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2 **Title**

3 Terrestrial vertebrate survey of Motukawanui

4 **Authors**

5 Zachary T. Carter<sup>1\*</sup> ORCID: <https://orcid.org/0000-0002-0709-4412>

6 Thomas W. Bodey<sup>1,2</sup>, ORCID: <https://orcid.org/0000-0002-5334-9615>

7 James C. Russell<sup>1,3</sup>, ORCID: <https://orcid.org/0000-0002-5901-6416>

8  
9 **Affiliation**

10 <sup>1</sup>The University of Auckland, School of Biological Sciences

11 <sup>2</sup>The University of Aberdeen, School of Biological Sciences

12 <sup>3</sup>The University of Auckland, Department of Statistics

13 \*Corresponding author, [zach.carter@auckland.ac.nz](mailto:zach.carter@auckland.ac.nz)

14  
15 **Abstract**

16 We describe the history of Motukawanui, the largest island of the Cavalli Islands, off New  
17 Zealand's Northland east coast, and report on a survey of terrestrial vertebrates undertaken in  
18 February 2020. We compare our findings to the previous survey conducted December 1979 -  
19 January 1980. Over the last 40 years, the island's landscape has changed dramatically from  
20 one of farmland to predominantly native forest. As a result, the habitat has shifted toward  
21 supporting a larger assemblage of endemic and native birds, and away from supporting those  
22 that are non-native. Kiore, or Pacific rats (*Rattus exulans*), remain abundant across the island,  
23 though densities are lower compared to estimates of the previous survey. The richness of  
24 reptile species also appears to have declined over the past few decades. Overall, we suggest  
25 Motukawanui is a relatively straightforward island from which to eradicate rats. Such an  
26 eradication would require approval from local *iwi* but would directly contribute to meeting  
27 interim goals of the Predator Free 2050 initiative.

28  
29 **Keywords**

30 Ecological management; eradication; invasive species; kiore; Pacific rat; Predator Free 2050;  
31 *Rattus*; reptiles; seabirds

32

### 33 **Introduction**

34 Motukawanui (also known as Motukawa; -35.00°S, 173.95°E) is a 382-hectare (ha) island  
35 centrally located in the Cavalli Islands, 2.80 kilometres off the east coast of Northland. Other  
36 islands in the chain include Motukawaiti (Step Island, 46 ha), Panaki Island (15 ha),  
37 Nukutaunga (13 ha), and numerous smaller islands (n = 21 between 1 and 10 hectares) and  
38 rock stacks. Motukawanui was once connected to mainland New Zealand but separated  
39 sometime during the Holocene as a result of rising sea levels (Gibbs 2016). Subaerial erosion  
40 directed away from the island's centre created two south-facing bays, leaving an interior  
41 network of undulating hills centred around two major valleys (Moore and Ramsay 1979).  
42 Along the eastern coast near-vertical sandstone cliffs have been exposed as a result of  
43 extensive wave action (Moore and Ramsay 1979). Motukawanui is rich in archaeology due to  
44 extensive history of Māori inhabitation. Seventy archaeological sites have been found on the  
45 island, including fortified pa sites, terraces, storage pits and middens (Hayward et al. 1979)  
46 and evidence of a large indigenous population is provided in records of James Cook's visit to  
47 the island in 1769. Kiore (or the Pacific rat, *Rattus exulans*), a commensal rat species  
48 historically associated with Polynesian (Māori) voyagers, were also brought to the island  
49 (Hitchmough 1980). Māori inhabitation of Motukawanui persisted until the early 19<sup>th</sup> century  
50 (Goddard 2011); however, kiore maintain their presence through to the current day.

