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Dispersal of endemic passerines to islands in Dusky Sound, Fiordland, following translocations and predator control

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Abstract Many New Zealand forest bird species have poor flying ability, limiting their ability to recolonise vacant habitat, and restricting gene flow between populations separated by water. Three endemic passerines considered to have poor dispersal ability have been reintroduced to 3 islands in Dusky Sound where stoats (*Mustela erminea*) have been eradicated: South Island robins (kakaruwai, *Petroica australis*) to Anchor Island (1,137 ha), Indian Island (168 ha) and Pigeon Island (73 ha), mohua (yellowhead, *Mohoua ochrocephala*) to Anchor and Pigeon Islands, and South Island saddleback (tīeke, *Philesturnus carunculatus*) to Anchor Island only. Mohua have also been reintroduced to nearby Resolution Island (20,887 ha), where stoats are controlled to low density. Stoat traps set on numerous 'stepping stone' islands around and between these 4 islands have created a network of predator-free habitat at varying distances from the reintroduction sites. We recorded sightings of these species during landings on 56 islands in Dusky Sound in November 2016. South Island robins had the greatest dispersal ability of the 3 species, and were found on 33 additional islands up to 1.4 km from the nearest potential source population. In contrast, mohua and South Island saddlebacks had each crossed a single water gap only, of 90 m and 100 m respectively. One or more of these 3 species have been translocated to more than 40 islands and a few mainland sites around the South Island and Stewart Island. Information on their dispersal ability across water could guide decisions on whether further translocations are necessary, both in respect to whether birds are likely to colonise nearby islands or forest patches unassisted, and in order to manage gene flow within dispersed metapopulations. South Island robins have apparently displaced tomtits (*Petroica macrocephala*) on at least 9 small islands in Dusky Sound.

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INTRODUCTION

Loss of forest bird species from Dusky Sound

Dusky Sound, Fiordland, was the site where European naturalists first documented a New Zealand forest bird community. On his second voyage to New Zealand, Captain James Cook took *HMS Resolution* into 'Dusky Bay' for 6 weeks in March-May 1773 (Beaglehole 1961; Hoare 1982). The naturalists on board (including father and son Reinhold and Georg Forster) recorded 36 bird species during their stay, including 19 species of forest-dwelling birds (Hoare 1982; Watola 2009). Among the 12 passerine species recorded were 3 species that are now probably extinct (bush wren *Xenicus longipes*, South Island kōkako *Callaeas cinerea* and South Island piopio *Turnagra capensis*), and a further 3 species that became extinct in Dusky Sound within 200 years of European contact, but that survived elsewhere in Fiordland and/or further afield (South Island saddleback / tīeke *Philesturnus carunculatus*, mohua / yellowhead *Mohoua*

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Table 1. Changing composition of the native forest-dwelling passerine community in Dusky Sound over 243 years. The 6 species that became globally or locally extinct within 200 years of European contact are shown in bold. C = collected, ✓ = recorded, x = not recorded. Note that South Island saddleback, mohua and South Island robin were reintroduced to Dusky Sound between 1979 and 2016. [1]Medway (1976a & b), Hoare (1982); [2]Ogilvie-Grant (1905), Hill & Hill (1987); [3]Bull *et al.* (1985); [4]This study.

Species		1773[1]	1894-1908[2]	1969-79[3]	2016[4]
Rifleman	*Acanthisitta chloris*	C	C	✓	✓
Bush wren	***Xenicus longipes***	**C**	**C**	**x**	**x**
South Island kōkako	***Callaeas cinerea***	**C**	**C**	**x**	**x**
South Island saddleback	***Philesturnus carunculatus***	**C**	✓	**x**	✓
South Island piopio	***Turnagra capensis***	**C**	**C**	**x**	**x**
Grey warbler	*Gerygone igata*	x	C	✓	✓
Bellbird	*Anthornis melanura*	C	✓	✓	✓
Tūī	*Prosthemadera novaeseelandiae*	C	✓	✓	x
Mohua	***Mohoua ochrocephala***	**C**	**C**	**x**	✓
Brown creeper	*Mohoua novaeseelandiae*	C	C	✓	✓
New Zealand fantail	*Rhipidura fuliginosa*	C	C	✓	✓
Tomtit	*Petroica macrocephala*	C	C	✓	✓
South Island robin	***Petroica australis***	**C**	**C**	**x**	✓
Silvereye	*Zosterops lateralis*	x	✓	✓	✓

ochrocephala and South Island robin / kakaruwai *Petroica australis*; Table 1).

The 6 passerine species that disappeared from Dusky Sound between 1773 and 1973 were all endemic species considered to have limited flying ability (see below). All 6 species survived there until at least 1895, based on the observations of Richard Henry, curator of the newly-reserved Resolution Island from 1894 to 1908 (Hill & Hill 1987). Henry was mainly employed to catch and translocate kākāpo (*Strigops habroptilus*) and kiwi (*Apteryx* spp) to islands in Dusky Sound, in a futile attempt to save them from introduced stoats (*Mustela erminea*) that were spreading rapidly through the South Island (Hill & Hill 1987). Henry's records of smaller forest birds were largely in relation to his collecting of specimens for the British Museum (Natural History) in 1901, at the request of the Governor of New Zealand, the Earl of Ranfurly (Ogilvie-Grant 1905).

