Likely future pandemic agents and scenarios:

An epidemiological and public health framework

Te Niwha

Ko te Whakakitenga.

Mai Aotearoa ki te Ao katoa, na ratou e mōhio ana. Nei ra matou te kaha rawa, te takatū me te kotahitanga ō mātou whakahoki ki ngā mate urutā me ngā mate hōrapa i nāianei ā kia puta mai.

Vision.

Ensuring Aotearoa New Zealand's response to current, ongoing and emerging infectious disease threats is characterised domestically and internationally as strong, prepared and unified.

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Dr Amanda Kvalsvig has a dual background in clinical paediatrics and epidemiology, and is a Research Associate Professor in the Department. Her research activities currently have a strong focus on Aotearoa New Zealand's response to the COVID-19 pandemic; she is the lead researcher of Co-Search, a COVID-19 research collaborative led by Professor Michael Baker. She is also lead researcher of SYMBIOTIC, a newly-funded HRC programme led by Michael Baker which aims to investigate the two-way relationships between infectious disease and long-term conditions.

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Michael Plank is a Professor in Applied Mathematics at Te Whare Wānaga o Waitaha | University of Canterbury. During the pandemic, he played a leading role in mathematical modelling of Covid-19 to inform the government response. He has also devoted significant effort to public communication about the contribution of modelling to the pandemic response strategy. He has ongoing research interests in mathematical modelling for pandemic preparedness and response.

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Dr Pippa Scott is a Principal Advisor in Te Pou Hauora Tūmatanui (the Public Health Agency) at Manatū Hauora (the Ministry of Health). She began her career in veterinary medicine after completing a Bachelors in Veterinary Science at the University of Queensland, but soon developed an interest in the patterns of disease which led her to study a Masters of Epidemiology at the London School of Hygiene and Tropical Medicine. Pippa then completed a PhD in Epidemiology at the University of Bern, where she worked on a major clinical trial of a measles vaccine study and completed reviews of the effects of vaccines for the World Health Organization. Pippa joined Manatū Hauora as a Principal Advisor during the early stages of the COVID-19 response, where she aided in providing scientific advice and analysis to aid in decisions around COVID-19 vaccination and the impacts of COVID-19 on Aotearoa New Zealand. Outside of Manatū Hauora, her field of research is infectious diseases with a focus on vaccine preventable diseases and bacterial pathogens.

Kaiarotake. Reviewers.

Professor Michael Baker

MBChB, FNZCPHM, FAFPHM, FRACMA, DComH, DObst (University of Otago) [1]

Michael is a public health physician and Professor in the Department of Public Health, University of Otago, Wellington. He has a wide range of public health research interests, with a focus on infectious diseases, environmental health, and improving housing conditions. He took a leading role in shaping Aotearoa New Zealand's Covid-19 pandemic response, particularly the elimination strategy. Michael leads a multidisciplinary research group, the Health Environment & Infection Research Unit (HEIRU), which has researched and published extensively on Covid-19 and pandemic preparedness. He has a strong interest in science communication and directs the newly launched Public Health Communication Centre.

Dr Euan Russell

Dr Euan Russell is a Senior Advisor in Te Pou Hauora Tūmatanui (the Public Health Agency) at Manatū Hauora (the Ministry of Health). Euan completed a Bachelors with Honours in Cell and Molecular Bioscience and a Masters in Biomedical Science at Victoria University of Wellington. He then went on to complete a PhD in Microbiology at Otago University on Listeria monocytogenes bioenergetics before joining Manatū Hauora in late 2021 as part of the COVID-19 response. Euan provided scientific advice and analysis to aid in decisions around COVID-19 vaccination, SARS-CoV-2 variants, and the impacts of COVID-19 on Aotearoa New Zealand.

Te Pora Thompson

Te Pora is the Director of Te Niwha, the Infectious Diseases Research Platform. She has a wealth of experience in local regional and national research and has served in many leadership, advisory and governance positions. During the COVID-19 pandemic, Te Pora contributed to the Initial COVID-19 Māori Response Plan. Te Pora also held three concurrent positions across the pandemic response: Pouaarahi – Advisor to the Regional Group Controller of Civil Defence; Chair of the Iwi Maaori Council and member of the Commissioner Group for Waikato District Health Board and Maangai Maaori within Local Government – Hamilton City Council. Te Pora also supported her iwi Ngaati Hauaa, Waikato-Tainui. She has an enduring vision to achieve Mana Motuhake for Maaori in hauora.

1 Professor Baker provided continuous review of the document throughout its development and contributed material to some sections (notably sections 3.1 and 4.1).

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Aotearoa New Zealand's Ministry of Health published an influenza pandemic plan in 2017.

The plan was intended to "be adopted and applied to any pandemic event"[2] however, recent experiences with the COVID-19 pandemic underline the need to be better prepared for a wider range of potential pandemic agents and scenarios.

The influenza pandemic plan assumed that influenza could not be eliminated and did not recognise that an effective public health response could completely alter the course of an epidemic. This potential eventuality needs to be recognised and planned for.

This document is motivated by the need for a more comprehensive approach that considers a range of likely scenarios and agents, new technologies, and learnings from the COVID-19 experience.

2 www.health.govt.nz/your-health/healthy-living/emergency-management/pandemic-planning-and-response/influenza-pandemic-plan

Kaupapa. Purpose.

The purpose of this document and the accompanying spreadsheet is to:

- Identify and characterise agents that are most likely to cause future pandemics/Public Health Emergencies of International Concern (PHEICs) and possible scenarios resulting from such events[3].
- Capture the key features that need to be considered during the interpandemic period (i.e. preparedness) and the multiple phases of an extant pandemic/PHEIC (i.e. response).
- Provide a framework and essential material for the preparation of a pandemic plan that is fit-for-purpose now and into the future.
- Identify capabilities that are needed to aid rapid decision making in the event of a new pandemic/PHEIC.

3 N.B. An assumption throughout this document is that a future pandemic/PHEIC will be the result of an incursion into Aotearoa New Zealand.

Te horopaki ō Aotearoa. New Zealand context.

There are multiple distinctive characteristics of Aotearoa New Zealand that need to be considered and incorporated into pandemic/PHEIC preparedness, planning and response, in order to achieve equitable and effective outcomes. These include the following:

Te Tiriti o Waitangi is the founding document for Aotearoa New Zealand that provides for an obligation to the protection of Māori rights, ensures Māori exercise authority over their affairs and asserts protection and equity in achieving outcomes that are fair and just. All must be actively given effect to and applied in the development of future pandemic plans and responses. Te Tiriti affirms Māori Rangatiratanga in decision making and requires a partnership approach with the Crown. These relationships must be proactively developed and maintained to ensure equitable outcomes in future pandemic scenarios.

During the recent COVID-19 pandemic, Māori undertook a significant effort to ensure the safety and protection of their communities. A range of responses were considered and deployed and tikanga and kawa were adapted where required. The extensive and effective networks with their people and the wider community reinforced the requirement of partnership within pandemics. The future pandemic plan must heed to Te Tiriti o Waitangi to deliver an empowering, partnered and resourced strategy that will serve the Māori context.

Historically, Māori have experienced inequitable wellbeing impacts during pandemics and are persistently underserved by the healthcare system. In an outbreak, Māori partnered, led and delivered responses are key to ensuring the principles of Te Tiriti o Waitangi are given effect and upheld.

- Aotearoa New Zealand has a large, diverse population of Pacific Peoples, with strong ties to the Pacific Islands and specific obligations to Pacific Realm countries. The demography, location, community structure, employment and disproportionate impacts of disease outbreaks on Pacific Peoples needs to be incorporated into preparedness and pandemic planning. This includes continued Pacific community and provider engagement and participation in planning and responses.
- Aotearoa New Zealand's relative isolation and ability to control borders facilitated the rapid implementation of high stringency measures during the early phases of the COVID-19 pandemic. In addition, the population has been relatively compliant to reasonable, proportionate and clearly justified public health measures.

> **"Te Tiriti affirms Māori Rangatiratanga in decision making and requires a partnership approach with the Crown. These relationships must be proactively developed and maintained to ensure equitable outcomes in future pandemic scenarios."**

Wāhanga A | Part A:
Potential pandemic agents.

Influenza remains one of the most likely pandemic agents, but Aotearoa New Zealand needs to be prepared for a wider range of other pathogens. We have assembled a table of potential pandemic agents and described their biological and epidemiological characteristics.

Wāhanga B | Part B: **Pandemic preparedness and planning.**

Pandemic typologies provide potential pandemic scenarios based upon knowledge of past events, allowing pandemic preparedness and assessment during the early response phases. These can be refined as the pandemic progresses. Typologies allow planning by predicting the physical, psychological and socioeconomic harm that might be caused, and guide the development and implementation of appropriate responses.

We consider two approaches to typology, one based on the type of scenario, informed by features of previous PHEICs, and one based on characteristics of the pathogen. Important characteristics include transmissibility, clinical severity, visibility, controllability and certainty of knowledge. We show how some example pathogens can be mapped onto these typologies, which can inform an assessment of the potential pandemic impact on the population.

The following are important considerations for pandemic preparedness and planning:

- Being prepared for a pandemic requires investing in the range of capabilities needed to respond effectively. Capabilities, including **relationship building and trust**, need to be developed and maintained during the interpandemic period.
- **Reactive and proactive preparedness**. Planning for the range of scenarios identified requires consideration of both reactive preparedness (capacity to stand up an effective pandemic response very rapidly if need be) and proactive preparedness (having resources already in day-to-day operation that prevent the spread of infectious diseases). Reactive preparedness includes assessment of the controllability and impact of an emerging pandemic to determine an appropriate response, but these characteristics are themselves modifiable. Proactive preparedness, including surveillance, can thus be seen as an ongoing, purposeful activity of setting resources in place to maximise the controllability and minimise the impact of a range of infectious diseases with pandemic potential.
- **Equity.** It is essential that equity is centred in pandemic planning. Evaluation of preparedness begins by identifying generic and specific resources needed for a range of pandemic scenarios, but also includes assessment of how readily and how equitably these resources can be accessed.
- **Supporting, enabling and partnering with Māori.** This will ensure preparedness is undertaken in the context of their relationships, aspirations and priorities.
- **Community empowerment.** Reinforcing Māori and Pacific Peoples considerations, self-determination, community networks and data sovereignty.
- **Legislation.** Reviewing current legislation, with reference to the range of likely scenarios, would help the preparation of relevant material that could form the basis of future legislation. If conducted during the interpandemic period as part of pandemic planning and preparedness, this would expedite the preparation and passage of new bespoke legislation through Parliament when the need arises and avoid attempting to design general legislation for national emergencies that may not be suitable for particular situations or partnership under Te Tiriti o Waitangi.
- **All of government response.** Adopting a coordinated, all-of-government response is essential to any successful pandemic response and is more likely to succeed if people have trust in government, which is built upon good governance. Currently, frameworks are in place with the Coordinated Incident Management System (CIMS) and National Security System (NSS) to coordinate across agencies. These are designed to be adapted to the needs of a specific emergency, such as a pandemic.
- **Triaging signals in the early phase of a potential outbreak.** All pandemics start with an outbreak, but most outbreaks do not become pandemics. There is usually a high degree of uncertainty at the earliest stages, and it is unclear if an emerging incident has the potential for national impact. Manatū Hauora | Ministry of Health (MoH) utilises its incident management process to triage and escalate as needed.

> **Mathematical modelling is a powerful tool for supporting impact assessment and strategy development, interpreting raw epidemiological and clinical data streams, providing situational awareness, evaluating control measure effectiveness, and comparing alternative policy options.**

- **One Health and zoonoses**. Many outbreaks are zoonotic in origin involving either spill over or sustained transmission. Responses require a coordinated One Health-based, cross-agency approach, with additional challenges that need to be considered compared to a pandemic involving clinical cases only.
- **Surveillance, diagnostics and laboratories.** Surveillance systems need to be capable of detecting unusual clinical infections as well as outbreaks of disease to ensure data is available to inform pandemic planning. Systems are also needed to characterise vector populations capable of transmitting disease. Diagnostic tests must be available for known agents and consideration needs to be given to how diagnostic tests would be developed for unknown pathogens, how highly virulent agents would be handled, how scalable the diagnostic tests are, digital management of testing and reporting, and the stability of supply chains. Laboratory testing capacity and expertise needs to be maintained for a future pandemic response. Contingency planning for supply of medications and equipment that can be challenging to source in a pandemic (e.g., reagents, diagnostic assays, and medications for non-pandemic conditions) is also needed.
- **Genomics and modelling.** Real-time genomic analysis can enhance understanding of dominant transmission pathways, outbreak investigation and contact tracing, prevalence and impact of different pathogen subtypes and overall epidemic dynamics. Mathematical modelling is a powerful tool for supporting impact assessment and strategy development, interpreting raw epidemiological and clinical data streams, providing situational awareness, evaluating control measure effectiveness, and comparing alternative policy options. These capabilities need to be developed and resourced.

- **Healthcare.** The capacity of hospitals and intensive care units is critical to responding to an infectious disease outbreak and maintaining population health. Health care systems are complex, and a fuller evaluation of capacities in these areas is warranted. Aspects for consideration include: the treatment of severe cases of pandemic illness; isolation of infectious hospitalised people; and the management of rapid diagnostics to allow rapid treatment and limiting transmission. In addition, the system will need to maintain "business as usual" healthcare, ensuring that cultural and equitable care is uncompromised for Māori, Pacific Peoples, Tāngata Whaikaha, and the medically vulnerable, while maintaining an adequate workforce and protecting health care workers.
- **Therapeutics and vaccines.** Access to treatments could potentially reduce severity of pandemic illness and/or reduce transmission. Mechanisms must be in place to optimise existing treatments, and ensure their affordability, accessibility, and availability to Māori, Pacific Peoples, Tāngata Whaikaha and those that are medically vulnerable. Additionally, establishing local capacity for vaccine manufacture could be considered to allow participation in distributed manufacturing of pandemic vaccines (avoiding reliance on vaccine supply from overseas).
- **Contact tracing.** Outbreak investigation and contact tracing that is community led and trusted, complements public health teams in traditional outbreak investigation and contact tracing, which needs to be well resourced. Aotearoa New Zealand would also benefit from developing a strategy for digital contact tracing and being prepared to rapidly roll out a well-designed and inclusive system. Trust in the system and data confidentiality are paramount for both methods to be effective.
- **Borders.** A border response can prevent, reduce or delay importation of the pandemic pathogen into Aotearoa New Zealand. This would require a coordinated response between multiple government agencies and private sector organisations. Attention should be given to minimising risk of transmission within and from any isolation facilities and developing mechanisms to take individual circumstances into consideration when prioritising travellers for access to isolation facilities. Options for home isolation should also be explored.

