Improvements and Persisting Challenges in COVID-19 Response Compared with 1918–19 Influenza Pandemic Response, New Zealand (Aotearoa)

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Exploring the results of the COVID-19 response in New Zealand (Aotearoa) is warranted so that insights can inform future pandemic planning. We compared the COVID-19 response in New Zealand to that for the more severe 1918–19 influenza pandemic. Both pandemics were caused by respiratory viruses, but the 1918–19 pandemic was short, intense, and yielded a higher mortality rate. The government and societal responses to COVID-19 were vastly superior; responses had a clear strategic direction and included a highly effective elimination strategy, border restrictions, minimal community spread for 20 months, successful vaccination rollout, and strong central government support. Both pandemics involved a whole-of-government response, community mobilization, and use of public health and social measures. Nevertheless, lessons from 1918–19 on the necessity of action to prevent inequities among different social groups were not fully learned, as demonstrated by the COVID-19 response and its ongoing unequal health outcomes in New Zealand.

The world is continuing to experience the COVID-19 pandemic, which has resulted in >767 million reported cases and ≈6.9 million deaths (≈870 deaths/1 million persons) through June 2023 (*1*). Those numbers are likely a huge undercount; mortality has been estimated to be ≥3 times higher (*2*). New Zealand (Aotearoa, the commonly used Indigenous Māori language name for the country) experienced ≈2.4 million confirmed COVID-19 cases and ≈3,077 COVID-19 attributed deaths (≈597 per million population) reported up to mid-June 2023 (*3*). The country has also experienced severe effects of the COVID-19 pandemic through disruptions to the healthcare system and economy and wider societal harms (*4*–*7*). However, in terms of deaths, the influenza pandemic of 1918–19 still remains "New Zealand's worst recorded natural disaster" (*8*).

The 1918–19 influenza pandemic occurred in the final stages of World War I (WWI) and is estimated to have killed 50–100 million persons worldwide, equaling >1% of the world's population (*9*). This particularly lethal strain of influenza A(H1N1) virus spread to almost all parts of the globe, leaving just a few isolated locations untouched. In New Zealand, the 1918–19 influenza pandemic spread the length of the country through railway and shipping routes and is estimated to have killed >9,000 persons (*8*). The effects of this pandemic were severe, stressing the existing healthcare system (already stretched by the war effort) and, as in other nations, affecting all aspects of daily life and compounding existing societal and economic inequities.

Past pandemics provide insight into how societies, governments, and communities are affected and how they might respond to an emerging disease threat. Indeed, failure to examine past pandemic experiences limits our understanding and reduces the clarity of evidence and justification for future pandemic management and control. Given this background, we completed a historical review (Appendix, https://wwwnc.cdc.gov/EID/article/29/9/22-1265-App1.pdf) to consider how this island nation responded to these 2 severe pandemics and to explore

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whether ongoing lessons exist that are relevant both for today and for future pandemic planning.

1918–19 Influenza Pandemic in New Zealand

The first, relatively mild, wave of the 1918–19 influenza pandemic spread in New Zealand during July–October 1918. The more virulent second wave largely occurred during November–December 1918 (Appendix Table 1, Figure 1, panel A). Most pandemic deaths in New Zealand occurred during this second wave, which spread nationwide in a matter of weeks; some localized examples of prevention measures, such as quarantine and travel restrictions, have been documented (*8*). Vaccine use for bacterial pathogens during this pandemic is documented in New Zealand and in overseas-based New Zealand military personnel, who were part of vaccine studies (*11*). Some limited international evidence of vaccine efficacy for influenza-associated bacterial pneumonia (a common secondary infection) during this pandemic exists, but there was no coordinated distribution of vaccines to the public in New Zealand. This pandemic had a profound effect on children in New Zealand, not only as a result of influenza infection itself but also through detrimental effects on family and caregiving structure and by deaths of caregivers that left children orphaned (*8*). Evidence also exists for a sudden decrease in the annual birth rate in the country in 1918 and particularly 1919, a possible result of the association between influenza infections, social effects, and stillbirths or fetal loss (*12,13*).

In late 2018, we published a systematic review of all known literature on the experience of the 1918–19 influenza pandemic in New Zealand (*12*). We found epidemiologic patterns among residents during this pandemic that were consistent with international literature, such as a w-shaped age distribution for deaths (Figure 1) (*8,14,15*). Mortality rates were high among Indigenous Māori civilian and military populations compared with the European-origin population (*8,16*), and risk for death was higher among New

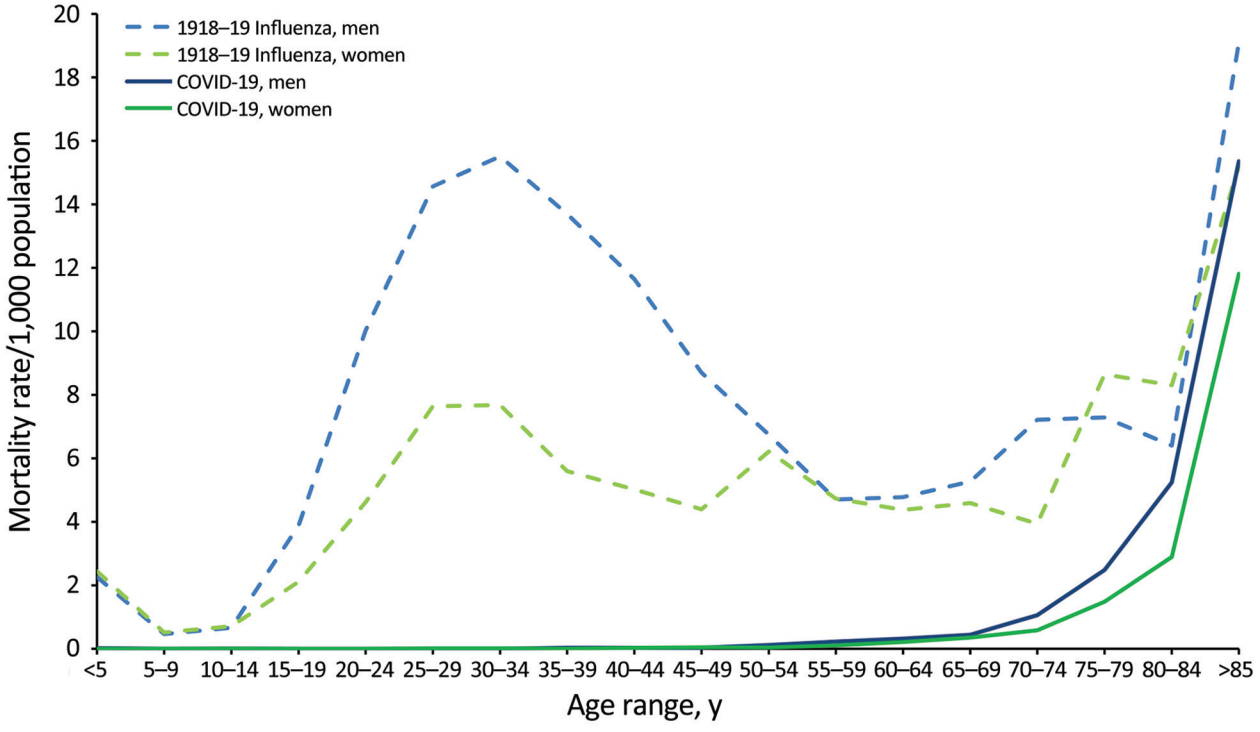

Figure 1. Cumulative mortality rate (deaths/1,000 population) in New Zealand (Aotearoa) during the 1918–19 influenza pandemic (for European-origin persons) and during the COVID-19 pandemic (all origins), by age and sex. The 1918–19 pandemic mortality data cover the entire period of the pandemic in NZ and are reproduced from Summers (*10*) and derived/approximated from publicly available sources (*8*; https://www3.stats.govt.nz/New_Zealand_Official_Yearbooks/1924/NZOYB_1924.html). Mortality data from 1918–19 for the Māori population are not available; therefore, mortality rates are likely underestimates. COVID-19 mortality data cover the period of January 2020–December 31, 2022. Mortality data were provided by the New Zealand Ministry of Health/Manatū Hauora, and population totals were sourced from Stats NZ/Tatauranga Aotearoa (https://www.stats.govt.nz/topics/population). Death was classified as a COVID-19 death when COVID-19 was the underlying cause of death or a contributory cause of death. The figure does not include 3 deaths with missing demographic information or the 589 deaths that were unclassified as of December 31, 2022 (and might subsequently be classified as COVID-19 deaths).

Zealand military personnel who had a preexisting chronic disease or were recent military recruits (*8*,*15*–*17*). Unique findings focused on the novel risk factors for death, such as larger chest size in men (possibly an indicator of a different immune system response in men with larger bodies) (*17*) and lack of difference between mortality rates in men and women in the Māori population. The lack of difference in mortality rates by sex contrasted with the relatively higher death rates of men than women in the European-origin population in New Zealand (as was found in many other countries) (*12*,*15*,*18*). Although this H1N1 influenza virus was considered endemic by 1920, it continued to cause more severe influenza seasons for several more years, and long-term sequelae from the pandemic strain have been documented internationally (*19*,*20*) (Appendix).

COVID-19 in New Zealand

The first identified case of COVID-19 in New Zealand was reported on February 28, 2020; the first outbreak peaked in March 2020 alongside the first national stay-at-home order (lockdown), border closures for noncitizens, and introduction of wide-ranging public health protections (Appendix Figure 1, panel B). The government initially adopted an elimination response strategy to manage the pandemic, which required tight border management to prevent the importation of COVID-19 cases and systems to extinguish outbreaks if they occurred (*21*).

