NEW ZEALAND JOURNAL OF ECOLOGY

RESEARCH

Frog-predator interactions in Aotearoa | New Zealand: observations and two case studies using molecular and visual gut-content analyses

Emily R. Hotham[1], Amanda Haigh[2], Sara Smerdon[3] and Jennifer M. Germano[2]

[1]Australian Museum Research Institute, Australian Museum, 1 William St, Sydney, NSW 2010 Australia
[2]Biodiversity Heritage and Visitors Group, Department of Conservation, Wellington, New Zealand
[3]Mahakirau Forest Sanctuary, Coromandel, New Zealand
*Author for correspondence (Email: emhotham@hotmail.co.nz)

Published on: 3 March 2025

Abstract: Interactions between endemic frogs and introduced predators in Aotearoa | New Zealand are important to document for consideration in species management. Predation has emerged as a formidable threat to the survival of native frog populations in Aotearoa, with most research focusing on predation by *Rattus* species. Here we collate unpublished observations of mortality events or predator interactions in introduced and endemic frog species. At Mahakirau Forest Estate (Coromandel, North Island) and Whareorino Conservation Area (King Country, Central North Island), molecular and visual gut-content analyses were also used to assess frog consumption by ferrets (*Mustela furo*), stoats (*Mustela erminea*) and feral pigs (*Sus scrofa*). These unpublished observations and case studies document intensive predation events by feral pigs, rats, stoats, and ferrets on native frogs. In addition, weka (*Gallirallus australis*) and cats (*Felis catus*) have been observed preying on introduced *Litoria* species, with the potential to also prey on native frogs where they co-exist. These observations raise concerns for threatened frog populations and emphasise the importance of targeted management programmes.

Keywords: feral pig, *Leiopelma*, *Litoria*, mortality, mustelids, predation.

Introduction

Documenting interactions between predators and native frogs (Anura; *Leiopelma*) is important for the conservation and management of amphibians in Aotearoa | New Zealand. Worthy (1987) suggested that the extinctions of several leiopelmatid species and the early range reduction of extant species were likely caused by the arrival of the Polynesian rat (*Rattus exulans*). There is now strong evidence of *Rattus* species preying on endemic frogs (Thurley & Bell 1994; Egeter & Bishop 2016; Crossland et al. 2023; Germano et al. 2023a), and the Native Frog Recovery Plan identifies predation by rats as an ongoing threat to native frog populations (Bishop et al. 2013). The significance of other species as predators, such as feral pigs (*Sus scrofa*) and mustelids (*Mustela spp.*), however, has yet to be determined. Due to the severely reduced numbers and populations of remaining leiopelmatid species, their restriction to areas largely uninhabited by people, and their nocturnal and cryptic nature, predation events are unlikely to be observed. It is therefore critical that any predation events observed are documented. Observations of predation on the more widely distributed and more easily detected introduced *Litoria* species may also provide further information about threats to native frogs.

Understanding the full extent of predation pressures on native frogs is a key component to being able to effectively manage them in the wild. Here, we present findings from two case studies of predator-frog interactions in areas where control programs for mustelids and feral pigs overlap with native frog habitats. These programs provided an opportunity to analyse the gut contents of culled mammals, both visually and through molecular analysis, offering insights into the prevalence of native frog consumption by these mammals. We also document anecdotal observations of mortality events and predatory interactions involving amphibian species across Aotearoa | New Zealand. Collectively, these findings contribute crucial data to inform conservation strategies for threatened frog populations.

Methods

Anecdotal observations

Anecdotal observations were gathered in 2022 through email or phone interviews conducted by the authors with members of the conservation community who had either worked with native frogs in Aotearoa | New Zealand, operated in areas where native frogs occur, or were known by the authors to have observed predatory events on amphibians. Observations could be from any location or time within Aotearoa and include both introduced or native species depredating or interacting with frogs. These observations were gathered opportunistically and do not represent an exhaustive record of all observations that may exist.