"Mechanisms must be in place to optimise existing treatments, and ensure their affordability, accessibility, and availability to Māori, Pacific Peoples, Tāngata Whaikaha and those that are medically vulnerable."

Wāhanga C | Part C: **Pandemic response.**

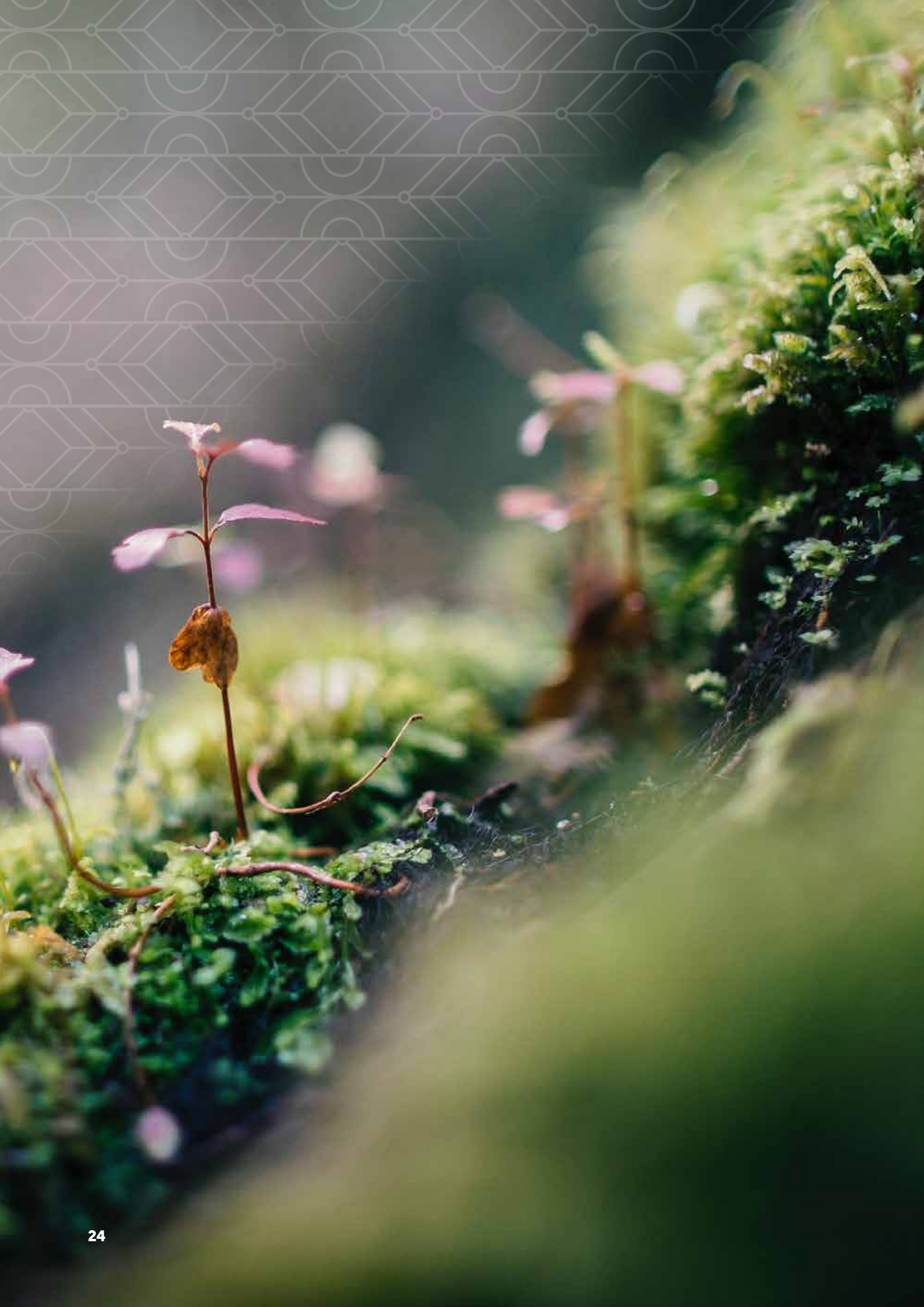
A pandemic is a highly dynamic situation, and an effective response must be adaptable and recognise that the best course of action depends on the current epidemiological situation and likely future trajectory. This is reliant on high-quality surveillance and data management systems and real-time analytical and modelling tools to deliver situational awareness.

With this in mind, we identified three broad, inter-dependent elements of a pandemic response:

1. **Impact assessment** – an evaluation of the potential impact of the pandemic on Aotearoa New Zealand's population. This includes direct impacts of the infectious disease itself and indirect impacts on health (including mental health), education and the economy. Indirect impacts may stem from increased demands on the healthcare system or from the measures taken to control the pandemic. It is also important to assess how impacts are distributed. It is highly likely that Māori and Pacific Peoples will be at an elevated risk during a pandemic.
2. **Strategy development** – designing an overarching strategy to guide the response, for example elimination ("keep it out"), suppression ("stamp it out") or mitigation ("manage it"). Strategy choice is not a one-off event: it is likely that strategy will shift during a pandemic, for example from elimination to suppression to mitigation. However, this may not be a straightforward progression with predictable timings, and strategy needs to be responsive to unexpected events or new information.
3. **Control measures** – selecting and implementing control measures to deliver strategic aims. The choice of control measures will depend on: the characteristics of the pathogen and its amenability to different interventions; the impact assessment, which will inform the appropriate level of intervention and proportionate response; and the strategic objectives. It is important to monitor and evaluate the effectiveness and costs (including indirect harms) of control measures.

These elements are supported by the key capabilities outlined in Part B. These three elements will need to be revisited, refined and updated over time as new information about the pathogen and the interventions used to control it becomes available, and as the epidemiological situation evolves.

> **Strategy choice is not a one-off event: it is likely that strategy will shift during a pandemic, for example from elimination to suppression to mitigation.**



1. Timatanga Kōrero. Introduction.

This document report was commissioned to support Te Manatū Hauora, the Public Health Agency and overall decision makers and partners involved in pandemic planning to ensure our collective strategy and legislation is up-to-date and well-prepared for future pandemics.

The commissioning was divided into three parts which are summarised as:

Part A: Specific potential pandemic agents. A table of likely future pandemic agents, with important characteristics of these agents.

Part B: Scenarios of pandemic agents and capabilities required. A typology of pandemic agents by characteristics and generic capabilities required for effective responses across all pandemic scenarios/typologies and those that are needed for specific categories.

Part C: Weighting of public health controls. A narrative that illuminates and points to the likely differences in weighting of public health controls that might be most useful in the event of such a pandemic.

Wāhanga A | Part A: Specific potential pandemic agents

In this section we describe the process undertaken to decide which pathogens are in-scope and out-of-scope for inclusion in the detailed table provided in the spreadsheet "Part A Characteristics of potential pandemic" found at TeNiwha.com.

2. Methods used to develop scoping and determining priority pathogens

Scoping and prioritisation decisions for this project were made **iteratively** within the working group. Decisions were informed by existing lists of priority pathogens and consultation with key stakeholders. A new World Health Organization (WHO) prioritisation process is underway, and this may become available in the weeks following the publication of this report [4,5].

Priority pathogens under consideration are those that could become a Public Health Emergency of International Concern (PHEIC) and/or a pandemic agent. Definitions of a PHEIC and pandemic and implications for their detection in Aotearoa are provided in Appendix B.

Our prioritisation process aims to:

- Provide evidence of decision making and processes.
- Provide a framework for deciding if certain pathogens/scenarios should be included.
- Help identify the characteristics that should be present for a pathogen/scenario to be considered.

4 www.who.int/activities/prioritizing-diseases-for-research-and-development-in-emergency-contexts

5 cepi.net/research_dev/priority-diseases/

2.1 Out of scope for pandemic/outbreak preparedness project

Table 1. Exclusion criteria for pathogens considered out of scope for this project.

Pathogen/scenario type	Reason
Pandemics in livestock/plant populations that are not human pathogens, but that could otherwise have substantial impact on the Aotearoa New Zealand population via food supply disruption and economic damage from either the disease or control measures e.g. *Mycoplasma bovis, Foot and mouth disease virus.*	This is beyond the remit of the project and would need considerable additional resourcing and a different approach.
Pathogens that cause human illness without infection (e.g. toxin secretion such as in foodborne botulism or harmful algal blooms).	Control strategies and measures differ from those needed to control human infections. This would need additional resourcing and a different approach.
Established human pathogens which are (or previously have been) endemic in Aotearoa New Zealand, do not evolve rapidly, and for which control measures are readily available (e.g. vaccines). Examples are pertussis, polio, leptospirosis, listeria and other food and waterborne pathogens.	There are already risk mitigation, control measures and planning in place. However, although beyond the scope of this project, a review of plans and their fitness for purpose (with particular reference to equity issues) is essential to mitigate costs to Aotearoa New Zealand and its people. For vaccine preventable diseases, this would include an assessment of likely vaccine availability (and ability to distribute within Aotearoa New Zealand to whom and to where it is most needed) during a pandemic or large outbreak.

2.2 In scope for pandemic/outbreak preparedness project

Table 2. Inclusion criteria for pathogens considered in scope for this project.

Pathogen/scenario type	Commentary
Vector-borne human pathogens (that is, pathogens transmitted by living organisms, many of which are bloodsucking insects or ticks), where viable vectors are: • Currently in Aotearoa New Zealand, or • Not currently in Aotearoa New Zealand but would be likely to establish if introduced, or • Not currently in Aotearoa New Zealand but would be likely to establish if climate change modifies habitats and the vector subsequently introduced	Vector-borne diseases are caused by a range of pathogens. These pathogens have caused major outbreaks around the world, including a PHEIC (Zika virus), and depending on the pathogen can cause substantial harm to different at-risk groups. Many vector-borne diseases are preventable, but Aotearoa New Zealand has not experienced them due to its geographic isolation, climate and lack of vectors.
Pathogens with bioweapon potential	These pathogens are included because they have been proposed as potentially amenable to 'weaponisation', by definition, with the intent to cause harm [6].

6 www.niaid.nih.gov/research/emerging-infectious-diseases-pathogens

Pathogen/scenario type	Commentary
Other pathogens that infect humans that present substantial health risks to the population, or equally importantly, to sub-groups of the population. Including: • Human pathogens that are not in Aotearoa New Zealand but already exist (e.g. Ebola virus, anthrax). • Pathogens that currently have limited or no human-to-human transmission but could potentially evolve to do so (e.g. Highly Pathogenic Avian Influenza (HPAI) H5N1). • Pathogens yet to evolve and emerge with pandemic potential (including "disease X"). The key categories (based on syndrome and mode of transmission) are: • "Flu like" illnesses. • Haemorrhagic illnesses. • Disease X –type (includes variations on current pathogens, possibly plasmid or prion related disease). • Vector-borne illnesses. • Water and foodborne illnesses.	"Substantial health risk" is challenging to define simply. The risk posed by a pathogen is a combination of: • Transmissibility. • Clinical severity of the acute infection and its sequelae. • Impact of disease and control measures (more broadly than just clinical severity, including aspects such as ability to work, and psychological outcomes). • Who bears the impact (for example, whether Māori and Pacific Peoples, children, elderly, or those with disabilities are most harmed). There is no simple metric that will capture these issues. Although, for existing pathogens, transmissibility and clinical severity can be explored in mathematical modelling to assess the burden of disease (and when it will occur), there will still be judgement required around what constitutes a substantial risk (for example, a pathogen with rapid transmission and fatalities will present a very different picture to a pathogen with slow transmission with long-term burden on health care, but both could be considered a substantial risk). Additionally, systems will need to be in place for rapid assessments (e.g. of transmission routes, clinical severity, predictions of long-term harms) of newly emerged pathogens. Equity and Treaty of Waitangi/Te Tiriti o Waitangi obligations will be central to assessments of which pathogens present a substantial risk. Factors including ethnicity (including differential age and co-morbidity distribution), disability, socio-economic, addiction, occupational exposure/risk (e.g. lab workers, migrant workers, sex industry) will need to be considered. A key principle is that those most at risk must be at the table when risk management decisions are being made.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Wāhanga B | Part B: Pandemic planning and preparedness: Scenarios of pandemic agents and capabilities required.

Here we provide a generic typology of potential pandemic scenarios and agents, considering a range of characteristics including epidemiological features, impacts and amenability to prevention and control methods.

The agents included in Part A are then mapped against this typology to assess the likely effectiveness of public health controls and identify essential capabilities for an effective response.

This section is structured in the following way:

- A framework (typology) capturing generic properties of potential pandemic or PHEIC scenarios and agents is developed, with reference to public health outcomes and a range of scenarios.
- Pathogens described in Part A are then mapped against this framework to determine which agents fall into each 'type' and potential novel agents are discussed with reference to particular scenarios. Pathogens are also mapped against a broader range of metrics, indicating implications for control.
- Generic capabilities needed to respond effectively to a pandemic/PHEIC are described.

3. Generic properties of pandemic scenarios and agents

The purpose of identifying generic properties and devising pandemic typologies is to inform preparedness and the development of an effective pandemic plan that is tailored to Aotearoa New Zealand and can be adapted for any pathogen/disease, including "Disease X" (i.e. the emergence of previously unknown human pathogen). As new information becomes available, the mapping against typology can be revised, and adjustments made to the national response.

