ASSESSMENT OF RISKS AND OPPORTUNITIES FOR THE NAPIER POPULATION OF NORTHERN SPOTTED SKINK (*OLIGOSOMA KOKOWAI)*

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1. INTRODUCTION

Northern spotted skink (*Oligosoma kokowai*) is a large, diurnal and terrestrial skink. In Hawke's Bay, it is known only by a single population located at Awatoto. This is the northernmost extent of northern spotted skink in Aotearoa/New Zealand, and therefore is considered to be regionally significant. The closest other known population to Napier is a 26-year-old record (1994) located at Owahanga Station 130 kilometres to the south, in the Wairarapa. Based on current knowledge, it is assumed there are no other populations in the Hawke's Bay Region, however this cannot be discounted.

Prior to this work, nothing was known about the current abundance, range and conservation status of the northern spotted skink population in Napier, or whether it is sustainable on a medium to long-term basis. Upon rediscovery of northern spotted skink in Napier in 2006, experts at the Department of Conservation had serious concerns about the sustainability of the population. The Napier population is known to face a multitude of threats, including:

- Predatory mammals: cats, rats, mice, ferrets, stoats, weasels, hedgehogs.
- Bird predators are also likely and may include starlings.
- Argentine ants are likely to be present.
- Proximity to a major urban centre, and adjacent land/industrial development.
- Human interference, including poaching.
- Habitat loss and modification, including active management of the Marine Parade esplanade strip (mowing and removal of natural driftwood habitat).
- Risk of inundation by the sea due to the effects of storm surges, king tides, and sea level rises.
- Flooding during storms.
- Liquefaction in a major earthquake.
- Tsunami.

If no management is undertaken, these threats are likely to eventually cause the localised extinction of the species in Hawke's Bay.

Hawke's Bay Regional Council, Napier City Council, Department of Conservation, National Aquarium of New Zealand, NZ Landcare Trust, and Predator Free Urban Hawke's Bay (PFUHB) are all interested in implementing practical conservation action for the sole known population of northern spotted skink in Napier. Consequently, Hawke's Bay Regional Council contracted Wildland Consultants to undertake a survey for northern spotted skink in Napier, supported by significant staff time from the Council, Department of Conservation and the National Aquarium.

This survey is to be followed by a risk and opportunities assessment (this report) that assesses both current and new information as a result of the survey. The situational risk component includes an assessment of current threats — predators, human–wildlife threats, land management, natural hazards and climate change — while the opportunities assessment identifies management options. Options are required for management of the population.

This report will be followed by a draft consultative conservation management plan for the Napier northern spotted skink population, to be finalised in June 2021. Stakeholders from many organisations (Department of Conservation, iwi, Hawke's Bay Regional Council, Napier City Council, and others) will consider these options and help select a preferred option. The aim is to provide a 10-year northern spotted skink management plan for the species in Hawke's Bay (2022–2032).

2. NORTHERN SPOTTED SKINK

The northern spotted skink is a large indigenous skink species, reaching 110 mm snout-vent length, and up to 200 mm total length. It is a diurnal (daytime-active) species that is terrestrial (lives on the ground) although it may climb to sun-bask or forage. Northern spotted skinks are found in coastal and lowland sites within grassland, scrub habitat or open forest, often associated with protective rock habitat, such as coastal shingle and boulder beaches, river terraces, talus slopes and scree (van Winkel *et al.* 2018). The species is omnivorous (eating invertebrates, fruits, nectar and even smaller lizards) (Spencer *et al.* 1998, Hare *et al.* 2016).

Plate 1: Northern spotted skink (*Oligosoma kokowai*) at Napier.

The species likely has a slow life history with slow growth rate, late to mature and low annual reproductive output. Females produce 1–4 young in the summer (February–March) (Spencer *et al.* 1998). Longevity is estimated to be 8–14 years in the wild (Hoare *et al.* 2005) but there is a record for 19 years in the wild (Trent Bell, unpub. data). Potential longevity is based on the subsequent recapture of skinks that were part of previous mark-recapture studies on three predator-free islands (East *et al.* 1995, Phillpot 2000, T. Bell, unpub. data). They appear to show strong site fidelity, with recaptures within 7–15 metres of initial capture over five years, both on North Brother Island and Takapourewa., although movements of up to 60 metres are also recorded (Phillpot 2000, Hoare *et al.* 2005).

The northern spotted skink distribution includes the lower North Island and upper South Island, typically as small and extremely isolated populations, and some predator-free islands where it is often abundant (as high as 3,700 per hectare): Takapourewa, East *et al.* 1995, Stephens 2004; North Brother Island, Phillpot 2000. The only known secure populations therefore exist on such islands — the Brothers Islands, Mana Island, Matiu/Somes Island and Takapourewa — where mammalian predators have either been eradicated or were never present (Greaves *et al.* 2007, Melzer *et al.* 2017). Northern spotted skinks were translocated from Matiu/Somes Island to Mana Island in 1998 (Griffiths 1999) and more recently from Matiu/Somes Island into Wellington's Zealandia Eco-Sanctuary (D. Shanahan, pers. comm., 2016). Post-translocation population monitoring of populations at both Mana Island and Zealandia Eco-Sanctuary is currently underway (L. Adams and D. Shanahan, pers. comm., 2018).

Northern spotted skink is considered to be rare and vulnerable, with a formal classification of 'At Risk - Relict' (Hitchmough *et al.* 2016). The Department of Conservation considers the conservation situation for mainland populations of the species as 'very serious', although it is secure on predator-free offshore islands. Northern spotted skink survive in high numbers on these conservation islands, including Matiu/Somes Island, Brother Islands, and Takapourewa/Stephens Island. On these islands, it is the most abundant reptile (with captures as high as 95 skinks for every 100 trap days, amounting to 50% of all trapped reptiles). On the mainland, it is extinct throughout most of its former range (Hawke's Bay – upper South Island). Where remnant populations still exist on the mainland, these are typically near extinct in many locations (represented by 40+ year-old sighting records at 12 locations around the Wairarapa where population persistence is unknown). The absence of this species across the remainder of its known range, along with plummeting populations to the point of localised extinction at St Arnaud (Dumont 2015, Nelson *et al.* 2016), and lack of recent records (30+ years) from <12 historical mainland sites is strongly indicative of vulnerability to exotic predatory mammals and habitat loss. For the most recently monitored population in Wellington, trap rates of 0.1 skinks per 100 trap days were typical during the 2010s, i.e. one skink is caught for every 1,000 traps checked (Trent Bell, unpub. data 2018); although new data for that site now indicate a potentially sustainable population using a more intensive monitoring programme (Trent Bell, unpub. data, 2021).

Historically, northern spotted skink would have been one of, if not the most, abundant lizard species in central New Zealand, including along the Napier coast. This is supported by relative abundances approximating 50% of all reptiles, including tuatara, on Takapourewa (East *et al.* 1995), or 75% of all lizards captured in pitfall traps on the same island (Stephens 2004); 86% of pitfall captures of skinks on North Brother Island and measured densities in the low to mid-thousands per hectare on North Brother Island (Phillpot 2000), plus similar (unmeasured) densities on Matiu/Somes (T. Bell, pers. obs.).