DOI: https://doi.org/10.20417/nzjecol.49.3583

Case studies

Mahakirau Forest Estate

Mahakirau Forest Estate (hereafter Mahakirau) is located on the Coromandel Peninsula, on the North Island of Aotearoa | New Zealand (36°50′20.9″ S, 175°31′45.9″ E). Mahakirau encompasses 24 individual properties under a Queen Elizabeth II Open Space Covenant, covering a 580-hectare area of native broadleaf-podocarp forest. The Mahakirau Forest Estate Society Incorporated (MFESI) was established in 2001 to support landowner members in restoring and preserving the natural environment. Both Archey's frogs (*Leiopelma archeyi*) and Hochstetter's frogs (*L. hochstetteri*) are present within Mahakirau. A mustelid trapping programme targeting stoats (*Mustela erminea*) and ferrets (*M. furo*) was established in 2001. Operations have since expanded to include ten target species, utilising trapping, baiting, hunting, and monitoring, with over 3000 devices in service. Culling of feral pigs (*Sus scrofa*) by a ground hunter using indicating/bailing dogs was specifically undertaken between 2023 and 2024 to evaluate the presence/absence of frogs in the diet of feral pigs.

Between 2023 and 2024, the gut-contents of feral pigs, stoats, and ferrets culled at Mahakirau were visually inspected for evidence of native and introduced frogs. For feral pigs, stomach contents were fully examined *in situ* immediately after capture. Stoats and ferrets trapped at Mahakirau had their stomach and small intestine contents examined *in situ*, though the time of death for these animals was unknown.

Following visual inspection, molecular samples were collected to determine gut-contents from a randomly selected subset of culled feral pigs and stoats, and from all captured ferrets. For each feral pig, ingested material was collected using three sterile 2 ml tubes supplied by Wilderlab NZ Ltd.; one tube for stomach contents, one for small intestine contents, and one for large intestine contents. For mustelids, two sterile 2 ml tubes were used per animal to collect ingested material, with one tube for the stomach contents and another tube for the intestinal contents. Samples were preserved in Zymo DNA/RNA Shield and sent to Wilderlab NZ Ltd. for metabarcoding analysis using 75 bp of the mitochondrial CO1 gene (Laboratory methods for Wilderlab NZ Ltd. metabarcoding panels can be found in Wilkinson 2023). Species-specific primers for frogs (Egeter 2014) were not used as MFESI sought a general overview of the diet of these animals.

Whareorino Conservation Area

Whareorino Conservation Area is the largest forested area (16 000-hectares) of mostly podocarp-hardwood in the western King Country, Central North Island, Aotearoa | New Zealand. Almost 4% (600 hectares) of the total forest area in Whareorino is dedicated to the conservation of Archey's frogs and the sympatric Hochstetter's frog. Rat control was established in 300 hectares of the frog conservation area by the Department of Conservation (DOC) in 2003 and established in the remaining 300 hectares in 2018 and 2019 (Germano et al. 2023a). As part of this initiative, rodent predation on native frogs is recorded if observed. Ungulate control (primarily feral goats (*Capra hircus*) and feral pigs) has been undertaken annually since 2019 for habitat protection by ground hunters using indicating/bailing dogs.

Feral pigs culled during control operations in 2022 and 2023 had their entire stomach contents visually inspected *in situ*. Stomach contents were collected from all pigs captured within areas of forest where Archey's frogs and Hochstetter's frogs co-occur; these samples are awaiting further analysis by DOC to identify the presence of frogs when visually non-recognisable to the species level.

Results

Anecdotal observations

Fifteen people were contacted and asked if they had information on a frog predation event. Four people responded with reports, and six observations were recorded. The authors provided two additional observations. Five of these observations were on introduced frogs, and three observations were on native frogs (Table 1). Observations are summarised in Table 1, and we present them in more detail below.

During kōkako (*Callaeas wilsoni*) nest checks in the Hunua Ranges, Auckland, in late April 2005, a stoat was observed carrying a Hochstetter's frog in its mouth along a walking track. As the observers were downwind of the stoat, it was unaware of the observers. One observer pounced and the stoat dropped the frog, escaping into the bushes. The frog was dead upon inspection and the specimen was collected for the Auckland Museum (Tony Woodroofe, Auckland Council Volunteer, pers. comm.).