3.1 A typology of pandemic scenarios

A key tool to support pandemic planning is having a well-developed **typology of pandemic scenarios**. A pandemic typology provides a description of a comprehensive range of conceivable and plausible pandemic scenarios. It is informed by historic patterns, including the range of previous PHEICs and is useful during two phases of the pandemic response: **pandemic preparedness** (usually during the transition and interpandemic phases), and **pandemic assessment** (during the alert and early response phases).

During the transition and interpandemic phases, a typology helps build preparedness by:

Periodically reviewing and updating the **threat assessment,** based upon new knowledge about emerging infectious diseases and advances in technology that might decrease or increase the risk from specific scenarios.

Identifying **surveillance strategies** to detect emerging infections early, particularly for emerging pathogens transmitted between people with significant asymptomatic transmission, often with long incubation periods where specific screening methods may be needed.

Developing **response infrastructure** by providing a base for identifying and prioritising the development of surveillance, prevention, and control capabilities for a full range of plausible scenarios and identifying capacity gaps that need to be filled.

Periodically **exercising response systems** by providing a base for identifying scenarios where exercises are important to assess real-world

capabilities and identify gaps that need to be filled, and for staff training purposes.

Identifying ways of **improving prevention and resilience** based on the defined scenarios and potentially using them as a base for **commissioning research**.

During the alert and early response phases a typology helps shape an effective response by:

Assigning new pandemics to a likely scenario to support planning and delivering a suitable response. An early decision will be about the nature of the threat and how to combat it.

Refining the scenario with new knowledge as the pandemic progresses. This is likely to be an iterative process, particularly if the pandemic involves a novel agent.

Infectious diseases, and therefore pandemics, may be categorised in several ways, ranging from the **causal agent** (e.g. viral, bacterial, or protozoa), their **mode of transmission** (e.g. vector-borne), **syndromes** (e.g. haemorrhagic fevers), **portal of entry** or **site of replication** (e.g. respiratory infections) and other epidemiological features, such as transmissibility.

Two broad modes of transmission include **directly** and **indirectly** transmitted infectious diseases. These infections may or may not include other host species, and if so are called **zoonoses**. These direct and indirect transmission modes themselves include other sub-modes of transmission, so for example directly transmitted infections require direct or very close contact, like ebola virus, and includes **sexually transmitted infections**[7], such as for HIV. Indirectly transmitted diseases include **vector-borne8** and non-vector-borne diseases, with vector-borne diseases typically classified as those that require transmission via an arthropod bite (i.e. arachnids such ticks, or insects such as mosquitoes). Note these are typically classified as zoonoses only if other non-vector species are part of the life cycle, despite these technically being animals, so falciparum malaria and dengue are not typically classified as zoonoses. Vector-borne disease spread is limited by the distribution and spread of the vectors, and example of vector-borne diseases include malaria (protozoan), plague (bacterial) and dengue (viral). Those non-vector-borne indirectly transmitted diseases include environmental and vehicle-borne transmission, including food-borne diseases such as new variant Creutzfeldt-Jakob Disease (nvCJD) (a prion) or salmonellosis, and water-borne diseases such as cholera (both bacterial). Lastly, infections many be **horizontally** or **vertically** transmitted, where vertical transmission is across generations and typically mother-to-child transmission (MTCT).

Each classification has strengths and weaknesses. For example, by classifying by **type of pathogen**, there are often more similar techniques that can be used for diagnosis and control, such as being amenable to similar vaccine development strategies. However, measles virus, influenza virus and HIV, for example, cause diseases with differing mortality and morbidity rates, different modes of transmission and differing vaccine development success. Classifying organisms by their **mode of transmission** can result in grouping different agents together, such as the malaria (protozoan), plague (bacterial) and dengue (viral) due to all being vector-borne diseases but may have benefits when considering control. For example, several agents have the same species of mosquito as their vector, with *Aedes aegypti*, the yellow fever mosquito, being able to spread the viruses that cause dengue fever, chikungunya, Zika fever and yellow fever. Some infectious agents may also be transmitted in several ways, such as via direct and indirect contact, making these useful but not perfect categories. An example includes HIV, which may be spread via direct sexual contact, indirect contact through intravenous needle sharing or vertically from mother to child. However, the mode of transmission (such as for agents that are spread via faecal-oral route) can lead to the use of generic control measures such as food hygiene and water sanitation that cover a range of infections and is a useful typology[9].

7 www.cdc.gov/csels/dsepd/ss1978/lesson1/section10.html

8 www.who.int/news-room/fact-sheets/detail/vector-borne-disease

9 www.who.int/news-room/fact-sheets/detail/drinking-water#:~:text=Water%20and%20health,hepatitis%20A%2C%20typhoid%20and%20polio

Mode of transmission partially overlaps with the **portal of entry** or **site of replication** approach to characterising pandemics. These approaches, for example, may be used to cover respiratory[10] or gastrointestinal diseases and again can be a convenient approach to finding common solutions to diseases caused by different agents that have multiple modes of transmission. These may overlap considerably with the classifications by **syndrome**, such as gastrointestinal diseases that primarily cause vomiting and diarrhoea, but syndromic classification groups infections with multiple modes of transmission (e.g. haemorrhagic fevers include vector-borne and directly transmitted infections) and so have multiple control mechanisms. However, these classifications may be useful for things such as syndromic surveillance (e.g. influenza-like illness), diagnostics (e.g. multiplex molecular panels for gastrointestinal diagnostics) and treatment regimens (e.g. supportive care for haemorrhagic fevers).

Lastly, alternative typologies may be used that integrate different aspects of **infection biology**. An adaptation of Baker's 2016 proposed typology for pandemics of concern for Aotearoa New Zealand is included in Table 3[11]. This typology has integrated both mode of transmission and epidemiological features, such as incubation period, which is one epidemiological aspect that can impact the visibility of an infection and its speed of spread (see Section 3.2 below).

Table 3: Possible typology of pandemic scenarios. This typology identifies seven potential future pandemic scenarios which are grouped into three broad functional bands. The table includes examples of infectious diseases (IDs) which have caused previous epidemics and PHEICs.

Pandemic Type	Examples (*PHEIC)
A. Pandemic IDs transmitted between people with short to medium incubation periods	
1. ID with well-established pandemic potential	Pandemic influenza 1918, 1957, 2009*
2. Poorly characterised emerging ID with pandemic potential	SARS 2002, MERS-CoV 2012, COVID-19 2020*, Ebola 2014*, Mpox 2022*
3. Synthetic or weaponised ID with pandemic potential	Synthetic bioterrorist agent (e.g. gain-of-function influenza viruses), or stored agent that could be weaponised (e.g. smallpox)
4. Well characterised ID with re-introduction potential	Diphtheria 1998, Polio 2014*, Measles (post-elimination)
B. Pandemic IDs transmitted between people with predominantly asymptomatic transmission, with long incubation periods	
5. ID with high asymptomatic transmission, long latency and pandemic potential	HIV/AIDS 1981
6. Increase in serious antimicrobial resistance	Drug resistant tuberculosis (MDR / XDR / TDR), *Candida auris*
C. Pandemic IDs predominantly transmitted from animals, vectors, food, and water	
7. Exotic vector-borne and zoonotic ID with moderate to high introduction potential	Arboviral diseases e.g., Zika 2016*, Dengue, Chikungunya

Source: Adapted from Baker's 2016 "Pandemics: Would a typology improve our ability to prepare and respond?"[11]

10 www.who.int/publications/i/item/WHO-2019-nCoV-Policy_brief-pandemic_preparedness-2022.1

11 www.idrec.ac.nz/symposium-archive.html

The typology in Table 3 and the categorisations above can all play a key role in pandemic preparedness for Aotearoa New Zealand, allowing systems to be prepared that consider different aspects of the biology of the infection and their diseases to plan and ultimately limit the physical, psychological and socioeconomic harm any pandemic may cause.

3.2 A typology of pandemic agents

The impact of a pandemic is largely determined by the characteristics of a potential pandemic agent including the **transmissibility** of the agent, and **clinical severity** of the infection [1]. Other generic properties discussed below include **visibility**, **controllability** and **certainty of knowledge.** The certainty of knowledge about these features can initially be low [1]. This typology informs **Impact assessments** that are essential to support decisions about taking a proportionate response to new pandemics.

3.2.1 Transmissibility

Typically quantified by the **basic reproduction number, *R0***, is defined as the average number of secondary infections caused by an infected individual in a fully susceptible population [2]. A pathogen with $R_0 < 1$ may cause localised outbreaks but cannot cause sustained transmission. A pathogen with $R_0 > 1$ has epidemic potential. The larger R_0 is, the faster the epidemic will grow, the more difficult transmission is to control, and the higher the population attack rate will be in the absence of effective control.

R_0 is a combined property of the pathogen and the population in which it is spreading. For example, a population with higher contact rates or where a greater proportion of the population is in demographic groups causing the majority of transmission, will typically have a higher value of R_0.

In situations where the population has some degree of **immunity** to the pathogen, for example via vaccination against or historic exposure to a related pathogen providing some cross-reactive immunity, the more relevant quantity is the **effective reproduction number *Re*,** which can be characterised as $R_e = R_0 \times S$, where S is the fraction of the population that is susceptible. The effective reproduction number may also be affected by control measures or behavioural changes in response to the outbreak.

Diseases with higher R_0 can cause **faster growing epidemics**. Typically, there is a time lag from individuals becoming infected to developing symptoms and getting tested, that is correlated with the generation interval. This implies that by the time new cases have been detected the total number of infections has already increased by a factor of approximately R_0. Therefore, a potentially large amount of future epidemic growth is inevitable due to the accumulated infections, which has important implications for the timing of control measures, particularly those designed to prevent healthcare demand exceeding some threshold level.

Control measures act to reduce *R0* so diseases with moderate R_0 tend to be easier to control or mitigate than ones with high R_0. For example, if $R_0 = 1.5$, then a 33% reduction in transmission will prevent epidemic growth, whereas if $R_0 = 4$, a 75% reduction would be needed.

Diseases with higher R_0 have a higher **herd immunity threshold (HIT),** meaning that a higher proportion of the population need to be immune (e.g., via vaccination and/or prior infection) to prevent epidemic growth. For the same reason, pathogens with higher R_0 will, in the absence of any control measures, have a higher attack rate. Simple mathematical models predict HIT by the equation of $HIT = 1 - 1/R_0$, e.g. if $R_0 = 3$ the HIT is 67%, meaning that if at least 67% of the population is immune, the effective reproduction number will be below 1 and the epidemic will decline. This simple equation assumes that the population is well mixed. In reality, populations have heterogeneous contact patterns and this typically means the HIT is lower than in the well mixed model [3, 4]. On the other hand, epidemics

can significantly "overshoot" the HIT as a significant fraction of the population can be infected after the epidemic has peaked. This means that even pathogens with moderate values of R_0 (around $R_0 = 2$) have the potential to infect the majority of the population.

3.2.2 Clinical severity

Clinical severity may be quantified by the proportion of all infections (or proportion of symptomatic infections) that lead to specified clinical outcomes, such as hospital attendance, intensive care unit (ICU) admission or death. Like R_0, clinical severity is a **combined property of the pathogen (virulence) and the population in which it is spreading**. For example, populations with a large elderly demographic will experience higher clinical severity if there is a strong age gradient in risk of severe disease. Importantly, clinical severity measures are likely to differ greatly between population groups due to factors such as age-dependent severity and high-risk groups, which may include Māori and Pacific People or groups with specific comorbidities.

Common measures of clinical severity include the **infection fatality ratio (IFR)** or **case fatality ratio (CFR)** (i.e. proportion of all infections or proportion of notified cases respectively that cause death). Pathogens will have different severity levels for different outcomes, e.g., a pathogen may have a relatively low fatality rate but a high hospitalisation rate and/or cause people to have prolonged disability or illness and require treatment for a long period of time, so it is important to consider a range of outcomes not just one.

3.2.3 Visibility

McCaw *et al.*, [5] suggest visibility as another key characteristic, roughly corresponding to the **case ascertainment rate**. High visibility is dependent on good diagnostics and widespread testing of symptomatic individuals. Visibility may be hindered if there are high rates of **subclinical or asymptomatic infection, long incubation periods, a non-specific syndromic profile (e.g. common respiratory symptoms), or lack of access to testing.** Case-targeted control measures (test-trace-isolate-quarantine) will be less effective if visibility is low, whereas population-wide control measures (e.g. mass masking, social distancing) will be less sensitive to visibility. The HIV/AIDS pandemic is a classic example in which visibility played a crucial role in its widespread distribution. The first reported AIDS diagnosis was in 1981, and yet HIV infection has a long incubation period and viruses were circulating in at risk communities for many years before this diagnosis. Those communities included marginalised groups like homosexuals, intravenous drug users and sex workers in Europe, North America and communities in Africa with limited access to healthcare [6]. In 2021 more than 38 million people are infected[12]. The emergence and global spread of Mpox in 2022 highlights how these factors remain unresolved and contribute to global spread.[13]

3.2.4 Controllability

Controllability can be thought of as a joint property of the **pathogen**, the **host population**, and the **available resources**.

Pathogen characteristics such as high human-to-human transmissibility and the potential for onward transmission prior to the onset of symptoms, can lead to explosive outbreaks that are difficult to control and present challenges to the success of outbreak control measures such isolation and quarantine. Factors such as presymptomatic or asymptomatic transmission and a short latent period, can hamper efforts to find and isolate cases before they transmit. The presence of environmental or wildlife reservoirs, including vectors, is a barrier to elimination or eradication.

Host characteristics that influence controllability include contact rates, patterns of disease-specific immunity and susceptibility in the population and the extent of human contact with vectors.