Pacific rats (kiore, *Rattus exulans*) would have been present on at least the mainland of Dusky Sound in 1773, and it is presumed that Norway rats (*R. norvegicus*) were introduced to the mainland and larger islands there before 1850 (Atkinson 1973, 1985; Hill & Hill 1987). Henry recorded the disappearance of rats from Dusky Sound in 1900 coincident with the arrival of stoats (Hill & Hill 1987, p.195). While he reported the return of rats 6 years later, stoats evidently extirpated Norway rats (the only species likely to have been present) from all islands in Dusky Sound, as rats of all species were absent from Resolution, Anchor and Pigeon Islands by 2000 (DOC trapping records per P.G. McMurtrie, and see Thomson 1921, and Taylor 1978). Ship rats (*Rattus rattus*) remain widespread on the adjacent mainland (DOC trapping records per PGM).

At least 2 passerine species were already scarce in Dusky Sound before the arrival of stoats. Henry recorded South Island saddlebacks at Supper Cove (at the head of Dusky Sound) in 1895, but failed to find them in 1901 (Hill & Hill 1987, p.264). He also referred to South Island piopio as "among the first birds to disappear before the settlers, and they are never plentiful even in the most suitable and uninhabited places" (Ogilvie-Grant 1905), although he did secure 1 specimen in Dusky Sound in 1901, along with specimens of 9 other forest passerine species (*ibid*.). This suggests that saddlebacks and piopio at least were impacted by European rats (Norway rats and ship rats) in the absence of stoats; note that cats *Felis catus* were rare or absent in western Fiordland (Begg & Begg 1975; Hill & Hill 1987).

South Island saddleback, South Island piopio, South Island kōkako and bush wren all became extinct (or functionally extinct) throughout the South Island following the spread of stoats in the 20th century, with few accepted mainland records after 1920 (Tennyson & Martinson 2007). Two further passerine species that disappeared from Dusky Sound after 1900 are still present within small portions of their mainland ranges, although both have been severely impacted by introduced predators. South Island robins disappeared from western Fiordland, apart from a single population on stoat-free Breaksea Island, north of Resolution Island (Morrison 1984; Bull *et al.* 1985; Taylor & Thomas 1993). While the decline of mohua was more gradual, their disappearance from much of their historic range (including western Fiordland) has also been attributed to stoat predation (Gaze 1985; Elliott & O'Donnell 1988; Elliott 1996).

Henry reported that robins and parakeets had gone from Dusky Sound by 1902, and that piopio were disappearing in 1904 (Henry 1903; Hill & Hill 1987). He reported robins surviving on 1 small island in 1906 (possibly Breaksea Island, but he did not name the island; Henry 1906). Henry's reports became increasingly pessimistic after 1904, and by 1907 "he had come to the unhappy conclusion that in Breaksea and Dusky Sounds most of the native birds were disappearing rapidly" (Hill & Hill 1987). While Henry did not explicitly link the disappearances of robins and other small forest birds to the spread of stoats and ship rats, this is now the most widely accepted explanation for the decline of forest birds on mainland New Zealand in the 20th century (King 1984; Atkinson 1996; King & Murphy 2005; Elliott, Wilson *et al*. 2010; Innes *et al.* 2010; Brown *et al.* 2015).

Stoats are able to swim to islands at least 1 km offshore in Fiordland (Elliott, Willans *et al*. 2010; Veale *et al.* 2012), which includes all islands >2 ha in Dusky Sound.

Ecological restoration of islands in Dusky Sound

Restoration of islands in Dusky Sound has focussed primarily on control of stoats and red deer (*Cervus elaphus*), to benefit recovery of kākāpo and other threatened forest birds (Elliott, Willans *et al*. 2010; Clayton *et al.* 2011; Edge *et al.* 2011; Wildland Consultants & DOC 2016). Trapping for stoats began on Indian Island in 1999, Parrot, Cormorant, Useless, Nomans and Front Islands and Thrum Cap in 2000, Anchor, Seal, Many and Petrel Islands in 2001, Pigeon Island in 2005, Resolution Island in 2008, and Long Island in 2012 (*ibid*.). Ship rats and mice (*Mus musculus*) were eradicated from Indian Island by aerial application of brodifacoum in 2010 (Wildland Consultants & DOC 2016; Murray Willans, *pers. comm*. to CMM, 2 May 2017).

Translocations of locally extinct birds back to Fiordland Islands began in 1992, when 59 South Island saddlebacks from Kundy and Big Islands (off Stewart Island) were released on Breaksea Island 4 years after Norway rats were eradicated there (Rasch & McClelland 1993; Taylor & Thomas 1993). This was followed by the translocation of 32 mohua from Blue Mountains, Southland, to Breaksea Island in 1995 (Miskelly & Powlesland 2013; Wildland Consultants & DOC 2016). Breaksea Island was subsequently the main source of South Island robins, South Island saddlebacks and mohua translocated to islands in Dusky Sound (Table 2).

Dispersal ability of passerines reintroduced to Dusky Sound

All 6 passerine species that disappeared from Dusky Sound between 1894 and 1969 are considered to have (or had) poor powers of dispersal. The 2 species of saddlebacks (*Philesturnus* sp.) are frequently described as being weak fliers (Merton 1973; Newman 1980; Higgins *et al*. 2006), with Buller (1887-88) describing their flight as "very laboured, and always confined to a short distance." Buller (*ibid*.) further described the flight of the North Island kōkako (*Callaeas wilsoni*) as "feeble and generally limited to short distances", the North Island piopio (*Turnagra tanagra*) as "rarely performing any long passage on the wing", and the bush wren (*Xenicus longipes*) as having "very limited" powers of flight. While the mohua is a stronger flier, it is considered to have a fear of flying over water (Diamond 1981, 1984). The South Island robin is also considered to have "poor dispersal abilities" (Flack 1976).