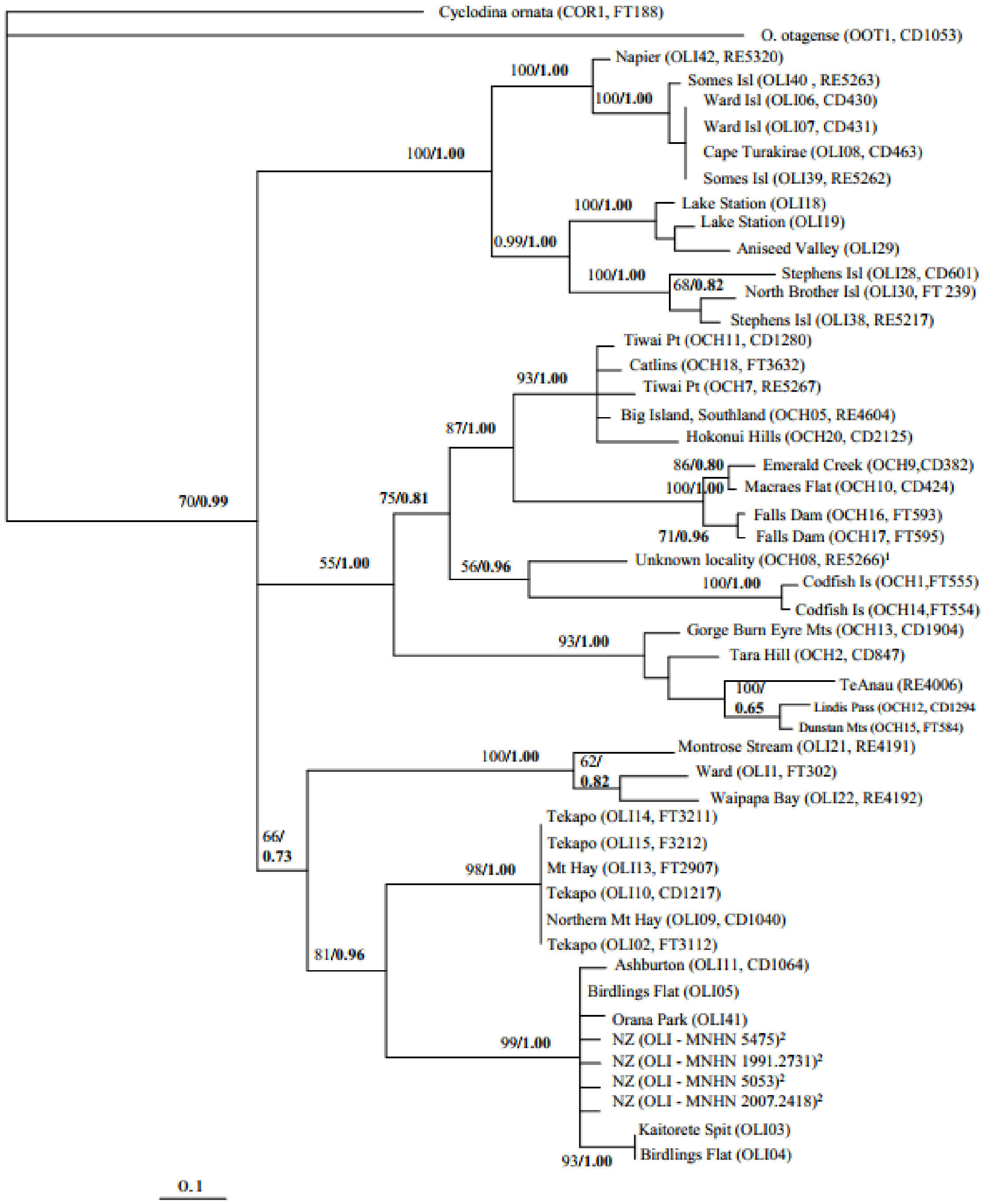

Figure 1: Maximum likelihood phylogram for the *Oligosoma lineoocellatum-O. chlorononton* species complex, which northern spotted skink (*O. kokowai*) is part of; represented in this phylogram by populations at Napier, Somes Island, Ward Island, Cape Turakirae, Lake Station, Aniseed Valley, Stephens Island, and North Brother Is (top part of phylogram). Note the relatively deep separation for Napier populations from those at Somes and Ward Islands and Cape Turakirae, indicating relative reproductive isolation for several hundred thousand years. The *O. lineoocellatum* species complex has now been resolved although work continues on the *O. chloronoton* component (from Melzer *et al*. 2017).

The Napier northern spotted skink population is an important conservation management subunit within the 'North Island Evolutionarily Significant Unit' (R. Hitchmough, Department of Conservation, pers. comm.). No North Island mainland population is secure, and many have disappeared in the last few decades; the species may well be not far from extinction in most known sites on the mainland. This would leave two natural populations on very small islands (Matiu/Somes and Ward Islands in Wellington Harbour), and two translocated populations (of Matiu/Somes origin) on Mana Island and in ZEALANDIA. In this context, the Napier population is very important in terms of capturing the remaining North Island genetic diversity within the species, as well as securing the northern extreme of the known range for the species (Rod Hitchmough, Department of Conservation, and Geoff Patterson, pers. comm.).

The Napier northern spotted skink population has some genetic divergence (*c*.1.5%, Greaves *et al.* 2007), indicating several hundred thousand years of divergence (Figure 1; R. Hitchmough, Department of Conservation, pers. comm.). Such divergence could be expected between Napier and Wellington populations considering the geographical distances involved, but no genetic sampling has been undertaken for the Wairarapa populations, which could be intermediate and/or share haplotypes with one or both sampled groups. (Melzer *et al.* 2017; R. Hitchmough, Department of Conservation, pers. comm.). The significance is more in terms of this population being the last known for the Hawke's Bay Region.

3. CHRONOLOGICAL HISTORY OF THE NAPIER POPULATION

The first record of northern spotted skink in Hawke's Bay was made in 1965 by A.H. (Tony) Whitaker, a reputable New Zealand herpetologist. Sporadic records were made up to 1972 and then the species was not seen again for the next 34 years. It was then rediscovered on the Marine Parade foreshore by Kerry Hewitt of the National Aquarium in 2006, after the Napier City Council's beautification works along the foreshore, which involved removal of large areas of rank grassland and driftwood habitat in order to create a manicured landscape and cycle/walkway.

The significance of the rediscovery in 2006 was recognised at the time by the Department of Conservation and supported by Tony Whitaker. The northernmost record for the species, and the species' vulnerability to threats of predation and habitat loss was noted in internal Departmental correspondence at the time. Habitat extent at that time was a *c*.300 × 5 metre strip on Napier City Council's Foreshore Reserve (1,500 m^2). The highly modified state of the habitat was a major concern, with little cover and safe habitat available for the species. The habitat at the time consisted of mown grass, pest weeds (such as prickly pear *Opuntia ficus-indica*, and "rope weed", species indeterminable), shingle beach material, and sparse cover from dumped concrete slabs. The state of the population was recognised as likely to be very tenuous.

In 2006–2007, a three-way informal partnership was formed between the Department of Conservation, Napier City Council, and the National Aquarium of New Zealand to help implement a management strategy to conserve the species and improve existing habitat. The intention of this management strategy was to redevelop the site to enhance, protect and extend the current known skink habitat. The risk of human interference and reptile collectors was noted at the time, especially with the new public coastal walkway.

The species' rediscovery and location was to remain confidential. An insurance population held in captivity at National Aquarium was an option, and this was followed through in 2007 with 10 animals brought in as part of a rescue from development of a major stormwater construction project (the Napier City Cross Country Drain) located to the south of the core population. Napier City Council funded initial rehabilitation and habitat enhancement work in the adjoining foreshore areas through placement of 115 m of concrete pathway removed for the drain construction and relocated on top of coastal shingle, creating protective habitat. Other options considered including fencing off the site (and potentially also additional small sites c. 10–15 m wide × 40–50 m long) to exclude the public and animals, allowing predator management, planting of *Muehlenbeckia* and other suitable species, addition of further artificial cover, and control of weeds. Restorative planting between the concrete pathway slabs to enhance local habitat was intended, but by 2021, there was apparently no site fencing or restoration evident, although pest prickly pear was removed. Between 2010 and 2020, it does not appear that any further actions have been implemented, and there are no records in the Department of Conservation's BioWeb Herpetofauna database during that time period (however, additional sightings not in the database are now known for the population (K. Hewitt and R. Romijn, pers. comm. 2021).

An intensive northern spotted skink survey was implemented during January 2021 by Wildland Consultants, supported by Hawke's Bay Regional Council, National Aquarium of New Zealand, Napier City Council and the Department of Conservation. This survey covered 30 kilometres of coastline between Whirinaki and Clifton, and resulted in only 4 individuals from 2 locations.

The below is a chronology of events and work to date with the northern spotted skink population in Napier. The information contained below is based on records in the Department of Conservation's BioWeb Herpetofauna database combined with archives in the National Aquarium. It is likely to be an incomplete record, particularly for the time period between the years 2010 and2020. New information is welcome from stakeholders to assist in completing the chronology as much as possible.

Table 1: Chronological history of northern spotted skink in Hawke's Bay. Sources: National Aquarium of New Zealand's archives, Department of Conservation's BioWeb Herpetofauna Database and records from recent surveys.

Date	Event
1965	First record of northern spotted skink in Hawke's Bay (BioWeb ref: 484003) – one individual found in Napier just south of Napier Hill by Tony Whitaker.
1966	Two individuals found by Tony Whitaker, just south of Napier city on the foreshore (BioWeb ref: 491750).
1972	One individual found southern Awatoto by L. Coham, identified by Tony Whitaker (BioWeb ref: 484005).
1972	One individual found near Haumoana, 8 kilometres NE of Hastings by R. Cooper (BioWeb ref: 484004). This is the southernmost record for the species in the Hawke's Bay region.
September 2006	On 24 September 2006, northern spotted skink rediscovered on Napier's foreshore by Kerry Hewitt (National Aquarium) (1 individual; BioWeb ref: 550199).
September 2006	On 27 September 2006, 3 northern spotted skinks found by Kerry Hewitt, Benno Kappers and Rhys Burns in follow-up visit to the northern spotted skink site (BioWeb ref: 550201).

