrel, has taken place largely by proxy on nearby Adams Island. However, even with all the uncertainties such hands-off monitoring produces, a trend of decline has become apparent in several important species.

White-chinned petrels are the seabirds most frequently killed in Southern Hemisphere fisheries by-catch (Rexer-Huber 2017). In 2015 the use of a burrowscope across Disappointment Island provided the first rigorous estimate of the size of the white-chinned petrel population there, with an estimate of 155,500 breeding pairs (Rexer-Huber *et al.* 2017), down from the 294,000 pairs estimated in 1993. The abundance of white-headed petrels and sooty shearwaters also appears to have decreased over time (Table 3), although the limited burrow sampling in 1993, a lack of burrow-occupancy data, and difficulty in distinguishing white-headed petrel burrows from sooty shearwater burrows means that this conclusion must be treated with caution.

White-capped mollymawk are effectively endemic to the Auckland Islands, with only a few pairs on Bollons Island in the Antipodes group (Tennyson *et al.* 1998). Virtually the entire population breeds on Disappointment Island (95%), with only 4.7% at South West Cape on the main Auckland Island and small numbers at Adams Island (Baker *et al.* 2015). In the early 1980s, thousands of white-capped mollymawks regularly scavenged around a large fishing fleet trawling for squid north-east of the Auckland Islands (Robertson & Jenkins 1986) and large numbers of mollymawks were killed in collisions with the vessels' net-sonde cables (Bartle 1991; Murray *et al.* 1993) until these were banned in the early 1990s. In addition, high numbers of white-capped mollymawks were killed in fisheries off southern Africa 1998–2005 (Ryan *et al.* 2002; Watkins *et al.* 2008). White-capped mollymawks remain a substantial incidental by-catch in commercial fisheries in New Zealand (Abraham & Thompson 2015) and southern Africa (Rollinson *et al.* 2017), with mortality rates in high-seas fisheries largely unknown. Assessment of the conservation status of the species has been hindered by confusion in their identification at sea with the shy mollymawk (*T. cauta cauta*), which is endemic to the Tasmanian offshore islands. Due to the inaccessibility and fragility of Disappointment Island, information as to the effect interaction with fisheries has had on the white-capped mollymawk

population has been extremely limited. The sheer numbers of white-capped mollymawk, the seamless merging of their nesting sites along the coastal slopes of Disappointment Island, and the island's remoteness has made it difficult to measure the size of the population accurately, and to detect population changes reliably.

The addition here of two historical whole-island aerial counts made in 1985 and 2002 to the eleven aerial counts in 2006–17 already reported (Baker *et al*. 2015, 2018), and the inclusion of ground-correction information on the proportion of birds sitting on nests without an egg, has allowed a fuller picture of the population's trajectory over the past three decades. A mean 30% (21–49%) of birds on the ground in early- to mid-Jan are not breeding, and adjustment of population estimates accordingly indicates a gradual rise in the population since 1985, a peak around 2002–06, then a decline (see Appendix). The white-capped mollymawk population on Disappointment Island appears to have been declining since 2006 at 4.1% per annum. In 2009–17 the mean number of pairs breeding on Disappointment Island was 63,856, significantly fewer than the 85,969 pairs previously estimated using aerial correction for the same period (Baker *et al*. 2015, 2018), and back to numbers not seen since 1985 when mortality was high due to mollymawk collisions with net-sonde cables.

Changes in the number of species present on Disappointment Island

In 1993, subantarctic diving petrel, Antarctic prion, black-bellied storm petrel, yellow-eyed penguin, Auckland Island rail, and common starling were added to the list of birds known from Disappointment Island. None was a surprising addition, the discoveries simply resulting from a more thorough look than had previously been possible. However, the discovery of the Auckland Island rail on the island was important as it showed that the species inhabits two islands, and that there are many more of these birds than was previously thought. Similarly, the finding of a large population of Auckland Island teal on the island changed the conservation status of this species.