Jared Diamond (1984) divided New Zealand land and freshwater birds into 'water-crossers and non-crossers' based largely on their distributions, plus any additional evidence of migrancy and vagrancy. New Zealand robins (*Petroica* sp.) were listed as water-crossers due to the presence of the black robin *P. traversi* on the Chatham Islands, based on the assumption that the South Island robin, North Island robin *P. longipes* and black robin formed a superspecies (Diamond 1984). Subsequent genetic research has indicated that the black robin is more closely related to tomtits *P. macrocephala* than to *P. australis* and *P. longipes* (Miller & Lambert 2006). With the Chatham Island link removed, *P. australis* and *P. longipes* meet Diamond's criteria for 'non-crossers', as do the 5 other passerine species that disappeared from Dusky Sound (Diamond 1984).

The only published account of South Island saddlebacks crossing water gaps that we are aware of was 2 birds that flew at least 160 m from Erin Island to the easternmost of the Doubtful Islands in

Table 2. Translocations of endemic passerines to islands in Dusky Sound (data from Miskelly & Powlesland 2013; Wildland Consultants & DOC 2016, Appendix 2).

Species	Release site	Source	Date	No. of birds
South Island saddleback	Anchor I	Breaksea I	Oct 2002	31
	Anchor I	Breaksea I	Apr 2004	24
Mohua	Anchor I	Breaksea I	Oct 2002	24
	Pigeon I	Anchor & Breaksea Is	Jul 2007	29
	Resolution I	Landsborough Valley	Oct 2011	60
	Resolution I	Catlins	Nov 2013	22
South Island robin	Anchor I	Breaksea I	Oct 2002	24
	Anchor I	Breaksea I	Apr 2004	32
	Pigeon I	Anchor & Breaksea Is	Jul 2007	31
	Indian I	Breaksea I	Apr 2013	71

Lake Te Anau in 2003-04 (Taylor & Jamieson 2007). North Island saddlebacks (*Philesturnus rufusater*) have been recorded flying further. They colonised Coppermine Island from Whatupuke Island, 190 m away, and single birds have twice been seen on a small stack 260 m from Lady Alice and Whatupuke Islands, both of which have translocated North Island saddleback populations (Newman 1980; Hooson & Jamieson 2003; plus a bird seen there on 10 December 1994, *A.J.D. Tennyson unpublished data*). Five of the 27 mohua released on Ulva Island (off Stewart Island) were found on nearby Tamihau Island 2 months later (Oppel & Beaven 2004), which required crossing minimum water gaps of 300 m between vegetated stacks.

Some of the 12 South Island robins translocated from Breaksea Island to Hawea Island in 1987 returned to the larger island 560 m away (Peat & Patrick 1996, p.85). Stewart Island robins (*P. australis rakiura*) released on Ulva Island flew even further, with 5 of 16 birds found back at their source location (Freshwater Flats, Stewart Island, c.20 km away) within a month of translocation (Oppel & Beaven 2002). This required crossing a minimum water gap of 1.4 km (via Native Island) or 1.7 km direct to the northern shore of Paterson Inlet, or 1.2 km via the Bravo Islets for the longer route back to Freshwater Flats via the southern shore of Paterson Inlet.

We report on a rapid survey of islands in Dusky Sound, and the presence or absence of South Island robins, South Island saddlebacks, mohua and other land bird species on each island. Previously unpublished data on dispersal of these 3 species at other sites is also summarised. The distribution of each species is discussed in relation to their translocation history and dispersal ability.

METHODS

A boat-based survey of islands in Dusky Sound, Fiordland National Park, was undertaken by the first 3 authors between 15 and 24 November 2016. While our main focus was locating petrel breeding colonies (Miskelly *et al*. 2017), we recorded all bird species encountered on each island, and noted evidence of breeding. Landings were made from a small inflatable dinghy, with 1-6 team members landing on each island for between 10 minutes and 4 hours (average 64 min, Appendix 1).

A total of 56 islands was surveyed during daylight by 1 or more team member. Few of the smaller islands had individual names on available maps and charts (where most are named as clusters of islands), and so we created names/numbers for them, usually numbering islands in each cluster from north to south and west to east. A central latitude and longitude reference point for each island is provided in Appendix 1, along with the reference number for each island used by DOC, from a GIS database of 713 islands in Dusky and Breaksea Sounds created by Wildland Consultants (see Wildland Consultants & DOC 2016). Island areas were obtained from the DOC GIS database.

Details of predator control history and effort on islands in Dusky Sound were provided by PGM. There are currently more than 3300 'DOC150' stoat traps set in Dusky Sound (2351 on Resolution Island), which are checked 3 times per annum.