12 https://unaids.org/en

13 www.who.int/publications/m/item/multi-country-outbreak-of-mpox--external-situation-report--25---24-june-2023

Availability and equitable distribution of resources strongly influence controllability. Examples of key resources include the existence and availability of an effective vaccine and/or treatment, sensitive and specific test modalities, trust in leadership, workforce expertise and scalability (e.g., for contact tracing), financial resources and social welfare systems that enable the population to adhere to infection control requirements, digital infrastructure to enable remote working, community infrastructure, geographical and environmental factors such as having no land borders with other jurisdictions, and (for airborne pathogens) the capacity to mitigate climate and seasonal factors such as increased indoor transmission during winter months.

The important role of resources in determining controllability and the reality that resources are much more modifiable in the early phases of a pandemic than either pathogen or host factors, indicate the need for pandemic planning that purposefully directs resources towards infrastructure that can maximise the controllability of an emerging pathogen.

3.2.5 Certainty of knowledge

The early phases of the response to an emerging pandemic requires highly consequential decisions to be made before robust evidence is available. There are multiple measurement challenges for early assessment of transmissibility and clinical severity.[14] **Emerging infectious diseases may not be fully characterised** and emerging pathogens may be **rapidly evolving**.

Some important parameters are subject to **biases** [7] in their estimation and it is important to understand how these biases arise and how they may influence the face value of key parameters in initial assessments. For example, the basic reproduction number is typically overestimated[15] early in an outbreak [8] and requires a combination of data and modelling assumptions about the generation interval and reporting lag [9]. The epidemic growth rate (often expressed as the doubling time) is another important metric that can be estimated empirically from case notifications without the need for assumptions about the generation interval. However, it may also be subject to biases caused by variability in case ascertainment.

Likewise, parameters may be subject to **measurement error** because key data are incomplete. CFRs are often available early in a pandemic but a valid estimate is hard to establish initially. The denominator may not be easily measurable in the absence of a reliable and widely-used test and it is also sensitive to changes in the clinical case definition. The numerator may be undercounted because fatalities lag cases by many days [1]. Moreover, this parameter refers to cases, whereas the IFR that includes asymptomatic and undetected cases is actually the key parameter for understanding the true likely impact.

It can be hard to disentangle transmissibility from clinical severity in the early stages of an outbreak of a novel pathogen with incomplete case ascertainment – for example, the number of deaths in a population with a 10% attack rate and a 0.1% IFR is the same as with a 1% attack rate and a 1% IFR, but the implications for what will happen next are very different. This may be resolved by collecting more data, such as data from intensively tested cohorts like international travellers, First Few "X" (FFX) studies, household and contact tracing studies and from seroprevalence data.

There is a need to apply **precautionary principles** when risks are not fully understood.

3.2.6 Mapping pathogens to the pandemic agent typology

The following section provides illustrative maps of some of the pathogens described in Part A onto axes capturing transmissibility, clinical severity, generation interval and population level and health system impacts.

14 www.health.govt.nz/system/files/documents/publications/report_for_moh_covid-19_surveillance_outbreak_analytics_final.pdf

15 With some exceptions – the UK underestimated its reproduction number in March 2020

3.2.7 Transmissibility – clinical severity mapping

Transmissibility and clinical severity together enable an assessment of the potential health impact of a pathogen. Although there are other factors that determine impact, these are two of the most important, and form the basis for impact assessment in influenza pandemic plans in several countries and the WHO [10].

Figure 1 shows an example mapping of some exemplar pathogens onto two axes representing transmissibility and clinical severity. Pathogens could be classified as having low or high transmissibility and clinical severity, creating four broad regions of the mapping:

- **Low transmissibility, low clinical severity** (bottom-left, grey). May be manageable with a relatively astringent or business-as-usual public health approach (e.g., 2009 swine flu).
- **High transmissibility, low clinical severity** (bottom-right, yellow). Have the potential to cause significant impact due to the high number of infections. It may be difficult to entirely suppress transmission in these cases, but mitigation measures aimed at "flattening the curve" may be appropriate. An example might be a highly infectious but relatively mild influenza strain.
- **Low transmissibility, high clinical severity** (top-left, magenta). May be more amenable to measures aimed at preventing or delaying an epidemic wave, which are likely to include case-targeted measures (test-trace-isolate-quarantine) (e.g. Ebola virus, SARS-CoV-1).
- **High transmissibility, high clinical severity**. Likely to require a more stringent response and preventing healthcare system overwhelm will be a key concern (e.g. smallpox).

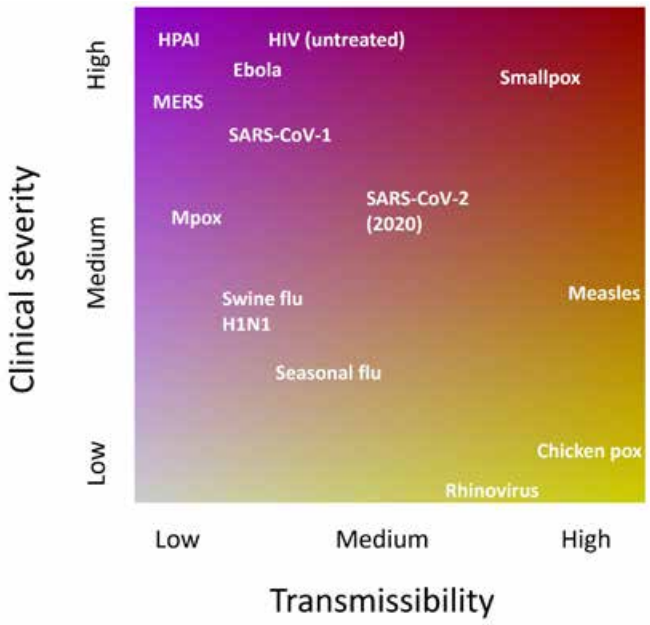


Figure 1. Simplified mapping of potential pandemic agents according to two characteristics: transmissibility (measured by basic reproduction number R_0) and severity (measured by the proportion of infections leading to a specified clinical outcome such as death). These categorisations may be applied at the population level or to different age groups or specific population groups such as Māori. Note pathogens are positioned approximately along these two axes and reflect the transmissibility and severity in an immune naive population.

> "A disease can only have pandemic potential if its value of R0 is greater than 1."

Measures of transmissibility and clinical severity will be updated and refined over time. In the early stages of an outbreak of a new or emerging pathogen, there is likely to be high uncertainty in estimates, due to limited data availability and potential biases in early data. Over time, uncertainty is likely to be reduced as more clinical, experimental and surveillance data becomes available. Note that along with more information leading to changes in estimates for these parameters, other factors such as pathogen evolution or changes in understanding and, for example, clinical management, can also lead to changes in understanding and outcomes over time.

As an illustration of how mapping based upon transmissibility and clinical severity can affect the number of deaths from a pathogen, the total number of deaths can be calculated as the proportion of the population that gets infected (determined by transmissibility) multiplied by the infection fatality ratio (a measure of clinical severity) – see Figure 2. This gives a graphical method of categorising the potential health impact of a pandemic agent according to two axes representing **transmissibility** and **clinical severity**. This type of approach is used to assess potential impact of influenza epidemics and pandemics [11], and could also be applied to different age groups or specific population groups such as Māori. Importantly, even pathogens with moderate values of R_0 can have a high attack rate (>50%), which combined with a relatively low IFR can cause a severe health impact.

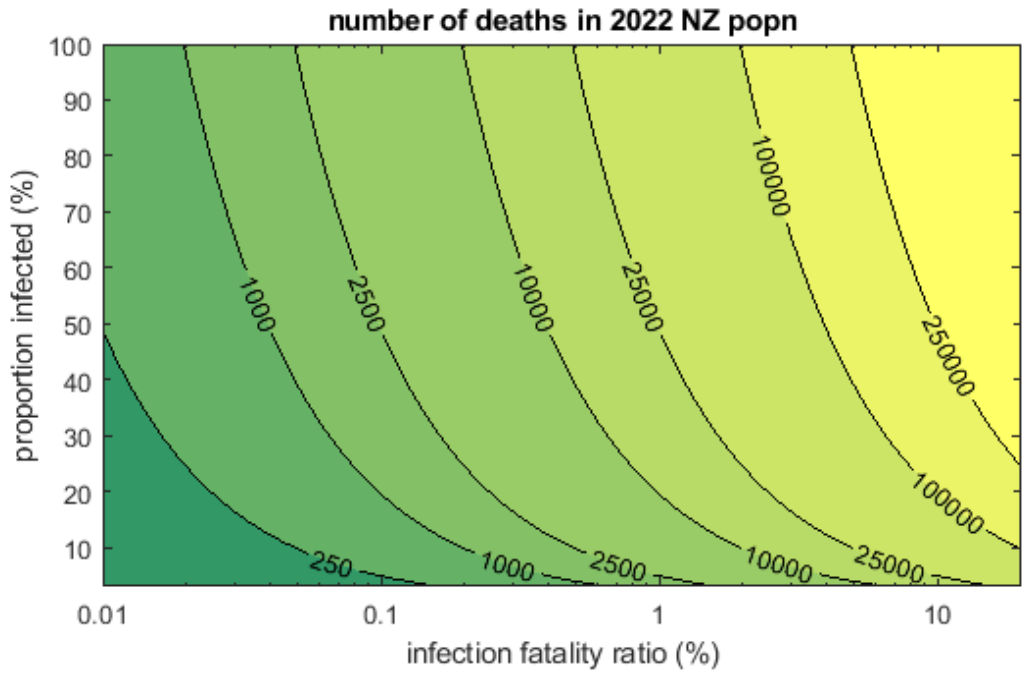


Figure 2. Mapping of the average infection fatality ratio (a measure of clinical severity) and the proportion of the population that is infected (determined by transmissibility) onto the total number of deaths (indicated by the numbers on the contours) in a population of 5.1 million people (adapted from Reed at al. [11]).

3.2.8 Transmissibility – generation interval mapping

Figure 3 illustrates a mapping exercise of some exemplar pathogens onto two axes representing transmissibility (measured by R_0) and mean generation interval (time between infection and onward transmission). The mean **generation interval** is the same as the mean **serial interval** (time between symptom onset times of an infector-infectee pair), although the serial interval has a larger variance and can include negative values. The contour lines divide the space up into different ranges for the **doubling time** (time taken for new daily infections to double in the early stages of the epidemic). This mapping does not take account of severity so only relates to the transmission dynamics and not the health impact (although it should be noted that the epidemic growth rate can affect clinical severity if there is an intense escalation in numbers of severely ill cases leading to insufficient resources to meet medical need).

Doubling time is an important metric because it determines how much time is available to respond. The doubling time depends on R_0 and generation interval, a higher R_0 or a shorter generation interval will lead to a shorter doubling time. Short doubling times can be especially difficult if there is a significant time lag from infection to outcomes measurable by surveillance such as hospital/ICU admission. In these situations, by the time hospital admissions meets some threshold, a large amount of additional epidemic growth is already "baked in".

Pathogens with **high *R0* tend to have short doubling times** (<4 days), even if the generation interval is relatively long (e.g., smallpox, chicken pox, measles) (dashed red region in Figure 3). For pathogens with low R_0, the doubling time depends on the generation interval. If the generation interval is relatively short, the doubling time will also be short (this is true of many airborne respiratory pathogens, e.g., seasonal/pandemic influenza viruses) (dashed blue region in Figure 3). Pathogens with moderate R_0 and long generation interval (> 10 days) have the potential to cause a "slow burn" epidemic (e.g., HIV) [12], which unfolds relatively slowly but may also be harder to control than a pathogen with low R_0 (dashed purple region in Figure 3). Pathogens with low R_0 and long generation interval are likely to be less of a threat (though there may be exceptions, e.g. highly severe haemorrhagic fevers).

> **"Doubling time [time taken for new daily infections to double in the early stages of the epidemic] is an important metric because it determines how much time is available to respond."**

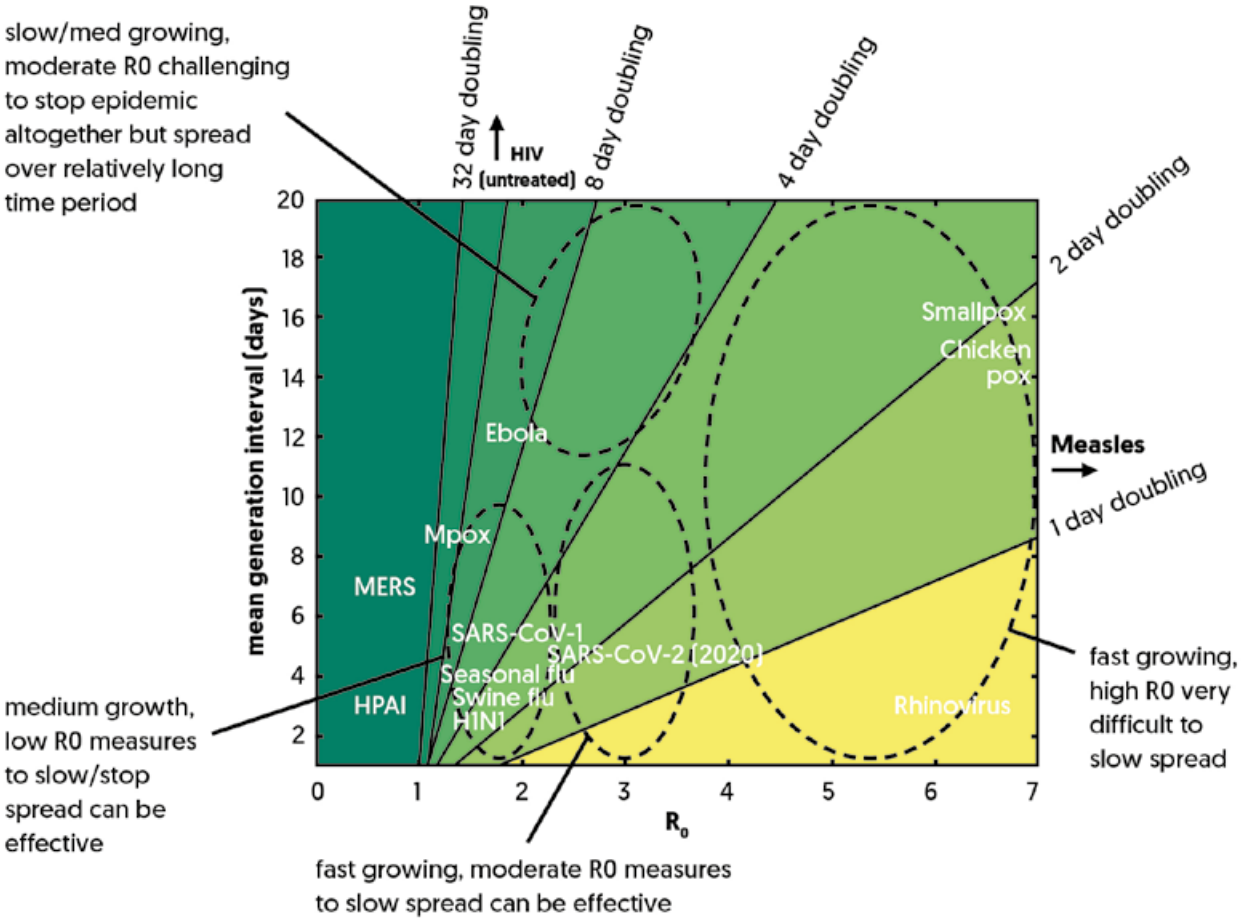


Figure 3. **Transmissibility – generation interval mapping showing the epidemic growth rate, measured by the doubling time, from slow growth (dark green) to fast growth (yellow). Note the positions of the pathogens are approximate and will depend on other factors. The dashed regions are indicative of different scenarios and are not intended to provide a definitive categorisation scheme. This mapping does not include severity (see Figure 1), so only relates to transmission dynamics not the health impact. The values of the doubling time shown are for an exponentially distributed generation interval (as assumed by a simple SIR model) and will vary slightly for different generation intervals.**