Relatively small COVID-19 outbreaks occurred in 2020 and 2021 because of incursions coupled with new COVID-19 variants (*3*,*22*). In response, local (including iwi [tribal]–led), regional, and national public health and social measures (including lockdowns) were put in place to contain community spread. During those periods, businesses were closed, work was restricted unless deemed essential, and the government provided some financial assistance to businesses and employees.

A switch from an elimination strategy to a suppression strategy occurred in late 2021 during the Delta variant wave with the introduction of the COVID-19 Protection Framework (*21*,*23*). This framework focused on vaccination requirements for various indoor and public venues and included some limited travel restrictions. However, the framework was retired mid-September 2022, and only limited public health protections, such as mask-wearing in healthcare facilities, remained in place. The pandemic plan in New Zealand at the emergence of COVID-19 was (and remains as of mid-June 2023) based on a hypothetical influenza pandemic and predominantly uses a mitigation strategy (*24*). Therefore, the applicability of this plan to the characteristics of COVID-19 has been questioned (*4*).

Compared with other high-income countries, New Zealand experienced decreased excess winter deaths, a net decline in overall deaths, and an increase in life expectancy during the first 2 years of the COVID-19 pandemic (*25*). The largest waves to date in terms of cases, hospitalizations, and deaths have been from the Omicron variant (and its sublineages), which began in early 2022 and spread nationwide (*26*). By mid-June 2023, a total of 3,077 estimated deaths attributed to COVID-19 had occurred in the country (*3*).

The effects of COVID-19 in New Zealand have varied; the burden of hospitalizations and deaths have disproportionately affected Māori and Pacific persons (another ethnic grouping), and those groups have had lower rates of COVID-19 vaccination (although the difference varies by age group) (*3*,*6*). As of June 9, 2023, ≈89.3% of the total eligible New Zealand population had received 2 vaccine doses, and ≈73.2% had received ≥1 booster (third) vaccine dose (*3*). The pandemic has also had a major effect on children and adolescents because of widespread disruption to education at all ages (*27*).

Just over a year into the COVID-19 pandemic, the New Zealand government confirmed that the health system would be restructured to create 1 national service delivery organization to function alongside the continuing Ministry of Health (focused on policy), a dedicated Public Health Agency, and a Māori Health Authority (https://www.futureofhealth.govt.nz). The transformed health system aims to create a "more equitable, accessible, cohesive and people-centered system that will improve the health and wellbeing of all New Zealanders" (https://www.futureofhealth.govt.nz). This health system restructure was planned before the COVID-19 pandemic, however; unlike the health system restructuring and legislative changes that occurred in New Zealand after the 1918–19 influenza pandemic, this restructuring began during the COVID-19 pandemic.

Comparison of 2 Pandemics

We identified key similarities and differences between hazards and responses across the 2 pandemics (Table). Both pandemics occurred among largely immunologically naive populations (with some exceptions in 1918–19) (*43*), and large proportions of the population were infected with marked ethnic health disparities, manifesting as higher rates of illness, hospitalization, and death, among Māori and Pacific peoples.

Table. Comparative summary of distinct features of 1918–19 influenza pandemic and the COVID-19 pandemic hazard and responses, New Zealand*

1918–19 influenza pandemic	COVID-19 pandemic	Similarities
Hazard and effects (both globally and in NZ, where data available)		
Caused by influenza virus H1N1	Caused by SARS-CoV-2	Likely zoonotic origins for the pandemic viruses
RNA virus that showed relatively slow genetic drift through mutation	Global infection fatality risk of 0.1%–2.0% up to June 2021 (*28*); NZ infection fatality risk 0.79% (estimated, January 2021 before vaccination) (*29*)	Transmitted between humans as a respiratory viral pathogen
Probably originated in domestic and wild birds (*30,31*)	RNA virus showing rapid genetic shifts through mutation and recombination, including within-host evolution during chronic infection of immunocompromised patients (*32*)	Immunologically naive population
Moderately transmissible, with R_0 estimated at 2.4–4.3 (*33*)	Probably originated in bats (*31*)	High proportion of population infected
Incubation period of ≈a few hours to 2 d reported in a large US civilian hospital in 1918 (*34*) and general influenza estimates of 1–4 d (*35*)	Highly transmissible with estimated R_0 of 9.5 for Omicron variant (*36*)	Marked ethnic health disparities experienced globally. For example, in NZ, notably higher death rates in the Māori population
Global case-fatality risk ≈1–2.5% (*20,37*)	Incubation period estimates differ by variant, with one meta-analysis reporting a pooled mean incubation time of 6.6 d (*38*)	Higher death rates in men internationally
Global infection fatality risk >2% (*28*)	Global estimate for case fatality risk of 1.12% as of July 26, 2022 (*1*). NZ case-fatality risk of 1.15 in 2020 (before vaccines), reduced to 0.09% as of July 2022 (with high vaccine coverage) (*3*)	Post-acute infection syndrome common
Infection gives long-term immunity (*39*)	Infection gives protection that fades over ≈3 y (*40*)	
Net effect is symptomatic infection in ≈8% of population each year (*41*)	Net effect is reinfections are common (*3*)	
Short, intense pandemic wave, with some smaller waves in subsequent years	Repeated, prolonged pandemic waves	
Relatively more severe illness in young adults and elderly	Relatively more severe illness in elderly and immunosuppressed	
Devastating spread of infection from NZ to surrounding Pacific nations	Regional border quarantine measures probably limited spread from NZ to South Pacific jurisdictions	
Response in NZ		
Lack of strategic response	Highly strategic national control response (elimination for first 20 mo of pandemic) with vigorous public communication	Large community/voluntary sector mobilization
No use of external border controls	Use of tight external border controls (in the first 2 years)	Use of physical distancing through closure of public facilities, businesses, schools, and cancellation of large public events, although less systematically in 1918–19
No specific test for pathogen available	Accurate diagnostic test and organized testing program	Some use of internal border controls
Limited use of case isolation and contact quarantine	Active contact tracing and quarantining of contacts	No specific curative treatment initially (although supportive management and treatment options for COVID-19 sufferers were developed, including antivirals)
Limited infection control in institutions	Infection prevention and control in health care and aged care	Iwi, hapū and marae-led care and support† (*7,8,42*)
No specific vaccine available	Highly effective vaccines in late 2020 (within 1 year)	Royal Commissions of Inquiries to investigate pandemic responses
Lack of economic and social support from government	Extensive economic and social support from government	
No widespread mask-wearing	Requirements (mandates) to use masks in some settings to limit transmission	

*For greater detail of the hazards, response, and various impacts of the two pandemics in NZ, see Appendix Table 1 (https://wwwnc.cdc.gov/EID/article/29/9/22-1265-App1.pdf). NZ, New Zealand; R_0, basic reproductive number.
†Indigenous Māori language terms: iwi refers to tribe and hapū refers to subtribe. Marae (meeting grounds) are the focal point of Māori communities and are a complex of carved buildings and grounds that belongs to a particular iwi, hapū, or whānau (family).

Both viruses are moderately to highly infectious; basic reproductive numbers (R_0) were estimated to be >2.4 (Table) (*37*,*42*). A key difference is that the incubation period (and serial interval) is much shorter for influenza. An estimate of the incubation period for 1918–19 influenza is a few hours to 2 days (*34*); for influenza A, 1.4 days (*35*). For SARS-CoV-2, by contrast, one mean estimate of incubation is 6.57 days (*38*). The longer incubation period for COVID-19 has made contact tracing and quarantine of contacts much more feasible.

The 1918–19 influenza pandemic caused a short, intense pandemic wave with high death rates that swept through New Zealand in <2 months (November–December 1918) and likely infected ≈50% of the population (*8*). The first Omicron variant wave of the COVID-19 pandemic moved through New Zealand in a similarly short period (February–April 2022). Unlike the 1918-19 influenza pandemic, it was followed by a succession of waves; a second occurred in June–August 2022, a third began in November 2022, and a fourth began in April 2023. These waves were each dominated by different Omicron subvariants (BA.1 and BA.2 for the first wave, BA.4 and BA.5 for the second, and a mix of multiple Omicron subvariants in the third and fourth waves) (*3*). Influenza H1N1 (such as the 1918–19 influenza virus) and SARS-CoV-2 are RNA viruses that mutate more readily than DNA viruses (*44*). However, SARS-CoV-2 has demonstrated a capacity for sudden and frequent antigenic shifts that result in new variants and subvariants with multiple mutations, which enables it to escape existing immunity and cause high levels of reinfection and a succession of pandemic waves (*32*). One change in human populations between 1918–19 and 2020 onward is the likely increase in the proportion of persons now living with known immune suppression. SARS-CoV-2 appears able to cause chronic infections in such patients, during which it can have rapid within-host evolution (*32*).

Of note, the lethality of H1N1 in 1918–19 (global infection fatality risk >2%) overlapped with the range reported for SARS-CoV-2 (global infection fatality risk 0.1%– 2%) before vaccines were introduced (*28*,*29*). After widespread COVID-19 vaccination, the case-fatality risk in New Zealand dropped by an order of magnitude, from 1.15% in 2020 to ≈0.13% by the end of May 2023 (*3*). This decline might also reflect the reduced severity of the Omicron variant relative to the Delta variant, although Omicron appears to have similar virulence to the original variant that dominated during the first year of the COVID-19 pandemic (*45*). Furthermore, immunity after infection with H1N1 virus in 1918–19 appeared to be long-lasting (*39*). By contrast, immunity against infection generated by SARS-CoV-2 appears to fade over ≈3 years (*40*). In addition, this immunity is much less effective at preventing infection with subsequent COVID-19 subvariants, although protection against severe infection appears to be well sustained after both natural infection and vaccination (*40*).