Information on dispersal of South Island robins,

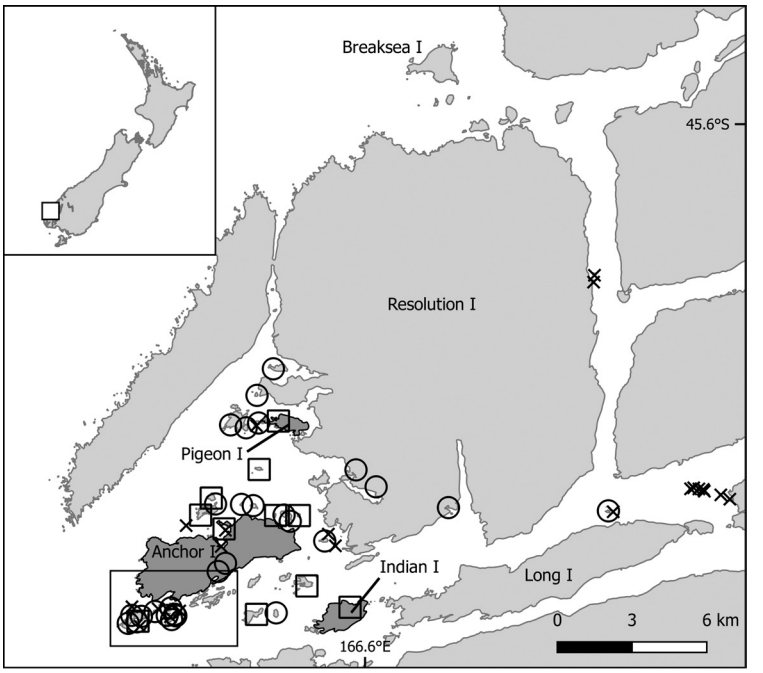

Fig. 1. Distribution of South Island robins on islands in Dusky Sound in November 2016. The 3 release sites are shown in darker grey. Circles = adult robins seen or heard; squares = evidence of nesting, crosses = islands visited without robins being recorded. The area enclosed in a rectangle at the south-west of Anchor Island is shown in more detail in Fig. 2.

South Island saddlebacks and mohua elsewhere in Fiordland, the Marlborough Sounds and around Stewart Island was sought from conservation workers and muttonbirders.

Scientific names for bird species mentioned in Results are given in Appendix 2.

RESULTS

Records of land birds on islands in Dusky Sound

At least 1 species of land bird was recorded on 47 of the Dusky Sound islands surveyed in November 2016 (Appendices 1 and 2). The 9 islands where no land birds were recorded ranged in size from 0.2 to 1.7 ha and were each visited for between 15 minutes and 3 hours.

The most widespread land bird species was bellbird (recorded on 42 islands; Appendix 2), followed by South Island robin (36 islands), kākā (19 islands), yellow-crowned parakeet and blackbird (14 islands each), grey warbler (7 islands), and New Zealand falcon (6 islands). Nine species were recorded only on islands >70 ha: mallard, kea, long-tailed cuckoo and silvereye on Resolution Island; kākāpo and little spotted kiwi (translocated 2005-2015) on Anchor Island; brown creeper on Resolution and Anchor Islands; New Zealand fantail on Resolution and Indian Islands; and mohua on Anchor and Pigeon Islands (translocated 2004 & 2007; Table 2).

Translocated passerines were recorded on 33 islands that they had naturally dispersed to after release, with robins found on all 33 of these islands (Fig. 1; Appendix 2). The smallest island that robins were seen on was 0.04 ha 'Seal Islet 3' (Fig. 2), and the most isolated was 2.1 ha 'Centre Island', 1.4 km from the nearest 'stepping stone' islands, both of which had robins present. 'Centre Island' is considered unlikely to have ever been visited by stoats (Miskelly *et al*. 2017). However, a survey by Fiordland National Park staff on 16 January 1981 made no mention of robins (Fiordland island survey file held by DOC Te Anau), and so the birds are considered to have colonised since 2002.

Evidence of breeding by robins was noted on Pigeon Island (73 ha; a dependent fledgling), 'Main' Petrel Island (21.1 ha; a recent fledgling), Nomans Island (20.1 ha; nest with 2 chicks), Passage Island (16.4 ha; a recent fledgling), 'North' Petrel Island (5.5 ha; nest with 2 eggs, plus a fledgling), 'Centre Island' (2.1 ha – but only 1.1 ha of vegetation; 2 recent fledglings), 'North-east Anchor Islet 6' (1.3 ha; 2 recent fledglings), 'North-east Anchor Islet 3' (0.6 ha; adult carrying food), 'Anchor Island Harbour Islet 1' (0.3 ha; nest with 2 chicks), and 'Seal Islet 3'(0.04 ha; adult carrying food).

Robins have apparently displaced congeneric tomtits on small islands in Dusky Sound. The smallest island that we recorded both species on was 40 ha Parrot Island. We failed to record tomtits on 9

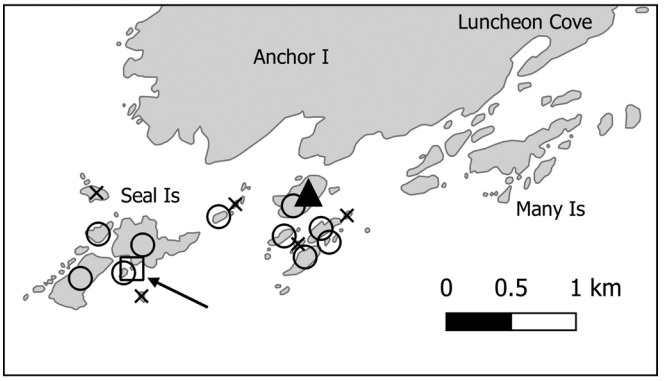

Fig. 2. Distribution of South Island robins and South Island saddlebacks on islands south-west of Anchor Island, Dusky Sound, in November 2016. Both species were released on Anchor Island. Circles = robins seen or heard; square = robin seen carrying food; solid triangle = saddlebacks seen; crosses = islands visited without robins or saddlebacks being recorded. The arrow points to the smallest island in Dusky Sound on which robins were seen (2 adults, 1 carrying food). None of the islands in the main cluster of Many Islands was included in the survey.

smaller (1-21 ha) islands where they were recorded from during 1979-84 (Fiordland island survey file, *ibid*.), all of which now have robins. Sites where tomtits were present before (but not after) robins recolonised included islands 51, 53, 54, 64, 66, 106, 276, 308 and 511 (island locations and areas are listed in Appendix 1). We also recorded robins (but not tomtits) from 19 additional islands (0.2-20 ha) for which we have no 'pre-robin' data (Appendices 1 and 2). The only small island where we recorded tomtit was 0.6 ha 'Shag Island 5'. Robins have not yet recolonised the Shag Islands, which are east of Long Island (Fig. 1).

