

New locality records for two species of protected weevils, *Anagotus fairburni* (Brookes, 1932) and *Hadramphus stilbocarpae* Kuschel, 1971 (Coleoptera: Curculionidae), from southern Fiordland, New Zealand

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ABSTRACT: The flax weevil *Anagotus fairburni* (Brookes, 1932) and knobbed weevil *Hadramphus stilbocarpae* Kuschel, 1971 were among the first New Zealand insects to be granted legal protection. Both are large flightless species with narrow host–plant requirements. Their disjunct distributions are probably the result of predation by introduced rodents, with populations of both having apparently been extirpated by ship rats (*Rattus rattus*) at one documented site (Taukihepa/Big South Cape Island). Within Fiordland, flax weevils were previously known from a single small island in Breaksea Sound, and knobbed weevils had been reported from five outer islands, from Secretary Island south to Resolution Island. We report the presence of both species in Dusky Sound, and flax weevils in Chalky and Preservation Inlets, based on surveys of 134 islands in 2016 and 2017. Signs of flax weevil feeding were recorded on 56 widely scattered islands, with live or dead animals found on seven of these during the limited search time available. A single knobbed weevil was found at night on a small island in the Seal Islands, southwest of Anchor Island. The status of both weevil species is discussed in relation to the past and present distribution and control of rodents and stoats.

KEYWORDS: *Anagotus fairburni*, conservation, distribution, Fiordland, flax weevil, *Hadramphus stilbocarpae*, knobbed weevil, rats, *Rattus norvegicus*, *Rattus rattus*, threatened invertebrates.

Introduction

The large invertebrates of Fiordland, New Zealand, are poorly known. Most survey effort has been focused on Dusky Sound, which has been a focal site for scientific discovery and conservation management for nearly 250 years (Henry 1903; Beaglehole 1961; Hill & Hill 1987; Miskelly *et al.* 2017a,b). It was the first site in New Zealand to receive prolonged scrutiny by European naturalists, when Captain James Cook based HMS *Resolution* there for six weeks in March–May 1773 (Beaglehole 1961; Hoare 1982). Johann and Georg Forster and Anders Sparrman prepared extensive illustrations and descriptions of plants, birds, seals, fishes and molluscs, although ‘The only insects mentioned specifically were the pestilential ones, the sandflies [*Austrosimulium* spp.] and the human lice [*Pediculus humanus*]’ (Andrews 1986).

In 1894, Richard Henry was employed as the curator of the newly created Resolution Island bird sanctuary, at the northern entrance to Dusky Sound (Hill & Hill 1987). During his 14 years in residence, Henry was an astute observer of wildlife, but made little mention of terrestrial invertebrates during his travels throughout Dusky and Breaksea Sounds. Apart from discussing sandflies and vegetable caterpillars (hepialid moth larvae mummified by *Ophiocordyceps* fungus), his only mention of insects and spiders was as a food source for birds (Henry 1898, 1902), although he did provide samples of caterpillars and beetles to James Hector at the Colonial Museum and William Benham at the University of Otago (Hill & Hill 1987). The focus on management of threatened birds in Dusky Sound, including vertebrate pest control to achieve this end, has continued to the present day (Elliott *et al.* 2010; Edge *et al.* 2011; Wildland Consultants

and Department of Conservation 2016; Department of Conservation 2017; Miskelly *et al.* 2017a,b).

The *Tamatea/Dusky Sound conservation and restoration plan* (Wildland Consultants and Department of Conservation 2016) acknowledged that the area had not been fully explored for terrestrial invertebrates, but identified several features of the invertebrate fauna considered to be distinctive (p. 44). The conservation and restoration plan covers both Dusky Sound and the adjacent Breaksea Sound, which joins the Tasman Sea north of Resolution Island. Within this broader area, some of the notable invertebrates listed were known only from Breaksea Sound and the outer coast of Resolution Island, including the flax weevil *Anagotus fairburni* (Brookes, 1932) and knobbled weevil *Hadramphus stilbocarpae* Kuschel, 1971. These large (16–22 mm long) flightless weevils were discovered on two rat-free islets in the outer Gilbert Islands in Breaksea Sound during preparations to eradicate Norway rats (*Rattus norvegicus*) from nearby Hāwea Island and Breaksea Island (Meads 1990; Taylor & Thomas 1993). Both weevil species were translocated to Breaksea Island in 1991, three years after the rats were eradicated there (Thomas *et al.* 1992; Peat & Patrick 1996; McGuinness 2001).

The flax weevil and knobbled weevil were among the first New Zealand insects to receive absolute legal protection, through their inclusion in the original Seventh Schedule of the Wildlife Act 1953, in 1980 (Miskelly 2014). Protection for the two species was initiated by their inclusion in a list of endangered insects that ‘occur in very low numbers, have a very restricted distribution, or have only one or two surviving populations’, published in the first issue of *The Wēta* (Ramsay & Gardner 1977). This listing came soon after reports of the vulnerability of these weevils to rodent predation (Kuschel 1971; Watt 1975). Both species were among the large flightless beetles apparently extirpated from Taukihepa/Big South Cape Island, off southern Stewart Island/Rakiura, during an irruption of recently colonised ship rats (*Rattus rattus*) there in the early 1960s (Kuschel 1971, 1982; Bell 1978; Ramsay 1978). Live weevils of both species were last collected on Taukihepa/Big South Cape Island in 1964, but only rat-gnawed elytra (of both species) were found in 1968 (Kuschel 1971; Grace Hall, pers. comm., 27 April 2017).

The flax weevil and knobbled weevil both have extensive distributions, with the flax weevil recorded from Manawatāwhi/Three Kings Islands south to Taukihepa/Big South Cape Island (Kuschel 1982; Marris 2001), and the knobbled weevil from Secretary Island, Fiordland, south to the Snares Islands/Tini Heke (Kuschel 1971;

McGuinness 2001). They are both currently ranked ‘At Risk – Relict’, as they are believed to occupy less than 10% of their original range (Townsend *et al.* 2008; Leschen *et al.* 2012). Flax weevils feed only on harakeke (*Phormium tenax*) and wharariki (*P. cookianum*) (Kuschel 1982; Meads 1990). Knobbled weevils were originally considered host-specific on two species of pūnui (*Stilbocarpa lyallii* and *S. robusta*) on islands from Foveaux Strait south to the Snares Islands/Tini Heke (Kuschel 1971). However, populations subsequently discovered in Fiordland were feeding on *Anisotome lyallii* (Meads 1990; Peat & Patrick 1996; Craw 1999).

Dusky Sound, Chalky Inlet and Preservation Inlet are within the broad geographic range of both the flax weevil and knobbled weevil, but we were unaware of any previous records of these species from islands within the fiords before our visits in 2016 and 2017 (based on specimens in the New Zealand Arthropod Collection and a literature search). Although we were primarily engaged in surveys for petrel (Aves: Procellariiformes: Procellariidae) breeding colonies (Miskelly *et al.* 2017b), we searched for flax weevils and knobbled weevils, or their feeding sign, on all the islands visited. Much of the evidence we found of weevil presence was indirect (i.e. feeding sign), and no live specimens were collected of these protected species. We provide details of what we found as evidence of their presence, and to provide a baseline of distribution records for further surveys for these two species within coastal areas of southern Fiordland.

Methods

Two boat-based surveys of islands in southern Fiordland, Fiordland National Park, were undertaken during 15–24 November 2016 (Dusky Sound) and 20–26 November 2017 (mainly Chalky Inlet and Preservation Inlet). Landings were made from a small inflatable dinghy, with one to nine team members landing on each island for between three minutes and four hours (average 54 minutes: Tables 1 and 2).

