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

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

In the late 1800s, native bush was cleared from Motukawanui in preparation for agriculture (Cochran 1954). The island came in to European ownership shortly after this period (c.a. 1918) when George Nelson Shepard Hows purchased it from the Māori Land Court (Pātete 2016). Hows was an absentee owner and farmer, however; George Macdonald and his family were the first Europeans to live on, and intensively farm, Motukawanui. The Macdonald family purchased Motukawanui from Hows in 1947 and further transformed the landscape by draining swamps and burning vegetation in order to support a large livestock population (Goddard 2011). The island passed through multiple different owners and caretakers from 1954 to 1973 (including Janet White who recorded her time on the island in her book *The Sheep Stell*) who farmed the island until its abandonment in 1974 (Pātete 2016). The crown purchased Motukawanui in 1974 and subsequently sold it to the Maritime and History Park Board in 1987 (Department of Conservation 2020a). At this time, only three old growth forest fragments (comprising approximately 5% of land-area) were present on the island (Taylor 1988). The Department of Conservation (DOC) now administers Motukawanui as a Scenic Reserve where its vegetation has been left to largely regenerate naturally, though firebreaks of taupata (*Coprosma repens*) were planted in the 1980s by the Bay of Islands Maritime and Historic Park Board to prevent the spread of fire to the interior of Motukawanui (Taylor 1988). Community-based restoration planting has also taken place near the island’s southern and northern ends in Waiiti Bay and North Beach, respectively (Figure 1), where over 13,500 native plant seedlings were planted from 2000 to 2008 (R. Brown pers. Comm. 2021).

Prior to our visit, the only published biological survey of Motukawanui took place over ten days between 1979 and 1980 by the Auckland University Field Club (Hayward 1979) (although see Goddard 2011). Records were published in volumes 25 & 26 of the journal *Tane* of the island’s ornithology (Millener 1980), mammalogy (Hitchmough 1980), herpetology (Hitchmough 1979), entomology (Roberts 1979), botany (Wright 1979), lichenology (Hayward and Hayward 1979), geology (Moore and Ramsay 1979), and archaeology (Hayward et al. 1979). A visit over three days in June 1988 by DOC is recorded in an unpublished report investigating kiore eradication feasibility, but the status of native fauna was not surveyed (Taylor 1988). Significant conservation advances have been made on the island in the time following these surveys; North Island saddleback (*Philesturnus rufusater*) were translocated from Hen Island in February 1983 (n = 16) and March 1984 (n = 12) (Lovegrove 1996), North Island brown kiwi (*Apteryx mantelli*) were released from captivity in May 1995 (n = 10), January 1997 (n = 2) and October 2013 (n = 5) as part of Operation Nest Egg (Kiwis for Kiwis 2013; Miskelly and Powlesland 2013), and other native birds have self-colonised. However, no updated surveys have been made of the terrestrial vertebrates on Motukawanui since regeneration began. Our goal was to document the status of birds and reptiles (*sensu* Russell and Russell 2018) on Motukawanui. Our assessment is timely given the recent Predator Free 2050 aspiration of eradicating mammalian predators from all uninhabited offshore islands by 2025.
Figure 1. Motukawanui in respect to (A) New Zealand, (B) the Bay of Islands, and (C) the Cavalli Islands. Prominent geographic features mentioned in-text have been labelled.
Ecologically restoring Motukawanui would contribute to this interim goal.

**Materials and methods**

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

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

**Results**

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

Birds recorded in February 2020 were compared against those recorded between December 1978 – January 1979 (Table 1). Skinks were regularly heard in undergrowth across the island and, when occasionally found, were reliably identified as moko skink (*Oligosoma mocho*). Our targeted searches for shore skink (*Oligosoma smithii*) along
rocky shorelines and Pacific gecko (*Dactylocnemis pacificus*) on coastal plants were unsuccessful. Kiore were common in areas where trapping occurred. We caught 23 individuals over six trapping nights, with 30 captures overall. The density of kiore was

**Figure 2.** Comparison of the vegetation on Motukawanui and surrounding islands from aerial photos taken in (A) 1983 by Whites Aviation (Photo retrieved from the Alexander Turnbull Library) and (B) 2013 by Stephen Western (Photo provided by Stephen Western Photography: https://stephenwestern.smugmug.com/).
Table 1. Comparison of birds observed on Motukawanui in February 2020 to survey from December 1979 to January 1980. Nomenclature follows the checklist of the birds of New Zealand (Gill et al. 2010).