More recent visits to Disappointment Island have added one further species (fulmar prion). It seems unlikely that future trips to the island will discover many more resident breeding birds. The winter-breeding grey petrel (*Procellaria cinerea*) might nest on the island, but no sign has been found of its remains in skua middens; a winter trip would be necessary to confirm the species' absence. A few native and self-introduced species found on the main Auckland Island might occasionally straggle to Disappointment Island, but their failure to establish populations so far suggests that they are unlikely to do so in the future. Goldfinches and erect-crested penguins have made it to the island in the past, but are no longer present.

There appear to have been few major changes to the composition of the avifauna of Disappointment Island since it was discovered. Starlings, blackbirds, silvereyes, redpolls, and dunnocks have introduced themselves from New Zealand, presumably via the main Auckland Island. The only species known to have gone extinct on the Auckland Islands, the Auckland Island merganser (*Mergus australis*), may never have occurred on Disappointment Island due to a lack of habitat. If it did occur there, the small size of the island would probably have precluded the persistence of a self-sustaining population once predators had eliminated merganser from the rest of the archipelago.

During 1993–2019 there have been only a few other changes in the fauna of the island. The rockhopper penguin colony is no longer as extensive as it was, suggesting either colony movement or, more likely, decreased numbers in line with decreases locally and globally (Morrison 2017). Erect-crested penguins are no longer present, which is consistent with a general decline in the species (Miskelly 2013). Giant petrel numbers are comparable across two decades 1993–2015 (Parker *et al*. 2020 – Chapter 13). More worryingly, there appears to have been a decline in the numbers of all four seabird species, which together dominate the Disappointment Island bird fauna: sooty shearwater, white-headed petrel, white-chinned petrel, and white-capped mollymawk. While Disappointment Island has been able through its remoteness to remain essentially pristine, it is clearly not immune to the problems of the oceans around it.

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APPENDIX: Calculating size of white-capped mollymawk population from aerial photographs

Background

Aerial counts at their main breeding colony on Disappointment Island might provide a useful way of detecting trends in white-capped mollymawk populations. However, detecting trends in aerial counts is hindered by variation in the numbers of non-breeding birds at the colonies, which cannot necessarily be distinguished from breeding birds in aerial photographs. This problem is exacerbated in species like white-capped mollymawks because most adults do not breed every year (Francis 2012), and non-breeding adults, as well as failed breeders, pre-breeding-age birds, and partners of the incubating bird, come and go into the colonies. In an attempt to reduce variability, aerial counts of breeding pairs undertaken since 2006 have relied on close-up aerial photography of parts of the colony to identify 'loafers' (standing birds or those not associated with nests), which comprised 1–22% of birds in close-up photographs (Baker *et al.* 2015, 2018). However, many apparently incubating birds have been found sitting on empty nests (dubbed 'triers' by Francis 2012) and their presence adds variability to aerial counts because these birds cannot be detected from the air.

The aerial counts used in this analysis

In this Appendix, all available aerial counts of white-capped mollymawks on Disappointment Island are used to look for trends, and to examine the effect of attempting to 'correct' counts. Corrections were made using estimates of the number of loafers determined from close-up aerial photographs ('aerial correction'), estimates of the number of loafers and triers detected from the ground ('ground correction') as well as the uncorrected number of birds counted in the photographs ('raw counts'). Aerial counts of the white-capped mollymawk colonies on Disappointment Island include 11 whole-island aerially corrected counts already reported (Baker *et al.* 2009, 2010, 2011, 2013, 2014, 2015, 2018) and three counts (Rebergen 1991, 1995) presented here for the first time (part of the island only in 1993; whole island in 1985 and 2002). In 1985, 1993, and 2002, photographs were taken from a helicopter using a 35 mm single-lens reflex camera with a telephoto zoom lens and with ISO 400 slide film. The camera was hand-held, and oblique photographs were taken out the window or door of the helicopter. Slides were subsequently projected onto large sheets of gridded paper, and each bird, or a pair very close together, was marked on the paper as a 'nesting pair' to produce a raw count. As many photographs overlapped, each grid-area was counted from only one slide to avoid double-counting.