A total of 134 islands was surveyed by one or more team members. 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. Central latitude and longitude reference points for each island are provided in Tables 1 and 2; Table 1 also includes a reference number for each island surveyed in Dusky or Breaksea Sounds, or off Resolution Island, based on a GIS database of 713 islands in Dusky and Breaksea Sounds created by Wildland Consultants for

the Department of Conservation (DOC) (see Wildland Consultants and Department of Conservation 2016). Areas for islands in Dusky Sound or near Resolution Island were obtained from the DOC Dusky + Breaksea GIS database; areas for islands in Chalky Inlet and Preservation Inlet were estimated using 'DOCgis' software, by tracing the vegetation edge of each island.

Most islands were surveyed in daylight, and only five islands were visited at night. We were aware of the possibility of encountering flax weevils and knobbled weevils (both of which feed only at night), and so searched for evidence of their presence wherever their host plants (wharariki and *Anisotome lyallii*, respectively) were noted. Authors Colin Miskelly and Alan Tennyson had encountered the weevils and their feeding sign on numerous occasions previously. We have seen many hundreds of flax weevils on six islands between the Poor Knights Islands and Cook Strait (particularly on Mana Island), and dozens of knobbled weevils on the Snares Islands/Tine Heke and also Solander Island (Hautere) (on two species of pūnui).

Wharariki leaves were checked for insect browse damage on the edges of their blades, with ragged, asymmetrical damage considered diagnostic for flax weevil presence (Fig. 1A; and see Martin 2015). This feeding sign was readily distinguished from the straight-edged, symmetrical notches made by *Tmetolophota* sp. (Noctuidae) caterpillars (Martin 2015). Knobbled weevil browse sign was searched for on *Anisotome* stems. Where browse sign was noted, and time permitted, we searched for live or dead animals among the plant bases and dead foliage of the affected plants. We

searched for feeding animals on foliage of both plant species at night on three islands (one site for *Anisotome*, two sites for flax).

Details of predator control history on islands in Dusky Sound were provided by Pete McMurtrie (DOC Te Anau) and former DOC staff member Murray Willans. Similar data were summarised for islands in Chalky Inlet and Preservation Inlet by author Colin Bishop. There are currently more than 2900 DOC 150 stoat traps set on 23 islands in Dusky Sound (2351 on Resolution Island), which are checked three times per annum. Trapping effort in Chalky and Preservation Inlets was initially focused on removing stoats (*Mustela erminea*) from Chalky Island, the Passage Islands and Coal Island, and preventing them re-establishing. Traps targeting two rat species and stoats have recently been placed on many medium-sized islands in Chalky and Preservation Inlets, but the mammalian pest status of most of these islands is not well known, particularly for rodents.

Results

Weevils and their host plants

Wharariki was a minor component of coastal vegetation on most islands visited, but was absent from those sites most exposed to salt spray. In contrast, *Anisotome lyallii* was present only on the most exposed, outermost islands and headlands, forming dense patches on just a few of the islands we visited (e.g. 'Centre Island', Entry Island, 'Northern Seal Islet' and 'Seal Islet 1').

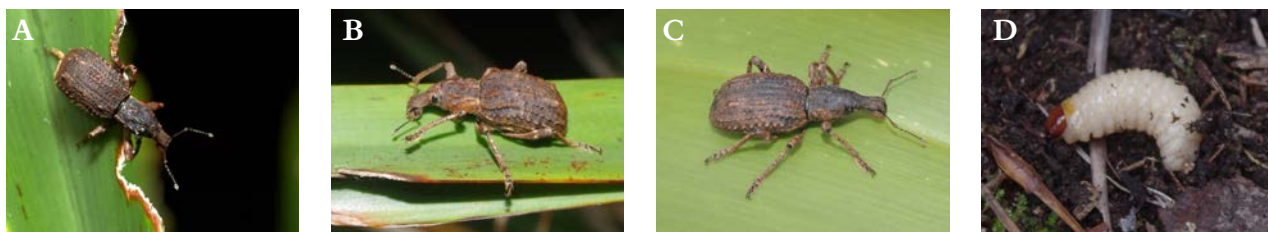


Figure 1. A. Adult flax weevil (*Anagotus fairburni*) on wharariki (*Phormium cookianum*) at night, showing characteristic flax weevil feeding sign, islet in Anchor Island Harbour, Dusky Sound/Tamatea. Photograph: Jean-Claude Stahl, Te Papa. B. Adult flax weevil on wharariki at night, Small Craft Harbour Islands (western main island), Chalky Inlet. Photograph: Colin Miskelly. C. Adult flax weevil on wharariki, Round Island, Preservation Inlet. Photograph: Colin Miskelly. D. Flax weevil larva, Round Island, Preservation Inlet. Photograph: Colin Miskelly.

Flax weevil feeding sign was noted on wharariki on 56 widely scattered islands ranging in size from 0.02 ha to 514 ha (Figs 2 and 3; Tables 1 and 2). Confirmation of our ability to identify flax weevil feeding sign correctly was obtained on seven islands where we had sufficient time to search for adult weevils, which remain well hidden during daylight. Live adults were found on five islands, and parts of dead adults (a head and an abdomen) on two other islands (Table 3). On ‘Anchor Island Harbour Islet 1’, a single weevil was found at the base of a large wharariki plant (which had feeding sign) after 10 minutes of searching in daylight. When the same plant was checked after dark (11pm), five adults were out feeding on separate leaves (Fig. 1A). Two live adults were found at night on the western main island of the Small Craft Harbour Islands, Chalky Inlet (Fig. 1B), and two adults and five larvae (the latter among wharariki roots) were found on Round Island in Preservation Inlet (Figs 1C and 1D).

Knobbled weevil feeding sign was recorded on ‘Seal Islet 1’ in Dusky Sound, where a single adult weevil was found feeding on *Anisotome* during a night-time visit (Figs 4 and 5). South of Dusky Sound, possible knobbled weevil feeding sign was also noted on the largest Zero Nugget islet, off the north coast of Chalky Island.

Rodents and mustelids

With the exception of mice (*Mus musculus*) (on 11 islands), along with stoats and red deer (*Cervus elaphus*) (both on Resolution Island only), other species of introduced mammals were considered absent from the islands surveyed

in Dusky Sound (Wildland Consultants and Department of Conservation 2016; Department of Conservation 2017).

Ship rats were eradicated from Indian Island in 2010, and single animals were caught on Resolution Island in 2006 and 2017 (Pete McMurtrie, pers. comm., 1 September 2017). Elsewhere in Dusky Sound, ship rats are present on Long and Cooper Islands and some adjacent islands, while Norway rat and Pacific rat or kiore (*Rattus exulans*) are not known to be present (Pete McMurtrie, pers. comm., 27 March 2017).

Mice were also eradicated from Indian Island in 2010, but were considered to be present on 11 islands we surveyed, including six where we found flax weevil feeding sign (mouse records from Pete McMurtrie, pers. comm., 27 March 2017 based on incidental catches in stoat traps; Table 4).

Stoats were present throughout Dusky Sound from c. 1900 to c. 2000, and are likely to have visited all islands other than ‘Centre Island’ (Miskelly *et al.* 2017b). Stoats were eradicated from Anchor Island in 2001, Parrot Island in 2005 and Indian Island in 2010, and have been controlled to low density on Resolution Island since 2008. Other than Resolution Island, none of the islands we surveyed in Dusky Sound currently support resident stoats. However, single stoats were caught on ‘Shag Island 3’ in May 2007, and on Front Island and ‘Shag Island 6’ in July 2014 (Miskelly *et al.* 2017b).