Date	Event
October 2006	On 7 October 2006, 11 northern spotted skinks and 8 northern grass skinks were found by Kerry Hewitt. Several individuals had tail damage ranging from recent tail loss to total tail regeneration, and one had lost 2 limbs (right front and right hind) (not in BioWeb; co-ordinate in ARDS card unable to be converted and mapped).
November 2006	On 19 November 2006, another northern spotted skink was found by Andrew Wilson (not in BioWeb; no grid reference on ARDS card).
November 2006	On 24 November 2006, 7 individuals were found by Kerry Hewitt, Tony Billing and John Adams at the northern spotted skink site (BioWeb ref: 551153).
November 2006	On 29 November, 5 northern spotted skinks and 4 northern grass skinks were found by Kerry Hewitt at one location (BioWeb ref: 551754) and 2 northern spotted skinks and 1 northern grass skink at another (BioWeb ref: 551756).
December 2006	On the 12 December 2006, 4 northern spotted skinks and 8 northern grass skinks found in survey of northern spotted skink site at Marine Parade (BioWeb ref: 551763). An additional 3 skinks seen running from the beach to the grassy bank, but 2 were not identified. A deceased specimen was found (BioWeb ref: 551752); presumably this is the specimen that DNA analyses were undertaken on. Five mice were seen during the survey.
December 2006	On 13 December 2006, northern spotted skink partnership meeting held; notes discussed further surveys, collecting DNA samples, control of prickly pear and "rope weed", fencing, planting, option of collecting insurance population. Noted that drain [works] commence in February [2007].
December 2006	On 26 December 2006, 2 northern spotted skinks and 3 northern grass skinks were found by Kerry Hewitt (BioWeb ref: 551765), of which one was brought into the National Aquarium. Two mice were seen during the survey.
January 2007	Seven adult northern spotted skinks were rescued from flood prevention dam (along with 10 northern grass skinks) [date of rescue as yet unknown]. One of the northern spotted skinks was pregnant and gave birth to 3 young in captivity. As a result, 10 northern spotted skinks are now in captivity at National Aquarium.
August 2007	Early indications that the northern spotted skink population is very small (<100 animals, probably <50). Discussion about translocation to Cape Sanctuary from National Aquarium stock (John Adams, Department of Conservation to Paul Jansen, email correspondence, 27 August 2007). Current number of northern spotted skinks in captivity at National Aquarium: *c.*5 adults and 3 juveniles.
November 2008	Nine tin coffee containers [size unknown] used as pitfall traps, run for one day (26-27 November 2009) by Kerry Hewitt and Hans Rook. No lizards were captured in survey, but checking concrete blocks found 3 individuals. However, there was evidence that all large concrete blocks and rubble had been lifted recently, using crowbars as the masonry is far too heavy to shift without use of leverage. The disturbance was clearly targeted at northern spotted skink, and poaching was suspected.
March 2009	Four northern spotted skinks detected in 2-day survey (4-6 March 2009) undertaken by Hans Rook using 14 tin coffee containers used as pitfalls, 2 captured in pitfall traps, 1 seen by agapanthus (*Agapathus praecox*) (BioWeb refs: 579435, 579436, 579437) and another on gravel near sea. No hand searching of boulders and concrete pavement, so as not to disturb the habitat. Ant (species unknown) risk in pitfall traps was noted (as a consequence, traps were checked twice a day). Recognised extreme vulnerability in small confined area at the northern spotted skink site.
c. 2018-2019	[date uncertain] Kerry Hewitt mentioned seeing a couple when walking by with his dog.
January 2020	On 21 January 2020, National Aquarium undertakes a health check of the single female remaining in captivity. It is 86 mm SVL, 84 mm tail length, and 15 g in weight. The remainder of the captive population had either apparently been cannibalised by dominant adults or passed away.
December 2020	On 28 December 2020, a northern spotted skink was found at the northern spotted skink site, along with 3 northern grass skinks, by Richard Romijn. No skink measurements were taken, and the sex is not known.
January 2021	An intensive survey was undertaken between 18 and 23 January 2021 by Wildland Consultants herpetologists with support from Hawke's Bay Regional Council, National Aquarium, Department of Conservation and other volunteers.

Date	Event
	This survey systematically searched the 30 kilometres of the Napier coastline from Whirinaki to Clifton, using day search methods. Day searches consisted both of visual survey for active lizards and turning over driftwood and other cover objects (both natural or man-made), including repeated searches of the agapanthus row. A total of 94 pitfall traps (4L) with an Onduline layer as a trap cover were installed and checked 5×. The weather conditions during most of the time of trapping were warm to hot (15°+ Celsius), sunny and mainly settled, with nil rain. These are conditions that are mostly considered favourable for lizard activity. Only 4 individuals of northern spotted skink were detected, 3 around the core population at Marine Parade and one in a location to the south near Awatoto. Three northern spotted skinks were captured by pitfall traps (470 trap nights; resultant trap return of 0.006 skinks / 100TN), while the fourth was found by turning over driftwood. Throughout the Napier coastline, northern grass skink were also in very low numbers. The January 2021 northern spotted skink capture data is listed below: • Skink ID01 19/01/2021; female, 96 mm SVL, 81/23 mm tail length/tail break, at northern spotted skink site. • Skink ID02 19/01/2021: male, 71 mm SVL, 84 mm tail length, found under log 910 metres south of northern spotted skink site. • Skink ID03 21/01/2021; male, 81 mm SVL, 60/47 mm tail length/tail break, northern spotted skink site. • Skink ID04 23/01/2021; male, 59 mm SVL, 58/23 mm tail/tail break, northern spotted skink site. Mice were recorded around the concrete slabs and pitfall traps were affected by ants, so pear bait was removed and the traps were modified to allow skink escape. A cat was also seen around the slabs and 5 ship rats were seen around the NCC drain, indicating a high number of predators in the immediate area. There is virtually no habitat available for northern spotted skink along most of the Napier coastline, except for small sites near Whirinaki, behind the Awatoto industrial buildings, or the Ngaruroro-Clive and Tukituki river mouths (which are probably flood-prone). The National Aquarium population was revisited: the lone individual, an adult female, remains in captivity.
March 2021	On 11 March 2021, another northern spotted skink was found by Nick Harker. This was an adult female (81 mm SVL, 93 mm tail length, no regeneration, 9.75 g) found underneath a driftwood log on the gravel beach. The location is *c*.950 m south of the northern spotted skink site, and 46 metres south of the southernmost individual (ID02) found during the January 2021 survey.

4. SITUATIONAL RISK ASSESSMENT

4.1 Overview

The vulnerability of a species (or a population) to extinction depends on the impact of extrinsic threats as well as their intrinsic ability to respond or adapt to such threats (Tingley *et al.* 2013). This section identifies and describes the extrinsic threats facing the population of northern spotted skink at the northern spotted skink site and their intrinsic vulnerability to these threats. Extrinsic threats include predation (by both native or introduced predators), competition, human–wildlife conflicts (including poaching, land use change), and habitat modification (whether natural, e.g., flooding, or human-caused). Direct human pressures on populations (human interference, poaching) and their habitat (habitat losses and fragmentation) could be termed direct or indirect anthropogenic risk. Natural hazards are now becoming recognised as threats and may be geological (volcanism, earthquake, tsunami, liquefaction) or meteorological (storms, flooding, king tides). Climate change contributes towards other hazards by magnifying these directly or indirectly and has an underlying anthropogenic cause. Climate change may lead to increased temperatures, precipitation, storms, drought or sea level rises, and consequently lead to changes in ecosystems and communities, flooding and coastal inundation. Any of these threats alone or combined may have population-level consequences such as small population sizes, demographic stochasticity, and/or inbreeding risk, thus triggering the extinction process. A key part of this work was to quantify the threats and hazards, particularly earthquake and tsunami risk and meteorological hazards, as a result of climate change.

The northern spotted skink has intrinsic vulnerabilities to such threats. These include large body size (for example, being physically unable to escape similar-sized predators, such as weasels or mice, while immobile in retreats), limited annual reproductive output, reproductive mode (vivaparity) and small population sizes (occurring as unnaturally small population isolates) across their historical geographical range on the mainland (Tingley *et al.* 2013). These traits place the skink at enhanced risk to localised threats and catastrophes (Allendorf and Luikart 2007).

It is important to understand both ecological threats and natural hazards, and the risk of climate change magnifying such threats to the population at the northern spotted skink site, since through risk management, these risks may possibly be avoided or minimised. In natural hazard planning, relationship risk models are commonly used to express hazards, value and vulnerability in regards to human lives, assets and infrastructure (Fournier d'Albe 1979, Reese and Schmidt 2008, Power 2013). The simplest is the model: *Risk = value × vulnerability × hazard* (Fournier d'Albe 1979). These models could potentially be adapted for assessing risk to biological systems and values. Value could refer to our assigned value for certain ecosystems, species or populations, and vulnerability could infer to their intrinsic ability (or inability) to recover from catastrophic events. A qualitative risk analysis matrix assessing the likelihood and consequences of risks given combinations of frequency, magnitude and outcome could be useful in future analyses and decision-making in wildlife population management. This insight is not discussed further as this is beyond the scope of this report, however threats and hazards are discussed below.

4.2 Population

In 2007, the Napier population was non-scientifically thought to be at a maximum of probably <100, and likely <50 individuals. At the time, trap rates, based on a calculation from the March 2009 survey, were 0.07 skinks per 100 trap nights (TNs). The most recent survey undertaken during January 2021 at the northern spotted skink site returned a rate of 0.006 skinks per 100 TNs. While it is uncertain whether the two monitoring surveys can be directly compared (especially as in the second survey in 2021 pitfalls had to be made 'escapable' in case of predator interference), it does appear that there has been continued decline and numbers are now very low. In addition, *c.*160 person hours were spent during January 2021 searching a 30-kilometre length of coastline for only one individual skink (0.006 skinks per person-hour). At the same time, the captive population declined from 10 to a single individual skink through attrition and cannibalism.

It is possible that the Hawke's Bay survey may have missed sub-populations from the south of Tukituki River mouth towards the Cape Kidnappers, particularly around Te Awanga. It is recommended that these areas could receive further survey work.

Capture rates of northern spotted skink on Takapourewa ranged from 0.33 to 0.95 individuals per 4L pitfall trap night (Table 2; East *et al.* 1995; Stephens 2004). Similarly, on North Brother Island, rates were as high as 1.53 individuals per trap night (Phillpot 2000). However, on the mainland at St Arnaud, capture rates dropped from 0.045 in 1995 to 0.003 by 2010–2011 (Dumont 2015, and unpub. data). At another mainland location, Romijn (2012) recorded this species at Baring Head as 0.004 skinks per trap night, but by 2017 and 2019, capture rates slowly increased to 0.036 and 0.065 skinks per trap night (T. Bell, unpub. data). This appears to show a delayed response to the intensive long-term (*c.*10-year) predator management programme at Baring Head. This would be reflected in Napier should a similar programme be implemented here.