| Species                                      | February 2020 survey                                                                 |
|----------------------------------------------|--------------------------------------------------------------------------------------|
| *Apteryx mantelli* (North Island brown kiwi) | Five individuals observed (figure 1). Occasionally heard across all of island. Active in late afternoon suggesting drought stress. |
| *Coturnix ypsilophora* (Brown quail)         | Occasionally flushed from grasslands. Maximum 4 individuals at one time.              |
| *Callipepla californica* (California quail)  |                                                                                      |
| *Phasianus colchicus* (Common pheasant)      | No sightings but a feather was found.                                                |
| *Anas platyrhynchos* (Mallard)               | Found beach wrecked on North Beach near trail terminus.                               |
| *Eudymptula minor* (Little penguin)          | A few heard from summit in eastern bays.                                             |
| *Puffinus bulleri* (Buller’s shearwater)     | Seen in large numbers (hundreds) between island and mainland.                         |
| *Puffinus gavia* (Fluttering shearwater)      | Seen in medium numbers (tens) between island and mainland and in hundreds off Cormorant Bay on one occasion. |
| *Morus serrator* (Australasian gannet)       | Regularly seen foraging around the coast.                                            |
| *Phalacrocorax varius* (Pied shag)           | Half a dozen birds seen regularly roosting in western bays.                          |
| *Phalacrocorax melanoleucos* (Little shag)   |                                                                                      |
| *Egretta novaehollandiae* (White-faced heron)| One individual seen in Cormorant Bay.                                                |
| *Egretta sacra* (Reef heron)                  | One individual seen in Papatara Bay.                                                |
| *Circus approximans* (Swamp harrier)         | One pair and two single birds observed in the island’s southern bays. Single birds seen circling the island. A nest with young chicks was found. |
| *Gallirallus philippensis* (Banded rail)      | Four birds observed in the swamp inland of Waiti Bay.                                |
| *Porphyrio melanotus* (Pukeko)               | Two pairs with chicks seen around Waiti and Papatara Bays.                           |
| *Haematopus unicolor* (Variable oystercatcher) | One pair and a few single birds were observed.                                     |
| *Charadrius obscurus* (Northern New Zealand dotterel) | One pair seen around Waiti and Papatara Bays.                                      |
| *Stercorarius parasiticus* (Arctic skua)     | Multiple pairs observed.                                                            |
| *Larus dominicanus* (Southern black-backed gull) | Nesting was observed in seven location. Each site had 1–4 nests occupied by young chicks. Medium numbers (tens) observed in total. |
| *Larus novaehollandiae* (Red-billed gull)     | One individual observed in Papatara Bay.                                             |

(Continued)
estimated as 28 rats ha\(^{-1}\) (95% CI 13.5–58.5). This density estimate is low compared to the previous estimate provided by Hitchmough (1980).

**Discussion**

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

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

Hitchmough (1980) concluded that Motukawanui might have the densest rodent population in New Zealand. However, our density estimate of 28 rats ha$^{-1}$ is comparatively low (Wilmshurst et al. 2021). This difference may have occurred for two reasons. First, kiore densities are generally highest in grassland environments, either due to niche exclusion from other rat species or due to dietary preferences (Russell and Clout 2004; Wilmshurst et al. 2021). As Motukawanui’s pastoral landscape has transitioned to scrub and forest, the density may have decreased overall. Second, a period of drought was occurring in Northland at the time of our study (NIWA 2020). Stress caused by a lack of food may have also reduced rat densities.

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

Motukawanui is one of seventeen offshore and outlying New Zealand islands upon which kiore remain (Table 2). The island would be a relatively straight-forward site for...
rat eradication given the Cavalli Islands are geographically isolated from reinvasion sources (Carter et al. 2020). As such, the island is predicted to have a high probability of rat-eradication success by the Predator Free 2050 interim deadline (meeting an eradication probability threshold of 80% by 2025) (Carter et al. 2021). Moreover, Motukawanui now meets the criteria for eradication since other regionally important islands identified by the DOC have already had rats eradicated (Taylor 1988). Findings from this survey demonstrate Motukawanui has increasing native conservation values; the island is home to large and growing populations of endemic and native birds, including morepork, grey warbler, fantail, tui, and silvereye, as well as threatened endemic species, including the North Island brown kiwi, northern New Zealand dotterel and moko skink. Further species could be translocated following rat eradication. For this reason, Motukawanui has globally been identified as a priority for mammal eradication (Holmes et al. 2019). However, we note that stoats intermittently reach the island group and kiore are recorded as being present on Haraweka (Figure 1, Table 2), though this has not been confirmed recently (Atkinson and Towns 2001). Verification of kiore on Haraweka, and the other islands comprising the Cavalli Islands, is a critical next-step in eradication planning for Motukawanui. Project Island Song – a collaborative effort between local residents, iwi and government to restore the islands of Ipipiri (eastern Bay of Islands) from rats and stoats (Russell and Broome 2016) – provides an excellent framework for the Cavalli Islands. The members of Project Island Song have successfully navigated the complexities of stakeholder interests and have demonstrated continued vigilance through multiple incursions to ecologically restore the island group (Towns et al. 2013). Corroborated by other scientific studies, and our findings of increasing conservation values, Motukawanui is well situated to be an early success of the Predator Free 2050 programme.

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**Table 2.** New Zealand offshore and outlying islands (≥5 ha) that are host to kiore (*Rattus exulans*).

| Island                  | Group                        | Latitude (°S) | Longitude (°E) | Area (ha) |
|-------------------------|------------------------------|---------------|----------------|-----------|
| Conea                   | Stephenson                   | 34.95         | 173.77         | 7.0       |
| Stephenson Ririwha/Mahinepua\(^a\) | 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 Muuitaha   | Cavalli                      | 35.89         | 174.70         | 22.8      |
| Kaikoura (Selwyn)a      | Cavalli                      | 36.18         | 175.33         | 528.8     |
| Great Barrier Aotea     | Cavalli                      | 36.20         | 175.42         | 27,700    |
| Slipper Whakahau        | Slipper                      | 37.05         | 175.94         | 234.6     |
| Penguin                 | Slipper                      | 37.07         | 175.93         | 9.5       |
| Rabbit                  | Slipper                      | 37.07         | 175.93         | 9.6       |
| White Whakaari          | Slipper                      | 37.52         | 277.18         | 177.18    |
| Motiti                  | D’Urville                    | 37.63         | 176.42         | 701.4     |
| Victory Moutiti         | D’Urville                    | 40.74         | 173.91         | 14.9      |
| D’Urville Rangitoto ki te Tonga | D’Urville             | 40.83         | 173.86         | 16,530    |
| Arapawa (Arapaoa)       | D’Urville                    | 41.18         | 174.30         | 7600      |
| Chatham Rekahu          | Chatham                      | 43.90         | 176.56         | 74,570    |
| Stewart Rakiura         | Chatham                      | 46.99         | 167.86         | 168,500   |

\(^a\)Location of a failed eradication resulting in kiore population recovery.
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