We observed a w-shaped distribution of deaths in New Zealand during the 1918–19 pandemic that was more pronounced for men than women in almost all age groups (Figure 1). However, we observed no evidence of a w-shaped distribution of deaths by age for COVID-19 in New Zealand; the mortality rate increased exponentially with older age. The rate of overall attributable deaths was higher among men than women, which is consistent with international findings (*3*,*46*). For both pandemics, higher mortality rates were observed in specific populations, such as Māori and Pacific peoples (*3*,*6*,*8*). Reported rates of COVID-19 illness have been generally higher among children and younger adults in New Zealand (*3*). However, this difference might reflect increased exposure to infection because they have higher levels of social contact than older adults; rates of self-reporting among the younger population could also be higher.

A wide-ranging government response with robust community mobilization was observed during both pandemics, as was a substantial reliance on charitable contributions to support persons and communities (Appendix Table 1) (*4*,*8*,*47*). Physical distancing measures and travel/border restrictions were used in both pandemics, but public health protections were far tighter during the COVID-19 pandemic (particularly during 2020 and 2021). Additional external border controls used the advantage of New Zealand being a remote island nation and having a brief window of time to implement controls before widespread domestic COVID-19 transmission occurred. However, during 1918–19, use of internal border restrictions was limited and inconsistent, and no substantial external travel restrictions or border control was in place. For example, a discriminatory travel ban on public transport for Māori (unless issued a health permit) was implemented, and other unofficial bans were extended to other premises, such as business places (*8*).

Institutional infection control and prevention was limited during 1918–19, although some temporary hospitals were established for influenza patients, in addition to separate hospitals for Māori patients (*8*). The response in 1918–19 was unlike the response during COVID-19, in which extensive prevention and

control measures were used in a range of healthcare and aged-care settings and integrated into the initial Alert Level System and the subsequent COVID-19 Protection Framework (*21*,*47*).

Discussion

More than a century has now passed since the 1918–19 influenza pandemic, but it remains the worst public health disaster in recorded New Zealand history. More than 9,000 influenza deaths occurred in just a couple of months, and during the final stages of WWI, New Zealand residents faced a uniquely difficult period in the nation's history. In particular, the Māori population was disproportionally affected by the pandemic, and many Māori pandemic deaths probably remain undocumented (*8*). The response during and after this period provides insight into how New Zealand society might respond to future disease threats, as well as to the continuing COVID-19 pandemic.

Probably the most fundamental difference in responses to COVID-19 and influenza was the use of a national control strategy, namely an elimination strategy for SARS-CoV-2 (*48*). The early use of the elimination strategy in New Zealand in 2020 helped maintain a relatively low death rate in the first 2 years and reduced the economic impact of the COVID-19 pandemic compared with other nations (*1*). New Zealand also observed an increase in life expectancy during this period (*25*) and low estimates of excess deaths compared with a pre–COVID-19 period (≈0.02% as of May 2023), unlike other high-income nations, such as the United States (12.8%), United Kingdom (10.0%), and Sweden (5.1%) (*1*). This proactive response to COVID-19 is markedly different from 1918–19, when no clear strategy was implemented for preventing or managing the influenza pandemic, resulting in substantial deaths and reduced birth rates in the following years (*12*,*13*).

The death patterns observed in 1918–19 highlighted health inequities and the factors driving them, such as household crowding, comorbidities, and unequal access to healthcare. Reasons for poorer health outcomes among Māori are complex; Māori persons in 1918–19 experienced higher rates of chronic disease (compared to the European-origin population in New Zealand), barriers in access to healthcare, and discriminatory outbreak management approaches. For example, in 1918–19, the Māori population had a substantially higher pandemic influenza mortality rate of 42.3 per 1,000 compared with 5.8 per 1,000 among the European-origin population; as a result, in the final 2 months of 1918, an estimated 4% of the Māori population died from pandemic influenza (*8*).

Those health inequities persist today (*16*). Although the New Zealand government has acknowledged failings in the COVID-19 pandemic response and provided some targeted support to Māori providers (and other services such as those for Pacific and disabled persons), cases, hospitalizations, and death rates for COVID-19 have been disproportionally higher among those groups (*3*). Rates of COVID-19 vaccination are also lower among Māori adults and children than among other ethnic groups. Therefore, the principles of equity, partnership, and active protection, as guaranteed in the Te Tiriti o Waitangi–Treaty of Waitangi between the Government (Crown) and Māori, continue to be inadequately addressed 100 years after the first pandemic. Fortunately, some of this deficit was addressed through Māori-led initiatives during the COVID-19 pandemic, such as basic living support (for example, food parcels to families [*7*]) and health service provision (for example, testing and vaccination drives by community groups, with or without government support). Several iwi (tribes) also initiated border controls for their tribal areas, emulating the approaches used in 1918–19 to limit the spread and severity of disease and thus protect their whānau (families) and communities.

When comparing the 2 pandemics, considering how scientific understanding has progressed and given us better ways of identifying, measuring, and describing the effect of infectious diseases is key. For example, the first human influenza virus was not isolated until 1933, more than a decade after the 1918–19 influenza pandemic (*8*). One distinct research area is the growing awareness of post–acute illness effects. The long-term effects of COVID-19 infection, which include both post–acute infection syndrome (long COVID) and organ system–specific effects (manifesting as excess deaths for at least 1 year after acute infection), appear to be relatively common. Long-term effects after the 1918–19 influenza pandemic were recognized, but fewer scientific tools to investigate them existed (*19*). Recent comparisons of COVID-19 with influenza suggest that sequelae from influenza appear less common (*49*).

During 1918, WWI was continuing to have a substantial impact on daily life; ≈40% of the New Zealand adult male population served in the military during the war, and many doctors and nurses were stationed overseas. This huge disturbance to normal life meant that when the pandemic hit, fewer able-bodied adults were available in traditional roles to provide assistance, and this gap was compounded by the higher rates of illness and death in younger adults. Therefore, many other residents stepped up

Figure 2. Medicine department at the Wellington Town Hall during the 1918 influenza epidemic. Shows where the standard mixture and tonic were prepared and bottled. Mrs. Waters (right) was in charge. Taken by an unidentified photographer. Reproduced from New Zealand Free Lance: 1/2-C-016207-F, 1918, Alexander Turnbull Library: National Library of New Zealand, Wellington, New Zealand.

to help by volunteering in temporary hospitals, providing food and medical supplies, transporting those who were ill, and serving on block committees that managed and supported local communities by coordinating relief (Figure 2) (*8*). Numerous examples of children playing essential roles during the 1918–19 pandemic by delivering supplies and working in hospitals have also been detailed (*8*). Similar examples were observed during the COVID-19 pandemic; local communities provided food and other supplies throughout New Zealand (Figure 3) (*7*), and children in secondary schools took employment in essential roles in supermarkets while schools were closed to support their families and fill labor shortages. The government also provided economic assistance during COVID-19, although this assistance was intermittent and was particularly focused on localities experiencing the tightest controls.

Unlike the 1918–19 influenza pandemic, which was largely over in 2 months, the COVID-19 pandemic has sustained itself globally for >3 years. Consequently, the effect of the COVID-19 pandemic on societal cohesion in New Zealand might be different from that observed during 1918–19; the ongoing COVID-19 response, vaccine provision and mandates, and overall management by the government has led to increased displays of social division. This division suggests the ongoing need for a more equitable and effective pandemic response, at both national and international levels.

Surprisingly, after 3 years of the COVID-19 pandemic, New Zealand still lacks a generic pandemic plan, and little evidence of planning for future disease threats (other than COVID-19 or influenza) exists (*47*). Therefore, it appears that New Zealand has not yet fully learned the lessons of 1918–19; the COVID-19 response has largely taken a reactive approach to new challenges, rather than a proactive stance (*47*). A more proactive approach could have implications

Figure 3. Workers at Kōkiri Marae preparing food and sanitation packages for the Lower Hutt and Wainuiomata communities during COVID-19 pandemic, New Zealand. Photograph by Luke Pilkinton-Ching, University of Otago, Wellington, New Zealand.

for controlling other infectious diseases (for example, improving infrastructure to support improved public health and social measures) and managing COVID-19 aftereffects such as long COVID and long-term effects on children.

Restructuring the health system during the COVID-19 pandemic might not have been optimal timing and is unlikely to incorporate all potentially relevant lessons from the entire period of the pandemic, unlike the restructuring after 1918–19. A Royal Commission of Inquiry investigating the response in New Zealand to the COVID-19 pandemic was announced in December 2022, but the scope of the inquiry is constrained. It excludes, for example, any assessment of the effect of the health system reforms, the epidemiology of the COVID-19 virus, private sector involvement, or various judgments and decisions related to the pandemic in various courts and independent agencies. A major positive feature is its focus on improving future pandemic preparedness (*50*).

New Zealand's "team of 5 million," as former Prime Minister Jacinda Ardern voiced in 2020 in reference to the population, is arguably now somewhat fractured by the prolonged COVID-19 pandemic and spread of the Omicron variant. Every aspect of the pandemic response has also been scaled back, with less use of public health and social measures and slowing uptake of vaccination and boosters. Therefore, it is difficult to identify, from a public health perspective, the government's ongoing strategy for managing COVID-19, how persisting inequities associated with infection are to be addressed, or how those most at-risk are to be protected. However, it is worth remembering that New Zealand emerged from the devastating 1918–19 influenza pandemic by strengthening its health system with the goal of learning lessons from its pandemic response. At this point, there remains an opportunity for New Zealand and the rest of the world, to build capacity to prevent future pandemics and to better respond to them when they are unavoidable.