In September 2019 in Glen Innes, Auckland, an attack by a domestic house cat (*Felis catus*) on an introduced green and golden bell frog (*Litoria aurea*) was observed by the first author at 06:45. The cat was chased away, dropping the frog in the process.

Between 2021 and 2022 at Manaroa, Marlborough Sounds, weka (*Gallirallus australis*) were observed preying on introduced *Litoria* frogs (R. Powlesland, Department of Conservation, pers. comm.). A weka was observed killing and eating a brown tree frog (*L. ewingii*) at 21:50 on 7 December 2021. The frog was in an artificial trough. During the predation event, the frog could be heard squealing. Another predation event was observed in 2021 when the observer rolled a log over in the daytime and exposed a frog (*Litoria* spp.) that was quickly seized by a weka and eaten. At 20:48 on 23 August 2022 a weka was observed to have a frog (*Litoria* spp.) in its beak and, when offered bread, dropped the dead frog and took the bread. The frog looked freshly killed. In August 2022, a frog (*Litoria* spp.) was heard squealing in long grass at 11:20 am while being attacked by a male weka. After killing the frog, the weka carried it away.

In September 2007, a Hamilton's frog (*Leiopelma hamiltoni*) was caught on Long Island, Marlborough Sounds, that had a chunk taken out of its jaw and damage to its eye. Though it cannot be confirmed, the injury may have been caused by predation by either weka or little spotted kiwi (*Apteryx owenii*).

In the Wharekirauponga Valley, Coromandel, an adult feral pig was caught in a small stream bed during a diurnal hunting trip in 2010 (C. Duyvenbooden, pers. comm.). While cutting open the animal, the hunter saw the gastrointestinal tract moving, and when opened, a small frog jumped out. It was likely either a Hochstetter's frog or Archey's frog, based on the presence of these species in the Wharekirauponga valley and the description from the hunter.

Mustelids caught in targeted traps at Kopuatai wetland, Hauraki, 2023, were stored in a freezer for ten months before the visual inspection of the stomach and intestines. The jaw of a green and golden bell frog was found in a male ferret, and molecular gut content analysis confirmed bell frog DNA (Table 1).

Table 1. Summary of individuals, evidence type, and findings of interactions or mortality events involving native and introduced frog species in Aotearoa | New Zealand.

Species	Number of individuals	Location	Date	Type of evidence	Findings
Feral pig	18	Whareorino Conservation Area	May–June 2022	Visual gut-content inspection	9 pigs (50%) containing native frog remains
Feral pig	18	Whareorino Conservation Area	September 2022	Visual gut-content inspection	4 pigs (22%) containing native frog remains
Feral pig	15	Whareorino Conservation Area	October 2022	Visual gut-content inspection	4 pigs (27%) containing native frog remains
Feral pig	13	Whareorino Conservation Area	July–August 2023	Visual gut-content inspection	4 feral pigs (31%) containing native frog remains
Feral pig	16	Mahakirau Forest Estate	July 2023	Visual gut-content inspection Molecular gut-content analysis of 9 feral pigs	No frogs found 4 pigs (44%) contained native frog DNA
Feral pig	3	Mahakirau Forest Estate	April– May 2024	Visual gut-content inspection Molecular gut-content analysis	No frogs found 2 pigs (66%) contained native frog DNA
Feral pig	1	Wharekirauponga Valley, Coromandel	2010	Anecdotal observation	Native frog found in the gastrointestinal tract
Stoat	1	Hunua Ranges	April 2005	Anecdotal observation	Hochstetter's frog in the mouth of a stoat
Stoat	37 (19 females + 18 males)	Mahakirau Forest Estate	December 2023–April 2024	Visual gut-content inspection Molecular gut-content analysis of 16 stoats	No frogs found 1 female stoat contained Hochstetter's frog DNA
Ferret	3 (2 females + 1 male)	Mahakirau Forest Estate	January – March 2023	Visual gut-content inspection Molecular gut-content analysis	1 female ferret contained 4 Hochstetter's frogs and 1 Archey's frog 1 female ferret contained Hochstetter's frog and Archey's frog DNA
Ferret	1 (female)	Mahakirau Forest Estate	April 2024	Visual gut-content inspection Molecular gut-content analysis	Frog bones found Hochstetter's frog DNA detected
Ferret	4	Kopuatai wetland, Hauraki	May 2023	Visual gut-content inspection Molecular gut-content analysis	1 ferret contained the jaw of a frog 1 ferret contained green and golden bell frog DNA
Rodent	1	Whareorino Conservation Area	March 2008	Anecdotal observation	Archey's frog with damage to the abdominal cavity
Rodent	1	Whareorino Conservation Area	March 2022	Anecdotal observation	Archey's frog with flesh stripped from the upper hind legs exposed to the bone
Cat	1	Glen Innes, Auckland	September 2019	Anecdotal observation	Green and golden bell frog attacked
Weka	1	Manaroa, Marlborough Sounds	December 2021	Anecdotal observation	Brown tree frog killed
Weka	1	Manaroa, Marlborough Sounds	2021	Anecdotal observation	Litoria species eaten
Weka	2	Manaroa, Marlborough Sounds	August 2022	Anecdotal observation	Litoria species killed and eaten
Weka or kiwi (unconfirmed)	1	Long Island	September 2007	Anecdotal observation	Hamilton's frog found with damage to the jaw and eye