Rodents have never been known to occur on 514 ha Chalky Island; stoats were eradicated here and on the nearby Passage Islands in 1999 (Department of Conservation 2017).

Table 1 [p 24–25] Island locations, search effort and evidence for the presence of flax weevils and knobbled weevils on islands in Dusky Sound, November 2016, and off the west coast of Resolution Island and the entrance to Breaksea Sound in November 2017. ID ISLAND is the Department of Conservation (DOC) Dusky + Breaksea Sound island database reference number for each island. Island names within inverted commas are tag names derived from nearby named geographical features or island group names. ‘Weevils’ refers to whether evidence of flax weevils or knobbled weevils was recorded during the surveys: Live = 1 or more live weevils of either species found; Dead = remains of a dead flax weevil found; Sign = flax weevil feeding sign observed without live or dead weevils being seen. ‘Stoat trap’ refers to whether at least one stoat trap was maintained on the island by DOC at the time of our visit. Observers: AS = Andrew Smart; AT = Alan Tennyson; CB = Colin Bishop; CM = Colin Miskelly; DA = Dougal Austin; GT = Graeme Taylor; HE = Hannah Edmonds; J-CS = Jean-Claude Stahl; LM = Lawrie Mead; RP = Riki Parata; RW = Rick Webber; TG = Terry Greene. ‘Time’ is the approximate length of time (hours:minutes) that observers were ashore.

Table 1

Island name	ID	ISLAND Area (ha)	Latitude S	Longitude E	Weevils	Stoat trap	Date	Observers	Day/night	Time
'Roof-top stack'	699	0.3	45.5567°	166.6666°	No	No	26 Nov 17	AT, CM	Day	25
'North-west Resolution islet'	661	0.9	45.6035°	166.6089°	Sign	No	25 Nov 17	AT, CM	Day	15
'Nth Five Finger Peninsula stack'	619	2.5	45.6387°	166.5292°	Sign	No	25 Nov 17	AT, CB, CM, LM, RP	Day	50
'Outer Finger' (Five Fingers)	353	0.9	45.7447°	166.4991°	Sign	No	25 Nov 17	AT, CM	Day	35
'Inner Finger' (Five Fingers)	361	1.7	45.7435°	166.4481°	Sign	No	25 Nov 17	CB, LM	Day	25
'Acheron Islet 1'	586	0.9	45.6547°	166.7183°	Sign	No	20 Nov 16	AT, CM, HE & RW	Day	1:00
'Acheron Islet 2'	583	0.9	45.6573°	166.7180°	Sign	No	20 Nov 16	AT, CM & HE	Day	55
Resolution Island	28	20887	45.6700°	166.6300°	No	Yes	17 & 24 Nov 16	AT & CM	Day	4:00
'Cormorant Cove Islet' (west end)	530	13.6	45.6885°	166.5524°	No	Yes	18 Nov 16	AT & CM	Day	50
'Goose Cove Islet 1'	511	1.3	45.6982°	166.5442°	No	No	18 Nov 16	AS & J-CS	Day	30
Parrot Island	4	40.2	45.7075°	166.5344°	Sign	Yes	18 Nov 16	AT & CM	Day	2:25
'Parrot Islet 1'	484	3.6	45.7100°	166.5387°	No	No	18 Nov 16	AS & J-CS	Day	20
Pigeon Island	3	72.8	45.7083°	166.5605°	Dead	Yes	22 Nov 16	AT, CM, J-CS & HE	Day	1:45
'Pigeon Islet 1'	485	0.6	45.7094°	166.5437°	Sign	No	18 Nov 16	AS	Day	15
'Pigeon Islet 2'	491	2.4	45.7083°	166.5451°	No	No	18 Nov 16	AS & J-CS	Day	30
'Centre Island'	444	2.1	45.7250°	166.5454°	Live	No	18 Nov 16	AT, CM, J-CS & AS	Day	1:50
'North' Petrel Island	66	5.5	45.7353°	166.5206°	Sign	No	22 Nov 16	AT & CM	Day	40
'Petrel Islet'	65	0.5	45.7376°	166.5227°	Sign	No	23 Nov 16	AT & CM	Day	25
'Main' Petrel Island (west end)	64	21.1	45.7413°	166.5148°	Sign	Yes	22 Nov 16	AT & CM	Day	2:05
Entry Island	26	0.6	45.7455°	166.5078°	Dead	No	23 Nov 16	AT & CM	Day	30
Anchor Island (nth headland)	21	1136.6	45.7594°	166.5180°	No	Yes	24 Nov 16	AT & CM	Day	30
'Anchor Island Harbour Islet 1'	363	0.3	45.7467°	166.5272°	Live	No	17 Nov 16	AT, CM & J-CS	Day + night	1:50
'Anchor Island Harbour Islet 2'	360	0.1	45.7471°	166.5279°	No	No	18 Nov 16	AT & CM	Night	5
'Anchor Island Harbour Islet 3'	337	0.1	45.7530°	166.5256°	No	No	17 Nov 16	AS	Day	20
'North-east Anchor Islet 1'	400	1.0	45.7378°	166.5365°	Sign	No	17 Nov 16	AT, CM & J-CS	Day	1:30
'North-east Anchor Islet 2'	397	3.0	45.7384°	166.5428°	No	Yes	17 Nov 16	AT, CM & J-CS	Day	1:30
'North-east Anchor Islet 3'	386	0.6	45.7419°	166.5538°	No	No	17 Nov 16	AT & J-CS	Day	50
'North-east Anchor Islet 4'	391	6.3	45.7415°	166.5584°	No	Yes	17 Nov 16	AT & J-CS	Day	25
'North-east Anchor Islet 5'	388	4.6	45.7437°	166.5613°	No	Yes	17 Nov 16	CM & AS	Day	40
'North-east Anchor Islet 6'	389	1.3	45.7417°	166.5661°	No	Yes	17 Nov 16	CM & AS	Day	30
Useless Island	25	3.2	45.7509°	166.5791°	Sign	Yes	22 Nov 16	AT, CM & J-CS	Day	1:45
'Useless Islet 1'	368	0.2	45.7485°	166.5812°	Sign	Yes	22 Nov 16	CM	Day	35

Table 1 (continued)