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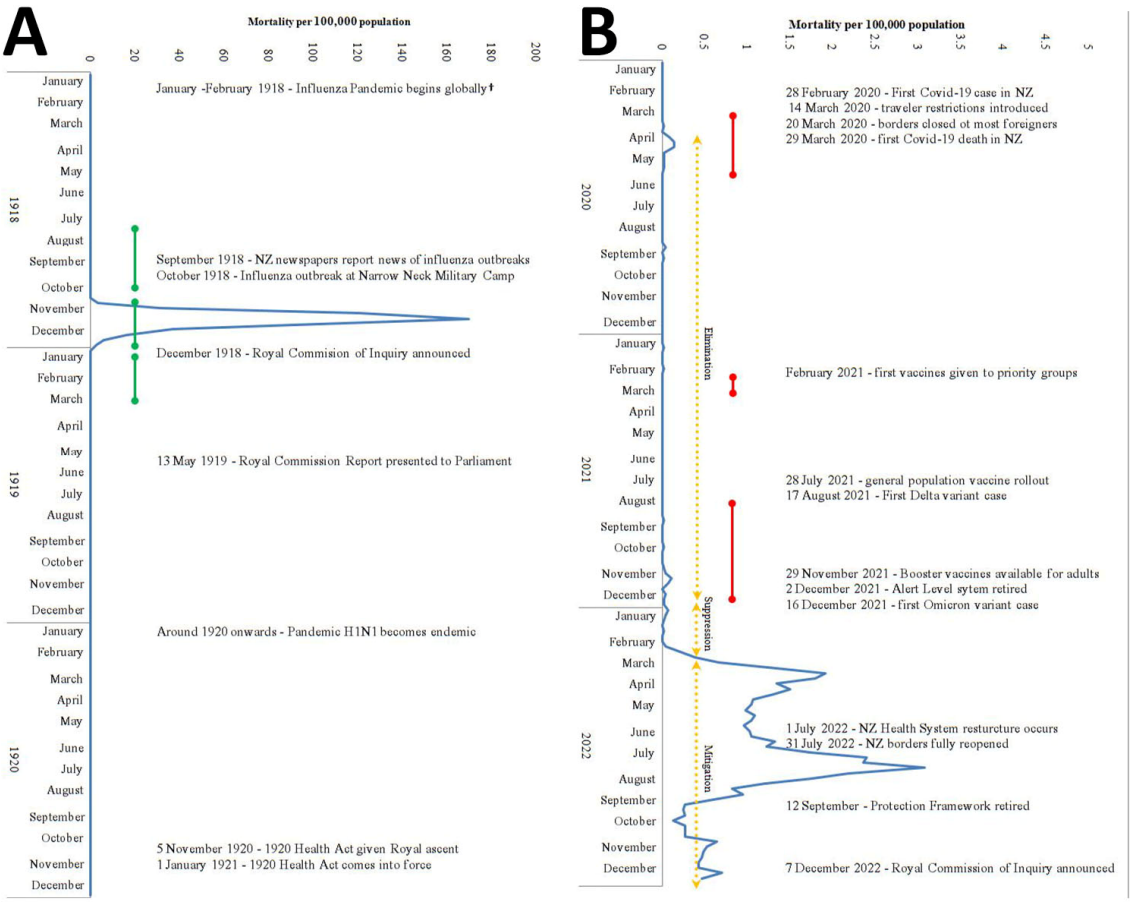
Improvements and Persisting Challenges in COVID-19 Response Compared to 1918-19 Influenza Pandemic Response, New Zealand (Aotearoa)

Appendix

Methods

We aimed to review and summarize relevant literature related to the two pandemics (1918–19 influenza pandemic and the first 3 years of the Covid-19 pandemic) in relation to NZ and where applicable, international literature. We conducted literature searches using online databases, such as Google Scholar, Embase, PubMed, NZ Government sources (as listed in the references), various media sources and gray literature, with searches undertaken between May and December 2022. We also drew upon our own expert knowledge with regards to both pandemics in NZ. Mortality data for both pandemics was sourced from a variety of sources including publicly available data, by previous research conducted by one of the authors *(1–5)* and provided directly from the NZ Ministry of Health in January 2023 for the purposes of this study *(6)*.



Appendix Figure 1. A) The 1918–1919 influenza pandemic mortality by week per 100,000 in New Zealand with pandemic waves and select pandemic related events. B) Covid-19 pandemic mortality by week per 100,000 in New Zealand, with corresponding lockdown periods and select pandemic related events. Green bars indicate three influenza pandemic waves of cases in NZ during 1918 and 1919: a first wave occurring in July-October 1918 with relatively low mortality, a more severe and lethal second wave between November-December 1918, and a relatively mild third wave in early 1919. Red lines indicate periods of national or local lockdowns in NZ during 2020 and 2021 - defined as Alert Levels 3 and 4 and used in various periods during 2020 and 2021. See Appendix Table 2 for further details of lockdowns in NZ. Yellow dotted lines and arrows indicate phases of responses: elimination (begins 25 March 11.59pm), followed by suppression (begins 2 December 2021 11.59pm), and finally mitigation (begins 16 February 2022 11.59pm). 1918 Influenza Pandemic mortality derived from several sources *(2,7,8)*, and population denominators (for the European population) estimated from population values between 1916 and 1921 in NZ *(3)*. Mortality totals include civilian deaths occurring in NZ along with identified military deaths occurring in the Southern Hemisphere during the pandemic period as previously described (note: there may be some minor overlap between civilian and military deaths) *(8)*. NZ military pandemic deaths occurring either 'at sea' or in the Northern Hemisphere are not included. Civilian deaths do not account for undocumented pandemic deaths occurring within the Māori population, so total civilian deaths are likely to be an underestimate. Covid-19 mortality, population denominators and details of lockdowns and select pandemic related events

derived from publicly available data from NZ's Ministry of Health *(5)*, Statistics New Zealand *(4)* and other sources *(9–11)*. Data extracted on 2 January 2023 and covers the period of February 2020 (when first case identified) to week ending 1 January 2023 (data given in weekly totals). †There is scientific debate as to whether influenza waves before 1918 constitute evidence of earlier pandemic waves *(12,13)*.

Appendix Table 1. Comparison of some of New Zealand's 1918–19 influenza pandemic and Covid-19 pandemic experiences and responses

Research Domain	1918–19 Influenza Pandemic	Covid-19 Pandemic - up to 31 December 2022
Epidemiology	• A total of 8,831 influenza pandemic related deaths among New Zealanders have been identified, however, it is estimated that the true number is more than 9,000 if undocumented deaths among Māori are considered *(1,2,14)*.	• As of the end of 2022, NZ reported a total of 2,115,241 cases of Covid-19 (confirmed and probable) *(5)*.
	• Morbidity figures are unavailable for NZ, although global estimates suggest a cumulative infection of 25%–50% *(15–17)*.	• There were 2,174 Covid-19 reported cases in 2020, 12,032 reported cases in 2021, and 2,101,035 cases reported in 2022. A total of 2385 Covid-19 deaths occurred in NZ up to the end of 2022 *(5)*.
	• Estimates of the reproduction number (R_0) in NZ range from 1.3 to 3.1 in military settings and 1.2 to 1.8 in community settings *(7,15,18)*.	• For the first two years of the pandemic, reverse transcription polymerase chain reaction (RT-PCR) was the standard method used for testing for Covid-19. In early 2022, rapid antigen tests (RAT) were made available to the public along with a reliance on the public to self-report RAT results to health authorities.
	• Mean generation time estimate 'as short as 3 d', and the proportion of asymptomatic cases estimated 'as large as 45%' *(7)*.	• Of the confirmed and probable reported cases in NZ up to the end of 2022, ~54.3% were among females and ~45.6% among males *(5)*.
	• Mortality rates showed a 'w' shaped distribution for age with young adults, in particular males, experiencing unexpectedly high mortality rates (combined with a higher risk in children under five years and increasing risk for 65+ age-groups) *(1,2,19–26)*. This distribution was consistent with many mortality patterns observed internationally *(27,28)*.	• Estimates of R_o (basic reproduction number) and R_{eff} (effective reproduction number) for Covid-19 vary depending on the variant and transmission dynamics. Globally, the original wild type strain is estimated to have a R_o = 2.79 *(29)*, whereas variants of concern are generally higher.
	• There was a temporary ban on publication of official mortality statistics in NZ *(2)*.	• In early 2020, before the Alert Level 4 in March 2020, the R_{eff} in NZ was estimated to be R_{eff} = 1.8, and reduced in the period after the lockdown to R_{eff} = 0.35 (R.N. Binny et al., unpub. data, https://www.medrxiv.org/content/10.1101/2020.08.10.20172320v1). During the Delta outbreak in August 2021 with an Alert Level 4 lockdown, the median effective R_{eff} reduced from R_{eff} = 6 to R_{eff} <1 (with a corresponding 90% reduction in transmission) (R.N. Binny et al., unpub. data). However, this initial reduction waned, and the median effective R_{eff} increased to 1.4 (90% confidence interval [CI] = 0.5 to 3.7). The first Omicron variant wave beginning in January 2022 (initially fueled by the BA.2 sub-lineage), the R_{eff} reached a peak in mid-February 2022 of >2 in NZ *(30)*.
Long-term effects of infection	• Longer-term effects of the influenza pandemic included life-course impacts for those exposed in utero: in the U.S., this birth cohort experienced markedly reduced educational attainment and increased disability rates compared with earlier and later cohorts *(31)*.	• During the pandemic, a post-Covid-19 syndrome known as '*long* Covid' has emerged *(32)*. Those with long Covid report lingering symptoms from their Covid-19 infection, such as fatigue, pain, shortness of breath, and 'brain fog'. There are also various forms of organ and tissue pathology following Covid-19 infection which manifest in various ways including excess mortality for at least a year following acute infection *(33)*.
	• Long-term effects following influenza pandemics were also recognized internationally *(34,35)*. • A 2016 NZ study investigated the effect on lifespan from exposure to pandemic influenza, but found no statistically significance difference between an exposed and comparison cohort *(37)*.	• In late 2022, NZ's Ministry of Health produced clinical guidelines for the management of long Covid *(36)*. • Internationally there is evidence for multisystem inflammatory syndrome in both adults (MIS-A) and children (MIS-C) which is an ongoing concern for NZ *(38–40)*. • A comparison of Covid-19 with influenza (using international data) suggest that post infection sequelae are more common following Covid-19 infection *(41)*.
Virology	• The H1N1 virus is thought to have emerged from an avian reservoir as a spill over event.	• SARS-CoV-2 (the virus which causes Covid-19) is thought to have emerged from a bat reservoir to infect humans as a spill over event *(42)*. However, there is to date no clear consensus on this source for the pandemic.