Calculation of ground-correction indices

Attempts at ground correction have been undertaken at Disappointment Island and at South West Cape on Auckland Island on nine occasions since 1993 (Table A.1). These ground counts have not necessarily coincided with aerial photographic surveys. In Jan 1993, 2015, and 2016, they involved observers walking in parallel along transects through mollymawk colonies and counting all birds on eggs, birds sitting on nests without eggs (triers), and birds standing either on nests without eggs or on the ground between nests (loafers). In Dec 2007 only loafers were distinguished from the other categories, and in Dec 2008 only triers were distinguished; both categories were amalgamated by Francis (2012) into estimated Dec ground-correction indices (Table A.1).

In Jan 1993 and 2015 the ground checks were made on consecutive days, allowing multi-day comparisons within single years. In Jan 1993, 2015, and 2016 the ground count results were recorded in 30-min blocks, and these data provide an opportunity to determine whether time of day, day in Jan, and year have any systematic effects on the proportion of birds on the ground but not incubating. Unfortunately, the effect of time of year (thought to be important) could not be included in the analysis as no complete ground checks

TABLE A.1. Ground counts in white-capped mollymawk colonies used to identify birds on eggs, loafers and triers. ^ = estimated from ground counts made 1630–1730 h, adjusted for time of day; * = assumed from the number counted on Disappointment Island in 2008; ** = assumed from the number counted on South West Cape in 2007.

Date	Time (h)	Locality	*N*	% loafers	% triers	% not on egg	Source
20 Jan 1993	1640–1930	Disappointment I	924			33	This study
24 Jan 1993	1505–2030	Disappointment I	2113			28	This study
25 Jan 1993	1050–1125	Disappointment I	93			32	This study
1 Dec 2007	1130–1430^	South West Cape		1.3	6.5*	7.8	Francis 2012
1 Dec 2007	1430–1530^	South West Cape	109	3.7	11.5*	15.2	Francis 2012
9 Dec 2008	1200–1230	Disappointment I	478	1.3**	6.5	7.8	Francis 2012
6 Jan 2015	1345–1420	Disappointment I	201	24.4	14.9	39.3	Parker *et al.* 2017
10 Jan 2015	1000–1620	Disappointment I	1248	21.9	15.1	36.9	Parker *et al.* 2017
13 Jan 2016	1036–1508	Disappointment I	913	24.0	22.5	46.4	Parker *et al.* 2017

had been made on the same day in December. We explored these possible effects visually (for time of day; Fig. A.1) and by comparing the AIC values (Burnham & Anderson 2002) of eight plausible models (Table A.2) of the relationship between proportion incubating, time of day, day in Jan, and year, using generalised additive models in the package gamm4 (Wood & Scheipl 2017) in program R (R Core Team 2017). The statistical analysis (Table A.2) suggests that year is the best predictor of proportion incubating, and that day in Jan and time of day have little effect on the proportion of birds on the ground but not on an egg.

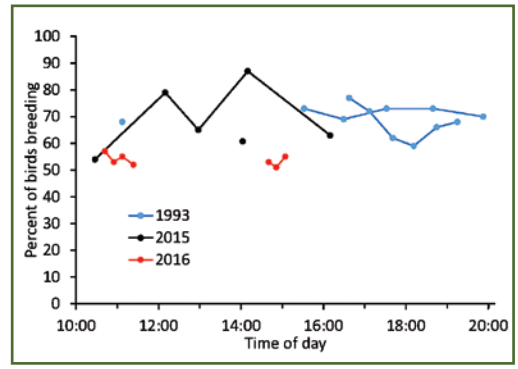

FIGURE A.1. Proportion of white-capped mollymawks that were incubating versus those on the ground that were not (both loafers and triers) on Disappointment Island in early- to mid-Jan 1993, 2015, and 2016. Connected points indicate a series of proportions measured in sequence on the same day.