3.2.8.1 Mapping against other characteristics

Table 4. Mapping of infectious disease agents against multiple metrics related to transmissibility, clinical severity and controllability.

	Metric	Definition	Level			Implications for control
Transmissibility	**Basic reproduction number, R0**	Average number of secondary infections per primary infection in a fully susceptible population	Low	Medium	High	A disease can only have pandemic potential if its value of R0 is greater than 1. Higher values of R0 make controlling transmission more effective interventions are needed to reduce R0 below 1. Higher R0 means a higher proportion of the population needs to be immune (e.g. via vaccination) to prevent transmission.
			Nipah	Influenza A	Measles	
	Serial interval / generation interval	Serial interval = time from symptom onset in the index case to symptom onset in a secondary case	Short	Medium	Long	The combination of R0 and generation interval determine the epidemic growth rate (often measured as doubling time). Pathogens with a short generation interval can typically grow very rapidly; pathogens with a longer generation interval may still grow rapidly if R0 is high, but may grow more slowly if R0 is closer to 1. Short doubling times are challenging for public health response as there is little time to act, and lags in clinical outcomes occurring and being reported mean that the epidemic continues to grow significantly larger even after effective control measures are introduced. A short generation interval also makes contact tracing more difficult as there is less time to find and quarantine contacts.
		Generation interval = time from infection of the index case to infection of a secondary case	Influenza, cornaviruses	Measles, ebola, smallpox	HIV, malaria	
	Incubation period	Time from infection to onset of symptoms	Short	Medium	Long	The length of the incubation period relative to the generation interval is related to the amount of presymptomatic transmission (see below). A long incubation period can make measures targeted at travellers (e.g. testing or quarantine of international arrivals) less effective as there is a higher likelihood infected individuals will be asymptomatic and test negative at the time of arrival.
			Influenza, cornaviruses	Measles, ebola, smallpox	HIV, malaria	

	Metric	Definition	Level			Implications for control
Transmissibility	**Pre/ asymptomatic transmission**		Negligible	Low	High	Pathogens with high levels of presymptomatic/asymptomatic transmission make case-targeted measures (e.g. test-trace-isolation-quarantine) less effective as it is more difficult to find infected individuals and intervene before they can transmit. High levels of asymptomatic transmission reduce the visibility of the epidemic which may affect other control measures.
				Ebola, mpox	Influenza, coronaviruses, HIV	
	Individual variability	The amount of variability between individuals in the number of secondary infections	Low	Medium	High	There can be significant variation between individuals in transmission. For some pathogens, the majority of individuals may not transmit at all or infect only a small number of other people, whereas a minority may infect large numbers of other people. Such pathogens are said to have "overdispersed" transmission (often termed superspreading). High overdispersion means outbreaks are very unpredictable in their early stages: many outbreaks will go extinct by chance but some may grow explosively. Overdispersion can also influence the effectiveness of control measures. High overdispersion means source investigation and measures targeted at preventing superspreading events can be effective. High variability in the latent period or infectious period makes case isolation and quarantine measures more challenging because it is more difficult to target the isolation period to the infectious period.
			Pneumonic plague, hantavirus, ebola	Smallpox, mpox	SARS-CoV-1, SARS-CoV-2, measles	

	Metric	Definition	Level			Implications for control
Clinical severity	**Infection fatality ratio**	Proportion of infections causing fatality	Low	Medium	High	As per the categorisation in Figure 1, pathogens with high severity but low transmissibility may be more amenable to measure designed to suppress or eliminate transmission; pathogens with low severity but high transmissibility may be more amenable to mitigation measures.
			Seasonal influenza subtypes, swine flu	SARS-CoV-2	SARS1, haemorrhagic fevers, smallpox	
	Infection hospitalisation ratio	Proportion of infections causing hospital attendance	Low	Medium	High	
	Infection ICU ratio	Proportion of infections leading to ICU admission	Low	Medium	High	
	Likelihood to contribute to health inequities		Negligible	Low	High	It is likely that many pandemic agents would exacerbate existing health inequities due to commonalities in social determinants of health across a wide range of pathogens and systemic inequities in the healthcare system. Māori have suffered disproportionately high hospitalisation and fatality rates from smallpox, pandemic influenza (1918, 1957 and 2009) and COVID-19. The age profile in severity is an important factor: a pathogen with high severity in younger or middle aged groups will disproportionately impact Māori and Pacific Peoples due to their relatively young age structure.

	Metric	Definition	Level			Implications for control
Controllability	**Pre-existing immunity**	Partial cross immunity with another pathogen or re-emergence of a previously endemic pathogen	Negligible	Low	High	
	Vaccine availability		None/ not yet approved	Available but subject to manufacturing/ supply constraints	Available	If a vaccine is not immediately available but likely to become available, measures to delay and slow transmission may be advantageous. Lipsitch et al. (2011) identified two alternative vaccination strategies: direct protection of groups at high risk of severe disease and indirect protection via vaccination of groups with high likelihood of transmission. Factors favouring direct protection are convincing data on who is at high risk; high vaccine effectiveness in those groups; vaccine effectiveness higher against severe disease than against transmission; limited quantity of vaccine; late availability of vaccine. Factors favouring indirect protection are: groups at high risk of severe disease are unknown; low vaccine effectiveness in those groups; high vaccine effectiveness against transmission (sterilising vaccine); vaccine available in early stages of epidemic.
			RSV, MERS, SARS1, SARS-CoV-2 (2020)	Smallpox, pandemic influenza subtypes	Measles, polio, pertussis	

4. Generic capabilities

The following section describes capabilities needed to respond effectively to a pandemic threat and areas for development as part of a pandemic plan. These generic capabilities include those that are applicable globally, and others that are more, or solely, relevant to Aotearoa New Zealand.

There are several characteristics of Aotearoa New Zealand that are directly relevant to preparedness and the development and implementation of a pandemic plan. These include:

- Our **Te Tiriti o Waitangi** obligations.
- A history of **racism and colonisation** that continues to have a negative impact on **health equity**.
- Regional links with other Pacific nations and our **obligations to Pacific Realm nations**.
- Our **relative isolation** as an island nation enables strict application of border control measures. This contributed to Aotearoa New Zealand having the fastest trajectory to reach the highest country score in the Government Response Stringency Index[16] during the COVID-19 pandemic [13].
- Our liberal democracy with a population that has been **relatively compliant** to reasonable, proportionate and clearly justified public health measures [14]. During the early phase of the pandemic, compliance may have been aided by elimination of community transmission for long periods, allowing several high-stringency measures to be lifted at a time when the rest of the world was experiencing prolonged implementation of physical distancing measures.
- A tendency to **'health nationalism'**, most evident during the early phases of the COVID-19 pandemic [15].

The capacity to respond effectively to a pandemic will depend on available resources, and at certain phases of the pandemic a number of key capabilities are likely to be **overwhelmed**. These include hospital capacity, including the number of ICU beds and ventilators, diagnostic testing services, contact tracing resources and genome sequencing capacity. During these challenging periods there may be a disconnect between official national statistics and the reality 'on the ground', and this can lead to tension, burn-out and loss of essential staff – further compounding the situation. Anticipation of needs throughout the full time course of a pandemic, and a realistic understanding of limitations in current response capability, will help planning, building and maintaining of such resources during the interpandemic period.

16 https://ourworldindata.org/covid-stringency-index

4.1 Pandemic planning and preparedness

An overriding capability for managing future pandemics is pandemic planning which provides the basis for pandemic preparedness. Many of the other capabilities described here depend on medium to long-term investment in facilities, systems, and a highly skilled workforce, which depends on evidence-informed planning. Successful implementation depends on the level of trust built between decision makers and society [16].

A key framework for this process is to consider the continuum of pandemic phases (see Figure 4). Pandemic planning occurs at all phases, but interest is likely to be most intense during the transition phase where there is a strong focus on recovery. Preparedness can also begin in the transition phase but is likely to be largely carried out in the interpandemic phase. One of the challenges of building and maintaining preparedness is that motivation and perceived value of pandemic planning will tend to fade during this interpandemic period. However, this is the critical period in which to make sure the response capabilities described in the following sections are developed, maintained and ready to respond when needed. This requires concerted action on each capability and ongoing investment. Once a new pandemic threat emerges, it is often too late to invest in significant capability development or expansion of capacity.

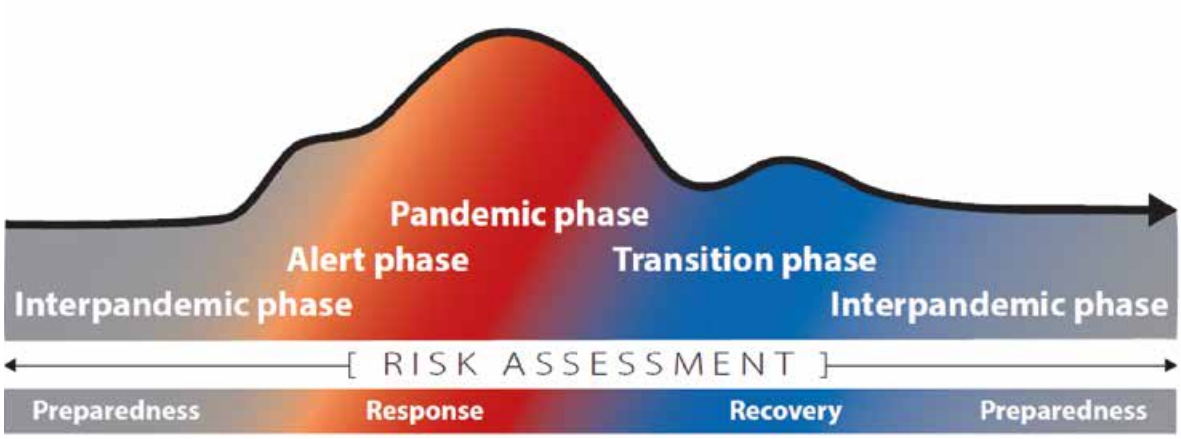


Figure 4: Major pandemic phases and actions. Source: World Health Organization 2017, Global influenza Programme, Pandemic Influenza Risk Management[17]

Pandemic preparedness is in many ways synonymous with resilience, but individualised concepts of resilience are unhelpful for pandemic planning because they fail to capture structural settings that determine the success or otherwise of a pandemic response. In this document we use a relational definition of **resilience, defining it as *a process of drawing on resources to sustain wellbeing*** [17].

This definition of resilience offers a more systematic approach for evaluating and improving pandemic preparedness and it aligns with Māori

17 https://apps.who.int/iris/bitstream/handle/10665/259893/WHO-WHE-IHM-GIP-2017.1-eng.pdf?sequence=1&isAllowed=y

and Pacific models of wellbeing, providing a stronger support for upholding tino rangatiratanga in community-led pandemic responses. Some key considerations for pandemic preparedness include:

- **Entities 'drawing on resources'** can be individuals, whānau, communities, or the whole of Aotearoa. Health inequities arise when populations are disconnected from the resources they need to sustain wellbeing. This definition ensures that instances of disconnection are made visible in assessments of pandemic preparedness, recognising the vital role of communities in the response and the need to resource them appropriately and equitably.
- **Resources to sustain wellbeing** in a pandemic can be material (e.g., financial, food security, vaccines, or laboratory supplies); human (e.g., leadership, workforce); knowledge-based (e.g., science capability, surveillance data), values-based (e.g., trust, communication networks), environmental (e.g., healthy homes, clean water), and structural (e.g., Te Tiriti, government policy). This broader scoping of resources for a pandemic recognises that intangible resources such as trust in leadership can be critical determinants of the success of a pandemic response.

From this definition, pandemic preparedness can be seen as an **ongoing process of building and sustaining a network of capabilities**. In practical terms this means that a comprehensive evaluation of pandemic preparedness would begin by identifying generic and specific resources needed for a range of pandemic scenarios but must also assess connectedness (i.e., how readily and how equitably these resources can be accessed).