Today, the Napier population is likely to be between *c.*10 and <25 individuals (non-scientifically), although this cannot be confirmed without significant effort in monitoring the remaining individuals. Isolated individuals persist 910 metres to the south of the northern spotted skink site, at the foreshore around the industrial area.

Table 2: Relative abundances of northern spotted skinks on predator-free islands and in managed and unmanaged mainland sites.

Year	Location	Capture Rate/Trap Night	Capture Rate/100 Trap Nights	Estimated Abundance	Reference
1992	Takapourewa (predator-free island)	0.33–0.71	33–71 skinks	50% of all reptiles	East *et al.* (1995)
2002-03	Takapourewa (predator-free island)	0.95	95 skinks	3,770–1,740/ ha/75% of all lizards trapped	Stephens (2004)
1998	Matiu/Somes Island (predator-free island)	0.29	29.5 skinks	No estimate	Griffiths (1999)
1999	North Brother Island (predator-free island)	0.76–1.53	76–153 skinks	3,700–1,200/ ha/86% of all skink captures	Phillpot (2000)
1995	St Arnaud, mainland (pests unmanaged)	0.045	4.5 skinks	No estimate	Spencer *et al.* (1998)
2010-11	St Arnaud, mainland (pests managed)	0.003	0.3 skinks	N/A	Dumont (2015)
2010	Baring Head, mainland (pests unmanaged)	0.004	0.4 skinks	N/A	Romijn (2012)
2014	Baring Head, mainland (pests managed)	0.002	0.2 skinks	N/A	Wiles *et al.* (2015)
2017	Baring Head, mainland (pests managed)	0.001	0.1 skinks	Density N/A / 0.02% of all skink captures	Bell & Herbert (2018), Bell 2018
2017	Baring Head, mainland (pests managed) - river escarpment pitfall traps only	0.036	3.6 skinks	N/A	Bell 2018
2021	Baring Head, mainland (pests managed) - river escarpment pitfall traps only: new design	0.065	6.5 skinks	N/A	T. Bell, unpub. data.
2021	Napier northern spotted skink site	0.063	6.3 skinks	N/A	This report

Due to the low numbers found during the January 2021 survey, a robust analysis of population demographics is not possible. There is insufficient number of individuals to determine true population sex ratios (1 female: 3 males). Typically, there is a female bias in other populations of the species (1.6:1 f:m, Spencer *et al.* 1998), and females are usually larger than same-aged males (mean 76 mm SVL to 70 mm SVL; Spencer *et al.* 1998). However, the Napier northern spotted skink population is represented largely by adult individuals (indicative of low recruitment). In other studies juveniles (<62 mm SVL) should form between 10 and 30% of a population sample (East *et al.* 1995, Spencer *et al.* 1998, Dumont 2015). Fortunately, there are some remaining adult females, including one in captivity. Northern spotted skinks have a relatively low reproductive capacity (3.82 eggs in ovaries/female, range 1–9) compared to the sympatric northern grass skink (5.79, range 1–13) (Spencer *et al.* 1998). It is likely that few young are added to this population per year (northern spotted skinks give birth around March; Spencer *et al.* 1998), and it may also be possible that survival rates of young are lower than for adult animals, especially as a result of congener cannibalism. Hence, recruitment into a recovering population is likely to be low and slow for this species. Northern spotted skinks have great potential longevity (8–19 years in the wild, Hoare *et al*. 2005, T. Bell, unpub. data), but nothing is known about actual survival rates of young or adults at the Napier site. Due to the very low numbers remaining in the population and the species' slow life history, very high survival rates of both young and adults (as high as 95% per annum) will be required for population persistence for the species in Napier, whether that be *in situ* or relocated elsewhere.

The survey results indicate that Napier has a small, likely near non-functional, population of northern spotted skinks restricted to the southern coastline. Numbers are very low at Napier relative to other sites, for example North Brother Island (Phillpot 2000), Takapourewa/Stephens Island (East *et al.* 1995, Stephens 2004), and Matiu/Somes Island (Griffiths 1999, T. Bell pers. obs.). This population is at a very significant risk of localised and functional extinction due to the combination of multiple stressors on the population (threats such as introduced predators), and demographic and genetic stochasticity affecting small populations. The loss of any remaining individuals will significantly increase the chance of population extinction. Due to the very small numbers, functional extinction can be expected within 5–10 years if no action is undertaken.

4.3 Habitat

Northern spotted skink habitat along the Napier foreshore consists of bare greywacke cobbles and gravel beaches forming a coastal barrier ridge (Komar and Harris 2015), with occasional taupata (*Coprosma robusta*) and sparse exotic grasses. In 2007, concrete pavement sourced from a cycle/walkway was broken up and deposited on cobble-gravel beach, in order to provide 115 × 2 metres (300 m^2) of permanent protective habitat for the skinks (Plates 2 and 3). Immediately adjacent to the site are wide expanses of manicured grass and concrete cycle/walkway. The altitude of the site is five metres above sea level, and the site is *c*.42 metres back from the high tide mark. Northern spotted skinks have also been detected in low numbers in a row of agapanthus plants next to State Highway 2 (Marine Parade).

In terms of habitat use, northern spotted skinks are currently known to be restricted to the concrete pavement (artificially created refugia habitat) and in isolated occasional driftwood or cover objects on the foreshore. Today, it is uncertain whether there are any individuals remaining in the row of agapanthus. Despite the extensive area systematically surveyed in January 2021 (30 kilometres, between Whirinaki and Clifton), the current delimited range for northern spotted skink in Napier is 0.03 hectares (300 m^2) of concrete pavement, and 2 isolated records of individuals up to 910 metres to the south. The 300 m^2 site is referred to in this report as the northern spotted skink site.

Plates 2a and 2b: The 300 m^2 northern spotted skink site in Napier, where the core population occupies artificially created concrete slab refugia.

Plate 3: Aerial imagery of the 300 m^2 northern spotted skink site occupied by the core population. Note the proximity to the highly manicured esplanade landscape and the sea, lack of ground cover (either coastal vegetation or driftwood), and vehicle tracks.

According to maps produced in 1865, the Napier area at the time consisted of a large northern lagoon (Ahuriri), Scinde Island (now land-locked Napier Hill), with Marine Parade a significant tidal backwater behind a long beach barrier ridge (Annabell 2012). The northern spotted skink site, as we know it today, would have been located on the barrier ridge between the tidal backwater and the ocean. Between 1888 and the 1931 Napier earthquake, land reclamation draining the tidal backwater allowed for construction of dwellings facing the coast along Marine Parade. The old Marine Parade road had coastal erosion issues, so continued work was undertaken by the Napier Borough Council between 1889 and 1893 to protect the foreshore from additional erosion. The Napier 1931 earthquake extended the foreshore significantly through uplift, allowing for complete reclamation. Since then, continued beautification work has continued to the present day. Historically, vegetation cover along an infrequently inundated Napier barrier ridge would have consisted of an open coastal scrubland/vineland/harakeke/grassland mosaic interspersed with driftwood and cobbles surrounding the tidal backwater behind the greywacke cobble-gravel barrier ridge.

Northern spotted skink would have occupied Scinde Island and the elevated vegetated-driftwood-rock habitat mosaic site along the barrier ridge, so the remnant population has been effectively displaced towards exposed cobble beach due to habitat clearance as a result of land reclamation and development.

The skinks' current habitat is highly degraded with a lack of habitat complexity, resulting in a severe lack of protective cover, foraging area, and dispersal possibilities. Recent research has revealed that for larger species, such as the northern spotted skink, habitat restoration alone will be insufficient to avert population extinction (Hoare *et al.* 2007, Herbert 2020).

4.4 Predators

The northern spotted skink is threatened by multiple species of introduced predatory mammal: domestic and feral cats (*Felis catus*), rats (*Rattus* spp.), stoats (*Mustela erminea*), weasels (*M. nivalis vulgaris*), ferrets (*M. furo*), hedgehogs (*Erinaceus europaeus occidentalis*) and even mice (*Mus musculus*) (Newman 1994, Norbury *et al.* 2013, Nelson *et al.* 2016, Herbert 2020). Avian predators are also likely, including starlings (Nelson *et al.* 2016).

Ants are also a potential, unquantified threat; the identity of the ant species at the northern spotted skink site should be confirmed, especially as Argentine ants (*Linepithema humile*) are widespread in Napier. Argentine ants are aggressive, with strong appetites, and are considered one of the world's worst invasive species. They have serious ability to attack lizards, especially if the lizards are constrained such as through a refuge or in a pitfall trap.

During the January 2021 survey, 5 individual rats were found active during the day less than 200 metres from the northern spotted skink site at the Napier city drain site. Mice and ants were abundant at the northern spotted skink site itself. Cats have been reported on the foreshore, and were probably domestic cats from dwellings on Marine Parade.

Even if the site was managed, the close proximity of the site to an urban centre indicates that domestic cats, rodents, and ants will never be eliminated. Any single predator is fully capable of extinguishing small populations through episodic predation events (Reardon *et al.* 2012). In such cases, it takes only one animal, such as a domestic cat, to learn about the presence of the skinks at the northern spotted skink site and stake it out until localised extinction occurs.