South Island saddlebacks were recorded at their release site on Anchor Island, plus a pair was seen and a third bird heard on 7.5 ha 'Many Island 1' to the south-west on 21 November 2016 (Fig. 2). This island is separated from Anchor Island by a water gap of 100 m.

Mohua were recorded only at their release sites on Anchor and Pigeon Islands in November 2016, but they have also naturally colonised Resolution Island from Pigeon Island (Wildland Consultants & DOC 2016). Following their release on Pigeon Island in July 2007, mohua were recorded at 4 sites in south-west Resolution Island in June, July and November 2008 and July 2009 (DOC Te Anau records per PGM). This is about 13.5 km south of where mohua were subsequently released on Resolution Island (at Disappointment Cove) in 2011 and 2013. The minimum water gap between Pigeon and Resolution Islands is 90 m.

Dispersal of South Island robins, South Island saddlebacks and mohua across water gaps at other locations

South Island robins have crossed water gaps on numerous occasions, although few of the records have been published.

Robins were first recorded on Long Island, Queen Charlotte Sound, in about 1984 (Bill Cash, *pers. comm*. to CMM 18 April 2017). This is 1.4 km from Motuara Island, where South Island robins were released in 1973 (Flack 1975; Armstrong 2000). The first 2 birds seen on Long Island were colour-banded males from Motuara Island, and Long Island now has a healthy population derived entirely from natural colonisation (Bill Cash, *ibid*.). Robins are also occasionally reported at Ship Cove (Bill Cash, *ibid*.), which is across a minimum 1.7 km water gap from Motuara Island.

South Island robins were also released on Allports Island, further up Queen Charlotte Sound, in 1973 (Flack 1975; Armstrong 2000). There have been multiple sightings of banded robins in gardens at Waikawa Bay (near Picton) since then (Bill Cash, *ibid*.), with the birds having to cross a minimum water gap of 1.4 km.

South Island robins were translocated to Adele Island (Abel Tasman National Park = ATNP) in 2009 from both Motuara Island and Canaan (Miskelly & Powlesland 2013; Peter Gaze, *pers. comm*. to CMM 13 April 2017). Soon a fter this, a colour-banded transferee was sighted at Moa Park, ATNP – possibly on its way back to Canaan (Peter Gaze, *ibid*.). This required crossing a minimum water gap of 830 m. Robins from Adele Island were transferred to Pitt Head, ATNP mainland, in autumn 2016; about 6 months later 1 of the colour-banded transferees was sighted back on Adele Island (Peter Gaze, *ibid*.), again requiring a water crossing of at least 830 m.

South Island robins were released on Puangiangi Island, east of D'Urville Island, in March 2013. In 2016, robins were found to be present in good numbers on Tinui Island (340 m away), where they had never been recorded previously (Peter Gaze, *ibid*.).

South Island robins released at Kaipupu Point Mainland Island, Picton, in March 2016 rapidly dispersed, with at least 2 birds apparently crossing water gaps (Bill Cash, *pers. comm*. to CMM 18 April

2017). Within a week, 1 of the robins was sighted on The Snout, which is across Picton Harbour from Kaipupu Point (minimum water crossing of 500 m). Another male took up residence on Wedge Point, 400 m across Shakespeare Bay to the west (Bill Cash, *ibid*.).

In addition to the report by Oppel & Beaven (2002), there are 3 other examples of Stewart Island robins (a subspecies of South Island robin) crossing water gaps. Ship rats were eradicated from Taukihepa (Big South Cape Island, 939 ha), Rerewhakaupoko (Solomon Island, 25 ha) and Pukeweka Island (2 ha), south-west of Stewart Island, in 2006 (McClelland *et al.* 2011). Robins recolonised northern Taukihepa by 2007, when they were noted as being uncommon there in late winter (the southern half of the island was not visited; Matt Charteris, *pers. comm*. to CMM 18 April 2017). They had reached Rerewhakaupoko by March 2008 (Ona Heaslip, *pers. comm*. to CMM 22 March 2012) and were common there in March 2012 (CMM, *pers. obs*.). There were 2 possible source populations for the robins – a natural population on Poutama Island, 320 m south of Taukihepa, and a translocated population on Putauhinu Island, 1.4 km to the north-west. Once the birds were on Taukihepa, it was only a further 190 m water crossing to Rerewhakaupoko. Or the birds may have moved there via Pukeweka Island (which lies partly between the 2 larger islands, and which robins have also subsequently colonised; Cliff Clelland, *pers. comm*. via Pete McClelland, 13 June 2017), reducing the maximum water crossing to Rerewhakaupoko to no more than 100 m.

We are aware of 3 records of South Island saddlebacks crossing water in addition to Taylor & Jamieson (2007) and the observation we report here. Birds released on Motuara Island, Queen Charlotte Sound, in 1994 crossed the 50 m gap between vegetation to Hippa Island to the south, although the water gap is only 2-5 m at low tide (Bill Cash, *pers. comm*. to CMM 18 April 2017). Saddlebacks released on Pohowaitai Island, west of Taukihepa, in 1999 soon crossed the 80 m gap to Tamaitemioka Island to the north (Miskelly & Powlesland 2013; Pete McClelland, *pers. comm*. to CMM 13 April 2017).