51 In the late 1800s, native bush was cleared from Motukawanui in preparation for agriculture  
52 (Cochran 1954). The island came in to European ownership shortly after this period (*c.a.*  
53 1918) when George Nelson Shepard Hows purchased it from the Māori Land Court (Pātete  
54 2016). Hows was an absentee owner and farmer, however; George Macdonald and his family  
55 were the first Europeans to live on, and intensively farm, Motukawanui. The Macdonald  
56 family purchased Motukawanui from Hows in 1947 and further transformed the landscape by  
57 draining swamps in order to support a large livestock population (Goddard 2011). The island  
58 passed through multiple different owners and caretakers from 1954-1973 (including Janet  
59 White who recorded her time on the island in her book *The Sheep Stell*) who farmed the  
60 island until its abandonment in 1974 (Pātete 2016). The crown purchased Motukawanui at  
61 this time and subsequently sold it to the Maritime and History Park Board in 1987  
62 (Department of Conservation 2020a). The Department of Conservation (DOC) now  
63 administers Motukawanui as a Scenic Reserve where its vegetation has been left to largely  
64 regenerate naturally, though community-based restoration planting has taken place near the  
65 island's southern and northern ends in Waiti Bay and Kikipaku Beach, respectively (Figure  
66 1). Over 13,500 native tree and plant seedlings were planted in these locations from 2000 –  
67 2008 (R. Brown pers. Comm. 2021).

68 Prior to our visit, the only published biological survey of Motukawanui took place between  
69 1979-1980 by the Auckland University Field Club (Hayward 1979) (although see Goddard  
70 2011). Records were published in volumes 25 & 26 of the journal *Tane* of the island's  
71 ornithology (Millener 1980), mammalogy (Hitchmough 1980), herpetology (Hitchmough  
72 1979), entomology (Roberts 1979), botany (Wright 1979), lichenology (Hayward and  
73 Hayward 1979), geology (Moore and Ramsay 1979), and archaeology (Hayward et al. 1979).  
74 Significant conservation advances have been made on the island in the time following these  
75 surveys; North Island saddleback (*Philesturnus rufusater*) were translocated in 1983 and  
76 1984 (Lovegrove 1996), North Island brown kiwi (*Apteryx mantelli*) were released in 1995 as  
77 part of Operation Nest Egg (Bassett 2012), and other native birds have self-colonised.

78 However, no updated surveys have been made of the terrestrial vertebrates on Motukawanui  
79 since regeneration began. Our goal was to document the status of birds and reptiles (*sensu*  
80 Russell J.C. and Russell 2018) on Motukawanui. Our assessment is timely given the recent  
81 Predator Free 2050 aspiration of eradicating mammalian predators from all uninhabited  
82 offshore islands by 2025 (Department of Conservation 2020b). Ecologically restoring  
83 Motukawanui would contribute to this interim goal.

#### 84 **Materials and methods**

85 We visited Motukawanui from 15 to 21 February 2020 as part of a wider study investigating  
86 rodent behaviour across multiple islands. Following Russell J.C. and Russell (2018), we  
87 observed and recorded all birds and reptiles with annotated qualitative notes of abundance,  
88 habitat, and location. We made our assessment in regions accessible by foot, including the  
89 established trail traversing the island, the interior of Motukawa Point, Waiiti Bay, Papatara  
90 Bay, wetland regions near Waiiti Bay, and North Beach (Figure 1). Areas inaccessible by  
91 foot (e.g., the western coast), due to either steep topography or dense vegetation, were  
92 surveyed by boat on the last day of our visit.

#### 93 **Figure 1 location**

94 To estimate rat density, we used spatially explicit capture recapture methods (full likelihood  
95 model correcting for removals) (Russell J.C. et al. 2011). We established a grid of 49 cage  
96 live-traps (Tomahawk model 102) near Waiiti Bay at precisely 12.5 metre spacing (Figure 1).  
97 We also conducted *ad hoc* trapping with 10 additional live-traps placed along the ridge track  
98 and 10 live-traps along the coastline of Waiiti Bay (Figure 1). Each trap was baited with  
99 peanut butter placed in a plastic milk bottle top (four centimetres diameter) or on a large leaf.  
100 Milk bottle tops were used to hinder bait accessibility from outside the trap in unstable or  
101 exposed locations. Traps were run for six consecutive nights; captured rats were individually  
102 marked and released alive each morning in the same location they were found.