Applying a ground-correction factor to white-capped mollymawk raw counts

The implication of these findings is that a ground-correction factor estimated in the same year as an aerial survey is a reasonable proxy for a ground-correction factor estimated at the time of the aerial survey, and that matching times and dates within Jan is less important.

Accordingly, ground-correction factors for each aerial survey were calculated from subsets of the ground counts (Table A.1) that were as close as possible to first, the year; second, the time of year; and finally, the time of day. These ground-correction factors were multiplied by the raw counts to produce ground-corrected indices (Table A.3).

TABLE A.2. Generalised additive models of the relationship between the proportion of birds breeding and year, date, day in year, and time of day.

Model	df	AIC	Δ AIC
~ smoothed year	3.9	172.8	0.0
~ smoothed year + smoothed day in Jan	4.9	172.9	0.1
~ smoothed year + smoothed day in Jan + smoothed time of day	6.2	174.4	1.6
~ smoothed year + smoothed time of day	5.3	174.6	1.8
~ smoothed day in Jan	3.8	183.3	10.5
~ smoothed day in Jan + smoothed time of day	4.8	183.6	10.8
~ smoothed time of day	3.0	185.3	12.4
~ intercept only	2.0	187.2	14.4

Trends in counts of ground-corrected indices, aerially corrected indices, and raw counts were then compared visually (Fig. A.2), and by using generalised additive models to fit smoothed lines to the relationships between counts and time (Table A.2).

Population trends

Smooth lines fitted to both the raw counts and the ground-corrected indices were both significant (raw counts $P = 0.0482$, ground-corrected indices $P = 0.0135$) and indicated that the population of white-capped mollymawks increased from 1985 to about 2006, after which it declined. To estimate the rate of decline after 2006 we fitted generalised linear models with negative binomial errors (Venables & Ripley 2002) to the raw counts, aerial indices, and ground indices. The decline estimated from raw counts was 0.1% per annum and was not significant ($P = 0.922$). The decline estimated from aerially corrected indices was 1.5% per annum but was also not significant ($P = 0.1952$). In contrast, the decline estimated from the ground-corrected indices was 4.1% per annum and was significant ($P < 0.001$).

Conclusions on aerial count correction indices

The proportion of the population loafing is similar to the proportion trying (Table A.1). A counting method that eliminates variability caused by loafers will increase the power of the counts to detect trends, but a counting method that eliminates variability caused by both loafers and triers will increase the power to detect trends even further. This is probably the explanation for the detection of a significant decline after 2006 in ground-corrected indices (which eliminate both loafer and trier variability), while there was no significant trend in aerially corrected indices (which eliminate only loafer variability) or the raw counts.

TABLE A.3. NOTES

1 Average of ground-truth counts along transects by three people on Disappointment Island on: 20 Jan 1993, 1640–1930 h, *n* = 924 birds, mean loafers + triers = **33%** (23–41%); 24 Jan 1993, 1505–2030 h, *n* = 2,113 birds, mean loafers + triers = **28%** (27–31%); 25 Jan 1993, 1050-1125 h, *n* = 93 birds, loafers + triers = **32%** (this study).

2 Combination ground-truth checks (**1**) at South West Cape on 1 Dec 2007, 1130–1430 h, 1.3% of birds were loafers and (**2**) on Disappointment Island on 9 Dec 2008, 1200–1230 h, *n* = 478 birds, 6.5% were triers, and so total non-breeders = **7.8%**; and at 1530 h 3.7% loafers + 11.5% triers, total non-breeders = **15.2%** (Francis 2012).

3 Average of ground-truth checks 10 Jan 2015 & 13 Jan 2016, 1117–1447 h, ***n*** = 650 birds, 212 of them (**33%**) not breeding ('loafers + triers'; Parker *et al.* 2017).

4 Ground-truth check 10 Jan 2015, 1200–1420 h, ***n*** = 363 birds, 75 of them (**21%**) not breeding (loafers + triers; Thompson *et al.* 2015).