4.5 Competitors

The northern spotted skink is sympatric with the northern grass skink (*Oligosoma polychroma*) at the northern spotted skink site and elsewhere. The latter small skink is not in high abundance, and is not considered a competitive threat at the northern spotted skink site. It is displaced locally by the northern spotted skink on Matiu/Somes Island, perhaps through competition and predation (Trent Bell, unpub. data).

However, congener competition (that is, competition between individuals of the same species) is likely for the northern spotted skink at the northern spotted skink site. The limited available habitat at the northern spotted skink site indicates that the population is severely limited in expansion and dispersal opportunities. Any population recruitment is likely to be diminished by depredations from co-habiting adult northern spotted skinks. This is likely especially due to limited food sources due to the highly degraded ecosystem of the foreshore. In addition, there will likely be severe competition for space between individuals, leading to poor body condition of submissive individuals. A lower body condition likely leads to lower reproductive capability in these individuals.

There is one introduced lizard species, the plague skink (*Lampropholis delicata*), which arrived in Aotearoa/New Zealand from Australia in the 1960s. This species does not appear to have established abundant populations in Napier; however, this is likely to occur eventually. Establishment of plague skinks, which can occur in high densities, at the northern spotted skink site could compound pressures on the skinks. However, it is also possible that northern spotted skinks would simply consume plague skinks.

Argentine ants, in addition to being potential predators, are also serious competitors for food. Argentine ant diet spans all food types, from insects to nectar, and the ants kill or displace invertebrates that lizards depend on.

4.6 Human impacts

The northern spotted skink population is under constant pressure from habitat modification, degradation, and human interference. Habitat modification and degradation can occur through coastal management practices, such as mowing, weeding, and removal or burning of driftwood material. Interference includes skink site disturbance, poaching, and use of motor vehicles across the gravel beach.

Over the decades, physical management and modification has already degraded the natural environment so much that it will be difficult to degrade it any further. The highly manicured state of the esplanade prevents establishment of natural habitat mosaics such as grasslands and driftwood. The rows of agapanthus on the esplanade could potentially be removed as there is no protections afforded to these. There has been almost complete removal of any terrestrial vegetation and natural driftwood stacks on the adjacent gravel beach.

The location of the northern spotted skink site is no longer secret, and can be seen using aerial imagery such as Google Maps or Google Earth, by identifying the series of concrete pavement slabs; it is also highly accessible. As early as 2008, the northern spotted skink site was apparently targeted by poachers, with evidence of the massive concrete slabs being lifted using tools and a lower number of skinks than expected found during a survey after the event. Even if the intention is not to take animals, the temptation to search for them to photograph will always be there for lizard enthusiasts. Constant use of motor vehicles across the gravel beach is apparent both by vehicles being seen during the January 2021 survey, and numerous tyre tracks formed across the gravel beach along the entire stretch of the southern Napier coast evident through aerial imagery. Evidence of beach driftwood campfires was constantly seen during the surveys. It is also difficult to undertake population monitoring programmes using any form of live capture trapping or even artificial cover objects, as such units, and related surveyor activity, will be highly visible from the cycle/walkway running parallel less than 10 m from the northern spotted skink site.

For a small and highly vulnerable population, there is a significant lack of protective cover and any additional and unnecessary impact will be far more severe than for other species or populations. Practical management options to reduce such human impacts at the northern spotted skink site are limited, other than inserting bollards to prevent 4WD movement across the site. The presence of such bollards could, however, attract more attention to the site and elevate other forms of human impact risk such as poaching or wildlife interference. Site restoration also comes with challenges (see Section 4.3 above).

4.7 Earthquakes

Aotearoa/New Zealand experiences a large number of earthquakes, along a belt from Fiordland to East Cape. The most common effect is ground-shaking, which can be very severe near the epicentre. The ground can be broken, deformation of the ground can cause landslides and liquefaction, and earthquakes can also generate tsunami waves.

Locally, earthquake events (epicentre, magnitude) have been as follows: 1863 (Waipawa, 7.0), 1904 (Cape Turnagain, 6.7), 1921 (central Hawke's Bay, 7.0), 1931 (Napier, 7.8), 1932 (Wairoa, 6.9), 1934 (Pahiatua, 7.6) (see Geonet: geonet.org.nz). The most recent earthquake with a significant rupture event was about 800–900 years ago from the Cook Strait to Gisborne, and probably had a magnitude between 8 and 9 (Clark *et al.* 2019). In total, there have been six to 10 large Hikurangi subduction zone earthquakes over the last 7,000 years, with the most recent around 500 years ago (Clark *et al.* 2019). However, there is insufficient evidence to be able to estimate recurrence intervals of such earthquakes.

It is difficult to forecast large earthquakes, although advances are being made with earthquake modelling. GNS leads the New Zealand National Seismic Hazard Model (NSHM) that calculates the likelihood and strength of earthquake shaking across New Zealand (Stirling et al. 2012). The NSHM is currently under revision, and is expected to be updated in later 2022 (Gerstenberger *et al*. 2021).

Currently, the Hawke’s Bay Civil Defence and Emergency Management (CDEM) Group uses a scenario of a large magnitude 8.9 Hikurangi earthquake and tsunami event as a serious and credible basis for response planning (Power *et al.* 2018). Potential impacts of a magnitude 8.9 Hikurangi earthquake would lead to widespread human fatalities (100–1,000) and injuries (1,000–10,000s), significant damage and disruption to the built environment across the country including 10,000s of damaged buildings, landslides and rockfalls, liquefaction, disaster waste and debris, subsidence/ uplift of land or permanent coastal inundation, and release of contaminants or hazardous substances into ecosystems, and probably a tsunami (East Coast Lab 2020).

Direct impacts from an earthquake on the northern spotted skink site is uncertain, as this would be event dependent (the shaking intensity at the specific site, the magnitude of the triggering event and the source to site distance), however it is possible that skinks could be killed, injured or entrapped underneath the large concrete slabs should these be displaced across the cobble rocks underneath. Low-lying areas in Napier, especially those near the coast, and reclaimed land, are particularly susceptible to liquefaction. The northern spotted skink site has been assessed to have medium liquefaction vulnerability (Rosser and Dellow 2017). A medium rating means there might be 'minor' to moderate damage as a result of a 500-year earthquake (typically larger than magnitude 6).

4.8 Tsunami risk

Tsunami are a natural phenomenon consisting of a series of waves generated when a large volume of water in the sea or in a lake is rapidly displaced (Power 2013). They are typically associated with earthquakes and landslides, but can also occur due to large rotational slumps, submarine slumping and submarine mud volcanism, pressure-coupling between the atmosphere and ocean due to volcanic eruptions, and meteors. Tsunami may be either generated from far source (distantly generated, such as those from earthquakes in Peru or Chile), or near source (locally generated, such as due to landslides or ruptures of nearby tectonic-plate margins at the base of the Hikurangi Trench, and associated submarine slumps). New Zealand is subject to tsunami risk both of pan-Pacific origins and the tsunamigenic seismic zone off the North Island (de Lange and Healy 1986). The East Coast has been identified as having the highest tsunami risk in New Zealand because of the subduction zone marked by the Hikurangi Trench (de Lange and Healy 1986, McSaveney and Rattenbury 2000). It is thought that the subduction zone has potential to generate severe tsunami from magnitude 8–9 earthquakes (Power *et al.* 2008). Other faults and a submarine slump exist in the immediate region capable of producing near source tsunami: the Lachlan fault, Waimarama fault, and the Kidnappers slump (van Dissen *et al.* 1994, Power *et al.* 2008). Tsunami large enough to leave palaeotsunami evidence affect Hawke's Bay on average approximately once every 900 years (New Zealand Palaeotsunami Database, accessed 10 May 2021) and such tsunami would be similar to the Indian Ocean tsunami of 2004 and the Japan tsunami of 2011. The highest waves have been derived from near source tsunami, however, effects are typically of limited geographical extent compared to distantly generated waves which have widespread impact (de Lange and Healy 1986). The February 1931 magnitude 7.8 Napier earthquake led to extensive regional uplift of the land by 1.8-5.5 metres and a limited on-shore tsunami (de Lange and Healy 1986, van Dissen *et al.* 1994, McSaveney and Rattenbury 2000). However, paleoseismological work indicates that Napier typically subsides in large earthquakes, and tsunami risk may be different in future events (Hull 1986, van Dissen *et al.* 1994). In the 1868 northern Chile earthquake and tsunami event, Napier experienced a 1.8 metre variation in tide level, and 1.2-1.5 metre waves went over the Boulder Bank in Nelson (northern spotted skink are also present at this location) (de Lange and Healy 1986).

Tsunami cannot be prevented but the risks associated with future tsunami can be assessed. McSaveney and Rattenbury (2000) determined that there was a 10% and 1% probability of occurrence for 11 metre and 20 metre high tsunami, respectively, within a 50-year period for Hawke's Bay. Power 2013 presented a hazard curve (Figure 6.19, p 148) that gives estimates of maximum shoreline tsunami height in the zone representing Napier given different return periods. The largest wave impact could be anywhere on the Napier coast, and not necessarily where the skinks are. For a 100-year event the estimated maximum height of such a wave is 4.35 m. A 500 year wave event is estimated to have a maximum height of 7.30 m (Power 2013). For the skink population at 5 m elevation, the annual probability of tsunami inundation can be assessed to be very approximately 1/200 or 0.5% (Power 2013, W. Power pers. comm.