Research Domain	1918–19 Influenza Pandemic	Covid-19 Pandemic - up to 31 December 2022
	• The influenza virus is generally spread through direct contact or through droplet dispersal (eg, from sneezing) *(43)*.	• SARS-CoV-2 has been found to be largely spread through respiratory particles (aerosols or and droplets), with aerosols increasingly recognized as the dominant mode of transmission; direct contact/ fomites may also aid virus spread *(44,45)*. The transmission risk is increased in indoor/crowded settings (particularly with poor ventilation), and when in close contact with an infected person *(46)*.
	• Secondary infections such as pneumonia (both viral and bacterial) are common, and account for a significant proportion of the final causes of death among influenza cases; as was the case for the 1918–19 influenza pandemic both globally and in NZ.	
Pandemic spread	• The 1918–19 influenza pandemic first spread in NZ between July and October in 1918 and this first wave was reported to be relatively mild. However, a substantially more lethal second wave occurred in November 1918 and spread to almost all parts of NZ.	• Covid-19 was first reported in NZ on 28 February 2020. Also in February 2020, New Zealanders in Wuhan, China were repatriated into a temporary isolation facility in Whangaparaoa *(47)*.
	• The second wave peaked in Auckland first, followed by the rest of the North Island, with the South Island peaking in mortality about a week later *(2)*. • The impact of crowds for Armistice celebrations and other events such as Christchurch's *'race-carnival week',* have often been described as likely to have helped spread the virus from both within cities and then to more rural areas of NZ *(2,14,23,28)*.	• NZ borders were closed to non-citizens/residents in March 2020. Initial requirements were for self-isolation *(11,47)*. • Managed Isolation and Quarantine (MIQ) facilities were introduced in April 2020 to accommodate all individuals returning to NZ (with few exemptions). The MIQ facilities helped to maintain the Covid-19 elimination strategy of the NZ Government for most of the first two years of the Covid-19 pandemic, albeit with some quarantine system failures *(48)*.
	• An earlier wave of the pandemic occurred in the East Coast and Poverty Bay-Wairoa regions, which has been described as possibly conveying immunity to some of the Māori population in these regions before the subsequent influenza waves *(49)*.	• An initial outbreak of Covid-19 peaked with 84 community cases on 25 March 2020 with cases throughout NZ. Smaller outbreaks occurred subsequently, for example in August 2020 *(50)*. In August 2021, a Delta variant outbreak was identified in Auckland with a first peak of 79 cases in the community on 26 August 2021, and a second peak of 226 cases in the community on 10 November 2021 *(5)*.
	• There are examples in NZ of successful measures to prevent outbreaks and spread (see below: ' Outbreaks and Land Borders') *(2,51)*. • At a global level, the 1918–19 influenza pandemic occurred in three waves: a first 'spring' wave beginning in March 1918, a second 'fall' wave from September to November 1918, and a third wave in early 1919 *(52)*. NZ experienced the severe second wave and milder third wave.	• An Omicron wave with associated community transmission began in early 2022. • At a global level, Covid-19 has occurred as a series of waves that have generally been dominated by successive variants. The NZ response greatly attenuated the waves experienced here, with relatively small outbreaks of the original variant in 2020 and the Delta variant in 2021. The Omicron variant waves in 2022 were large and comparable to that observed in other Asia-Pacific countries. At the time of writing, it was not clear whether Covid-19 can be considered to have become endemic in NZ (eg, since the waves have not fitted with any clear seasonal pattern).
	• The H1N1 virus became 'endemic' by around 1920 internationally, but continued to cause more severe influenza seasons for several years *(52)*.	
Outbreaks and local control measures	Local outbreaks in NZ are described for a variety of areas: • The town of Nightcaps in Southland experienced one of the highest mortality rates in the European population, due to high morbidity (estimated at 80%) plus *'general unpreparedness of the community'* despite instructions from the Health Department to do so *(53)*. Over a two week period, of the population of 911 of Nightcaps and surrounding area, 41 individuals died, a mortality rate of 45 per 1,000 population.	• In NZ, multiple clusters of Covid-19 cases emerged following the first identified case in February 2020 *(54)*; including several aged residential care facilities, onboard ships, and various family/whānau gatherings *(5)*. As of the end of 2021, there were 24 clusters identified by the NZ Ministry of Health (defined as *'groups of ten or more people who likely caught the disease from one another'*), the largest being the *'August 2021 Community'* cluster in Auckland *(5)*. Since the arrival of Omicron in 2022 and widespread community transmission, clusters were no longer reported publicly in NZ.

Research Domain	1918–19 Influenza Pandemic	Covid-19 Pandemic - up to 31 December 2022
	• In the Coromandel Peninsula relatively intensive control measures were used, such as quarantining of ferry boat passengers and road closures around the Coromandel peninsula *(51,55)*. When an outbreak occurred among the Māori population in Manaia, the local chief [name not listed] worked with health officials to ensure isolation of infected cases. Food/medicine parcels were delivered every second day to those in household isolation in Manaia. In the town of Coromandel, the mortality rate for Europeans was found to be significantly lower than the rest of the peninsula and the rest of the District *(51)*. There was no evidence for a significant difference in Māori mortality rates.	• In March 2020, the NZ Government introduced the four-tiered Alert Level system *(9)*. At the higher levels of 3 and 4, there were restrictions of movement outside of regions and homes. Between 2020 and 2021, the Alert Level settings changed by region between the lowest at 1 up to 4, in response to the identification of community cases of Covid-19, meaning that travel was restricted to certain parts of NZ.
	• Temuka - with disease spread reportedly occurring via Armistice Day (11 November 1918) and Christchurch Races and Show Day (6–9 November 1918). The Māori population in this area were assigned to a separate temporary hospital with an assigned nurse. Separate health provision for the Māori population also occurred in other areas in NZ.	• Public health measures such as physical distancing, mass testing and face covering requirements were introduced in early 2020.
	• Nelson - one account gives an overview of cases in Nelson in one hospital and describes the isolation/quarantine measures used for both Nelson College and those in infected houses *(56)*.	• Between April and July 2021, a 'trans-Tasman' quarantine travel bubble between NZ and Australia was in place, however, this was suspended due to increasing community cases in Australia.
	• HMNZT Tahiti - an outbreak of influenza occurred onboard a NZ troopship, the HMNZT 107 Tahiti. This is described *as 'one of the worst ship outbreaks of pandemic influenza worldwide in 1918–19'* with a mortality rate of 68.9 persons per 1,000 population *(20)*. Factors such as crowding, poor ventilation and a younger age were associated with increased mortality risk. An exhibition in 2021–2022 at NZ's National Army Museum in Waiouru explored the *'fateful voyage'* of HMNZT Tahiti *(56)*.	• In January 2021, quarantine free travel with the Cook Islands opened, although testing requirements were put in place *(47)*.
	• Narrow Neck Military Camp in Auckland experienced an earlier influenza outbreak in October 1918 (with no deaths), and had a relatively lower mortality rate compared to other NZ military camps whose first exposure occurred during the November 1918 wave *(8)*. Narrow Neck had a mortality rate of 3.9 per 1,000 population, compared to Featherston Camp with 20.4 per 1,000, Awapuni Camp with 22.1 per 1,000, and Trentham Camp with 23.5 per 1,000.	• As part of border entry restrictions in 2020 and 2021, NZ identified other countries by their level of risk, with no travelers allowed to enter from those classified as high-risk. For example, in late 2021, with the emergence of the Omicron variant, several African nations were classified as high-risk (even when Omicron cases had been identified in other non-African nations, such as the United Kingdom) *(10)*.
	• Te Urewera 1918 - travel was restricted into Te Urewera region largely protecting the Tūhoe iwi *(57)*.	• Additional border entry requirements introduced in 2021 required full vaccination (two doses) of Covid-19, along with the Covid-19 testing requirements (PCR and/or rapid antigen tests) introduced in 2020. • On 2 December 2021, NZ moved away from the Alert Level System and the NZ Government implemented the Covid-19 Protection Framework, also known as the 'traffic light' settings. This framework placed emphasis on vaccination requirements for indoor environments and less on movement restrictions in NZ as was part of the earlier Alert Level System *(58)*. • The Covid-19 Protection Framework was retired on 12 September 2022. Most mask-wearing requirements, all vaccine mandates, and vaccination requirements for incoming travelers were removed. Self-isolation requirements for 7 d were retained only for positive Covid-19 cases *(59)*. • In mid-2022, a new Strategic Framework for Covid-19 Variants of Concerns was developed to describe potential future scenarios for the Covid-19 pandemic in NZ along with response measures *(60)*. • During the early phases of the pandemic when elimination and suppression strategies were being used, the regional borders in NZ were patrolled largely by