Case studies

Mahakirau Forest Estate

Between 2023 and 2024, the stomach and intestines of 19 feral pigs, 37 stoats (19 female and 18 male), and 8 ferrets (4 female, 2 male, and 2 unknown sex) were visually inspected for frog remains at Mahakirau (Table 1). No frog remains were identified during inspection of the feral pigs or stoats. Visual inspection of the ferret stomachs revealed three ferrets (37.5%) had consumed frogs. The number of limbs present inside the stomach of one female ferret indicated that at least four frogs had been consumed, primarily Hochstetter's frogs and including at least one Archey's frog (Fig. 1). Frog bones were also found in the stomach of another female ferret caught at Mahakirau (Table 1).

Molecular gut-content samples were collected from 12 of the feral pigs culled (Table 1). Frog DNA was identified in six (50%) of these pigs (which had not shown signs of frog consumption from visual searches alone). All frog DNA was found in the stomach samples, with no detection in the small or large intestines. Hochstetter's frog DNA was the second highest DNA concentration in the stomach of two feral pigs, following nīkau palm (*Rhopalostylis sapida*). The highest concentrations of DNA detected in the remaining ten pigs were from nīkau palm, supplejack (*Ripogonum scandens*), kiekie (*Freycinetia banksia*), and worms.

For stoats, molecular gut-content samples were taken from 16 individuals following visual inspection (Table 1). Hochstetter's frog DNA was detected in the gut-contents from one female stoat. Other herpetofauna identified in stoat gut-contents included copper skink (*Oligosoma aeneum*) DNA in three females and one male, ornate skink (*Oligosoma ornatum*) DNA in one female, and northern striped gecko (*Toropuku inexpectatus*) DNA in one male. Additional prey species DNA detected included petrel (*Pterodroma* spp.), freshwater crayfish (*Paranephrops planifrons*), grey warbler (*Gerygone igata*), wood pigeon (*Hemiphaga novaeseelandiae*),

Figure 1. During a visual gut-content inspection of a female ferret (*Mustela furo*) trapped at Mahakirau Forest Estate on the Coromandel Peninsula, Aotearoa | New Zealand, remains of at least four native frogs were identified, primarily Hochstetter's frogs (*Leiopelma hochstetteri*), with at least one Archey's frog (*Leiopelma archeyi*) also present. Molecular analysis of the gut-contents confirmed the presence of DNA from both native frog species.

tūī (*Prosthemadera novaeseelandiae*), sacred kingfisher (*Todiramphus sanctus vagans*), and sheetweb spider (*Cambridgea fasciata*).