Before ship rats invaded the 3 'South Cape' islands in c.1963, South Island saddlebacks were found naturally on Taukihepa, Rerewhakaupoko and Pukeweka Island (Bell 1978). Saddlebacks became extinct on all 3 islands within 7 years of rat invasion (Merton 1973; Ballance 2007, p.78), but were translocated back to Taukihepa and Rerewhakaupoko in 2011 and 2012 respectively, 5-6 years after rat eradication (McClelland *et al*. 2011; Miskelly & Powlesland 2013). They have since recolonised Pukeweka Island, which lies 85 m from Rerewhakaupoko and 100 m from Taukihepa (Cliff Clelland, *pers. comm*. via Pete McClelland, 13 June 2017).

In addition to the movement of mohua between Pigeon and Resolution Islands reported here, there are 2 other examples of mohua crossing water gaps in Fiordland. Mohua were translocated to Secretary Island in 2008 (Miskelly & Powlesland 2013), and were reported from Bauza Island (190 m to the south) in December 2014, with 3-6 birds reported there again in February 2015 (Te Anau DOC records per PGM). H.K. Edmonds has also heard mohua calls on 'Little Passage' Island in Chalky Inlet (date not recorded). In order to reach this island, the bird(s) would have had to cross a water gap of 860 m from Chalky Island (where mohua were released in 2002) to the larger of the Passage Islands, followed by a further water crossing of 160 m to the smaller of the Passage Islands.

DISCUSSION

South Island robins, South Island saddlebacks and mohua all fly across water more often than is apparent in published accounts (Oppel & Beaven 2002 & 2004; Taylor & Jamieson 2007; Gaze & Cash 2008). The robin is the most frequent cross-water disperser of the 3 species, both within Dusky Sound and elsewhere. The presence of South Island robins on more than 30 islands in Dusky Sound within 15 years of their reintroduction to Anchor Island suggests that they routinely cross water gaps of several hundred metres.

The most isolated island where we found South Island robins was 1.4 km from other sites where robins were present. This is consistent with the length of at least 3 other water gaps crossed by the same species in the Marlborough Sounds and off Stewart Island. South Island robins are probably capable of direct flights in excess of 1.7 km, including the birds that departed Ulva Island (Oppel & Beaven 2002), and sightings at Ship Cove in Queen Charlotte Sound.

South Island saddlebacks and mohua crossed water less frequently, and over shorter distances, than robins. The maximum dispersal distance so far recorded for South Island saddlebacks is 160 m, with 3 other examples in the 80-100 m range. Small flocks of mohua crossed water gaps of 90 m to at least 300 m on at least 3 occasions (this paper, and Oppel & Beaven 2004), with 1 example reported here of a water crossing of at least 860 m.

Based on these dispersal distances, and the presence of all 3 species around Luncheon Cove on the south coast of Anchor Island, we predict that all 3 species will be found within the main cluster of the Many Islands, several of which are separated from Anchor Island by water gaps of no more than 65 m (Fig. 2).

The rapid recolonisation of Dusky Sound islands by South Island robins following their translocation, and supported by extensive stoat trapping, provides strong circumstantial support for stoat predation being the cause of extinction of robins in Dusky Sound in the early 1900s. Richard Henry reported that the formerly common robins had disappeared from the area by 1902, which was less than 2 years after the first sighting of a 'weasel' (probably a stoat) on Resolution Island in March 1900 (Hill & Hill 1987).

Stoat trapping in Dusky Sound since 2000 has created extensive habitat for robins to recolonise, beyond the sites that were the initial focus of the trapping. The programme is focussed primarily on removing stoats from large islands (particularly Anchor and Resolution Islands) and preventing their reinvasion (Elliott, Willans *et al*. 2010; Clayton *et al.* 2011; Edge *et al.* 2011; Wildland Consultants & DOC 2016). Trapping on numerous smaller 'stepping stone' islands to reduce the rate of stoat reinvasion of the large islands has probably benefitted other land bird species as well as the reintroduced robins (e.g. bellbird, kākā and yellow-crowned parakeet; Appendix 2), and has provided protection for c.50 colonies of 3 species of burrow-nesting petrels (Miskelly *et al*. 2017).

However, stoat control may have been to the detriment of tomtits on small islands in Dusky Sound, with recolonising robins apparently out-competing or displacing their smaller congener, as has occurred at 2 other restoration sites (Empson & Fastier 2013).

Many of the islands where we encountered South Island robins are too small to support robin populations without occasional immigration or recolonisation. The smallest island we found robins on was only 0.04 ha (2 birds, 1 carrying food), and the smallest island with an active nest was 0.3 ha. South Island robins can occur at densities up to 5.1 birds per ha on islands elsewhere, with a mean territory size of 0.2-0.6 ha (Flack 1976; Heber *et al*. 2013), indicating that some robin breeding islands in Dusky Sound may have held a single territorial pair only. In contrast to Flack's (1976) assertion that robins have poor dispersal abilities, we suggest that the 30+ islands that they occupy in Dusky Sound hold an unmanaged metapopulation, with regular movements of individuals between islands offsetting stochastic losses and detrimental effects of inbreeding (Jamieson *et al.* 2008; Jamieson 2011; Thrimawithana *et al*. 2013).

Our findings suggest that islands or forest fragments situated less than 1.5 km apart are within the dispersal range of South Island robins, reducing the need for initial and supplementary translocations (Armstrong 2000; Heber *et al.* 2013). In contrast, South Island saddlebacks are unlikely to cross gaps more than 160 m, limiting the number of sites where they will be able to establish new populations naturally, or maintain gene flow between adjacent populations. The distance that mohua will disperse across water is apparently situation or location dependent, and we recommend further survey of islands and shores near release sites or established populations, to guide management decisions.