5 Ground-truth check 13 Jan 2016, 1117–1447 h, ***n*** = 287 birds, 137 of them (**48%**) not breeding (loafers + triers; Parker *et al.* 2017).

TABLE A.3. Aerial counts of breeding pairs of white-capped mollymawk on Disappointment Island and in a subset of the total population in Castaways Bay in 1985–2017 (see notes opposite).

Date	Time (h)	Approx. wind speed (km/h)	Castaways Bay raw counts	All-island raw counts	All-island aerial photo-corrected breeding pairs	% birds on ground but not on eggs	Castaways ground-corrected breeding pairs	All-island ground-corrected breeding pairs
18 Feb 1985			2,956	71,799		30.0%[1]	2,069	**50,259**
22 Feb 1993	1100–1200	0	3,740			30.0%[1]	2,618	
21 Feb 2002	1100–1200	40	5,120	125,476		30.0%[1]	3,584	**87,833**
16 Dec 2006	1447–1610	0	5,233	110,649	109,542	15.2%[2]	4,478	**93,830**
13 Dec 2007	1318–1437	0	4,173	86,080	84,358	7.8%[2]	3,857	**79,366**
14 Dec 2008	1055–1155	0	4,187	91,694	90,777	7.8%[2]	3,960	**83,542**
3 Dec 2009	1200–1310	0	3,350	70,569	71,552	7.8%[2]	3,089	**65,065**
15 Dec 2010		0	3,618	72,635	71,909	7.8%[2]	3,336	**66,969**
11 Dec 2012	1315–1430	0	4,640	93,752	87,189	33.0%[3]	3,109	**62,814**
14 Dec 2013	1315–1430	0	5,577	111,312	96,841	33.0%[3]	3,637	**74,579**
20 Dec 2014	1310–1438	40	4,274	89,552	69,841	33.0%[3]	2,864	**60,000**
14 Dec 2015	1210–1315	0	4,556	96,864	91,052	21.0%[4]	3,599	**76,523**
13 Dec 2016	1310–1430	0	4,508	91,554	82,399	48.0%[5]	2,344	**47,608**
18 Dec 2017		0	3,799	85,510	76,959	33.0%[3]	2,545	**57,292**

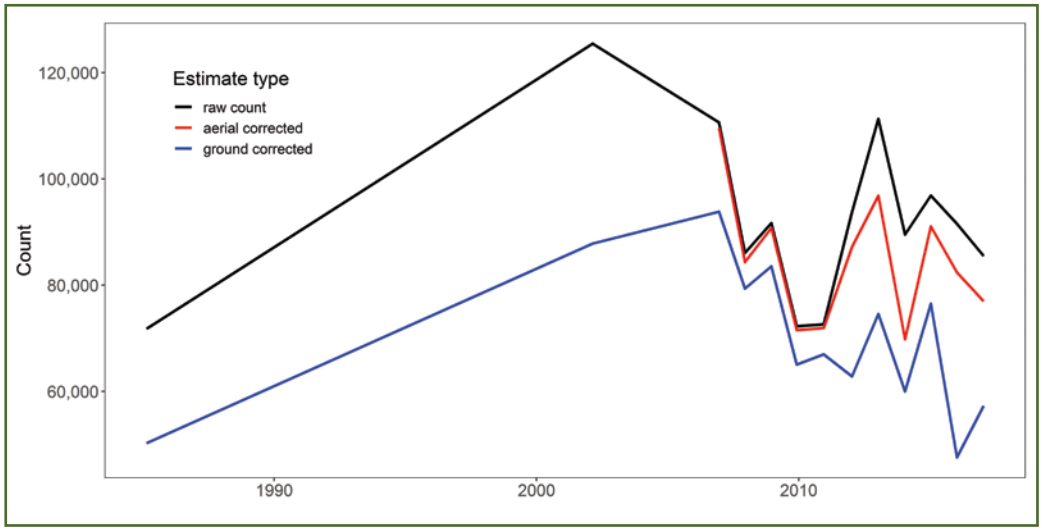

FIGURE A.2. Counts of white-capped mollymawks on Disappointment Island. Raw counts (black) are the total number of birds counted on the aerial photographs. Aerial-corrected indices (red) are the total counts corrected by the proportion of birds seen loafing in close-up photos. Ground-corrected indices (blue) are the total counts corrected by the proportion of birds not on an egg detected during ground counts.