Molecular samples were also taken from the gut-contents of all eight ferrets (Table 1). Hochstetter's frog DNA was detected in two female ferrets, confirming the visual identification of frogs in their stomach contents. In one of these females, Archey's frog DNA was also detected, and native frog DNA represented the highest concentration in the ferret's stomach. Other prey DNA detected in ferrets included rabbit (*Oryctolagus cuniculus*), possum (*Trichosurus vulpecula*), stoat, ship rat (*Rattus rattus*), and Norway rat (*R. norvegicus*).

Whareorino Conservation Area

In addition to previous observations of rat predation (e.g. Thurley & Bell 1994; Egeter 2014), two dead Archey's frogs were found with injuries consistent with rodent predation (A. Quinnell pers. com.). One individual had an injury to the abdominal cavity and the pathology report recorded cause of death as likely rodent predation. The other individual, a juvenile (snout vent length <15 mm), was found with flesh stripped from the upper hind legs and bone exposed (Table 1).

Sixty-four feral pigs were culled within the Whareorino Conservation Area between 2022–2023. Twenty-one (33%) of the 64 feral pigs culled had native frog remains identified in their gut contents during visual inspection (Fig. 2, Fig. 3, Table 1). The mean number of frogs per feral pig was 6.2. However, due to the various states of decay and segments of body parts found, not all remains could be confirmed *in situ*. One feral pig contained at least 56 individual identifiable frogs. Humus and hīnau (*Elaeocarpus dentatus*) seeds were the most abundant food source found within feral pig stomachs. Other organic material in the stomachs included grass, worms, flax, rats, and berries.

Discussion

These examples add to the growing body of literature on interactions and predation of frogs in Aotearoa | New Zealand by introduced mammalian species. While previous research has predominantly focused on the predation of native frogs by *Rattus* species, this paper emphasises the threats posed by feral pigs, mustelids, weka, and cats to both native and introduced frog populations. Molecular gut-content analyses, along with visual inspection, has proven to be invaluable for identifying predation events that might otherwise go unnoticed. Additionally, anecdotal observations provide important insights into predator-prey interactions, though they often go unpublished.

Observations of weka killing introduced frogs suggest that this native species should be considered as a part of frog conservation management, especially in the cases of newly translocated, small, or struggling frog populations. This may contradict earlier evidence that captive weka rejected native frogs as food items (Beauchamp 1996). It is worth noting that introduced frog species may be more likely to attract weka due to their loud calls and diurnal behaviour (Pyke & White 2001), in comparison to the cryptic leiopelmatid species, which rarely vocalise and are largely nocturnal (Bell 1978; Ramirez 2017). Weka co-occur with native frogs on Maud Island, where it is possible weka and/or little spotted kiwi

Figure 2. Native frog remains found during visual gut-content analysis of a feral pig (*Sus scrofa*) caught in Whareorino Conservation Area in the North Island of Aotearoa | New Zealand during targeted control.

Figure 3. Native frog remains were visually identified *in situ* from the gut-contents of a feral pig (*Sus scrofa*) as Archey's frogs (*Leiopelma archei*) due to the striped inner thighs and lack of feet webbing.

predation played a part in the decline of a newly translocated Hamilton's frog population (Savoca et al. 2018; Germano et al 2023b). At present, weka numbers are controlled for the benefit of other native species on the island. Further research is needed to assess the impact of weka and other bird species on native frog populations, particularly to determine the level of management required in future translocation efforts.