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APPENDIX 1. Island locations and search effort. ID ISLAND is the Department of Conservation (DOC) Dusky + Breaksea Sound island database reference no. for each island. 'Land birds' refers to whether evidence of land birds was recorded in November 2016 (see Appendix 2). 'Trap' refers to whether at least 1 stoat trap was maintained on the island by DOC at the time of our visit. Note that many islands receive protection by being adjacent to islands that are trapped. 'Time' is the approximate length of time that observers were ashore.

Island name	ID ISLAND	Area (ha)	Latitude S	Longitude E	Land birds	Trap	Date	Observers	Time
Resolution Island	28	20887	45.6700°	166.6300°	Yes	Yes	17 & 24 Nov	AT & CM	4:00
'Cormorant Cove Islet'	530	13.6	45.6885°	166.5524°	Yes	Yes	18-Nov	AT & CM	50
'Goose Cove Islet 1'	511	1.3	45.6982°	166.5442°	Yes	No	18-Nov	AS & J-CS	30
Parrot Island	4	40.2	45.7075°	166.5344°	Yes	Yes	18-Nov	AT & CM	2:25
'Parrot Islet 1'	484	3.6	45.7100°	166.5387°	Yes	No	18-Nov	AS & J-CS	20
'Pigeon Islet 1'	485	0.6	45.7094°	166.5437°	No	No	18-Nov	AS	15
'Pigeon Islet 2'	491	2.4	45.7083°	166.5451°	Yes	No	18-Nov	AS & J-CS	30
Pigeon Island	3	72.8	45.7083°	166.5605°	Yes	Yes	22-Nov	AT, CM, J-CS & HE	1:45
'Centre Island'	444	2.1	45.7250°	166.5454°	Yes	No	18-Nov	AT, CM, J-CS & AS	1:50
'North' Petrel Island	66	5.5	45.7353°	166.5206°	Yes	No	22-Nov	AT & CM	40
'Petrel Islet'	65	0.5	45.7376°	166.5227°	Yes	No	23-Nov	AT & CM	25
'Main' Petrel Island (west end)	64	21.1	45.7413°	166.5148°	Yes	Yes	22-Nov	AT & CM	2:05
Entry I	26	0.6	45.7455°	166.5078°	No	No	23-Nov	AT & CM	30
Anchor Island	21	1136.6	45.7594°	166.5180°	Yes	Yes	16 & 24 Nov	AT & CM	3:10
'Anchor Island Harbour Islet 1'	363	0.3	45.7467°	166.5272°	Yes	No	17-Nov	AT, CM & J-CS	1:50
'North-east Anchor Islet 1'	400	1.0	45.7378°	166.5365°	Yes	No	17-Nov	AT, CM & J-CS	1:30
'North-east Anchor Islet 2'	397	3.0	45.7384°	166.5428°	Yes	Yes	17-Nov	AT, CM & J-CS	1:30
'North-east Anchor Islet 3'	386	0.6	45.7419°	166.5538°	Yes	No	17-Nov	AT & J-CS	50
'North-east Anchor Islet 4'	391	6.3	45.7415°	166.5584°	Yes	Yes	17-Nov	AT & J-CS	25
'North-east Anchor Islet 5'	388	4.6	45.7437°	166.5613°	Yes	Yes	17-Nov	CM & AS	40
'North-east Anchor Islet 6'	389	1.3	45.7417°	166.5661°	Yes	Yes	17-Nov	CM & AS	30

APPENDIX 1. continued

Island name	ID ISLAND	Area (ha)	Latitude S	Longitude E	Land birds	Trap	Date	Observers	Time
Useless Island	25	3.2	45.7509°	166.5791°	Yes	Yes	22-Nov	AT, CM & J-CS	1:45
'Useless Islet 1'	368	0.2	45.7485°	166.5812°	Yes	Yes	22-Nov	CM	35
'Useless Islet 2'	351	0.5	45.7528°	166.5846°	Yes	Yes	22-Nov	AT	30
'Northern Seal Islet'	56	1.7	45.7749°	166.4796°	No	No	23-Nov	AT & CM	3:00
'Seal Island west'	51	9.5	45.7809°	166.4776°	Yes	No	23-Nov	J-CS, HE, RW & DA	2:40
'Seal Islet 1'	53	1.8	45.7780°	166.4796°	Yes	No	15-Nov	AT & CM	1:00
'Seal Island east'	54	13.7	45.7784°	166.4836°	Yes	No	21-Nov	AT, CM, J-CS & HE	4:00
'Seal Islet 2'	47	0.3	45.7803°	166.4822°	Yes	No	23-Nov	AT	35
'Seal Islet 3'	49	0.04	45.7801°	166.4828°	Yes	No	21-Nov	AT	10
'East Seal Islet 1'	290	0.6	45.7765°	166.4918°	Yes	Yes	23-Nov	AT & CM	30
'East Seal Islet 2'	295	0.2	45.7757°	166.4931°	Yes	Yes	23-Nov	J-CS & HE	50
'Southern Seal Islet'	41	0.3	45.7819°	166.4839°	No	No	23-Nov	CM	35
'Many Island 1'	308	7.5	45.7753°	166.4998°	Yes	Yes	21-Nov	AT & CM	1:25
'Many Island 2'	286	1.1	45.7780°	166.4978°	Yes	No	20-Nov	AT	45
'Many Island 3'	292	2.1	45.7775°	166.5016°	Yes	No	20-Nov	CM	1:00
'Many Island 4'	276	2.8	45.7794°	166.5000°	Yes	No	20-Nov	AT & CM	35
'Many Islet 1'	280	0.3	45.7785°	166.4994°	No	No	21-Nov	J-CS & DA	30
'Many Islet 2'	282	0.2	45.7781°	166.5022°	Yes	No	21-Nov	J-CS & DA	20
'Many Islet 3'	294	0.2	45.7763°	166.5042°	No	No	21-Nov	J-CS & DA	20
'South Dusky Islet 1'	257	1.3	45.7994°	166.4981°	No	No	23-Nov	AT & CM	15
Nomans Island (east end)	6	20.1	45.7776°	166.5441°	Yes	Yes	16-Nov	AT, CM & AS	2:00
Thrum Cap	14	4.1	45.7774°	166.5541°	Yes	Yes	16-Nov	AT, CM & AS	1:00