2021). Tsunami exceeding 5 metres at the coast will severely impact the skink population and those that are 10 metres in height at the coast are likely to be catastrophic in populated areas and require a national emergency response, aided by international trauma specialists (McSaveney and Rattenbury 2000). Rising sea levels will amplify tsunami impacts on the land so much that that even smaller waves would have similar impact that twice-larger tsunami would have at current sea levels (Li *et al.* 2018).

The CDEM Group uses a magnitude 8.9 earthquake and severe tsunami scenario as a serious and credible basis for response planning (Power *et al.* 2018). GNS Science developed GIS-based attenuation rules for potential tsunami run up events, viewable on the Hawke’s Bay Hazard Portal: hbmaps.hbrc.govt.nz/hazards/). This modelling indicates that both near-source and distant source tsunami events could completely inundate the northern spotted skink site, leading to lizard population loss due to drowning and complete destruction of skink habitat. During such tsunami events, there will be no time or priority for lizard rescue.

4.9 Volcanism

While there are no volcanoes in Hawke's Bay, volcanic ashfalls from Mt Ruapehu and Mt Tongariro have affected Hawke's Bay due to prevailing winds (Scott *et al.* 1998). Volcanic events that affected Hawke’s Bay within recorded history occurred in 1896, 1945, 1975, 1995, 1996, and 2012 (Scott *et al.* 1998). The 2012 Tongariro eruption coated inland Napier with a one millimetre depth of ashfall (Hawkes Bay Emergency Management Group). Earlier eruptions that spread thicker layers of ash included the Taupo (Hatepe) eruption *c*.1,800 years ago, and other eruptions from Taupo, Okataina, Ruapehu, and Taranaki over 22,500 years ago (Scott *et al.* 1998). Future eruptions from the Okataina and Taupo volcanic centres may produce sufficient volcanic ash to have significant impacts on Hawke’s Bay, and Ruapehu, Tongariro, Ngauruhoe and Taranaki may also produce ash of lesser impact (Scott *et al.* 1998). Napier is well within reach of ash falls of <1 mm ash thickness and 1–5 mm thickness from Ruapehu. Volcanic ashfalls of 0–1 mm in Hawke’s Bay can be expected at least once every 10–20 years; 1–5 mm every 100 years, 5–150 mm every 2,200 years, 50–100 mm every 3,000 years and over 100 mm every 5,000 years (Scott *et al.* 1998). Any ash fall between 1and 5 mm may possibly be a temporary nuisance for the northern spotted skink, however the risks of respiratory effects, sedimentation, soil and water chemistry, and food-chain disruption from small ashfalls to terrestrial lizards is unknown. Falls of 5–100 mm or greater will likely severely affect the northern spotted skink site.

GNS Science, MetService, and the Earthquake Commission (EQC) are currently working on a new project to enhance real-time forecasting models for volcanic ashfall, by combining eruption scenarios with weather forecasting to predict the likelihood of an area being affected by volcanic ashfall.

4.10 Coastal inundation and erosion

Coastal sites are affected by overtopping as a result of tides, long-term fluctuations in sea-level (e.g. El Niño/La Niña cycles), frequency and magnitude of storm surges, wave and swell conditions, and rainfall patterns and intensity (Lundquist *et al.* 2011). Climate change is likely to exacerbate coastal inundation through rising sea levels.

Areas most likely to be affected by coastal inundation (from wave over-topping of beach crests) have been modelled for present day, 2065 and 2120 (HBCoast 2016). Predictions have been based on the effects of spring/seasonal tides (king tides), storm surge events (when waves and sea level heights elevate) and the compounding effects of sea level rise. A 100-year storm event (i.e. those with a 1% probability of occurring in any year) could result in storm surges 2 metres above tides, flooding many shore-front properties (Komar and Harris 2015). As the Napier foreshore is highly developed there is a hard inland boundary between the sea and developed land; this means that the northern spotted skink will be affected by 'coastal squeeze' (Schleupner 2008) with no avenue to temporarily or permanently relocate to more inland sites as a result of inundation.

Probabilistic modelling indicated that the future shoreline position for the northern spotted skink site at 2065 and 2120 will be relatively stable, with addition of gravel from coastal erosion elsewhere. Even so, the impacts of coastal inundation and storm surge events exacerbated by climate change on the northern spotted skink population will need to be considered.

4.11 Climate change

Climate change is inevitable, accelerating and a major threat for New Zealand's biodiversity (Lundquist *et al.* 2011, McGlone and Walker 2011, IPCC 2014). The impacts of climate change are both direct and indirect, and include increasing temperatures, increasing number of hot days, increasing severity and frequency of droughts, increasing or decreasing rainfall (depending on location and season), increasingly strong storm events, sea level rises and wildfire risk (Ministry for the Environment 2018, Macinnis-Ng *et al.* 2021).

The Intergovernmental Panel on Climate Change (IPCC)'s Fifth Assessment modelled 4 possible climate change scenarios known as representative concentration pathways (RCP): RCP2.6, RCP4.5, RCP6.0 and RCP8.5 (Ministry for the Environment 2018). RCP2.6 is a mitigation pathway, requiring removal of some of the CO_2 presently in the atmosphere, while RCPs 4.5 and 6.0 represent 2 stabilisation pathways, and RCP8.5 represents little to no effort in managing greenhouse gases. Based on these modelled scenarios, the New Zealand average temperatures are predicted to increase by between 0.7°C (RCP2.6) and 1.0°C (RCP8.5) by 2040 (compared with 1986–2005) (Ministry for the Environment 2018). However, temperatures will continue to increase steeply in scenarios with less action, with 0.7°C (RCP2.6) and 3.0°C (RCP8.5) by 2090; and 0.7°C (RCP2.6) and 3.7°C (RCP8.5) by 2110. Mid-range estimates are for an expected increase of about 0.8ºC by 2040, 1.4°C by 2090 and 1.6°C by 2110. The frequency of hot days (25°C+) is also predicted to increase (by 2040, a 40% [2.6] to 100% [8.5] increase; by 2090, a 40% [2.6] to 300% [8.5] increase). There will be an increasing incidence of drought events in eastern regions. Rainfall will have substantial variation around the country, but increase in magnitude given higher emissions. The likelihood of storm events (frequency, magnitude) requires more analytical research, but severe rainfall events of high intensity are predicted (Ministry for the Environment 2018).

Over the past century the average global sea level has risen by about 20 cm due to climate change (IPCC 2007). While the Ministry for the Environment is yet to release an updated report on sea level rise forecasts, last projections of sea level appear to range from 18 to 59 cm by the 2090s (mainly from thermal and glacier contributions), plus a further 10 to 20 cm and up to 80 cm for ice sheet scenarios (IPCC 2007, Lundquist *et al.* 2011). However, even higher rises cannot be ruled out. In 2007, the IPCC projected a high-end estimate of 59 cm through 2099 (IPCC 2007) but since then, the high-end estimate has been raised to about 90 cm (IPCC 2014). A number of later studies have concluded that a global sea level rise of 200 to 270 cm this century is "physically plausible" (Sweet *et al.* 2017, Bamber *et al.* 2019). As a result, storm surges and wave-swash, coastal erosion and coastal inundation will pose increasing problems for near-shore environments as a result of climate change (Komar and Harris 2015, IPCC 2014).

Flooding is a frequent phenomenon in the Hawke's Bay Region, with major flood events occurring at least every 10 years, including the Napier 2020 event. However, flooding is not known to have affected the northern spotted skink site to date, as it is slightly elevated relative to central Napier. Drought and storms, including storm surges and wave swashes at high tides, are probably far more likely than flooding to severely affect the northern spotted skink site. Droughts may affect the food chain and access to water, while storms may temporarily inundate the site and cause localised habitat destruction. Sea level rises are likely to result in decreased habitat availability (Lundquist *et al.* 2011).

The most serious threats to New Zealand's biodiversity, however, may arise from interactions between climate change and pre-existing threats such as invasive species (including predators) and habitat loss and fragmentation, and such impacts may operate synergistically (Lundquist *et al.* 2011). Loss of ecological interactions can also erode ecosystem functions prior to extinction (Valiente-Banuet *et al.* 2015). The northern spotted skink population currently has multiple stressors, such as small population size, multiple predators, limited habitat, human interference and natural hazards. Climate change will only exacerbate these stressors and significantly increase extinction risk (Cahill *et al.* 2013, McGlone and Walker 2011). Fragmented and isolated populations are presumed to be less resilient to the effects of climate change (Lundquist *et al.* 2011, Macinnis-Ng *et al.* 2021). The northern spotted skink population readily meets the definition of an isolated population.

The impacts of climate change on species and ecosystems are unclear in the longer term, as insufficient knowledge exists about how species and communities may respond to environmental change (Lundquist *et al.* 2011). The best defences against biodiversity loss as a consequence of climate change are exactly those actions being undertaken right now to prevent loss due to predators and habitat loss (McGlone and Walker 2011). However, no conservation action is currently being undertaken for the northern spotted skink population.

5. OPTIONS AND OPPORTUNITIES

5.1 Overview

This section identifies the conservation management opportunities for the northern spotted skink in Napier.

- Option 1: Do nothing.
- Option 2: Restore habitat *in situ*.
- Option 3: Pest control *in situ*.
- Option 4: Restore habitat and pest control *in situ*.
- Option 5: Restore habitat and pest control *in situ*; establish insurance population.
- Option 6: Lizard sanctuary *in situ*; establish insurance population.
- Option 7: Relocation.