Island name	ID ISLAND	Area (ha)	Latitude S	Longitude E	Weevils	Stoat trap	Date	Observers	Day/night	Time
'Useless Islet 2'	351	0.5	45.7528°	166.5846°	Sign	Yes	22 Nov 16	AT	Day	30
'Northern Seal Islet'	56	1.7	45.7749°	166.4796°	No	No	23 Nov 16	AT & CM	Day	3:00
'Seal Island west'	51	9.5	45.7809°	166.4776°	Sign	No	23 Nov 16	J-CS, HE, RW & DA	Day	2:40
'Seal Islet 1'	53	1.8	45.7780°	166.4796°	Live	No	15 Nov 16	AT & CM	Night	1:00
'Seal Island east'	54	13.7	45.7784°	166.4836°	Sign	No	21 Nov 16	AT, CM, J-CS & HE	Day	4:00
'Seal Islet 2'	47	0.3	45.7803°	166.4822°	Sign	No	23 Nov 16	AT	Day	35
'Seal Islet 3'	49	0.04	45.7801°	166.4828°	Sign	No	21 Nov 16	AT	Day	10
'East Seal Islet 1'	290	0.6	45.7765°	166.4918°	Sign	Yes	23 Nov 16	AT & CM	Day	30
'East Seal Islet 2'	295	0.2	45.7757°	166.4931°	Sign	Yes	23 Nov 16	J-CS & HE	Day	50
'Southern Seal Islet'	41	0.3	45.7819°	166.4839°	No	No	23 Nov 16	CM	Day	35
'Many Island 1'	308	7.5	45.7753°	166.4998°	Sign	Yes	21 Nov 16	AT & CM	Day	1:25
'Many Island 2'	286	1.1	45.7780°	166.4978°	Sign	No	20 Nov 16	AT	Day	45
'Many Island 3'	292	2.1	45.7775°	166.5016°	Sign	No	20 Nov 16	CM	Day	1:00
'Many Island 4'	276	2.8	45.7794°	166.5000°	No	No	20 Nov 16	AT & CM	Day	35
'Many Islet 1'	280	0.3	45.7785°	166.4994°	No	No	21 Nov 16	J-CS & DA	Day	30
'Many Islet 2'	282	0.2	45.7781°	166.5022°	No	No	21 Nov 16	J-CS & DA	Day	20
'Many Islet 3'	294	0.2	45.7763°	166.5042°	No	No	21 Nov 16	J-CS & DA	Day	20
'South Dusky Islet'	257	1.3	45.7994°	166.4981°	No	No	23 Nov 16 & 25 Nov 17	AT & CM; GT & TG	Day	50
'South Dusky Stack'	253	0.6	45.8011°	166.4952°	No	No	25 Nov 17	AT, CB & CM	Day	35
Nomans Island (east end)	6	20.1	45.7776°	166.5441°	No	Yes	16 Nov 16	AT, CM & AS	Day	2:00
Thrum Cap	14	4.1	45.7774°	166.5541°	No	Yes	16 Nov 16	AT, CM & AS	Day	1:00
Passage Island (south coast)	71	16.4	45.7660°	166.5688°	No	Yes	16 Nov 16	J-CS	Day	1:20
Indian Island (north coast)	2	167.6	45.7780°	166.5897°	Sign	Yes	20 Nov 16	AT, CM, HE & RW	Day	3:10
Front Island	106	1.0	45.7404°	166.7256°	Sign	Yes	19 Nov 16	AT, CM, J-CS & AS	Day	1:25
'Little Front Island'	105	0.1	45.7403°	166.7281°	No	No	19 Nov 16	AT, CM, J-CS, AS & DA	Day	25
'Shag Island 1'	32	0.2	45.7321°	166.7680°	No	No	19 Nov 16	AS	Day	20
'Shag Island 2'	36	0.2	45.7318°	166.7697°	No	No	19 Nov 16	CM	Day	20
'Shag Island 3'	37	1.1	45.7322°	166.7725°	Sign	Yes	19 Nov 16	AT, CM, J-CS, AS & DA	Day	1:10
'Shag Island 4'	29+34	0.2	45.7324°	166.7746°	No	No	19 Nov 16	AT & J-CS	Day	1:15
'Shag Island 5'	31	0.6	45.7330°	166.7751°	Live	Yes	19 Nov 16	CM & AS	Day	1:15
'Shag Island 6'	458	0.3	45.7343°	166.7836°	No	Yes	19 Nov 16	AT	Day	20
'Cooper Islet'	454	0.3	45.7359°	166.7884°	No	No	19 Nov 16	CM & AS	Day	15

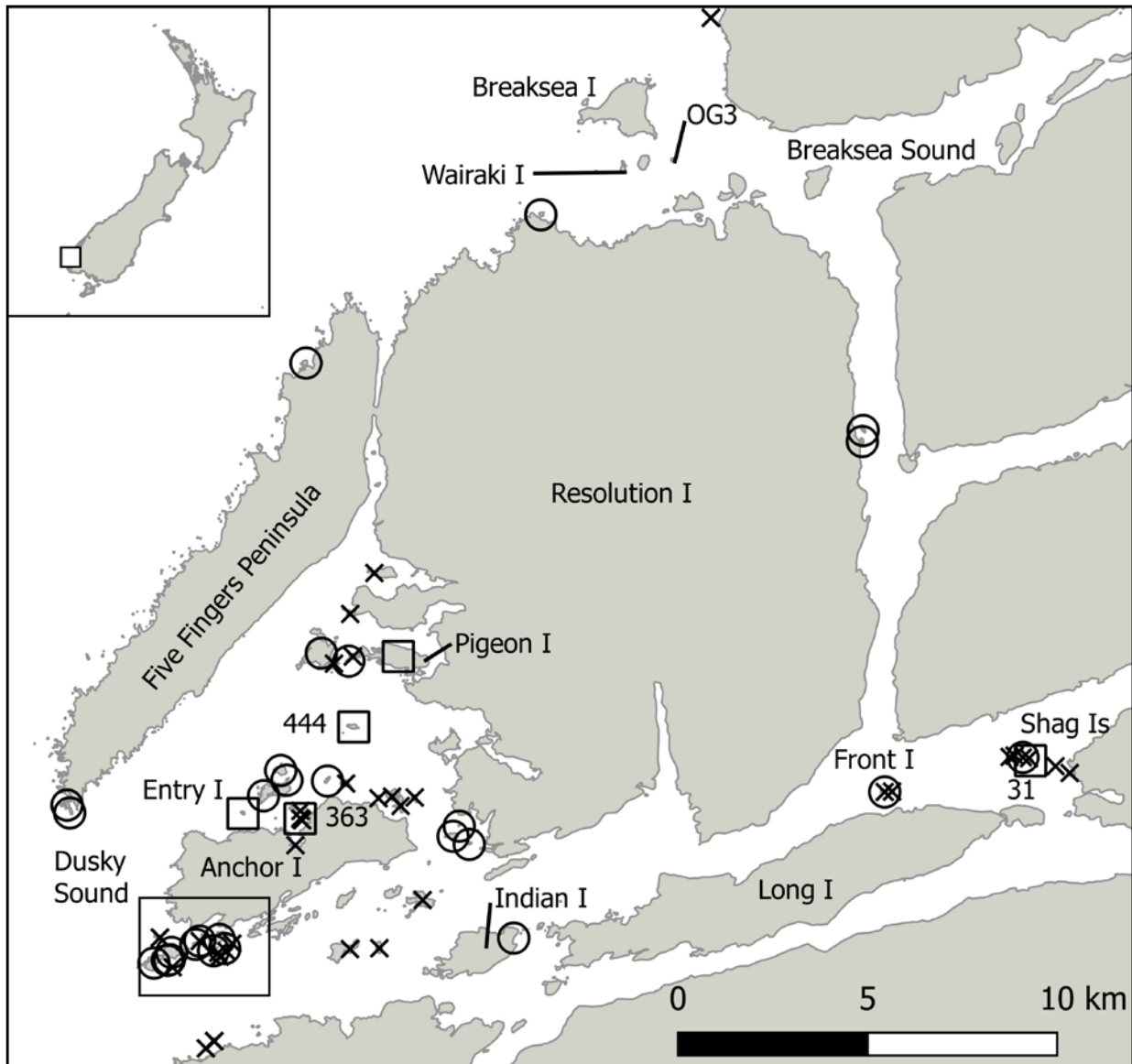


Fig. 2 Localities with evidence of flax weevil presence on islands in Dusky Sound and Breaksea Sound in November 2016 and November 2017. Circles = feeding sign only; squares = feeding sign plus live or dead animals; crosses = islands visited without flax weevil feeding sign being recorded. The numbers 31, 363 and 444 are the Department of Conservation Dusky + Breaksea Sound island database reference numbers for three unnamed islands where live flax weevils were found (see Table 3). Within Fiordland, flax weevils were known previously only from Wairaki Island in Breaksea Sound. Knobbled weevils were known from OG3 (= Outer Gilbert Island 3), Wairaki Island, and the outer coast of Resolution Island, including Five Fingers Peninsula. Both species were introduced to Breaksea Island in 1991. Further detail of the islands southwest of Anchor Island (inset) is given in Fig. 4.