#### 103 **Results**

104 The habitat types present have changed dramatically over Motukawanui's 35-year  
105 regeneration period (Figure 2). The island has reverted to a vegetated state of coastal scrub ( $\approx$   
106 25 % coverage) and forest ( $\approx$  75 % coverage) (Ministry for the Environment 2020); Mid-  
107 successional mānuka (*Leptospermum scoparium*) and kānuka (*Kunzea ericoides*) trees now  
108 comprise a majority of the interior, and harakeke (*Phormium tenax*) have established to form  
109 wetlands throughout major valleys. Pockets of mature forest, including old growth puriri  
110 (*Vitex lucens*), karaka (*Corynocarpus laevigatus*), and pōhutukawa (*Metrosideros excelsa*)  
111 have persisted along inaccessible areas and intermittently throughout the island's interior.  
112 However, the island's northern and southern extremities continue to display effects of  
113 human-mediated disturbance; exotic kikuyu grass (*Pennisetum clandestinum*) intermixed  
114 with harakeke and tī kōuka (*Cordyline australis*) dominate the areas near North Beach and  
115 the interior of Papatara Bay and Motukawa Point (Figure 1). Exotic fruit trees (identified by  
116 Goddard (2011) as feijoa (*Acca sellowiana*), pear (*Pyrus* sp.), peach (*Prunus persica*), plum  
117 (*Prunus domestica*), and fig (*Ficus carica*)) are also present around the old homestead at the  
118 north end of Papatara Bay.

#### 119 **Figure 2 location**

120 Birds recorded in February 2020 were compared against those recorded between December  
121 1978 – January 1979 (Table 1). Skinks were regularly heard in undergrowth across the island  
122 and, when occasionally found, were reliably identified as moko skink (*Oligosoma moco*). Our  
123 targeted searches for shore skink (*Oligosoma smithi*) along rocky shorelines and Pacific  
124 gecko (*Dactylocnemis pacificus*) on coastal plants were unsuccessful. Kiore were common in  
125 areas where trapping occurred. We caught 23 individuals over six trapping nights, with 30  
126 captures overall. The density of kiore was estimated as 28 rats ha<sup>-1</sup> (95 % CI 13.5-58.5). This  
127 density estimate is low compared to the previous estimate provided by Hitchmough (1980).

## 128 **Discussion**

129 Populations of native and endemic avifauna have increased dramatically since the last bird  
130 survey was conducted on Motukawanui. Multiple species previously restricted to unmodified  
131 habitats, or that were few in numbers, are now common, including tui (*Prosthemadera*  
132 *novaeseelandiae*), grey warbler (*Gerygone igata*), North Island fantail (*Rhipidura fuliginosa*),  
133 and silvereye (*Zosterops lateralis*). Banded rail (*Gallirallus philippensis*) represent the only  
134 addition of native avifauna to the island from apparent self-colonisation. An eastern rosella  
135 (*Platycercus eximius*) and one beach-wrecked mallard (*Anas platyrhynchos*) comprise the  
136 only non-native additions. North Island brown kiwi (*Apteryx mantelli*) is the sole extant  
137 translocated species; we visually observed five different individuals on the island, though  
138 more than 50 kiwi are estimated to be present (Kiwis for Kiwi 2013). North Island  
139 saddleback, (*Philesturnus rufusater*) translocated in 1983 and 1984, were extirpated from the  
140 island *ca.* 1985-1986 due to a stoat (*Mustela erminea*) incursion (Lovegrove 1996).

141 Multiple species of birds have apparently declined or been lost from the island, as well.  
142 However, the only native species that was previously present and not observed on our trip  
143 was white-fronted tern (*Sterna striata*). These are New Zealand's commonest tern species  
144 (Robertson and Heather 2015) and their absence could be attributed to our focus of surveying  
145 primarily terrestrial habitats. Other previously common non-native species that were not  
146 observed on our trip include chaffinch (*Fringilla coelebs*), greenfinch (*Chloris chloris*) and  
147 starling (*Sturnus vulgaris*). Fewer sightings of pied shag (*Phalacrocorax varius*) and red-  
148 billed gulls (*Larus novaehollandiae*) indicate both species may have declined on the island.  
149 While still common, this finding is significant because red-billed gull numbers are declining  
150 nationally (Frost and Taylor 2017). A single vagrant white-tailed tropicbird (*Phaethon*  
151 *lepturus*) was found beach-wrecked on a visit in December 1985 (Sale 1985). Overall, the  
152 assemblage of species on Motukawanui has shifted towards larger populations of endemic  
153 birds and away from non-native birds. Given that revegetation has been the only noticeable  
154 change to the island over the last 35 years, we attribute this outcome to increased native plant  
155 habitat extent and quality.