Research Domain	1918–19 Influenza Pandemic	Covid-19 Pandemic - up to 31 December 2022
		police-run check-points. Exemptions for crossing these borders were available, but were largely restricted to essential services and exceptional reasons such as attending funerals. • There are also examples of land border restrictions run by some iwi during the pandemic. Examples include the Tai Tokerau Border Control in Northland *(61)*, specific holiday spot closures such as the Maitai Bay Campground on the Karikari Peninsula by Ngāti Kahu *(62,63)*, and Tūhoe in the Urewera area who set up road closures/checkpoints and testing centers *(64,65)*.
Impact on Māori	• The best available estimate of Māori mortality using registered deaths is 2,160; although this is likely an underestimate *(14)*.	• Māori had a disproportionately higher number of Covid-19 cases and higher risk for mortality compared to the European/Other ethnic grouping *(5,66,67)*.
	• A comparative analysis of three pandemics in NZ found that during the 1918–19 influenza pandemic, Māori mortality was 7.3 times higher among the civilian population and 2.3 times higher in the military population when compared to European populations in NZ *(68)*.	• Māori had a higher hospitalization risk following Covid-19 infection and possibly a longer length of stay in hospital compared to European/Other *(67,69*)
	• Theories for the differential mortality among the Māori population compared to the European population include the impact of higher rates of chronic disease (such as tuberculosis), relatively poorer access to health care/social support (partially due to a larger proportion living in rural settings), and potentially less exposure to early waves which may have conferred some form of immunity to the later more virulent pandemic waves *(2,14,26,49,68,70–76)*.	• Vaccine rates among Māori were proportionately lower than non- Māori *(5,77)*. Requests for a more equitable vaccine roll-out given the younger Māori age structure were made *(78)*, but differential prioritization based on age was not used in 2021. Second boosters were made available in mid-2022, with some eligibility based on age and ethnicity.
	• One study exploring specific mortality data for Māori found that as the Māori population in 1918–19 faced the high mortality rate among young adults, a resulting issue was the reduced numbers of caregivers within Māori villages *(73)*.	• A July 2021 study found that Māori had 2.5 times higher odds for being hospitalized (95% CI: 1.3 to 4.51) compared to non-Māori non-Pacific peoples *(69)*.
	• A ban on tangihanga (funeral rite) and associated travel was put in place in November 1918 *(2)*. This ban became a complete ban on public transport use by Māori. Travel was then only permitted for Māori who had been issued a permit. This affected the Member for Parliament (MP) for Northern Māori, Taurekareka (Tau) Henare who was initially refused travel from Auckland to Wellington (for parliamentary duties) until he obtained a permit *(2,79)*. One example is where Māori were banned from entering Whangarei, and then later requiring a health permit to enter *(2,80)*. In some places in NZ, the ban on travel for Māori expanded to unofficial bans on Māori entering business premises *(2)*, and other forms of discrimination *(81,82)*. The ban on tangi occurred along with the *'officials insistence on prompt burial of epidemic victims, many Māori flu victims were buried without ceremony in shallow graves close by the temporary hospital or whare where they happened to die' (2)*.	• Early modeling and analysis predicted that Covid-19 could have disproportionate negative effects on Māori compared to European/others). For example, infection fatality risks >50% higher for Māori (particularly when age and underlying health conditions were taken into account) *(83–85)*.
	• Examples of dedicated medical aid provided to Māori communities include military aid/provision *(86)*, relief workers to Māori settlements, influenza treatment pamphlets from the Health Department printed in Te Reo (Professor Geoffrey Rice describes how these pamphlets were distributed both slowly and erratically), various relief parties and volunteers, and separate hospitals for Māori patients *(2,87)*.	• At early stages and ongoing throughout the pandemic, there have been numerous calls for the incorporation of Te Tiriti o Waitangi principles *(88)* in the management of Covid-19 *(78,89,90)*. The NZ Government developed a Covid-19 Māori Health Protection plan which was informed by Te Tiriti o Waitangi *(91)*.
		• During the first pandemic outbreak and among those in aged residential care, the rate of hospitalization was lower for both Māori (7.4% vs. 10.9%, p = 0.046) and European residents (7.4% vs. 10.9%, p = 0.046) compared to the

Research Domain	1918–19 Influenza Pandemic	Covid-19 Pandemic - up to 31 December 2022
		comparative period pre-Covid *(92)*. Māori residents also reported lower rates of loneliness compared to pre-Covid, while European residents *'reported more severe depressive symptoms'*. • National Māori led support, health and information programs were developed. For example, Te Rōpū Whakakaupapa Urutā - National Māori Pandemic Group, iwi and Māori-health providers *(93,94)*. • Nationwide restrictions and limitations on funerals/tangihanga periodically throughout the Covid-19 pandemic have had a negative impact on many New Zealanders. One article describes the impact of Covid-19 on tangihanga restrictions along with a description of how modern technology was used: *'Whānau Māori from across the country challenged to reimagine tangihanga and grieving during a global pandemic, highlighted the importance and therefore, the reliance of human beings on technology for connection' (95)*.
Risk factors for infection/ mortality and populations at increased risk	• The impact of poor-quality housing on mortality and morbidity from the 1918–19 influenza pandemic has been evaluated for several communities in NZ. For example, poor housing and crowded conditions have been shown to have negatively affected outcomes in Wellington, Christchurch and among the Māori community *(2,28,49,75,96–98)*. The *'slum'* conditions of many urban areas in NZ in 1918–19 was widely reported in newspapers discussing the pandemic at the time *(99)*, and a more recent study in 2018 found evidence for socio-economic gradients for mortality in NZ *(100)*.	• There was a higher risk for Covid-19 mortality among Pacific peoples when compared to European/Other group in analysis of data up to August 2022 *(66)*.
	• One study assessed the effect of rurality on mortality during the 1918–19 pandemic and found that individuals in small towns in NZ had a higher mortality rate than large towns and cities, possibly due to less previous exposure or perhaps less access to health care compared to cities *(101)*. Recent studies assessing NZ military populations found a variety of factors for mortality risk, with a rural background associated with increased mortality risk among Māori/Pacific personnel *(74)*, increased mortality risk with rural background among all military personnel in WW1 *(8)* and a larger chest size (as measured as part of uniform requirements and the increased mortality risk theorized as possibly an indicator of larger bodies and therefore an increased chance of a cytokine storm response *(102)*. Personnel based in the Northern Hemisphere during the pandemic had no difference in mortality risk based on rurality background. But for those located in the Southern Hemisphere during the pandemic (largely in NZ military camps), there was a increased mortality risk if from a large town or rural background (compared to a city background) *(1)*.	• Also, a higher hospitalization risk for Pacific people following Covid-19 infection and possibly a longer length of stay in hospital compared to European/Other *(69)*.
		• Early modeling and analysis predicted that Covid-19 could have disproportionate negative effects on Pacific peoples compared to European/others), particularly when age and underlying health conditions were taken into account *(83,85)*. • Pacific peoples had 3 times higher odds for being hospitalized from Covid-19 (95% CI: 1.75 to 5.33) compared to non-Māori non-Pacific peoples *(69)*. • Vaccine rates among Pacific peoples were overall proportionately lower than non-Māori-non-Pacific, however this difference varied by age group *(5)*. • Higher rates of severe depression were found among European residents in aged residential care compared to the pre-Covid period, while the authors

Research Domain	1918–19 Influenza Pandemic	Covid-19 Pandemic - up to 31 December 2022
		reported that they *'did not find any immediate negative impact of the first wave of Covid-19, which included a nationwide lockdown, on the health and psychosocial well-being among older Māori and Pacific Peoples living in ARC [aged-residential care]' (92)*. • The Covid vaccination program in NZ began by targeting particular groups at increased risk of being infected, such as MIQ workers and their families, those living in high-risk settings such as aged-care facilities and other priority groups (for example, Māori and Pacific providers, those living in Counties Manukau DHB and over 65 y of age or with an underlying condition) *(103)*. Targeted vaccine delivery programs were also incorporated into the vaccine roll-out, such as by working with Māori health providers. • Concern has been raised regarding the inequitable burden from Covid-19 (both in terms of infection but also the effects of management and economic impacts) on particular groups in NZ, such as Māori and Pacific peoples communities *(90)*.
Impact on children and pregnant women	• Pandemic mortality among children varied with age, with 0–4 y olds accounting for 5% of all deaths in NZ, 5–9 y olds 0.9%, 10–14 y olds 1.2% and 15 to 19 y olds 4.4%, with an overall total of 11.5% of all deaths from the pandemic in NZ *(2,73,97)*.	• As of the end of 2022, Covid cases among children aged 0 to 19 y account for 22.9% of total reported cases in NZ *(5)*.
	• During the second wave, many schools were closed, exams cancelled (with final marks assigned based on school records), and universities initially stayed open until the death of a student from the pandemic *(2)*. • A thesis examining the pandemics impact on children in NZ describes how children's *'understanding of the epidemic were often shaped by family members' participation in flu-relief work' (107)*. During this period, children were impacted by both the pandemic and the war.	• Children are generally considered to typically experience less severe illness from Covid-19 than adults *(104–106)*. • During periods of lockdowns (Alert Levels 3 and 4), schools and universities were generally required to close, unless needed to provide education for children of essential workers. Most education during these periods was provided digitally and at-home mainly by parents/caregivers. Notably, during the Omicron outbreak from early 2022, the Ministry of Education directed schools to stay open, although some schools chose online learning or were compelled to do so due to illness among students and staff.
	• Children were involved with the relief effort, such as delivering groceries and medical supplies throughout their communities. For example, the senior students at Auckland Marist Brothers School provided assistance by being messengers and also orderlies in the influenza wards *(2)*.	• Exposure to infection in schools appears to have been a significant factor in transmission, and there have been calls for improvements to ventilation within schools (with some subsequent action by the Ministry of Education), and also for the NZ Government to consider a whānau (family)-centered approach to protecting children *(108)*, rather than a school or child-centered approach where school closures are seen as a last resort for managing Covid *(109)*. One study found that many NZ parents and caregivers expressed concern about children getting infected with Covid-19 while in the school-setting *(106)*. National Covid-19 rates show that the highest rate by occupation is in school teachers *(110)*.
	• Christ College in Christchurch experienced an early infection wave in September/October 1918, with some evidence to suggest that it may have conferred some immunity to the later more lethal November 1918 wave *(2)*, similar to the effect observed at Narrow Neck Military Camp *(8)*. • Children whose parents were unwell were in some cases put into temporary care *(2)*.	• Criticism has been made about the lack of comprehensive guidelines for protecting children (and their whanau) from Covid throughout the pandemic *(108,111)*, and during pregnancy *(112)*, although the Ministry of Health provides some guidance on vaccination and managing Covid-19 while pregnant *(113)*. • One study evaluated the impact of Covid-19 lockdowns in terms of health and economic impacts among Pacific children and their families. The authors suggest that there were differential impacts on different cohorts of children, in particular Pacific children *(114)*.