In the sections that follow we summarise the capabilities required for an effective and equitable pandemic response, noting that population wellbeing during a pandemic depends on a wide range of resources and capabilities including, but not limited to, traditional domains of outbreak control.

4.2 Māori considerations

4.2.1 Tino rangatiratanga and partnership

In Aotearoa, Te Tiriti o Waitangi (Te Tiriti) forms the foundation of the relationship between Māori and the Crown. Te Tiriti affirms tino rangatiratanga (self-determination) of Māori. In addition, the United Nations Declaration for the Rights of Indigenous People (UNDRIP) affirm Māori indigenous rights. Therefore, **Māori must be supported and appropriately resourced to develop and deliver their own pandemic plan in accordance with their values and context to and with their people**, as is their responsibility as tangata whenua. This is giving effect to mana motuhake and tino rangatiratanga. Additionally, Te Tiriti also establishes a partnership between Māori and the Crown and therefore the Crown must also partner with Māori by prioritising relationship building with Iwi/Rūnanga, Māori Health Providers, and community groups according to each their overall responsibilities and mandates to ensure the development of a pandemic plan is embedded in **achieving equity by addressing the specific needs of their communities**. This ensures the Crown is able to deliver on their obligations as Tangata Tiriti.

Colonisation, racism and mistrust of the healthcare system, also contribute to negative health outcomes [18, 19]. Therefore, a pandemic response plan must account for these factors and acknowledge that the Crown may not be the most effective vehicle to implement this response. A 'one-size-fits-all' and/or a 'top-down' approach, can often marginalise Māori communities and unintentionally exacerbate negative health outcomes [20]. Therefore, some **measures should be Māori-led and flexible to meet the specific needs of Māori communities**. This requires a willingness to share power in decision making and proactive resourcing of Māori-led responses.

The most effective control/protection measure will likely be the same for all populations in a given scenario, e.g., vaccination, suppression. However, delivery of a vaccination programme for example, will require **partnership, Māori leadership and flexibility** in the delivery and strategy when in a Māori context, e.g., Marae based centres, mobile clinics and whānau centred care. These responses will also need to reflect appropriate tikanga and values in their implementation as determined by Māori.

Māori have extensive tribal, marae and whānau networks and can mobilise quickly to distribute resources, coordinate responses and gather information [21]. Marae are in themselves hubs for manaaki, communication and resource distribution that provide comfort and assurance to their people especially so during a pandemic or natural disaster (e.g., COVID-19, Christchurch earthquakes, Cyclone Gabrielle) [22]. This highlights the need to establish strong relationships and to partner with Māori to enable their delivery to be well supported in meeting the needs of their community [23].

4.2.2 Māori health equity

Māori have and continue to experience disparate outcomes in pandemics, infectious disease outbreaks and within the wider health system [18, 24, 25]. This is evident in smallpox, pandemic influenza (1918, 1957 and 2009) and the COVID-19 pandemic where Māori were overrepresented in mortality and hospitalisation [24, 26-28]. Furthermore, Māori are more than often exposed to factors that increase the communicability of infectious diseases such as **social deprivation, housing, crowding and poverty** [25]. In addition, the risk of infectious disease is amplified for those with existing **comorbidities**.

Despite the increased relative risk for many infectious diseases, Māori also experience inequities in access to primary care[18] [29, 30]. Additionally, there is reinforcing evidence across a range of diseases where Māori receive lower quality care and are subject to direct racism and experience the impacts of **institutionalised racism** [31]. These factors can be amplified when the health system is put under pressure, e.g., during a pandemic, and further embed health inequities in Aotearoa. A pandemic response plan should consider these factors in accordance with the Pae Ora (Healthy Futures) Act 2022[19] and indigenous data sovereignty principles, to ensure equity in future pandemic responses. Cultural Adaptation

Early in the COVID-19 pandemic Māori recognised the need to respond by implementing a range of protective measures to keep their communities safe. Iwi across Aotearoa were required to adapt **tikanga** (correct procedure) and **kawa** (protocols) in compliance with the Public Health Act. For example, to adapting cultural rites such as tangihanga. Naturally, in alignment with ensuring safety in cultural settings and contexts in response to challenges presented by COVID-19. For example, hongi and hariru were replaced by 'long distance' options, (e.g., the Kahungunu Wave) to mitigate close quarter spread of the virus [21, 22, 32]. Similarly, the use of Iwi checkpoints to limit community spread and ensure that only locals entered iwi boundaries. These checkpoints effectively established a rāhui (prohibition) over certain areas in accordance with tikanga Māori.

These and other methods of cultural adaptation should be considered in the development and implementation of a pandemic plan. Tikanga is context dependent, and the correct adaptation measures will depend on the specific nature of the pandemic agent, i.e., transmissibility, severity and impact. However, appropriate tikanga is determined and implemented by Māori to ensure collective safety. Therefore, strong relationships are required to **communicate the appropriate information to iwi, hapū and marae leaders** to lead these responses.

18 www.health.govt.nz/nz-health-statistics/surveys/new-zealand-health-survey#2012-13

19 www.legislation.govt.nz/act/public/2022/0030/latest/versions.aspx

4.2.3 Māori Data Sovereignty

Māori data sovereignty (MDSov) refers to the inherent rights that Māori have with in relation to the collection, ownership and application of Māori data. Te Mana Raraunga refers to Māori data as "digital or digitalisable information or knowledge that is about or from Māori people, language, culture, resources or environments"[20]. **Māori data is a living taonga** (treasure) with strategic value to Māori and their communities. Article 2 of Te Tiriti affirms that Māori have tino rangatiratanga over 'ngā taonga katoa' (all of their treasures). Therefore, Article 2 sets the foundations for Māori to be involved in the collection, governance and decision making in the use of Māori data. The Wai 2522[21] Waitangi Tribunal finding affirmed that Māori Data is a Taonga, and Māori data sovereignty was again reinforced in the Wai 2575 Health Services and Outcomes Inquiry.[22]

MDSov must be prioritised in the management, surveillance and intervention strategies to ensure Māori rights are upheld and to promote equitable outcomes during all stages of a pandemic. Furthermore, MDSov, in a pandemic plan, should realise the aspirations of Māori rights and interests in data to enhance the wellbeing of tangata whenua [33]. **Upholding MDSov principles is vital for Government to meet their obligations under Te Tiriti** and ensure socially just outcomes during a pandemic [34]. The Māori Data Governance Model[23] provides guidance for the governance of Māori data across the public service, consistent with the Government's responsibilities under Te Tiriti o Waitangi. Meeting these obligations relies heavily on partnership, shared power and shared decision-making. Many decisions will need to be made quickly in the emergence of a pandemic. Therefore, these partnerships and relationships must be established before an outbreak to adhere to MDSov principles. Te Mana Raraunga refers to the particularly relevant principles in a health context are: Rangatiratanga – the principle of Māori control over Māori data; Whakapapa – consideration of the context and future use of Māori data; Whanaungatanga – balancing rights and responsibilities in relation to Māori data; and Manaakitanga – principles of respect, consent and use of data to uphold the mana of Māori communities[24].

4.3 Pacific Peoples considerations

Policymakers have a duty to identify and anticipate the population groups likely to be disproportionately affected by disease outbreaks and take steps that build on the strengths of those groups to mitigate predictable harms. Future preparedness and planning for the next pandemic/PHEIC needs to consider the multiple unique features of Pacific Peoples living in Aotearoa New Zealand and the Pacific Islands.

These include the **multilingual and diverse nature of Pacific Peoples,** strong ties with other Pacific countries, specific obligations Aotearoa has to Pacific Realm countries, repeated impact of outbreaks, epidemics and pandemics, demography and location of Pacific Peoples in Aotearoa, housing, community structures and networks, employment and health inequities.

20 Principles of Māori Data Sovereignty

21 https://forms.justice.govt.nz/search/Documents/WT/wt_DOC_104833137/Report%20on%20the%20Trans-Pacific%20Partnership%20Agreement%20W.pdf

22 https://waitangitribunal.govt.nz/inquiries/kaupapa-inquiries/health-services-and-outcomes-inquiry/

23 www.kahuiraraunga.io/tawhitinuku

24 Principles of Māori Data Sovereignty

4.3.1 Diversity of the Pacific population in Aotearoa and the Pacific Region

Over 8% of the population of Aotearoa identify as being of Pacific ethnicity, with over 300,000 people living in the Auckland region. 'Pacific Peoples' is an umbrella term that includes 17 different ethnic groups who have ancestral ties to Pacific Island countries. There is also a growing mixed ethnic group with Māori. **Pacific Peoples residing in Aotearoa are highly diverse and multilingual**, with the predominant languages being Samoan, Tongan, Cook Islands Māori, Tokelauan, Niuean and Fijian. An understanding and embracing of this diversity is essential for pandemic planning and preparedness; for example, effective communication of public health messages and health promotion needs to be provided by trusted members of these diverse communities in multiple languages[25]. **Trusted leaders** and those with lived experience provide an effective 'feedback loop' to bolster public health intelligence and decisions about resource allocation to those communities, aiding the implementation of non-pharmaceutical measures, and in providing language and communication assistance. **Access to data[26]** relevant to the prevention and control of infectious diseases, such as case notifications, hospitalisations, multimorbidity and risk factor information, deaths and immunisation rates, also needs to be provided at the level of specific ethnic groups – i.e., not treating Pacific Peoples as a single homogeneous population.

4.3.2 Pacific Realm countries

There is an ongoing need to support South Pacific island nations to strengthen regional pandemic control measures and infectious disease surveillance. As part of the Realm of New Zealand, people from the Cook Islands, Niue and Tokelau, all have New Zealand citizenship. Tokelau is a dependent territory, and the Cook Islands and Niue are associated states. Aotearoa has very specific obligations to these Pacific Realm countries, including providing free travel and access to healthcare. This has important considerations for the prevention and control of infectious diseases, including legal obligations and the management of borders and the delivery of healthcare and immunisations.

4.3.3 The impact of outbreaks, epidemics and pandemics on Pacific Peoples

Pacific Peoples and Māori continue to be negatively impacted by longstanding inequities in healthcare in Aotearoa. Previous pandemics have had devastating and disproportionate impacts on Pacific peoples, including the 1918 influenza pandemic [35], and this inequity continued during the COVID-19 pandemic, with evidence of delayed care and a slow public health response for those at highest risk [36]. Measles was exported from Aotearoa to Samoa in 2019, just prior to the emergence of SARS-CoV-2, resulting in 83 deaths and 1868 hospital admissions, with ongoing impacts on the health system in Samoa [37]. This highlighted a **failure to protect Pacific Islands** and the need to have much better systems, community support and healthcare infrastructure in place to prevent transmission between Aotearoa and the Pacific islands, and reduce the impact of outbreaks, epidemics and pandemics in the Pacific Region as a whole[27].

The first small wave of COVID-19 in Aotearoa New Zealand was primarily transmitted by returning travellers and due to the ethnic origins of this group, cases were primarily in younger adults of European ethnicity, and of higher socioeconomic status. However, Pacific Peoples were overrepresented in locally acquired

25 Preliminary Report on the Pacific COVID-19 Case Review. Prepared by: Dr Corina Grey, Dr Siniva Sinclair, Dr Aumea Herman (Public Health Physicians, NRHCC Pacific COVID-19 Response Team)

26 N.B. This assumes that adequate (and accurate) information is already collected to understand the burden of disease, detect changes in risks/protective factors, detect changes in health practices, case/contact management, and intervention efficacy but in some cases what/how information is collected may not address information gaps e.g. for Pacific household attributes.

27 www.health.govt.nz/publication/health-sector-response-2019-measles-outbreaks

infections and severe outcomes during the first wave of infections [13]. In contrast, subsequent larger outbreaks, including the post-elimination phase Delta and Omicron variant outbreaks, had a major and disproportionate effect on both Māori and Pacific Peoples [24], with much higher rates of hospitalisations and deaths[28] compared to other ethnic groups.

While early decisions tend to focus on medical vulnerabilities, there are several overlapping **non-medical vulnerabilities** and costs related to social determinants and employment/occupations often experienced by Pacific communities; especially for those who are unable to work from home, require language support, and have additional childcare responsibilities. The combination of vulnerabilities compounds adverse outcomes and leads to over-representation of Pacific communities in outbreaks.

4.3.4 Demographic features of Pacific Peoples in Aotearoa of relevance to pandemic preparedness and the prevention and control of IDs

Approximately two thirds of Pacific Peoples in Aotearoa live in Auckland and around **half of this population reside in Counties Manukau**. This concentration of Pacific Peoples in tight knit communities has implications for both the spread of infectious agents and for the efficient targeting of public health measures. Auckland Airport is located in Counties Manukau and is a major source of employment for Pacific Peoples in the locality. This brings increased potential exposure to cross border and onward transmission of pandemic/PHEIC agents to the region. **Prioritising enhanced surveillance** in these communities would provide early detection of cross-border and community transmission.

Compared to other population groups, a higher proportion of Pacific Peoples live in larger, **multigenerational households**. This brings individuals at both ends of the vulnerable spectrum (very young and elderly) in much closer proximity (to each other and to people of working age) compared to other populations. This is compounded in some families by poor quality, crowded housing. Pacific Peoples are also overrepresented in occupations more vulnerable to exposure to infectious agents, including "essential worker" occupations such as healthcare, care homes, supermarkets and, as mentioned above, border workers. Pandemic planning and preparedness needs to consider how to protect those employed in these high risk occupations, with appropriate targeting of public health interventions[29].

Like Māori, Pacific peoples are, on average younger (median age 23, compared to 41 for Europeans) and have **higher rates of chronic disease earlier in life** compared to other ethnic groups. This information is important for the provision of healthcare and access to health services, including immunisation. Equitable rollout of vaccines requires targeted delivery to Māori and Pacific Peoples, with appropriate consideration of age and co-morbidity related eligibility for primary, secondary and booster vaccinations, and greater and more rapid access to funding for community-based initiatives.