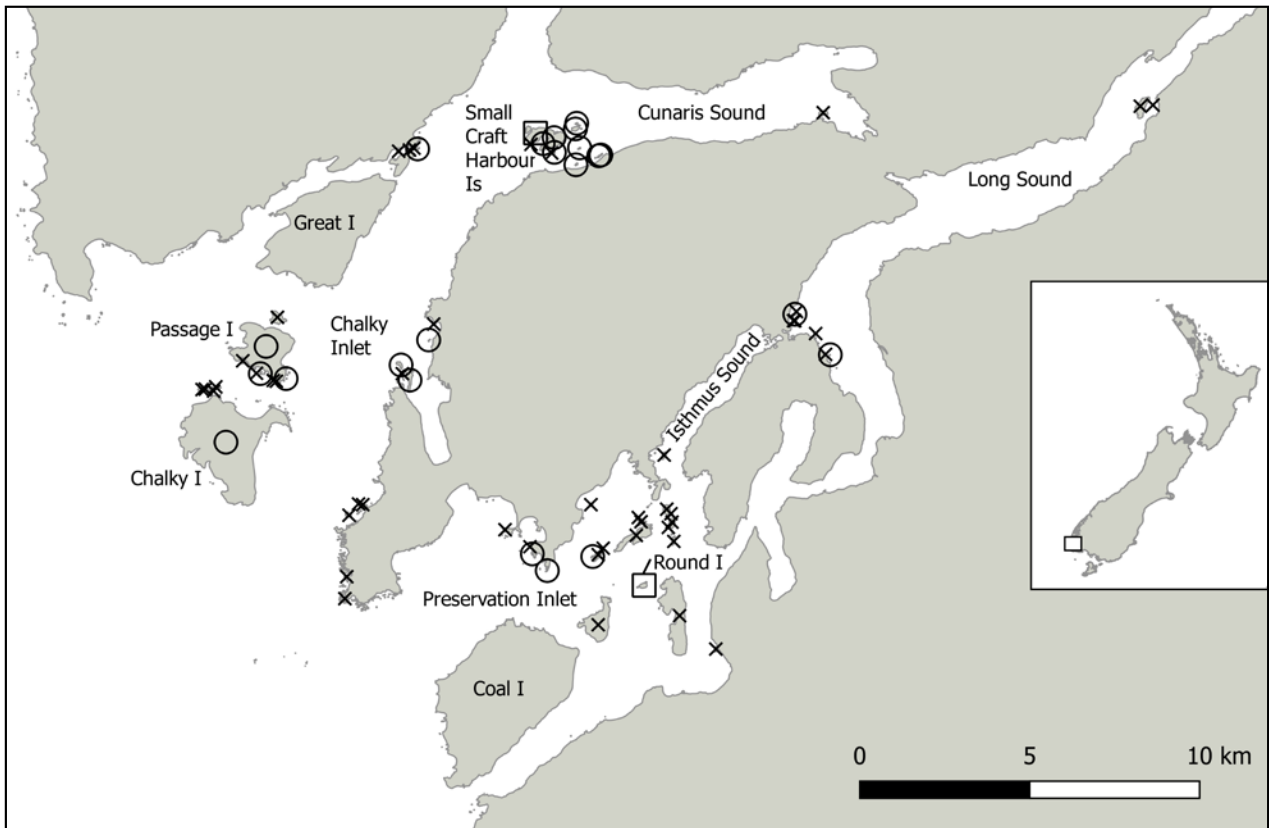


Fig. 3 Localities with evidence of flax weevil presence on islands in Chalky Inlet and Preservation Inlet and connected waterbodies (Cunarid Sound, Isthmus Sound and Long Sound) in November 2017. Circles = feeding sign only; squares = feeding sign plus live animals; crosses = islands visited without flax weevil feeding sign being recorded.

Table 2 [p 28-29] Island locations, search effort and evidence for the presence of flax weevils and knobbed weevils on islands in Chalky Inlet and Preservation Inlet and their inland extensions, November 2017. 'Waterbody' refers to whether the island is located in Chalky Inlet, Cunarid Sound, Preservation Inlet, Isthmus Sound or Long Sound. Island names within inverted commas are tag names derived from nearby named geographical features, island group names, or notable species found during the survey. 'Weevils' refers to whether evidence of flax weevils or knobbed weevils was recorded during the surveys: Live = 1 or more live weevils of either species found; Dead = remains of a dead flax weevil found; Sign = flax weevil feeding sign observed without live or dead weevils being seen. 'Trap' refers to whether at least one stoat trap (DOC 150) or resetting A24 trap was maintained on the island at the time of our visit. Observers: AT = Alan Tennyson; CB = Colin Bishop; CM = Colin Miskelly; CP = Chris Pascoe; GT = Graeme Taylor; LM = Lawrie Mead; PK = Pete Kirkman; RP = Riki Parata; TG = Terry Greene. 'Time' is the approximate length of time (hours:minutes) that observers were ashore.