5.2 Option 1: Do nothing

No site enhancement or pest management would be undertaken at the northern spotted skink site or along the foreshore. Periodic surveys will indicate fewer animals are found over time. Population is effectively isolated from the remaining congeners on foreshore, particularly from the sparse remaining individuals to the south, is largely non-functional, and localised population extinction can be expected within 1–10 years.

Pros: None, other than budgetary savings.

Cons: Predators, competitors, and human impacts will continue to affect the population over time. High numbers of rats, mice and ants already noted, and domestic cats also present. Due to limited space and food, adult northern spotted skink may consume young northern spotted skink from within the site, preventing population recruitment. Despite best efforts to leave alone, agapanthus row could potentially be removed any time by contractors for amenity reasons. Human interference with the population may increase, as more become aware of the location of the skinks. These may include disturbance or poaching. Such pressures will only continue to intensify in time. Localised population extinction within 10 years.

5.3 Option 2: Restore habitat *in situ*

Enhance the northern spotted skink site with additional rock or concrete slabs on the cobble/gravel beach. Addition of large amounts of driftwood. Planting of taupata, *Muehlenbeckia*, grasses. Site is fenced off. No pest control implemented, apart from PredatorFree 2050 initiatives.

***Pros*:** Increased local habitat carrying capacity, more protective habitat. Increased range of microclimates, including addition of cool shade, and local food sources through addition of plants that attract invertebrates. Some minor dispersal options for young and subadult skinks outwards of the northern spotted skink site into new microsites on site. Potentially better survival rates and improved population recruitment of young, due to dispersal effect. If ecological restoration effort is implemented foreshore-wide, increased range and habitat connectiveness may be possible within 10–20 years.

***Cons*:** Potential public resistance to addition of unsightly concrete slabs, may require visual impact assessment; significant habitat enhancement with driftwood and plants would remedy such visual impact. Enhanced habitat *in situ* could become a magnet for predators, as this could also provide habitat for these predators, given the highly degraded foreshore environment. Northern spotted skink unlikely to respond to habitat enhancement in measurable numbers. Population persistence without intensive predator control not guaranteed, and localised population extinction can still be expected within 10 years. There is a 5% probability that a major tsunami event (4.35 m wave amplitude) would wipe out the entire northern spotted skink population at any moment in the next 200 years, with the impact of waves amplified by rising sea levels.

5.4 Option 3: Pest control *in situ*

Implement extensive pest management around northern spotted skink site, inclusive of mice and ants. This will require an extensive network of predator traps every 50 × 100 metres along the entire foreshore from Napier Hill to the mouth of the Ngaruroro River, and inland as much as is possible (such as through PFUHB). 1.2 hectare mouse control programme subset around the northern spotted skink site.

***Pros*:** Possible population persistence for 5–20 years at least.

***Cons*:** Improved survival rates in dominant adult northern spotted skink, but poor recruitment due to cannibalism of young. Sublethal effects on subadults and submissive adults due to territorial disputes, leading to poor body condition in these individuals. No dispersal possible of young or subadults. Domestic cats will be socially difficult to manage, due to their proximity to the northern spotted skink site. Ants may be difficult, if not impossible, to control or eradicate. Removal of mesopredators (rats and mice) will likely result in prey-switching by cats, stoats and weasels to lizards (c.f. Norbury *et al.* 2013). PredatorFree 2050 initiatives may remove predator pressure on mice, causing significantly elevated mouse population numbers, requiring specific mouse control programmes at the northern spotted skink site (Newman 1994, Norbury *et al.* 2013, Nelson *et. al.* 2016). Dumont (2015) indicated decline of northern spotted skink to functional population extinction at St Arnaud despite intensive pest management operations, although trappability may also have been a factor. Tsunami risk (4.35 m) at 5% probability for the next 200 years.

5.5 Option 4: Restore habitat and pest control *in situ*

Combinations of Options 2 and 3.

***Pros*:** Population expands outwards, is slowly recovering in number. Periodic population monitoring indicates potential population sustainability may be reached within 20 years, after long lag period in recovery, if management efforts are sustained.

***Cons*:** Long-term commitment, requiring annual funding of habitat restoration and pest management efforts. If no funding or community support, population will revert to lower abundance with significant losses of recruited individuals. Cons are the same for Options 2 and 3, however enhancement of habitat may reduce cannibalism and sublethal effects on congeners, and population may persist longer (10+ years) due to improved survival rates as a result of both enhancement and predator control, although there will be significant uncertainty in how the population will respond, if at all. Tsunami risk unchanged.

5.6 Option 5: Restore habitat and pest control *in situ*; establish insurance population

Option 4 plus selected number of individuals taken into captivity for a breed-for-release programme back *in situ* or elsewhere. While there may be little or nothing that can be done in situ to mitigate tsunami events on the northern spotted skink site, insurance populations will assist in recovery from significant events.

Pros**:** Insurance population is secured and relocated back to northern spotted skink site or to a new site with better threat management options.

Cons**:** Insufficient number of animals that could be removed from the northern spotted skink site without adversely affecting the source population at the site. If a significant tsunami event threatens or affects the northern spotted skink site, the ability to eventually repatriate the northern spotted skink to the site may never be possible.

5.7 Option 6: Lizard sanctuary (restore habitat, eradicate predators *in situ*); eventual insurance population.

This is Option 5 however, instead of a non-fenced pest control programme, a predator-proof fence is established at the site, forming a 1-hectare Lizard Sanctuary on the Napier foreshore and all predatory mammals are eradicated within inclusive of mice, along with localized Argentine ant control. Remaining individuals along the Napier coast are relocated to within the fenced enclosure.

Pros**:** Population expands outwards in restored habitat within the confines of the 1 hectare predator-proof enclosure, slowly recovering in number. Periodic population monitoring indicates potential population sustainability may be reached within 20 years, and eventually approaches a new carrying capacity within the fence in 30-50 years. Local “ownership” of a predator-free site, including potential establishment of a “neighbourhood watch” for human interference. Ecotourism and advocacy opportunity involving a lizard sanctuary, from which the proceeds can be re-invested back into skink management. Other biodiversity values may benefit from a fence, such as northern grass skink and rare plants. Eventual insurance population harvested from the enclosure within 50 years.

Cons**:** Requires local authority approval for a sanctuary, which may require significant impact assessment and public consultation work, and resource consent. Significant expense in constructing a new predator-proof fence sanctuary (~$150-200k ballpark estimate) to construct the fence alone – such funding would be required within 6 months, unless skinks were all bought into captivity in the meantime until the funds are raised, the fence is built, habitat is enhanced and predators eradicated. Fence would be highly visible on Napier’s foreshore, and could be targeted by vandals, or lizard poachers. Visual effects of a predator fence would be significant, and may need a visual impact assessment, which could be softened by shrub planting around the fence spaced appropriately to prevent predator use for climbing into the enclosure. Other cons are the same for Options 2 and 3, however enhancement of habitat may reduce cannibalism and sublethal effects on congeners, and population is likely to persist due to improved survival rates as a result of both enhancement and predator exclusion. No dispersal opportunities beyond the fence for an expanding population. Ongoing fence maintenance and pest surveillance required. Coastal processes (storm surges, coastal erosion or inundation) may affect durability of fence, and salt corrosion of metal components in the fence may occur. Tsunami risk profile unchanged.

5.8 Option 7: Relocation

In an emergency programme, all trappable northern spotted skink would be systematically removed from the entire foreshore, including from the northern spotted skink site plus any additional individuals that may be found elsewhere. These animals would be brought into a captive breed-for-release programme firstly into National Aquarium for temporary holding (1-2 weeks) then moved to Wellington Zoo until at least 40 adult-aged individuals are available for a translocation event. Relocation thresholds could be set prior, where decisions are based on actual results. For example, in the event that ≤40 individuals are rescued from the Napier foreshore, these are would be taken into a captive breed-for-release programme. In the event that >41 individuals are recovered, these would be released via a direct wild-to-wild transfer to a suitable receptor site.

There are at least two possible sites in Hawke's Bay that could almost immediately receive a relocated northern spotted skink population from the foreshore: Cape Sanctuary and Motu-o-Kura (Bare Island).

Cape Sanctuary. At Cape, significant site enhancement work would be needed at a pre-identified release site (large lizard pen, rock/concrete slabs, addition of a new boulderfield, mouse incursion programme, lizard monitoring programme) before receiving animals. Some consideration is needed on potential interactions with the 'Nationally Vulnerable' Hawke's Bay skink (*O. auroraense*), however this risk could be managed since northern spotted skink are in sympatry with other speckled skink (for example the large Newman's speckled skink, *O. newmani,* on Takapourewa). Strategies could involve site selection within Cape where there is considerable distance between the two species and future interactions at any kind of describable densities remain at decadal timeframes. One potential receptor site could be the Cape Kidnappers golf course, beyond the Cape's predator-proof fence, where a mouse-proof enclosure could be established in the rough, providing highly manageable release sites that could be significantly enhanced through the addition of quarried rock. There are other possible locations within Cape where similar site establishment work could be undertaken. Ongoing skink monitoring and mouse surveillance programmes could be feasible. Northern spotted skink could eventually be allowed to expand outwards from the release site by removal of the pen.