Research Domain	1918–19 Influenza Pandemic	Covid-19 Pandemic - up to 31 December 2022
	• A 2015 review found that during the 1918–19 influenza pandemic, a lot of responsibilities shifted onto children as their parents were incapacitated, thus becoming primary caregivers *(115)*.	• A surveillance study undertaken in 2020 found evidence for a detrimental impact of Covid lockdowns particularly for newborns in terms of delayed care for non-Covid-19 related conditions. This study described the findings as showing the unintentional harms for children due to the Covid-19 lockdowns *(105)*.
	• The high mortality rate experienced by young adults resulted in issues with lack of caregivers for children in Māori villages *(73)*.	• The partial reopening of NZ's border restrictions to Australia in April 2021 was associated with a substantial increase in the incidence of children infected and hospitalized with respiratory syncytial virus (RSV) *(116)*.
	• One study explored the impact of the pandemic on pregnancy, reporting that pregnancy outcomes were adversely affected by infection with many pregnant patients *"aborted, or miscarried and did badly" (117)*. And one study reported a decrease in fertility among Māori women following the pandemic *(49)*.	• Concerns have been raised during the pandemic about teenagers not returning/finishing secondary education after lockdowns, with some teenagers taking up paid employment to support families *(118)*.
	• In 1918 and 1919 there was a sudden decrease in NZ's annual birth rate compared to 1917 *(3,28,119)*, which was possibly related to the relationship between influenza infections and stillbirth and fetal loss. A 2019 study estimated that in both 1918 and 1919 there were fewer births compared to 1917: for Māori, a reduction in birth rate per 1,000 population of 6.7% and 19.8% respectively, and for non-Māori, a reduction in birth rates per 1,000 population of 8.8% and 16.6% respectively *(119)*. Internationally, there is also evidence on negative impacts of influenza infection on birth rates *(120,121)*.	
Economic impacts	• Professor Rice describes how the cost of the pandemic *'in monetary terms was very considerable' (2)*. The costs to the NZ Health Department were substantial and included those of setting up temporary hospitals, epidemic relief work, and salaries contributing to the bulk of the direct costs. Alongside this, there was the cost of the Influenza Commission in 1919, and benefits for widows increased (along with the substantial increase in war widows due to WW1).	• In 2020, the NZ Government implemented a program to financially assist businesses and employees affected by the pandemic and related lockdowns, resulting in less economic harm from the pandemic compared to many other OECD countries *(122)*, with evidence this protection continued into mid-2021, also with an increase in unemployment which was less than the OECD average (N. Wilson et al., unpub. data, https://www.medrxiv.org/content/10.1101/2021.06.25.21259556v1). The international tourism sector and the education sector involved with overseas students were particularly severely impacted by the border restrictions.
	• There were issues with the inability for payment from the Government for services provided during the pandemic by individuals and businesses. One approach to handle the ill-feeling was to ask claimants to consider some of their services as a donation *(2,123)*.	• In December 2021, the NZ Government stated that GDP declined less than expected in the September 2021 quarter *(124)*.
	• Coastal shipping came to a *'complete standstill'* during the pandemic resulting in a shortage of essentials *(2)*. However, Professor Rice suggests that given that the pandemic was over so quickly, that there is no evidence of a significant impact on businesses, such as from closures.	• A March 2022 report from the NZ Treasury suggests that economic activity losses experienced in September 2021 had recovered substantially, although the effect of the war in Ukraine from February 2022 had affected market volatility *(125)*.
Response strategy	• The Department of Public Health was formed in 1903 in response to concerns about the potential arrival of plague in 1900.	• NZ produced its first pandemic influenza plan in 2002, which it revised periodically. The second edition was published in 2017 and was current at the emergence of Covid-19 (and remains so). It is based on a hypothetical influenza pandemic and predominantly takes a mitigation strategy *(126)*. This was the approach that the NZ Government seemed to take at the very start of the Covid-19 pandemic, before more clearly adopting an elimination strategy.
	• However, pandemic planning was not a well-established activity of NZ Governments until after the 1918–19 influenza pandemic.	• In response to the Covid-19 pandemic NZ effectively switched to an elimination strategy in March 2020 *(127,128)*. It subsequently shifted to

Research Domain	1918–19 Influenza Pandemic	Covid-19 Pandemic - up to 31 December 2022
		suppression during the Delta outbreak in 2021 *(129)*, and to a mitigation strategy during 2022 *(58,59)*. • Implementing an elimination response strategy resulted in rapid end to the first outbreak of Covid-19 infection followed by a prolonged period with very little transmission *(130,131)*. • Elimination and tight suppression were widely used response strategies in the Asia Pacific Region, though not always described explicitly *(132,133)*. • Subsequent analysis provides support for the value of a strong strategic response to emerging infectious diseases with pandemic potential, particularly the value of an elimination strategy if certain conditions are met *(133–135)*.
Health system impacts	Multiple authors have evaluated the impact of the 1918–19 influenza pandemic on both the workforce and the health system as a whole: • One substantial issue occurring in 1918 was that a significant proportion of the health workforce was absent due to war service or after falling ill with influenza themselves *(136,137)*. Furthermore, the Health Minister at the time, Mr GW Russell, was also responsible for multiple ministerial portfolios.	• The impact of Covid-19 management measures has been noted as impacting on management and treatment of other health conditions, such as acute coronary syndrome (although with a noted reduction of hospitalizations during lockdowns) *(138)*, and cancer diagnosis with delayed diagnosis during lockdown periods largely mitigated by *'catch-up'* activities post lockdowns *(139)*.
	• Pandemic mortality rates for medical practitioners and nurses were also notably high and nearly as high as for military personnel in the military camps *(2)*. • Temporary hospitals were used to manage pandemic cases *(2,21,96)*.	• In April 2021, it was announced that the NZ Health System would be restructured, following 2019 recommendations from a review of the health and disability system *(140,141)*. • The role of the Minister for Health was separated from the Covid-19 Response Ministerial portfolio in November 2020, with the Hon Chris Hipkins being appointed the first Minister for Covid-19 Response and the Hon Andrew Little taking up the role of Minister of Health.
	• A review of the nursing response in NZ found reports that in some places, the nursing ratio was 70–80 patients per nurse *(142)*.	• Vaccine mandates for certain work places such as health and education resulted in some redundancies, although financial support was made available for those who lost their jobs *(143)*.
	• The limitations of the NZ Health Department response were well documented, and were a substantial reason for the 1919 Royal Commission Report on the pandemic, which in turn led to the 1920 Health Act and the restructure of the NZ health system *(98,144–146)*. The Commission found that the NZ Health Department was unprepared for the pandemic emergency *(2)*. Professor Rice describes how even though the Commission was assembled quickly, there were aspects that were lacking in the report *(14)*. For example, there was little discussion of the impact of the pandemic on the Māori population.	• A Royal Commission of Inquiry was announced in December 2022 with the scope aimed at exploring the aspects of the NZ Covid-19 response that could be used to prepare for any future pandemics - for example, various legislative, regulatory and operational settings along with decision-making structures and *'consideration of the interests of Māori in the context of a pandemic, consistent with the Te Tiriti o Waitangi relationship' (147,148)*. Several aspects of the pandemic were deemed outside of the scope of the Inquiry, such as some epidemiologic features of the virus, strategies/measures *'devised in response to Covid-19'*, the health system reforms, vaccine efficacy, private sector response, response/adaption's in court proceedings, Reserve Bank monetary policies, and conduct of the general election during the Covid-19 pandemic *(148)*.
Vaccinations	• As the 1918–19 influenza pandemic was spreading, various vaccination studies were conducted worldwide, with some specifically among the NZEF located in Europe *(22,149–151)*. Some of these studies, when epidemiologically assessed using more modern statistical techniques, and despite the various methodological issues, suggest '*that whole-cell inactivated pneumococcal vaccines* [as used in 1918–19] *may confer cross-protection to multiple pneumococcal serotypes and that bacterial vaccines may play a role in preventing influenza-associated pneumonia' (152)*.	• At the beginning of the Covid-19 pandemic, there was no vaccine available, although clinical trials began in 2020.
	• In NZ, newspapers presented a mixed perception of the value of vaccination for the general public during the 1918–19 influenza pandemic,	• The Pfizer-BioNTech mRNA Covid-19 vaccine was approved for use among targeted groups in NZ from February 2021, with general roll-out for the wider