Surveillance supports the early detection of community transmission of potential pandemic/PHEIC agents, and this needs to be targeted towards the more vulnerable groups, for example respiratory disease surveillance in Pacific Peoples. This requires moving beyond a centrally-controlled, proportionally-equal but inequitable approach, and enhanced access and oversampling of vulnerable groups.

28 www.health.govt.nz/publication/COVID-19-mortality-aotearoa-new-zealand-inequities-risk

29 www.health.govt.nz/system/files/documents/pages/research_report_qualitative_study_28may_redacted_watermarked.pdf

4.3.5 Pacific Peoples community structures, connectedness and networks

During the COVID-19 pandemic Pacific community networks were **mobilised rapidly and responded well** to information and communication shared on a regular basis. This included reliable information provided in different Pacific languages, by **trusted individuals**[30]. These were often **community leaders** who were well-connected and respected (e.g. church ministers), not just health professionals. **Connection to family, community, culture and faith** was identified as an important source of strength and resilience during the pandemic[31]. Any future response will need continued Pacific community and provider engagement and participation. Faith based groups are an integral part of Pacific Peoples culture and community structure.

The COVID-19 Delta variant outbreak was largely focused in Auckland. Although not shown conclusively, there was evidence that this lineage entered the country through an isolation and quarantine facility in Auckland. The Delta outbreak featured a high proportion of cases in Counties Manukau and a large transmission event during the first wave associated with a Pacific Peoples church community. While this illustrated the potential for large gatherings to result in 'superspreader' events, it also demonstrated the ability of this community to respond rapidly to the outbreak, with effective communication, community support for the vulnerable, enhanced testing, contact tracing and immunisation. This resulted in a rapid decline and virtual disappearance of the lineage associated with this event, in contrast to other lineages and transmission chains, which persisted into the post-elimination phase [38].

Recognised Seasonal Employer (RSE) workers, and other seasonal work visa holders, represent another vulnerable population which need to be considered for future preparedness. Information on how this group, with relatively restrictive health service eligibility, were affected by public health measures during the COVID-19 pandemic is largely unknown. Such information would be valuable for future planning.

The aforementioned points, highlight the need for relationships with local health providers established during the COVID-19 pandemic need to be **maintained in place, during interpandemic periods**, including faith-based providers and other community groups. Pacific communities continued to demonstrate their strength and resilience when existing networks were reactivated effectively during the Auckland floods in 2023; providing healthcare, community support and public health services. This highlights the value of resourcing and maintaining these networks during interpandemic periods, and the need to avoid 'dialling down' of both hard and soft infrastructure during these periods.

> **"During the COVID-19 pandemic Pacific community networks were mobilised rapidly and responded well to information and communication shared on a regular basis."**

30 "The 'Trusted Faces and Trusted Places' model that was used decentralising the delivery of vaccinations, testing, and COVID-19 Care in the Community resulted in empowering the community by shifting workforce and resources and placing less strain on traditional health systems that are typically overwhelmed in the event of epidemics and pandemics." Quote from Capital, Coast and Hutt Valley District Community Provider Debrief Report, July 2022.

31 www.mhwc.govt.nz/news-and-resources/pacific-community-connections-key-to-wellbeing-during-COVID-19/

4.4 Surveillance

Infectious disease surveillance systems are important **epidemiological tools to monitor disease burden, monitor trends, and identify outbreaks**. They are needed to provide situational assessment in a fast-moving environment. Surveillance data provides information to public health authorities so they can better conduct risk assessments, plan appropriate control and intervention measures, determine the impact of public health interventions, allocate health resources, and make case management recommendations.

Much of the surveillance of infectious diseases in Aotearoa New Zealand is underpinned by the legal requirement under the Health Act and amendments including the Health (Protection) Amendment Act 2016. This legislation requires medical practitioners, and laboratories that handle human specimens, to notify named diseases[32]. The primary purpose of this notification system is to prompt public health action to manage the case and reduce risk.

Surveillance systems in Aotearoa New Zealand are reliant on infectious disease diagnostic data. Traditionally this data has been generated in a laboratory, although during COVID-19 community testing became widely used, due to the availability of rapid antigen tests this changed due to community testing. Transition from laboratory-based to community-based testing needs careful planning. This planning needs to consider things such as the current pandemic strategy, the impact on the collection of national surveillance data, the sensitivity and specificity of the tests in each setting, the expected positivity rates, the time taken to generate test results compared to the accuracy of results, and laboratory capacity.

In addition to surveillance of notifiable diseases, Aotearoa New Zealand also undertakes **sentinel surveillance** for other common diseases of public health importance, such as acute respiratory infections. Sentinel surveillance is the most efficient way to collect high-quality data in a timely way as it reduces the resources required, and efforts can be focused on a limited number of carefully selected surveillance sites. It aims to minimise the impact of the disease by providing useful information to public health authorities so they may better conduct risk assessment, plan appropriate control and intervention measures, allocate health resources, and make case management recommendations.

4.4.1 Early warning systems

Early warning systems are used to support the early detection of aberrant infectious diseases. The WHO recommends the layering of multi-source surveillance systems to support the triangulation of accurate and timely information, and to provide resilience should one system be disrupted or fail during an emerging event.

Aotearoa New Zealand's acute respiratory illness surveillance system is one of the most timely national systems in the world, with **real time reporting** enabled nationally using the web-based EpiSurv notifiable disease platform, routine reporting within a week of multi-source data generation, and the availability for ad hoc epidemic intelligence to be providing regarding emerging events within a matter of days. The acute respiratory illness surveillance systems, established following the 2009 influenza A (H1N1) pandemic, include the sentinel hospital-based severe acute respiratory infection (SARI) and general-practice (GP) based influenza-like illness (ILI) surveillance systems. These systems were tested for the first time during the COVID-19 response. High-quality hospital SARI surveillance with accumulation of historical data on severe respiratory diseases and infections allowed rapid comparative assessment before, during and after the COVID-19 pandemic for better understanding risk factors, clinical severity, impact on mortality/morbidity and public health and social measures. ILI surveillance proved to be less resilient, due to the demands on primary healthcare and changes to patient flow occurring

32 www.tewhatuora.govt.nz/publications/communicable-disease-control-manual/

through the pandemic, so this system continued with only the virological surveillance component.

The availability of multiple surveillance sources enables construction of a severity pyramid (Figure 5) to quantify the relative burden on primary care and hospital services, and to estimate key parameters such as IFR.

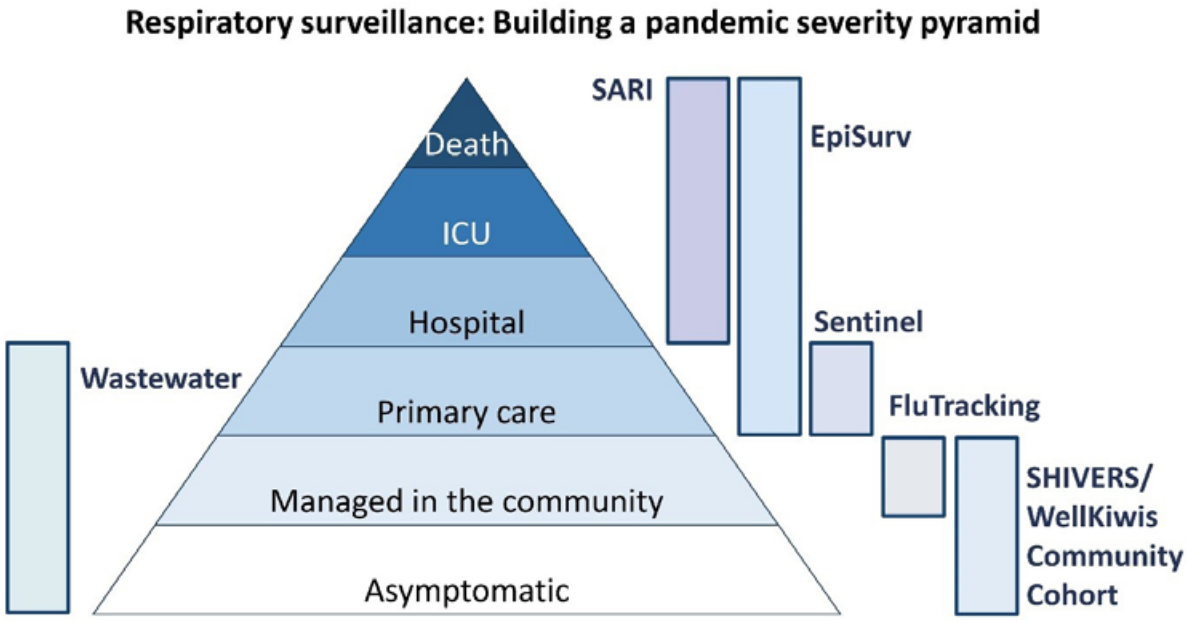


Figure 5. Construction of a pandemic severity pyramid from multiple surveillance sources in Aotearoa New Zealand during a respiratory pandemic.

The **Early Aberrant Reporting system** (EARS) is a widely used surveillance tool that applies aberration detection algorithms to surveillance data and flags anomalies to help with the timely detection of disease outbreaks. The Institute of Environmental Science and Research (ESR) has adapted Aotearoa New Zealand's EARS from the original Centers for Disease Control and Prevention (CDC) version and the rare disease alerts. Event based surveillance through the notification of acute respiratory illness outbreaks to EpiSurv, syndromic surveillance systems, and EARS were important during the COVID-19 response for early warning and the targeting of resource, including when testing was limited.

4.4.2 Surveillance in the early stages of a pandemic

In the early stages of a pandemic special studies may need to be established, in addition to routine surveillance, to provide critical information on the characteristics of the evolving pandemic and the effectiveness of control measures, enabling Aotearoa New Zealand to respond more effectively to the pandemic[33]. Examples of these pandemic studies include intensive **FFX studies**, **household cohort studies and population-based age-stratified sero-epidemiological studies[34].** These studies collect data needed to provide a robust assessment of transmissibility and severity

33 Reviewing the time to detection, notification and response to an outbreak can be carried out using timeliness metrics, such as a 7-1-7 Bottleneck Analysis

34 www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance/early-investigations

and population at risk (e.g. incubation period, generation time, health care seeking, R_0, clinical attack rates, secondary attack rates, proportion symptomatic/asymptomatic infection, pre-existing immunity, geographic distribution etc.) [10].

Obtaining multiple clinical samples from the few Aotearoa New Zealand cases in a pandemic (and potentially from close neighbours such as Australia) would be advantageous to provide control material for validation of diagnostic assays, development of assays and understanding the clinical presentation. The time needed to obtain ethical approval for these initial studies may prevent acquisition of samples, delaying access to valuable information and capabilities. Availability of **prior ethical approval** or access to a streamlined application process would assist timely sample acquisition.

4.4.3 Wastewater surveillance

Wastewater sampling has provided a new surveillance tool that was introduced during the for COVID-19 pandemic and can quantify the amount of SARS-CoV-2 RNA in the wastewater as a **proxy for the prevalence of the virus in the relevant catchment**. Wastewater sampling also has the potential to be used for other infectious diseases and is a useful complement to traditional surveillance systems [39], as it is non-invasive and sufficiently sensitive to pick up undetected cases in a low prevalence setting [40] and can test for multiple pathogens in the same sample and quantify the relative contribution of different genomic subtypes; and is unaffected by access to diagnostic testing or healthcare-seeking behaviour. It cannot however differentiate infection from illness burden or identify the epidemiological features of affected people.

4.4.4 Surveillance of vector-borne diseases

Surveillance of vector-borne diseases involves an integrated, cross sectorial approach involving **human health, animal health and the environment**. Case-incidence is collected through the normal notifiable disease surveillance system, with information on a cases recent international travel, as infections may have been acquired overseas.

Vector-borne disease risk is determined by the presence of **competent vectors**, the vector population size, and the proximity to human populations. Vectors capable of spreading infectious diseases are already in Aotearoa New Zealand[35]. However, climate changes threaten to enable new disease-carrying vectors to become established in Aotearoa New Zealand and enable others to increase their geographic range [41].

Vectors in Aotearoa New Zealand are **routinely monitored** to provide an understanding of their numbers and geographical spread, as well as to identify any new species that may have recently entered the country. Measures are taken to actively prevent the importation of new vectors into Aotearoa New Zealand, such as fumigation of aircraft and monitoring of international ports, however the number of times foreign vectors have been identified in Aotearoa New Zealand is increasing [41].

The information gathered through surveillance provides valuable insights into the dynamics of vector-borne diseases, such as their seasonal variations, geographic spread, and changes in vector behaviour. International examples of surveillance include interactive apps and web-based tools[36] and regional initiatives[37,38,]. It also provides information on the risk vectors pose to Aotearoa New Zealand, and the future surveillance that is needed to minimise the risk of new vectors becoming established. Knowledge from vector surveillance activities is essential for implementing and monitoring the success of vector control

35 www.reports.esriuk.com/view-report/553afde5b223492a9679379ebcf0b991/NZ

36 www.mosquitoalert.com/en/inovec

37 www.cdc.gov/mosquitoes/guidelines/west-nile/surveillance/environmental-surveillance.html

38 https://pacmossi.org

measures [42] (such as insecticide spraying, larval source reduction, and the distribution of bed nets and repellents[39]) and determining what future surveillance is needed.

4.4.5 Surveillance-informed severity assessment: a case study of influenza

This section describes an influenza-specific framework to assess pandemic influenza severity. However, the framework could be adopted to other respiratory viral threats, such as SARS-CoV-2 and RSV.

In 2011, the World Health Assembly adopted a report by the Review Committee on the Functioning of the International Health Regulations (2005) and on Pandemic Influenza (H1N1) 2009. The committee recommended that WHO should develop and apply measures that can be used to assess the severity of every influenza epidemic, whether seasonal or pandemic. A severity assessment provides the information needed to determine the timing, scale, emphasis, intensity and urgency of pandemic response actions. The report stated that, "by applying, evaluating and refining tools to measure severity every year, WHO and Member States can be better prepared to assess severity in a timely manner in the next pandemic"[40].