The results of this study raise significant concerns about the predatory impact of feral pigs on native frogs. We found direct evidence of feral pigs consuming native frogs, adding to prior records of feral pigs ingesting green and golden bell frogs (Krull & Egeter 2015). Notably, a high percentage of the feral pigs (22–50%) analysed had ingested native frogs, suggesting that feral pigs may preferentially target frogs rather than relying solely on opportunistic consumption. Cases of feral pigs selectively foraging for amphibians have been documented in the United States of America, where pigs have been observed consuming spadefoot toads (*Scaphiopus holbrooki*) (Buck Jolley et al. 2010). However, our results are the first published evidence of feral pigs consuming native frogs in Aotearoa | New Zealand. In addition, molecular analysis suggests that relying solely on visual inspection of gut contents may underestimate frog consumption by pigs, as demonstrated by findings from the feral pigs culled at Mahakirau Forest Estate. Similar issues have been noted in small mammal studies, where morphological techniques for identifying frogs in stomach and faecal samples have proven unreliable (Egeter 2014). A combination of visual inspection and molecular gut-content sampling, particularly in feral pigs due to their large stomach size, would therefore be optimal for accurate diet assessments. Currently, there is insufficient evidence to determine whether feral pigs are having a population-level effect on native frogs. However, ongoing control of feral pig populations is likely to reduce frog mortality events and provide broader ecosystem benefits. We recommend further research to evaluate the population-level impact that feral pigs pose to native frog species.

Anecdotal observations of probable rodent predation in Whareorino Conservation Area support current native frog conservation management regimes. Ground-based rat control has proven effective in suppressing rat populations, and evidence indicates that survival rates for adult frogs within rat-controlled areas are higher than in non-treatment areas (Germano et al. 2023a). However, juvenile and subadult frog survival was lower in the rat-controlled areas. Germano et al. (2023a) suggested that increases in house mice following rat control may have disproportionally affected smaller frogs, which are more frequently found on the forest floor and in small crevices (Powell et al. 2023). Predation events on native frogs by mice are difficult to observe due to the small size of mice. In addition, current landscape predator control often does not target mice, which significantly reduces the ability to opportunistically visually inspect gut contents or to collect molecular samples compared to other invasive mammals. We recommend that mice be actively trapped in areas inhabited by *Leiopelma* species to facilitate future gut-content analyses.

We acknowledge that while observations are valuable, they do not provide a complete picture of events occurring at the time. Some of the observations presented in the results are likely to be direct outcomes of predation; however, these cannot be conclusively proven through singular instances and without further investigation. These observations may have also stemmed from species scavenging on already dead frogs or from accidental consumption. To investigate the potential impact of introduced species on native frog populations, we recommend comparing frog population dynamics under various predator management regimes across the ranges of different frog species (Germano et al. 2023a). Understanding the impact of mice on juvenile frog survivorship is particularly crucial. However, observing frog population trends may take decades, as leiopelmatid frogs are slow to mature and can live for over 40 years (Bell & Pledger 2023). An additional focus on estimating the impact of predation on frog survival and modelling likely effects is therefore recommended. Molecular gut-content analysis has already proven to be a valuable tool and should continue to be utilised to determine the intestinal and stomach contents of mustelids, rodents, cats, and feral pigs.

The evidence gathered in this paper suggests that comprehensive predator management strategies may be needed to safeguard native frog populations in Aotearoa | New Zealand. The inclusion of targeted feral pig control measures alongside rodent and mustelid control programmes and habitat protection is likely critical for the long-term management of mainland native frog populations.

Acknowledgements

Special thanks to C Duyvenbooden, Tony Woodroofe, Rhys Burns, and Ralph Powlesland for sharing the details of their observations. Thank you to Doug Armstrong and Timothy Cutajar for contributing feedback and to the volunteers and landowners of the Mahakirau Forest Estate Society for their efforts to protect and learn about the management of native frogs on their land. Thank you to the handling editor of this paper for their comments, suggestions, and time.

Additional information and declarations

Conflicts of interest: The authors declare no conflicts of interest.

Funding: Funding for work in the Mahakirau Forest Estate came from the Mahakirau Forest Estate Society Incorporated, Waikato Regional Council, Auckland Zoo, and the Department of Conservation.

Ethics: Ethics approval was not required.

Data availability: The observations and gut content analyses presented in this manuscript can be accessed by contacting the corresponding author. There is no code associated with this article.

Author contributions: EH and JG wrote the article, and all authors contributed to the manuscript edits. EH and JG contacted members of the conservation community and followed up on anecdotes. SF collected the data in the field and analysed the results for the case study at Mahakirau Forest Estate. AH managed the data and results for the case study in the Whareorino Conservation Area.