APPENDIX 1. continued

Island name	ID ISLAND	Area (ha)	Latitude S	Longitude E	Land birds	Trap	Date	Observers	Time
Passage Island (south coast)	71	16.4	45.7660°	166.5688°	Yes	Yes	16-Nov	J-CS	1:20
Indian Island (north coast)	2	167.6	45.7780°	166.5897°	Yes	Yes	20-Nov	AT, CM, HE & RW	3:10
Front Island	106	1.0	45.7404°	166.7256°	Yes	Yes	19-Nov	AT, CM, J-CS & AS	1:25
'Little Front Island'	105	0.1	45.7403°	166.7281°	Yes	No	19-Nov	AT, CM, J-CS, AS, DA	25
'Shag Island 1'	32	0.2	45.7321°	166.7680°	No	No	19-Nov	AS	20
'Shag Island 2'	36	0.2	45.7318°	166.7697°	Yes	No	19-Nov	CM	20
'Shag Island 3'	37	1.1	45.7322°	166.7725°	Yes	Yes	19-Nov	AT, CM, J-CS, AS, DA	1:10
'Shag Island 4'	29+34	0.2	45.7324°	166.7746°	Yes	No	19-Nov	AT & J-CS	1:15
'Shag Island 5'	31	0.6	45.7330°	166.7751°	Yes	Yes	19-Nov	CM & AS	1:15
'Shag Island 6'	458	0.3	45.7343°	166.7836°	Yes	Yes	19-Nov	AT	20
'Cooper Islet'	454	0.3	45.7359°	166.7884°	No	No	19-Nov	CM & AS	15
'Acheron Islet 1'	586	0.9	45.6547°	166.7183°	Yes	No	20-Nov	AT, CM, HE & RW	1:00
'Acheron Islet 2'	583	0.9	45.6573°	166.7180°	Yes	No	20-Nov	AT, CM & HE	55

APPENDIX 2. Freshwater and land bird species recorded on 47 islands in Dusky Sound in November 2016. The numbers after each species are the 'ID ISLAND' reference codes for the islands that they were seen or heard on (refer Appendix 1 for island names, areas and locations). Additional data has been entered in eBird for all species and islands.

Little spotted kiwi *Apteryx owenii* 21; paradise shelduck *Tadorna variegata* 28, 53; mallard *Anas platyrhynchos* 28; New Zealand falcon *Falco novaeseelandiae* 21, 28, 53, 54, 286, 290; weka *Gallirallus australis* 51 (5 adults, 3 chicks), 53, 54; New Zealand pigeon *Hemiphaga novaeseelandiae* 31 (1 seen), 454 (1 flying past), 4, 6, 14, 37, 49, 54, 106, 386, 400 (last 9 islands all based on shed feathers only); kākāpo *Strigops habroptilus* 21; kākā *Nestor meridionalis* 2, 4, 14, 21, 28, 29+34, 31, 37, 105, 106, 276, 286, 292, 388, 391, 397, 444, 491, 583; kea *N. notabilis* 28; yellow-crowned parakeet *Cyanoramphus auriceps* 2, 4, 6, 14, 21, 25, 28, 105, 386, 388, 391, 397, 484, 491; long-tailed cuckoo *Eudynamys taitensis* 28; rifleman *Acanthisitta chloris* 28; 583, 586; South Island saddleback *Philesturnus carunculatus* 21, 308; grey warbler *Gerygone igata* 2, 14, 21, 28, 37, 53, 308; bellbird *Anthornis melanura* 2, 3, 4, 6, 14, 21, 25, 28, 29+34, 31, 36, 37, 47, 49, 51, 53, 54, 64, 65, 66, 105, 106, 276, 286, 290, 292, 295, 308, 351, 363, 368, 386, 388, 389, 391, 397, 400, 444, 458, 484, 491, 511, 530, 583, 586; mohua *Mohoua ochrocephala* 3, 21; brown creeper *M. novaeseelandiae* 21, 28; New Zealand fantail *Rhipidura fuliginosa* 2, 28; tomtit *Petroica macrocephala* 2, 4, 21, 28, 31; South Island robin *P. australis* 2, 3, 4, 6, 14, 21, 25, 28, 47, 49, 51, 53, 54, 64, 65, 66, 71, 106, 276, 282, 286, 290, 292, 308, 363, 386, 388, 389, 391, 397, 400, 444, 484, 491, 511, 530; silvereye *Zosterops lateralis* 28; blackbird *Turdus merula* 2, 4, 6, 14, 28, 36, 37, 54, 66, 106, 276, 308, 530, 586; chaffinch *Fringilla coelebs* 37; redpoll *Carduelis flammea* 37.