<b>Table 1 location</b>
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157 Hitchmough (1980) concluded that Motukawanui might have the densest rodent population in  
158 New Zealand. However, our density estimate of 28 rats ha<sup>-1</sup> is comparatively low (Wilmhurst  
159 et al. 2021). This difference may have occurred for two reasons. First, kiore densities are  
160 generally highest in grassland environments, either due to niche exclusion from other rat  
161 species or due to dietary preferences (Russell J.C. and Clout 2004). As Motukawanui's  
162 pastoral landscape has transitioned to scrub and forest, the density may have decreased

163 overall. Second, a period of drought was occurring in Northland at the time of our study  
164 (NIWA 2020). Stress caused by a lack of food may have also reduced rat densities.

165 The apparent rarity of reptiles on Motukawanui is likely due to predation pressure from  
166 ongoing rat occupation, and to stress from the drought occurring at the time of our study.  
167 Although moko skink were the only reptile species found during our visit, shore skink and  
168 Pacific gecko were present during the previous survey (Hitchmough 1979) and the New  
169 Zealand common gecko (*Woodworthia maculata*) has been found in recent years (R.  
170 Hitchmough pers. comm. 2020). The relative abundance of moko skink, and apparent scarcity  
171 of these other species, may therefore represent a change in reptile abundance and distribution  
172 on the island. To verify the effects of predation and stress from drought on local reptile  
173 populations, we suggest that future visits to the island focus on more systematic surveying for  
174 reptile species.

175 Motukawanui is one of seventeen offshore and outlying New Zealand islands upon which  
176 kiore remain (Table 2). The island would be a relatively straight-forward site for rat  
177 eradication given the Cavalli Islands are geographically isolated from reinvasion sources  
178 (Carter et al. 2020). As such, the island is predicted to have a high probability of rat-  
179 eradication success by the Predator Free 2050 interim deadline (meeting an eradication  
180 probability threshold of 80 % by 2025) (Carter et al. 2021). Findings from this survey  
181 demonstrate Motukawanui has increasing native conservation values; the island is home to  
182 large and growing populations of endemic and native birds, including morepork, grey  
183 warbler, fantail, tui, and silvereye, as well as threatened endemic species, including the North  
184 Island brown kiwi, northern New Zealand dotterel and moko skink. Further species could be  
185 translocated following rat eradication. For this reason Motukawanui has globally been  
186 identified as a priority for mammal eradication (Holmes et al. 2019). However, we note that  
187 stoats intermittently reach the island group and kiore are recorded as being present on  
188 Haraweka (Figure 1, Table 2), though this has not been confirmed recently (Atkinson and  
189 Towns 2001). Verification of kiore on Haraweka, and the other islands comprising the  
190 Cavalli Islands, is a critical next-step in eradication planning for Motukawanui. Project Island  
191 Song – a collaborative effort between local residents, *iwi* and government to restore the  
192 islands of Ipipiri (eastern Bay of Islands) from rats and stoats (Russell J. C. and Broome  
193 2016) – provides an excellent framework for the Cavalli Islands. The members of Project  
194 Island Song have successfully navigated the complexities of stakeholder interests and have  
195 demonstrated continued vigilance through multiple incursions to ecologically restore the  
196 island group (Towns et al. 2013). Corroborated by other scientific studies, and our findings of  
197 increasing conservation values, Motukawanui is well situated to be an early success of the  
198 Predator Free 2050 programme.

<b>Table 2 location</b>
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287

288 **Figure List**

289 **Figure 1.** Motukawanui in respect to (a) mainland New Zealand, (b) the Bay of Islands, and  
290 (c) the Cavalli Islands. Prominent geographic features mentioned in-text have been labelled.

291 **Figure 2.** Comparison of the vegetation on Motukawanui and surrounding islands from aerial  
292 photos taken in (A) 1983 by Whites Aviation (Photo retrieved from the Alexander Turnbull  
293 Library) and (B) 2013 by Stephen Western (Photo provided by Stephen Western  
294 Photography: <https://stephenwestern.smugmug.com/>).

295 **Table List**

296 **Table 1.** Comparison of birds observed on Motukawanui in February 2020 to survey from  
 297 December 1979 – January 1980. Nomenclature follows the checklist of the birds of New  
 298 Zealand (Gill et al. 2010).