Research Domain	1918–19 Influenza Pandemic building upon the various commentary on the mass-vaccination of the NZEF in previous years *(137,153)*. For example, a 1918 headline in the Nelson Evening Mail reports '*evidence is pouring in from doctors of the efficacy of influenza inoculation for other disease of chronic types, such as rheumatism, neuritis, sclerosis, catarrh, neuralgia and asthma' (154)*, while a 1919 headline in the NZ Herald states ''*Epidemic commission. Medical Association View. Brought from overseas inoculation and masks. Their value doubted' (145)*. These conflicting headlines, occurred throughout and after the pandemic, with the efficacy of the vaccines used being raised and evaluated during the NZ Influenza Commission in 1919. • Controversy and hesitancy for vaccination to various infectious diseases still persists into more modern times *(155)*, and is an ongoing cause for concern as vaccination rates fall in many countries.	Covid-19 Pandemic - up to 31 December 2022 population from July 2021 onwards, with children given approval later (12+ years from August 2021 and 5+ years in January 2022) *(103)*. • The roll-out of NZ's largest mass vaccination program was mostly successful with large sections of NZ's population receiving between one to four doses by early 2022. • There were requests in 2021 for a more equitable Covid-19 vaccine roll-out, for example, taking into account the younger Māori age structure *(78)*. • Among children, vaccine uptake has been particularly low with only ~27.8% of those aged 5 to 11 by the end of 2022 having received two vaccine doses (with boosters generally not available for children under 16 y of age) (*3*). • The roll-out was also introduced alongside various vaccine mandates in late 2021 for large sections of the population, and was integrated into the revised Covid-19 Protection Framework ('traffic-light' system) which superseded the original Alert Level System *(58)*. Vaccine mandates were removed in September 2022 when the Framework was retired *(59)*. • Throughout the Covid-19 vaccine program there was some public hesitancy and opposition to both receiving a vaccine or being required to be vaccinated to continue employment in certain occupations, to access education, or to gain access to various premises *(156)*. For example, the mandate for NZ Defense Force staff and NZ Police staff to be fully vaccinated (two doses) was challenged successfully in the High Court in February 2022 (although this decision was appealed by the Government) *(157,158)*. • There was a four-week long protest outside the NZ Parliament in Wellington in February/March 2022 with anti-mandate and anti-vaccine rhetoric being conspicuous concerns (albeit mixed with a wide-array of other themes). • At the same time, childhood vaccination levels for other infectious diseases have declined in NZ, particularly for Māori raising concerns for potential outbreaks of other vaccine-preventable diseases, and exacerbating existing health disparities. • Vaccine hesitancy is not a new phenomenon, however the Covid-19 pandemic has brought this issue into the forefront of public attention.

Details of the period after the 1918–19 influenza pandemic in NZ

The period both during and following the 1918–19 influenza pandemic was a uniquely difficult time for New Zealanders: 'Out of the blue, just as the Great War [WW1] was at last coming to an end, communities and families were suddenly confronted with a life and death struggle over which they seemed to have very little control' *(2)*. This collective trauma led to a period described as a 'reckoning' *(2)*. There were many questions to be answered about the handling of the pandemic, but also a desire to learn from the experience. Hence, the establishment of the 1919 Royal Commission on the pandemic *(2)*. This inquiry led to legislative changes such as the 1920 Health Act, substantial changes to the health system, establishing the Public Health Department, and requirements for authorities to improve public health through intervention in key areas, for example, sanitation and housing *(2,28)*.

Following the 1918–19 influenza pandemic, there were a further three influenza pandemics in 1957, 1968 and in 2009. While the 1918–19 influenza pandemic had the greatest mortality both in NZ and internationally, the other three pandemics still had significant impact, particularly when considering ethnic gradients. In NZ, the mortality rates for the Māori population was found to be higher than non-Māori in all three pandemics, although with evidence of some decline in the extent of this difference by 2009 *(66)*.

Later responses to the 1918–19 influenza pandemic include a 2002 formal apology to Samoa by then Prime Minister Helen Clark, for NZ's 'inept and incompetent' administration leading to the spread of influenza throughout the Pacific by the NZ ship SS Talune *(159)*. This spread led to Western Samoa losing around 25% of its adult population due to the pandemic, one of the worst mortality rates globally *(2)*.

A 2017 study surveyed the memorials in NZ for the 1918–19 influenza pandemic finding only seven publicly accessible memorials, with 11 in private settings (Appendix Figure 2), compared to the 941 memorials in NZ for WW1/WW2 *(160)*. The lack of pandemic-related memorials could be due to a range of factors, such as the timing so soon after WW1. The study authors recommended how memorialization could be improved along with public education and support for future pandemic planning. Further recognition of this pandemic included a NZ national memorial plaque for the 1918–19 influenza pandemic. The plaque was unveiled in November 2019 at the Pukeahu National War Memorial Park in the

capital city, Wellington (Appendix Figure 3), which, ironically, was likely to have coincided with the first emergence of Covid-19 in China.

Appendix Figure 2. Carved wooden Māori cenotaph at Te Koura Marae, in memory of those who died in the influenza pandemic. Photographed in 1920 by Albert Percy Godber. Cenotaph designed and carved by Tene Waitere of Ngati Tarawahi, APG-0786–1/2-G, Editor. 1920: Alexander Turnbull Library, Wellington, New Zealand

Appendix Figure 3. Geoffrey Rice, Emeritus Professor of History, University of Canterbury, and former Prime Minister Rt Hon Jacinda Ardern unveil 1918 Influenza Pandemic Memorial Plaque at Pukeahu. Photographed in 2019 by Mark Tantrum Photography. Available from Ministry for Culture and Heritage - Manatū Taonga. https://mch.govt.nz/significant-sites/1918-influenza-pandemic-memorial-plaque

Appendix Table 2. COVID-19 Alert Levels in NZ throughout 2020 and 2021*

Year	Date	Covid-19 Alert Level
2020	23 March	Level 3—all of NZ
	25 March	at 11.59pm—Level 4—all of NZ—Start of Elimination Strategy.
	27 April	Level 3—all NZ
	13 May	Level 2—all of NZ
	8 June	Level 1—all of NZ
	12 August	Level 3 in Auckland.
	30 August	Level 2 in Auckland (with travel and gathering restrictions). Rest of NZ remains at Level 2.
	21 September	All regions (except Auckland) at Level 1.
	23 September	Level 2 (without travel and gathering restrictions) in Auckland
	7 October	Level 1—all of NZ
2021	14 February	Level 3 in Auckland. Level 2 rest of NZ
	17 February	Level 1—all of NZ
	28 February	Level 3 in Auckland. Level 2 rest of NZ
	7 March	Level 2 in Auckland. Rest of NZ remains at Level 1.
	12 March	Level 1—all of NZ
	23 June	Level 2 in Wellington. Level 1 rest of NZ
	29 June	Level 1—all of NZ
	17 August	Level 4—all of NZ
	31 August	Level 4 in Auckland and Northland. Rest of NZ at Level 3.
	2 September	Level 4 remains in Auckland. Northland and rest of NZ at Level 3.
	7 September	Level 4 remains in Auckland. Rest of NZ at Level 2.
	21 September	Level 3 in Auckland and Upper Hauraki. Rest of NZ at Level 2.
	25 September	Level 3 remains in Auckland. Rest of NZ at Level 2.
	3 October	Level 3 remains in Auckland, and applied to various locations in the North Island. Rest of NZ at Level 2.
	5 October	Various locations in North Island remain at Level 3. Auckland and the rest of NZ at Level 2.
	7 October	Level 3 extended to wider Waikato in the North Island. Auckland at Level 3. Rest of NZ at Level 2.
	8 October	Level 3 extended to Northland.
	19 October	Northland at Level 2. Auckland and parts of Waikato at Level 3. Rest of NZ at Level 2.

Year	Date	Covid-19 Alert Level
	2 November	Upper Northland at Level 3. Auckland and parts of Waikato at Level 3. rest of NZ at Level 2.
	9 November	Level 2 in Auckland. Parts of Waikato and Upper Northland at Level 3. Rest of NZ at Level 2.
	11 November	Upper Northland at Level 2. Parts of Waikato and Upper Northland at Level 3. Rest of NZ at Level 2.
	16 November	Part of Waikato at Level 2. Auckland at Level 3. Rest of NZ at Level 2.
	2 December	At 11.59pm—COVID-19 Alert Level System retired and Covid-19 Protection Framework introduced. Start of Suppression Strategy.
2022	16 February	At 11.59pm—Official shift from identifying all Covid-19 cases as part of Phased reduction of protective measures. Start of Mitigation Strategy.
	12 September	Covid-19 Protection Framework retired.

*Alert Levels 1 (prepare) to 2 (reduce) = Non-lockdown rules with various public health restrictions/protections in place, such as mask-wearing, contact tracing and border entry restrictions in place (*9–11*). Alert Levels 3 (restrict) to 4 (eliminate) = Lockdowns in place (either nationally or locally) with heavy restrictions such as for travel, crossing borders, mass gathering cancellations and educational facilities closed (*9–11*).

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