Table 2

Island name	Waterbody	Area	Latitude S	Longitude E	Weevils	Trap	Date	Observers	Day/Night	Time
Chalky Island	Chalky	514	46.0491°	166.5233°	Sign	Yes	23 Nov 17	AT, CB, CM, GT, LM, RP & TG	Day	3:45
Zero Nugget ('main')	Chalky	0.12	46.0352°	166.5142°	Sign	No	23 Nov 17	AT, RP & TG	Day	1:26
Zero Nugget ('eastern')	Chalky	0.03	46.0351°	166.5154°	No	No	23 Nov 17	CB & LM	Day	19
Finger Rock ('inner')	Chalky	0.06	46.0356°	166.5186°	No	No	23 Nov 17	CB & LM	Day	10
Finger Rock ('eastern tall stack')	Chalky	0.04	46.0345°	166.5194°	No	No	23 Nov 17	CM	Day	47
Passage Island ('south or main')	Chalky	168	46.0238°	166.5386°	Sign	Yes	24 Nov 17	AT, CB, CM, GT, LM, RP & TG	Day	2:00
Passage Island 'sth coast stack 1'	Chalky	0.02	46.0323°	166.5462°	Sign	No	23 Nov 17	AT & LM	Day	10
Passage Island 'sth coast stack 3'	Chalky	0.06	46.0330°	166.5425°	No	No	23 Nov 17	CM	Day	15
Passage Island 'sth coast stack 4'	Chalky	0.1	46.0328°	166.5413°	No	No	23 Nov 17	AT & LM	Day	52
Passage Island 'sth coast stack 5'	Chalky	0.05	46.0310°	166.5364°	Sign	No	23 Nov 17	CM	Day	40
Passage Island 'sth coast stack 6'	Chalky	0.02	46.0309°	166.5349°	No	No	23 Nov 17	AT & LM	Day	13
Passage Island 'sth coast stack 7'	Chalky	0.2	46.0276°	166.5297°	No	No	23 Nov 17	AT, CM & LM	Day	1:05
Passage Island ('north')	Chalky	8.7	46.0161°	166.5429°	No	Yes	23 Nov 17	AT, CB, CM, GT, LM, RP & TG	Day	1:36
'Stack NW of Gulches Head'	Chalky	0.2	46.0846°	166.5693°	No	No	22 Nov 17	CB, LM & RP	Day	55
'Stack NE of Red Head 1'	Chalky	0.1	46.0684°	166.5702°	No	No	22 Nov 17	AT & CM	Day	1:10
'Stack NE of Red Head 2'	Chalky	0.05	46.0654°	166.5738°	No	No	22 Nov 17	RP & TG	Day	20
'Stack NE of Red Head 3'	Chalky	0.02	46.0656°	166.5754°	No	No	22 Nov 17	CB & LM	Day	15
Garden Island ('outer or little')	Chalky	1.0	46.0287°	166.5900°	Sign	No	24 Nov 17	AT, CB, CM, GT, LM, RP & TG	Day	48
'Islet NW of main Garden Island'	Chalky	0.01	46.0310°	166.5905°	No	No	24 Nov 17	CM & TG	Day	3
Garden Island ('main')	Chalky	5.7	46.0327°	166.5934°	Sign	No	24 Nov 17	AT, CB, CM, GT, LM, RP & TG	Day	1:05
'Islet south of Stripe Head 1'	Chalky	0.07	46.0221°	166.6005°	Sign	No	24 Nov 17	AT, GT & RP	Day	30
'Islet south of Stripe Head 2'	Chalky	0.1	46.0179°	166.6024°	No	No	24 Nov 17	CB, LM & TG	Day	12
Little Island – northern peninsula	Chalky	0.4	45.9719°	166.5932°	No	No	25 Nov 17	CB & LM	Day	32
Little Island ('west islet')	Chalky	0.7	45.9722°	166.5891°	No	No	25 Nov 17	CM, RP & TG	Day	25
Little Island ('middle tiny islet')	Chalky	0.01	45.9714°	166.5949°	No	No	25 Nov 17	CM	Day	3
Little Island ('east islet')	Chalky	0.1	45.9716°	166.5963°	Sign	No	25 Nov 17	AT & GT	Day	30
Small Craft Hrbr Is ('main west')	Chalky	18.2	45.9674°	166.6412°	Live	Yes	24 Nov 17	AT, CM, GT, LM & RP	Day + night	3:15
Small Craft Hrbr Is ('main east')	Chalky	24.2	45.9686°	166.6483°	Sign	Yes	24 Nov 17	CB, LM, RP & TG	Day	1:15
Small Craft Hrbr Is ('korure islet')	Chalky	0.1	45.9702°	166.6441°	Sign	No	24 Nov 17	AT, CB, GT & TG	Day + night	2:20
Small Craft Hrbr Is ('SW islet')	Chalky	0.1	45.9704°	166.6395°	No	Yes	24 Nov 17	CB & LM	Day	26
Small Craft Hrbr Is ('SE islet 1')	Chalky	0.03	45.9727°	166.6474°	No	Yes	25 Nov 17	AT	Day	15
Small Craft Hrbr Is ('SE islet 2')	Chalky	0.03	45.9725°	166.6484°	Sign	No	25 Nov 17	CM	Day	15
Small Craft Hrbr Is ('NE island')	Chalky	2.2	45.9663°	166.6564°	Sign	Yes	25 Nov 17	GT, LM & RP	Day	56
Small Craft Hrbr Is ('NE islet')	Chalky	0.06	45.9648°	166.6569°	Sign	No	25 Nov 17	AT & CM	Day	21
Small Craft Hrbr Is ('mid-channel')	Chalky	0.1	45.9713°	166.6580°	Sign	Yes	25 Nov 17	AT & CM	Day	15

Table 2 (continued)

Island name	Waterbody	Area	Latitude S	Longitude E	Weevils	Trap	Date	Observers	Day/Night	Time
'Cunaris SW islet (outer)'	Cunaris	0.1	45.9758°	166.6566°	Sign	No	25 Nov 17	CB & TG	Day	16
'Cunaris SW islet (middle)'	Cunaris	0.1	45.9734°	166.6653°	Sign	No	25 Nov 17	TG	Day	15
'Cunaris SW islet (inner)'	Cunaris	0.03	45.9732°	166.6661°	Sign	No	25 Nov 17	CB	Day	15
'Cliff Cove islet'	Cunaris	2.9	45.9620°	166.7508°	No	No	25 Nov 17	AT, CB, CM, GT, LM, RP & TG	Day	31
'Gulches Head stack'	Preservation	0.1	46.0904°	166.5686°	No	No	22 Nov 17	AT & CM	Day	30
Spit Island	Preservation	2.0	46.0722°	166.6296°	No	No	22 Nov 17	CB, GT, LM, RP & TG	Day	1:04
'Cavern Head islet'	Preservation	0.1	46.0830°	166.6457°	Sign	No	22 Nov 17	AT & CM	Day	40
'Stack west of Cavern Head'	Preservation	0.05	46.0786°	166.6400°	Sign	No	22 Nov 17	CM	Day	55
'Stack NW of Cavern Head'	Preservation	0.03	46.0767°	166.6391°	No	No	22 Nov 17	AT	Day	54
Steep-to Island	Preservation	57.6	46.0973°	166.6651°	No	Yes	22 Nov 17	AT, CB, CM, GT, LM, RP & TG	Day	2:00
Round Island	Preservation	2.6	46.0869°	166.6826°	Live	No	22 Nov 17	AT, CB, CM, CP, GT, LM, PK, RP & TG	Day	1:30
Weka or Long Island	Preservation	109.7	46.0949°	166.6961°	No	Yes	22 Nov 17	AT, CB, CM, GT, LM, RP & TG	Day	2:05
Cemetery Island	Preservation	0.7	46.1037°	166.7099°	No	No	20 Nov 17	AT, CB, CM, GT, LM, RP & TG	Day	35
Cording Is ('outermost islet')	Preservation	0.2	46.0793°	166.6630°	Sign	No	21 Nov 17	AT, CM & TG	Day	20
Cording Is ('outer')	Preservation	3.7	46.0788°	166.6651°	No	Yes	21 Nov 17	AT, CM & TG	Day	1:15
Cording Is ('outer, northern islets')	Preservation	0.4	46.0771°	166.6670°	No	No	21 Nov 17	AT, CM & TG	Day	30
Cording Is ('main')	Preservation	24.5	46.0737°	166.6796°	No	Yes	21 Nov 17	CB, GT, LM & RP	Day	2:04
Cording Is ('inner NW islet')	Preservation	1.6	46.0701°	166.6814°	No	Yes	21 Nov 17	CM & TG	Day	20
Cording Is ('outer NW islet')	Preservation	0.3	46.0690°	166.6804°	No	Yes	21 Nov 17	AT	Day	21
Cording Is ('NE 28 m asl')	Preservation	4.3	46.0668°	166.6912°	No	Yes	21 Nov 17	CB, CM & TG	Day	40
'Cording islet SE of NE 28 m asl'	Preservation	0.3	46.0680°	166.6928°	No	No	21 Nov 17	CB, CM & TG	Day	15
Cording Is ('NE 35 m asl')	Preservation	3.6	46.0702°	166.6932°	No	Yes	21 Nov 17	AT, GT, LM & RP	Day	53
'Cording islet SW of NE 35 m asl'	Preservation	0.4	46.0716°	166.6918°	No	No	21 Nov 17	CM & TG	Day	10
Cording Is ('east islet A, B & C')	Preservation	0.8	46.0753°	166.6939°	No	No	21 Nov 17	AT, CB, CM, GT, LM, RP & TG	Day	30
Single Tree Island	Preservation	0.3	46.0656°	166.6623°	No	Yes	21 Nov 17	AT, CB, CM, GT, LM, RP & TG	Day	20
'Isthmus Sound islet'	Isthmus	1.8	46.0525°	166.6902°	No	No	21 Nov 17	AT, CB, CM, GT, LM, RP & TG	Day	1:10
'Jane Cove south – sthmost islet'	Long	0.4	46.0260°	166.7535°	Sign	No	20 Nov 17	CB, LM & TG	Day	20
'Jane Cove south – main islet'	Long	0.6	46.0204°	166.7479°	No	No	20 Nov 17	AT, CM, GT & RP	Day	30
'Jane Cove sth – middle tiny islet'	Long	0.01	46.0259°	166.7517°	No	No	20 Nov 17	CB, LM & TG	Day	10
'Lady Bay main islet'	Long	0.5	46.0153°	166.7340°	Sign	No	20 Nov 17	AT, GT, LM & RP	Day	30
'Lady Bay northeast islet'	Long	0.1	46.0146°	166.7406°	No	No	20 Nov 17	CB, CM & TG	Day	15
'Lady Bay SE inner tiny islet'	Long	0.03	46.0170°	166.7395°	No	No	20 Nov 17	CB, CM & TG	Day	12
'Lady Bay SE outer tiny islet'	Long	0.01	46.0170°	166.7400°	No	No	20 Nov 17	CB, CM & TG	Day	7
Only Island	Long	13	45.9603°	166.8716°	No	No	21 Nov 17	AT, CM, LM, RP & TG	Day	1:35
'Only islet'	Long	0.2	45.9600°	166.8764°	No	No	21 Nov 17	CB & GT	Day	48