References

Beauchamp AJ 1996. Weka (*Galliralis australis*) and *Leiopelma* frogs - a risk assessment. Notornis 43: 59–65.

Bell BD 1978. Observations of the ecology and reproduction

of the New Zealand Leiopelmatid frogs. Herpetologica 34(4): 340–354.
Bell BD, Pledger SA 2023. Post-metamorphic body growth and remarkable longevity in Archey's frog and Hamilton's frog in New Zealand. New Zealand Journal of Ecology 47(2): 3528.
Bishop PJ, Daglish LA, Haigh AJM, Marshall LJ, Tocher MD, McKenzie KL 2013. Native frog (*Leiopelma* spp.) recovery plan, 2013–2018. Threatened Species Recovery Plan 63. Wellington, Department of Conservation. 39 p.
Buck Jolley D, Ditchkoff SS, Sparklin BD, Hanson LB, Mitchell MS, Grand JB 2010. Estimate of herpetofauna depredation by a population of wild pigs. Journal of Mammalogy 91 (2): 519–524.
Crossland MR, Kelly H, Speed HJ, Holzapfel S, MacKenzie DI 2023. Predator control to protect a native bird (North Island kokako) also benefits Hochstetter's frog. New Zealand Journal of Ecology 47(2): 3530.
Egeter B 2014. Detecting frogs as prey in the diets of introduced mammals. Unpublished PhD thesis, University of Otago, Dunedin, New Zealand.
Egeter B, Bishop PJ 2016. A synthesis of direct evidence of predation on amphibians in New Zealand, in the context of global invasion biology. Herpetological Review 46(4): 512–519.
Germano JM, Bridgman L, Thygesen H, Haigh A 2023a. Age dependent effects of rat control on Archey's frog (*Leiopelma archeyi*) at Whareorino, New Zealand. New Zealand Journal of Ecology 47(2): 3529.
Germano J, Wren S, Webster T, Bishop PJ 2023b. Responses at the source and release site following an inter-island translocation of *Leiopelma hamiltoni*. New Zealand Journal of Ecology 47(2): 3536.
Krull CR, Egeter B 2015. Feral pig (*Sus scrofa*) predation of a green and golden bell frog (*Litoria aurea*). New Zealand Journal of Ecology 40 (1): 191–195.
Powell J, Matthaei CD, Godfrey S 2023. Colour variation and behaviour of the cryptic New Zealand frog *Leiopelma archeyi*. New Zealand Journal of Ecology 47(2): 3534.
Pyke GH, White AW 2001. A review of the biology of the green and golden bell frog *Litoria aurea*. Australian Zoologist 31(4): 563–598.
Ramirez PAR 2017. Behavioural patterns of two native *Leiopelma* frogs and implications for their conservation. Unpublished PhD thesis, Victoria University of Wellington, Wellington, New Zealand.
Savoca MS, Gardiner J, Colbourne R, Tennyson AJD 2018. Vertebrate prey in the diets of free-ranging kiwi (*Apteryx* spp.). Notornis 65: 242–244.
Thurley T, Bell BD 1994. Habitat distribution and predation on a western population of terrestrial *Leiopelma* (Anura: Leiopelmatidae) in the northern King Country, New Zealand. New Zealand Journal of Zoology 21: 431–436.
Wilkinson S 2023. Laboratory methods for Wilderlab™ metabarcoding panels. Wilderlab NZ Ltd. https://s3.ap-southeast-2.amazonaws.com/wilderlab.resources/methods/Wilderlab_metabarcoding_methods_2.1.pdf (accessed 26 August 2024).
Worthy TH 1987. Osteology of *Leiopelma* (Amphibia: Leiopelmatidae) and descriptions of three new subfossil *Leiopelma* species. Journal of the Royal Society of New Zealand 17: 201–251.

Received: 31 August 2023; accepted: 14 November 2024
Editorial board member: Jo Carpenter