Species	February 2020 survey	December 1978 – January 1979 (taken from Millener 1980)
<i>Apteryx mantelli</i> (North Island brown kiwi)	Five individuals observed (figure 1). Occasionally heard across all of island. Active in late afternoon suggesting drought stress.	
<i>Coturnix ypsilophora</i> (Brown quail)	Occasionally flushed from grasslands. Maximum 4 individuals seen at one time.	Eleven individuals observed, frequently in open pasture. A single nest containing eggs was found.
<i>Callipepla californica</i> (California quail)		Two individuals observed.
<i>Phasianus colchicus</i> (Common pheasant)		No sightings but a feather was found.
<i>Anas platyrhynchos</i> (Mallard)	Found beach wrecked on North Beach near trail terminus.	
<i>Eudyptula minor</i> (Little penguin)	A few heard from summit in eastern bays.	Commonly observed at sea and storm wrecked on beaches. A juvenile was seen ashore on Cormorant Bay.
<i>Puffinus bulleri</i> (Buller's shearwater)	Seen in large numbers (hundreds) between island and mainland.	Commonly observed at sea. A group of approximately 700 individuals was seen flying northward off the island's eastern tip.
<i>Puffinus gavia</i> (Fluttering shearwater)	Seen in medium numbers (tens) between island and mainland and in hundreds off Cormorant Bay on one occasion.	Frequently seen offshore numbering in the hundreds. Corpses found storm wrecked.
<i>Morus serrator</i> (Australasian gannet)	Regularly seen foraging around the coast.	Small numbers ( $\leq 10$ individuals) observed at sea. Frequently observed in the eastern bays and infrequently in western bays (125 individuals in total). Cormorant Bay had a single abandoned nest, although up to 21 birds may have roosted in the trees at one time.
<i>Phalacrocorax varius</i> (Pied shag)	Half a dozen birds seen regularly roosting in western bays.	
<i>Phalacrocorax melanoleucos</i> (Little shag)		One individual observed.
<i>Egretta novaehollandiae</i> (White-faced heron)	One individual seen in Cormorant Bay.	One individual seen in Papatara Bay.
<i>Egretta sacra</i> (Reef heron)		One pair and two single birds observed in the island's southern bays.
<i>Circus approximans</i> (Swamp harrier)	A few solitary birds regularly seen circling the island.	Single birds seen circling the island. A nest with young chicks was found.
<i>Gallirallus philippensis</i> (Banded rail)	Heard on two occasions near Waititi Bay.	
<i>Porphyrio melanotus</i> (Pukeko)	Regularly seen in small groups around coastal grass and wetlands, primarily near Waititi Bay.	Four birds observed in the swamp inland of Waititi Bay.
<i>Haematopus unicolor</i> (Variable oystercatcher)	Two pairs with chicks seen around Waititi and Papatara Bays.	One pair and a few single birds were observed.
<i>Charadrius obscurus</i> (Northern New Zealand dotterel)	One pair seen around Waititi and Papatara Bays.	Multiple pairs observed.
<i>Stercorarius parasiticus</i> (Arctic skua)		One individual observed in Papatara Bay.
<i>Larus dominicanus</i> (Southern black-backed gull)	Commonly seen (up to a dozen) around Waititi and Papatara Bays.	Nesting was observed in seven location. Each site had 1-4 nests occupied by young chicks. Medium numbers (tens) observed in total.