Discussion

The main finding of these surveys was that flax weevils were widespread and apparently common on islands in southern Fiordland. Evidence of their presence was found on 56 widely spread islands, with live or dead animals confirmed on seven of these islands. Before the 2016 and 2017 surveys, only a single natural flax weevil population was known in Fiordland, on Wairaki Island in Breaksea Sound (Thomas *et al.* 1992; Peat & Patrick 1996; McGuinness 2001).

We found only a single knobbed weevil, but expect that more thorough searches (especially at night) will reveal them to be present on other islands with *Anisotome lyallii* in southern Fiordland.

The presence of both these weevil species on islands in southern Fiordland is primarily driven by the distribution of their host plants, overlain by the impacts of introduced predators. Large flightless weevils are considered particularly vulnerable to rat predation, and the presence of flax weevils or knobbed weevils on islands is a good indicator that rats are absent (Ramsay 1978; Bremner *et al.* 1984; Meads 1990; Craw 1999).

Norway rats were abundant around Dusky Sound in 1884 (Reischek 1888), and are likely to have been the species of rat that Richard Henry encountered on Pigeon, Resolution and Indian Islands in the 1890s (Henry 1895, 1901; Taylor 1978; Hill & Hill 1987). Although there is no direct evidence of rats on other islands in Dusky Sound, Medway (2011) and Miskelly *et al.* (2017b) argued that

rat predation was the likely reason broad-billed prions (*Pachyptila vittata*) disappeared from Anchor Island before the arrival of stoats in Dusky Sound in 1900. Rats are unlikely to have reached many of the other islands we surveyed in Dusky Sound, as few of them provide safe anchorages and most are beyond the swimming range of rats (Atkinson 1986; Russell *et al.* 2005). Norway rats disappeared rapidly from Resolution Island after the arrival of stoats, and they remain absent (Taylor 1978; Wildland Consultants and Department of Conservation 2016). The rapid extirpation of rats from several large islands in Dusky Sound after stoats arrived supports the contention that they were Norway rats, as this large burrowing species is particularly vulnerable to stoat predation compared to the ship rat (Thomson 1921; Taylor 1978). Ship rats are present on islands in the southeast of Dusky Sound (Pete McMurtrie, pers. comm., 27 March 2017); they were eradicated from Indian Island in 2010, but were not considered to have been present on any of the Dusky Sound islands we visited at the time of the survey.

Flax weevils can apparently persist in the presence of mice, based on records of flax weevils in alpine areas of the Tararua Ranges and Marlborough (McGuinness 2001), along with our discovery of flax weevil feeding sign on at least six islands where mice were believed to be present (and on Indian Island, where ship rats and mice were eradicated in 2010). These six islands (listed in Table 4) should be a priority for survey to confirm the presence and co-occurrence of flax weevils and mice.

Table 3 Details of flax weevils found on seven islands in southern Fiordland in 2016 and 2017. ID ISLAND is the Department of Conservation Dusky + Breaksea Sound island database reference number for each island. See Tables 1 and 2 for island locations and time spent ashore.

Island name	Waterbody	ID ISLAND	Area (ha)	No. of flax weevils seen
Pigeon Island	Dusky Sound	3	72.8	1 head
'Centre Island'	Dusky Sound	444	2.1	1 live adult
Entry Island	Dusky Sound	26	0.6	1 abdomen
'Anchor I Harbour Islet 1'	Dusky Sound	363	0.3	5 live adults
'Shag Island 5'	Dusky Sound	31	0.6	2 live adults
Small Craft Harbour Is – 'main west'	Chalky Inlet	–	18.2	2 live adults
Round Island	Preservation Inlet	–	2.6	2 live adults & 5 larvae