Motu-o-Kura. Motu-o-Kura is the only predator-free island in Hawke's Bay, and has been for the past 30 years. Currently the lizard values of the island are unknown (apart from northern grass skink, and an unidentified gecko species). Another northern spotted skink population could eventually be established on Motu-o-Kura once sufficient numbers are established at Cape Sanctuary. However, a lizard survey of Motu-o-Kura would be required before the skinks are released there.

Elsewhere, there are limited choices in Hawke's Bay for potential receptor sites that are legally protected. Potentially available alternative sites in Hawke's Bay have been explored at high level, but these sites do not appear to be ideal. These were as follows:

- **Waitangi Regional Park.** Located at Tutaekuri-Ngaruroro River mouth, closest in proximity to Napier foreshore. Predator-trapping operation in place. Significant flood risk especially as a result of climate change, and risk of tsunami amplification up-river.

- **Otatara Pa Historic Reserve.** Large site (58 hectares) in close proximity to Napier, however its historic values indicate that any physical works to construct predator-proof fence may not be possible. Habitat enhancement would also be required.

- **Te Mata Peak Open Space Covenant.** Private land, *Oligosoma auroraense* present. May be difficult to secure consent to construct predator-proof fence. Habitat enhancement would also be required.

- **Kahika Conservation Area.** Department of Conservation stewardship land infested with gorse, blackberry, broom, willow; currently grazed by sheep; would be difficult to manage.

- **Pekapeka Swamp.** Large swamp with small skinks present (probably northern grass skink). Habitat enhancement would also be required. Flood risk.

Once removed from the northern spotted skink site, they may possibly never be repatriated back to the Napier foreshore, unless chronic threats are completely removed and natural hazards are unlikely to lead to localised extinction of the species. While chronic threats such as predators and habitat can be addressed, natural hazards can never be eliminated.

***Pros*:** Translocations of this species (from Matiu/Somes Island to Mana Island, and to Zealandia; into the presence of potentially competitive species, such as the aggressive McGregor's skink, *O. macgregori*) appear to have had successful outcomes, with animals seen since release and population recruitment evident (L. Adams, D. Shanahan, and T. Bell, unpub. data). Improved survival rates of all northern spotted skink, including young and subadults. Improved population recruitment. Reduction in intraspecific competition. Removal of multiple threats to population (introduced predators, human interference, land management, coastal inundation, tsunami). Reduction of climate change threat. New populations are likely to establish successfully without requiring intervention apart from periodic post-translocation lizard monitoring and mammal monitoring network and incursion response readiness. If northern spotted skinks can cope with mouse population at Cape, the potential for a massive range expansion (2,400 hectares) over decadal timeframes is present. In time, two new populations could potentially be established as a result of the relocation programme.

***Cons*:** Loss of the northern spotted skink population on the Napier foreshore, but this is offset by establishment of new populations elsewhere in Hawke's Bay that are more likely to be sustainable. A Cape Sanctuary population will require (a) erection of a softrelease pen in a mouse-proof pod at a site without *O. auroraense* present in high numbers, (b) habitat enhancement work, and (c) periodic monitoring undertaken directly by lizard experts, due to the vulnerable status of a threatened population, and the need for quality control of monitoring data. This monitoring programme should include mice, so an incursion response programme can be triggered, until such a time that either (a) the population is large and sustainable enough to withstand predation by mice, or (b) large-scale mouse control becomes feasible in time through significant advances in pest management. Need to determine potential impact on *O. auroraense*, but northern spotted skink and speckled skinks (*sensu latero*) are known to occur in sympatry at high densities elsewhere. Priority must be made to survey Motu-o-Kura first to determine absence of the species before a translocation could proceed as it is not known whether there is already a population on the island (absence on Motu-o-Kura will likely be due to rodents, now eradicated, that were historically on the island). In addition, there is some coastal erosion issues at Motu-o-Kura, and the tsunami risk is not completely removed for skinks should they be relocated to the island. Wherever the slinks are released, continued access to the skinks by conservation managers will be essential, and these managers should continue be able to make decisions on skink management.

6. RECOMMENDED OPTIONS

We have shortlisted two recommended options for the Department of Conservation's Lizard Technical Advisory Group to consider. These are as follows:

A. **Lizard Sanctuary** (Option 6).

B. **Relocation** (Option 7).

The Management Plan will implement whichever of the two recommended options presented here, or any alternative options, that the Department of Conservation's Lizard Technical Advisory Group prefers.

The suggestion is to implement the preferred option under urgency (i.e. commencing within the next 6 months). A 10-year Northern Spotted Skink Management Plan for Napier is required urgently, and a Wildlife Act Authority application would also urgently be prepared to enable the implementation of management. Actions undertaken to urgently manage the skink population could be approved by managers ahead of formal Wildlife authorisations.

Decisions in a management plan could potentially be set on thresholds in accordance to actual results of any recovery effort, where in the instance $\leq$40 animals are recovered, they go into an *ex situ* captive breed-for-release programme with eventual repatriation at the site or elsewhere; or if there is still a good number of animals over 40 (i.e. ~60+), then a predator-fenced *in situ* population and insurance population could be concurrently established at Cape Sanctuary, or elsewhere.

It is recommended that decisions on options are based on securing certain outcomes over longer term timeframes (i.e. 100+ years) since unguided interim step-wise actions over shorter timeframes (10-20 years) are not likely sustainable, and risk eventual failure. This was seen during the late 2000s where a working group had the intention to restore habitat and protect the population *in situ* but this was not sustained over the subsequent decade (Table 1). It is clear that whatever option is selected, an end point needs to be identified and significant work will be required to secure the species in Hawke's Bay. Such is the urgency involved, it may be necessary to secure individuals from the Napier foreshore before any final decisions are made.

7. NORTHERN SPOTTED SKINK MANAGEMENT PLAN

A 10-year Northern Spotted Skink Management Plan (Napier populations: 2021–2031) to implement the relocation option will be in draft for consultation in June-July 2021. This plan, once finalised, will enable critically important decisions and actions to be implemented that will contribute to the species' long-term survival in Hawke's Bay.

8. CONCLUSION

It is remarkable that the northern spotted skink has persisted in Napier since the population was rediscovered in 2006. However, this by no means indicates the Napier population is secure. Numbers are low, the population is locally restricted and barely (if at all) functional, the habitat is highly degraded, chronic threats exist from the presence of introduced predatory pests and human interference; and there are identified risks (with computable probability) for the occurrence of rare natural hazard events of large magnitude, i.e. earthquakes and tsunami. Any of these, or a combination of these threats, could lead to localised population extinction of the species in Hawke's Bay. The threats are so pervasive that extinction is still likely *in situ* even with intensive management.

Currently, there appear to be two viable options for the management of northern spotted skink in Napier. One involves the creation of a Lizard Sanctuary on the Napier foreshore where the core northern spotted skink population is, protected by a predator-proof fence. The second is a relocation exercise towards either an existing predator-free sanctuary (Cape Sanctuary) and/or a predator-free island (Motu-o-Kura), where a potential captive breed-for-release programme may be required to restore population functionality before release. These options have a number of advantages and disadvantages, however, one major consideration for any type of *in situ* management are the threats of sea level rise and tsunami, indicating significant and irrecoverable losses *in situ* could eventually occur. That said, a predator-free sanctuary on the Napier foreshore has some interim short- to medium-term advantages, however this comes with significant financial and time costs relating to construction of the sanctuary. Translocation, on the other hand, is also a risky exercise, but the species has successfully established elsewhere as a result. It is also the more cost-effective and currently available option. The difficulty is determining the eventual receptor site.

If the relocation option is selected, it will be the first such project in Aotearoa/New Zealand involving the planning of potential actions that protect a threatened population in the face of a multitude of threats arising from natural hazards and climate change, in addition to predatory mammals. Parallels can be seen in the emergency relocation of cobble skink (*Oligosoma* aff. *infrapunctatum* “cobble”) from storms and coastal erosion at Granity in 2016, and Kapitia skink (*O. salmo*) at Chesterfield as a result of Cyclone Fehi (February 2018). Both species now have insurance populations at Auckland Zoo and eventual repatriation into the wild is planned at secure locations (R. Gibson, pers. comm. 2018). However, relocation of northern spotted skink would involve proactive planning to address potential threats that are predictable, rather than unplanned and reactive emergency responses to an imminent threat. Whichever of the options chosen, considerable urgency will be required going forward.

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RESOURCES ON-LINE

NIWA Our Future Climate New Zealand:
https://ofcnz.niwa.co.nz/#/home

GNS (earthquakes):
https://www.gns.cri.nz/Home/Our-Science/Natural-Hazards-and-Risks/Earthquakes

New Zealand National Seismic Hazard Model:
https://www.gns.cri.nz/Home/Our-Science/Natural-Hazards-and-Risks/Earthquakes/National-Seismic-Hazard-Model-Programme

GNS (tsunami):
https://www.gns.cri.nz/Home/Our-Science/Natural-Hazards-and-Risks/Tsunami

GNS (volcanoes):

https://www.gns.cri.nz/Home/Our-Science/Natural-Hazards-and-Risks/Volcanoes

Hawke's Bay Hazard Portal:
https://hbmaps.hbrc.govt.nz/hazards/

Newspaper articles:

- https://www.stuff.co.nz/national/124493765/the-science-of-tsunamis-and-what-parts-of-new-zealand-are-most-at-risk
- https://www.stuff.co.nz/national/nz-earthquake/101989915/megathurst-quake-could-bring-12mhigh-waves-to-nzs-east-coast
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