<i>Larus novaehollandiae</i> (Red-billed gull)	Occasional observations of a single bird, although 60 individuals were found roosting on the adjacent mainland (Taiaue Bay).	Sizeable flocks observed.
<i>Hydroprogne caspia</i> (Caspian tern)	A single bird observed in Waiiti Bay.	Single birds were regularly observed as well as one pair with two chicks.
<i>Sterna striata</i> (White-fronted tern)		Flocks of up to thirty birds were regularly seen at sea.
<i>Platycercus eximius</i> (Eastern rosella)	A single bird seen and heard in Waiiti Bay.	
<i>Ninox novaeseelandiae</i> (Morepork)	Commonly seen and heard throughout the island.	Regularly heard at night and at least three individuals were seen.
<i>Todiramphus sanctus</i> (New Zealand kingfisher)	A single bird seen in Waiiti bay. Multiple nesting burrows were found in the same location.	Nesting burrows frequent throughout Limonite and Waiiti Bays. A small number of birds frequently seen.
<i>Gerygone igata</i> (Grey warbler)	Commonly seen and heard throughout the island.	Common throughout island though most abundant in the coastal forest valleys.
<i>Prothemadera novaeseelandiae</i> (Tui)	Commonly seen and heard throughout the island.	A few individuals seen in the upper Kikipaku Stream Valley (near island summit) and Waiiti Bay.
<i>Rhipidura fuliginosa</i> (North Island fantail)	Commonly seen and heard throughout the island.	Rarely observed, five individuals seen in total.
<i>Alauda arvensis</i> (Eurasian skylark)	Two individuals seen at Motukawa Point.	A nest with eggs was found.
<i>Zosterops lateralis</i> (Silvereye)	Commonly seen and heard throughout the island.	Abundant in the island's unmodified habitat (tens of individuals).
<i>Hirundo neoxena</i> (Welcome swallow)	Commonly seen and heard throughout the island.	A large number of flocks regularly seen, each comprising 30-40 individuals.
<i>Turdus philomelos</i> (Song thrush)		Four individuals seen.
<i>Turdus merula</i> (Eurasian blackbird)	Occasionally seen and regularly heard throughout the island.	Occasionally seen throughout island (24 individuals in total).
<i>Aridotheres tristis</i> (Common myna)	Present in large numbers throughout the island. Two flocks of 20 individuals in conflict at Waiiti Bay.	Numerous and widespread throughout island.
<i>Passer domesticus</i> (House sparrow)	Commonly seen and heard in large numbers around coastal grasslands.	Found in considerable numbers near the old homestead in Papatara Bay.
<i>Anthus novaeseelandiae</i> (New Zealand pipit)	Solitary individuals seen on North Beach and Papatara Bay	Very rare, a sole bird with a nest was found.
<i>Prunella modularis</i> (Dunnock)	A single individual was seen and heard near the old homestead in Papatara Bay.	Sparingly distributed. Found regularly in the valley of Waiiti stream or in the valley adjacent to Waiiti stream.
<i>Carduelis carduelis</i> (European goldfinch)	Two individuals seen in grassland behind Papatara Bay	Regularly seen in pairs throughout the island (tens of individuals seen in total).
<i>Emberiza citrinella</i> (Yellowhammer)	Occasionally heard around coastal grasslands.	Very common in open scrub.
<i>Fringilla coelebs</i> (Chaffinch)		Widely distributed (33 individuals seen in total).
<i>Chloris chloris</i> (Greenfinch)		Frequently sighted in scrub-filled valleys (10 individuals in total)
<i>Carduelis carduelis</i> (Goldfinch)		Species regularly found throughout the island.
<i>Sturnus vulgaris</i> (Starling)		Seen in abundance at the islands southern end.

303 **Table 2.** New Zealand offshore and outlying islands ( $\geq 5$  hectares) that are host to kiore  
 304 (*Rattus exulans*).

Island	Group	Latitude ( $^{\circ}$ S)	Longitude ( $^{\circ}$ E)	Area (ha)
Cone <sup>†</sup>	Stephenson	34.95	173.77	7.0
Stephenson <i>Ririwha/Mahinepua</i> <sup>†</sup>	Stephenson	34.96	173.78	112.5
Haraweka	Cavalli	34.98	173.96	6.2
Motukawanui	Cavalli	35.00	173.94	382.1
West Chicken <i>Mauitaha</i>	Hen and Chicken	35.89	174.70	22.8
Kaikoura (Selwyn) <sup>†</sup>		36.18	175.33	528.8
Great Barrier <i>Aotea</i>		36.20	175.42	27,700
Slipper <i>Whakahau</i>	Slipper	37.05	175.94	234.6
Penguin	Slipper	37.07	175.93	9.5
Rabbit	Slipper	37.07	175.93	9.6
White <i>Whakaari</i>		37.52	277.18	177.18
Motiti		37.63	176.42	701.4
Victory <i>Moutiti</i>	D'Urville	40.74	173.91	14.9
D'Urville <i>Rangitoto ki te Tonga</i>	D'Urville	40.83	173.86	16,530
<i>Arapawa (Arapaoa)</i>		41.18	174.3	7,600
Chatham <i>Rekohu</i>	Chatham	43.9	176.56	74,570
Stewart <i>Rakiura</i>		46.99	167.86	168,500

305 <sup>†</sup>Location of a failed eradication resulting in kiore population recovery.