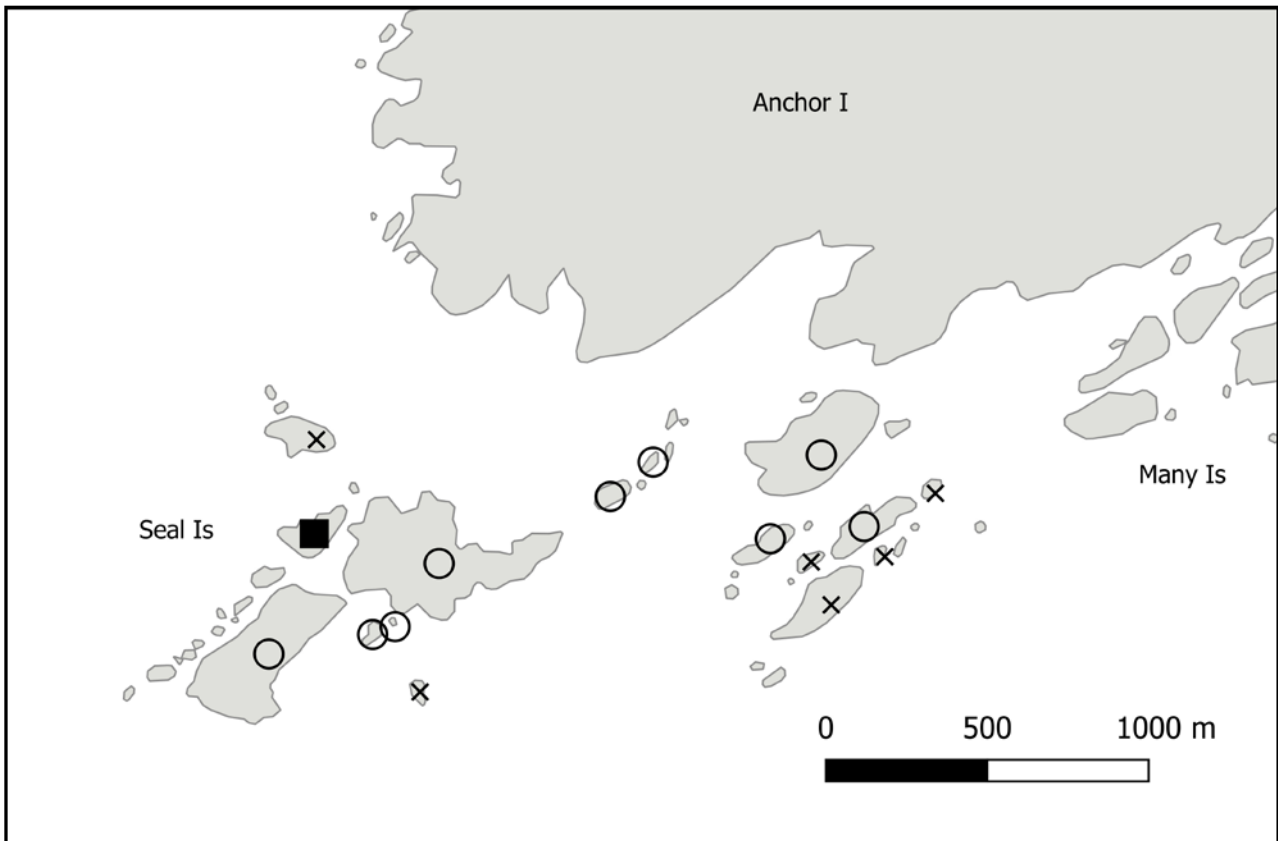


Fig. 4 Localities with flax weevil feeding sign and one live knobbled weevil on islands southwest of Anchor Island, Dusky Sound, in November 2016. Circles = flax weevil feeding sign; solid square = knobbled weevil (photographed; Fig. 5); crosses = islands visited without evidence of flax weevil being recorded. The two- or three-digit numbers are the Department of Conservation Dusky + Breaksea Sound island database reference numbers for the 16 unnamed islands that were surveyed in this portion of Dusky Sound (see Table 1). None of the islands in the main cluster of the Many Islands (on the eastern edge of the map) was included in the survey.

Stoats are competent swimmers and are likely to have reached more islands in southern Fiordland than rats (Elliott *et al.* 2010; Veale *et al.* 2012). While this would have exposed further weevil populations to predation by introduced mammals, stoats are far less damaging to invertebrates than are rats (Bremner *et al.* 1984). Stoats do eat insects (41% of guts from stoats collected from New Zealand national parks contained insect remains), but no weevil remains were identified in 1514 New Zealand stoat guts examined, including 451 from Fiordland (King & Moody 1982). The largest island on which we found evidence of flax weevils, the 514 ha Chalky Island in Chalky Inlet, supported stoats until they were eradicated in 1999, but no rodents have ever been recorded here (Department of Conservation 2017).



Fig. 5 Adult knobbled weevil (*Hadramphus stilbocarpae*) on *Anisotome lyallii* at night, on islet 53 in the Seal Islands, Dusky Sound (Photo: Colin Miskelly).

Most of the islands on which we found flax weevils are too small to sustain resident stoat populations, and are sufficiently far offshore that stoats are likely to be only infrequent visitors (Elliott *et al.* 2010; Miskelly *et al.* 2017b). It follows that predation pressure by rats and stoats on most Dusky Sound islands where we found weevils will have been negligible or non-existent. Exceptions to this were Indian Island (168 ha) and Pigeon Island (73 ha, and within 100 m of Resolution Island), where rats and stoats were formerly present (Henry 1895, 1901; DOC trapping records provided by Pete McMurtrie, pers. comm., 27 March 2017 and Murray Willans, pers. comm., 3 May 2017). The locations where we found flax weevil feeding sign (and one dead weevil) on these two islands are among the most visited historic sites in Dusky Sound: the 1773 ‘first encounter’ site between Māori and Captain Cook on Indian Island, and Richard Henry’s house site on Pigeon Island (Peat 2007). Either flax weevils survived in the presence of rats on Pigeon and Indian Islands, and have since recovered in numbers, or they arrived from elsewhere during the 100-plus years since Norway rats

were extirpated by stoats on Pigeon Island, and the six years since ship rats were eradicated on Indian Island.

Possible ways that flax weevils could move between islands include hitching rides on or with people, and rafting on clumps of floating flax. Wharariki often grows overhanging the vertical shores on islands in southern Fiordland, and clumps are commonly seen floating in the southern fiords after storms (Pete Young, pers. comm., 27 April 2017).

On Indian Island, we traversed 1.7 km along the north coast, and the only location where flax weevil sign was noted was at the much-visited historic site at the northeast point (Peat 2007), suggesting that recent human-mediated arrival is likely. The apparent distribution of flax weevils on dozens of islands throughout southern Fiordland with differing predator histories makes this an ideal area to study the dispersal ability of these flightless insects, and their vulnerability to mammal predation, by investigating the genetic structure of the metapopulation.

It is surprising that evidence of these weevils has not been reported from Dusky Sound previously. Not only

Table 4 Twelve islands in Dusky Sound visited in November 2016 that were believed to have (or have had) mice, with details of whether flax weevils or their feeding sign was found on each island. ID ISLAND is the Department of Conservation Dusky + Breaksea Sound island database reference number for each island. See Table 1 for island locations and time spent ashore.

Island name	ID ISLAND	Area (ha)	Flax weevil evidence	Mouse status
Resolution Island	28	20887	–	Present
‘Cormorant Cove Islet’	530	13.6	–	Present
‘Goose Cove Islet 1’	511	1.3	–	Present
Pigeon Island	3	72.8	Sign + dead	Present
‘Pigeon Islet 2’	491	2.4	–	Present
‘North-east Anchor Islet 6’	389	1.3	–	Present
Useless Island	25	3.2	Sign	Present
‘Useless Islet 1’	368	0.2	Sign	Present
‘Useless Islet 2’	351	0.5	Sign	Present
‘Acheron Islet 1’*	586	0.9	Sign	Present
‘Acheron Islet 2’	583	0.9	Sign	Present
Indian Island (nth coast)†	2	167.6	Sign	Eradicated 2010

* Rodent-gnawed seed noted on 20 November 2016

† Ship rats also eradicated in 2010

was flax weevil feeding sign evident at two sites frequently visited by tourists in November 2016, but 13 of the islands on which we found weevils or their sign are equipped with stoat traps (Table 1), meaning that they are visited at least three times a year by DOC staff or volunteers. With greater awareness of their characteristic feeding sign, followed by targeted night-time searches, flax weevil and knobbled weevil will undoubtedly prove to be more widely distributed in Fiordland than current knowledge suggests.

Acknowledgements

The 2016 survey was funded by the Museum of New Zealand Te Papa Tongarewa (Te Papa), Wellington, New Zealand, and the 2017 survey was funded by the Department of Conservation (DOC), New Zealand. Both surveys were based on the DOC vessel Southern Winds. We thank Andrew Smart, Hannah Edmonds, Graeme Taylor and Terry Greene of DOC; Jean-Claude Stahl, Dougal Austin and Rick Webber of Te Papa; and Riki Parata and Lawrie Mead for their assistance with the surveys. *Southern Winds* crew Chris Pascoe, Pete Young and Pete Kirkman are gratefully thanked for their skill in getting us safely on and off the islands, and for looking after us so well when on board. Grace Hall (Landcare Research, New Zealand), Pete McMurtrie (DOC), Murray Willans and Pete Young kindly provided information quoted here, and Susan Waugh (Te Papa) assisted with map preparation. The manuscript was improved by comments received from Eric Edwards and John Marris.

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