The finding that there is considerable inter-annual variation in ground-correction factors but less daily and hourly variation is consistent with the breeding biology of white-capped mollymawks. White-capped mollymawks are mostly biennial breeders: birds that breed successfully will most often not attempt to breed in the following year (Sagar 2017). However, the previously successful but not currently breeding birds may return to their colonies to maintain nests and pair-bonds (Sagar 2017). This means that the number of birds not currently breeding is affected by nesting success in the previous year. When nesting success is high, many birds will return to the colony in the following year but will not breed; and when nesting success is low, most birds returning to the colony will breed.

The finding that time of day made much less difference to the numbers of non-breeders present (Fig. A.1) than previously thought (Francis 2012) is probably a reflection of the larger dataset used in this analysis. Limited ground counts at South West Cape in Dec 2007 and 2008 had found the number of non-breeders to be lowest in the middle of the day (1130–1430 h) compared with earlier or later in the day (Baker *et al.* 2009; Francis 2012). While relatively few ground counts were undertaken around noon in 1993, 2015, and 2016, they suggested that any dip in numbers in the middle of the day in January is fleeting, if it exists at all (Fig. A.1).

The finding that there was little variation in the numbers of non-breeders present between days within a year is perhaps applicable only to the short period of time over which most data were collected. Most ground counts were undertaken in the period 6–25 Jan, after laying but before hatching. The proportion of birds on empty nests is likely to rise between laying and hatching, as nests fail (Thompson *et al.* 2015), and then fall as adults leave the island following nest failure or hatching.

Regardless of the correction factors applied, counts from photographs taken in early-Dec (i.e., 2006–10) may not be comparable with those taken in mid-Jan (i.e., 2011–17) as many nests will have failed during early incubation. Likewise, the 1985 and 2002 photos were taken a month later than the 2011–17 photos, and so the number of breeding pairs in both the 1985 and 2002 counts are probably under-estimates as more nests will have failed and a few chicks will have been left unguarded. A comparison of nests

with eggs mapped on the ground in a small study plot on 24 Jan 1993, and the position of birds in the plot at noon on 22 Feb 1993 mapped from an aerial photo, suggests that numbers of non-incubating birds present in February were lower than they were a month earlier. The small number of ground counts compared with aerial counts means that the correction factors used to calculate ground-corrected indices were sometimes constructed from ground count data collected during a different year or at a different time of year to the aerial survey. They should therefore be treated with caution, as should our findings about population change. However, the analysis indicates that the population has probably both increased and then decreased since 1985, and that the inclusion of correction factors to account for non-breeding birds can have a considerable impact on calculated trends.

Recommendations

For the future, aerial photographs of all or part of the island, or land-based photos of part of the island, can provide a useful index of population size. The best indices of population size will come from aerial photographs with simultaneous ground counts. Next best are aerial photographs with simultaneous close-up photos of a sample of birds. Worst are photographs with no attempt to correct for non-breeding birds. Counts from aerial photographs corrected for both loafers and triers taken soon after laying might reasonably be regarded as an estimate of the number of pairs breeding. Raw counts or counts corrected only for loafers may usefully detect trends, but cannot reasonably be regarded as population estimates.

To increase the accuracy of any future aerial counts, ground counts should be undertaken at the same time, and all sitting birds checked for eggs; more ground-checking should be undertaken in early-Dec and in mid-Jan to assess whether non-breeders are reliably in lower numbers around midday and in early incubation. Aerial counts should be made in early-Dec before many egg failures occur, as suggested by Baker *et al*. (2015).