Severity assessments should be conducted in the **early phase of a pandemic** and regularly thereafter as the pandemic evolves. Since the World Health Assembly highlighted this need, WHO has made great progress on developing a framework on **pandemic influenza severity assessment** (PISA). The framework was developed through several meetings, expert consultations, collaborative WHO projects and the establishment of a technical working group (TWG) on pandemic influenza severity assessment. The framework defines influenza severity in terms of three indicators: transmission, seriousness of disease and impact.

The **Southern Hemisphere Influenza and Vaccine Effectiveness Research and Surveillance (SHIVERS)** programme, initially funded by the United States CDC during 2012-2016, established modern surveillance methods which became essential national infrastructure and emergency response capability. To date, Aotearoa New Zealand's Manatū Hauora|MoH continues to fund hospital-based and general practice-based surveillance as components of the national acute respiratory illness surveillance system. These are important national surveillance capabilities to support the response to future influenza pandemics or other severe respiratory viral threats.

Aotearoa New Zealand's hospital-based SARI surveillance and GP-based ILI surveillance provide three indicators to define influenza severity: morbidity/mortality impact, seriousness of disease and virus transmission. These are reported by Aotearoa New Zealand regularly.

4.4.5.1 Morbidity/mortality Impact

Morbidity/mortality impact describes how the influenza epidemic or pandemic affects hospitalisation, ICU admission and in-hospital death. It is measured by influenza-associated SARI hospitalisation or ICU admission or in-hospital death incidence rates using hospital-based SARI surveillance (Figure 6).

> **"Severity assessments should be conducted in the early phase of a pandemic and regularly thereafter as the pandemic evolves."**

39 www.who.int/news-room/feature-stories/detail/new-frontiers-in-vector-control

40 Note the WHO report uses the term "severity" to refer to population-level outcomes. In this report, we use "severity" to refer to per infection risks and we use the term "impact" to refer to the aggregate impact across the population.

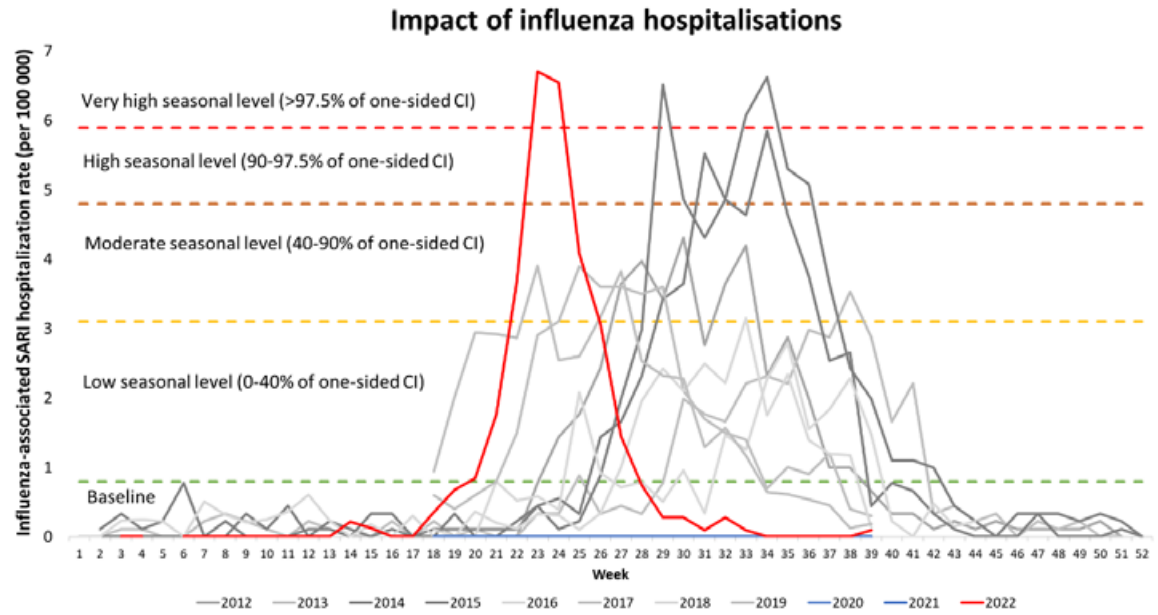


Figure 6. Monitoring the impact of influenza hospitalisations between 2012 and 2022 in Aotearoa New Zealand. Source: Unpublished data, ESR.

4.4.5.2 Disease seriousness

Seriousness of disease (i.e., clinical severity) indicates the extent to which individuals get sick when infected with the influenza virus. It is measured by the ratio of influenza-associated SARI-ICU admission/ influenza-associated hospitalizations using hospital-based SARI surveillance (Figure 7).

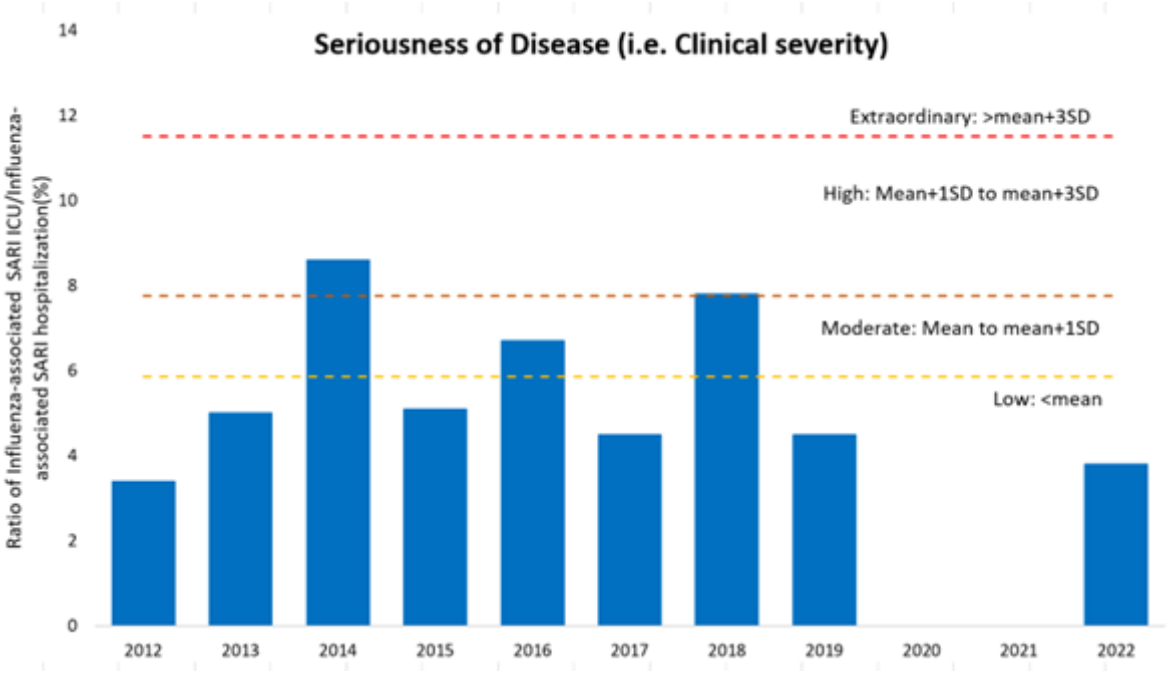


Figure 7. Monitoring disease seriousness using the ratio of influenza-associated SARI-ICU admission/influenza-associated hospitalizations using hospital-based SARI surveillance between 2012 and 2022 in New Zealand. Source: Unpublished data, ESR.

4.4.5.3 Virus transmission

Virus transmission reflects the ease of movements of the influenza virus between individuals and communities. It is measured by influenza-like illness (ILI) incidence rate and influenza-associated ILI incidence rates through GP-based ILI surveillance (Figure 8).

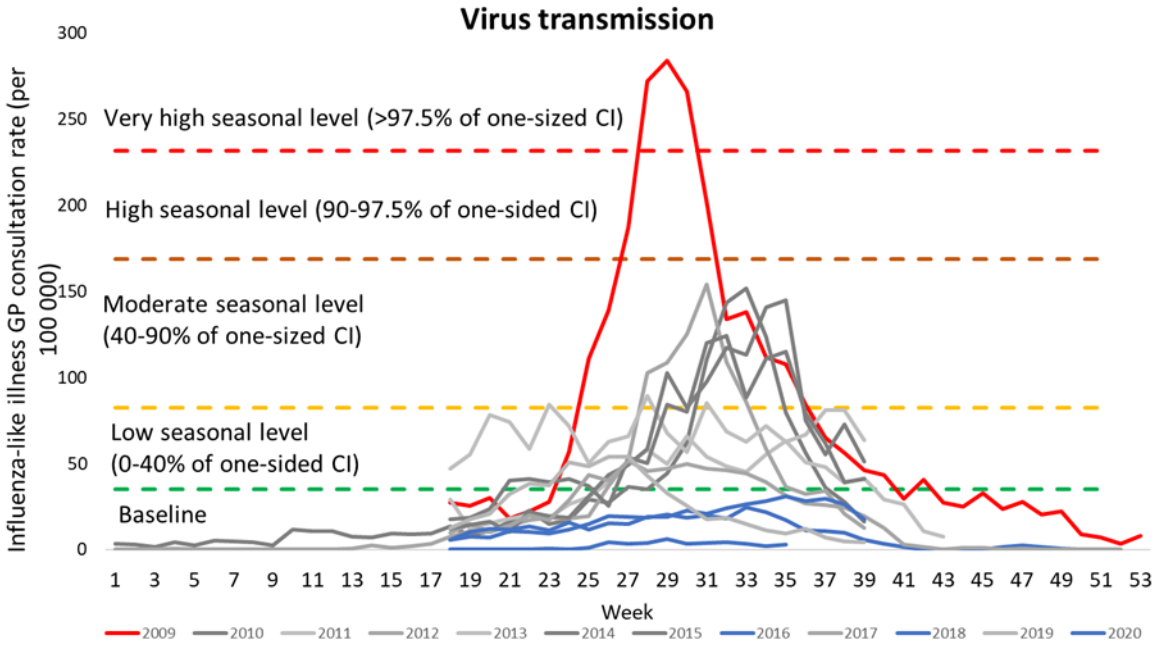


Figure 8. Monitoring virus transmission by measuring the influenza-like illness (ILI) incidence rate and influenza-associated ILI incidence rates through GP-based ILI surveillance between 2009 and 2020 in Aotearoa New Zealand. Source: Unpublished data, ESR.

4.4.6 Behavioural surveillance data and insights

Behavioural surveillance is the ongoing systematic collection, analysis, and interpretation of behavioural data [43] that is, in this context, relevant to understanding:

1. how public behaviour may influence the spread of a pandemic agent and,
2. how possible pandemic response measures might affect behaviours.

Such data can be obtained from a range of sources including **behavioural surveys** of a representative population sample, and more passively collected digital data (which is subject to privacy considerations e.g. mobility data). These data can then be used to inform both infectious disease modelling and public health decision-making.

In **modelling**, these data allow more accurate forecasting of possible caseloads and better estimation of the future epidemic trajectory under different policy options. Additionally, it may enable estimation of the potential for a pathogen to spread in a population even in situations where there are few or no data on notified cases, for example because community transmission is not yet established or has been eliminated [44]. Behavioural data that are particularly useful in modelling are those describing patterns of contact between people in the population, and how these patterns might change with interventions, and the magnitude of any spontaneous behavioural change.

In public health decision-making, behavioural data (and the outputs of above mentioned modelling) allows for **more informed choices** to be made around control measures. The behavioural data

that can be utilised in this setting is wide-ranging but can include, for example, the likely level of adoption of measures in the population and identified barriers to widespread uptake of these measures. An example of the type of data that might be collected can be seen in the WHO tool for behavioural insights on COVID-19[41]. Well-designed behavioural surveillance data collection is:

- evidence-based;
- able to be rapidly and regularly applied;
- simple and flexible to adjust to the changing situation;
- low cost and cost effective; and
- representative of the population.

There is often a **trade-off between rapidity of data collection and representativeness**. For example, the WHO survey tool for behavioural insights on COVID-19 utilises online surveys, with a 36-48 hour data collection window. This allows rapid data collection but limits the participation of potentially important population groups for transmission of and illness from pandemic pathogens, such as the elderly, migrants, homeless people and other vulnerable groups. Phone interviews over the same time frame are suggested by WHO as a supplement to (or instead of) online surveys to mitigate the risk of under-representation of important groups. However, phone interviews might also not reach all relevant groups, and other methods (such as snowball sampling [45]) have been used for data collection in populations historically under-served by, and poorly represented in health systems.

In addition to data arising from the use of specific behaviour data collection tools described above, there data that are, or could be, routinely collected (often for purposes other than behavioural research) that would provide useful behavioural insights if collated. Examples of such information include: public transport use; cell-phone use; border crossing data; frequency of use of legislative powers (e.g. police call outs relating to breaches of health orders); claims for any government sick leave subsidies; school absences; data held by iwi-Māori leadership and Pacific groups; and data relating to faith-based gatherings. Although such data would be useful in a pandemic setting, there are substantial barriers to its use including the lack of systems to rapidly collate such data, and legal and ethical issues around such data collection.

Given the rapid need for information in the early stages of a pandemic, it is essential to have **knowledge of pre-existing data collection tools** that can be in use prior to (or rapidly modified for use in) an unfolding pandemic. This includes both specific survey tools, having a developed plan for collating routinely collected data (with the plan covering where data could be obtained, how it could be obtained and used, and considered legal and ethical issues and Māori Data Sovereignty – see **Section. 4.2.4**) and building connections and trust between government and Māori and Pacific groups. These sources of information can provide quantitative behavioural data, and help to identify under-represented population groups where other data collection methods might be used, and areas where qualitative research might be used to gain more nuanced insights (for example to understand why certain beliefs are held[42]). Additionally, it is important that behavioural data is **collected regularly and consistently over time**. For example, data from regular behavioural surveys during the COVID-19 pandemic in Australia and the United Kingdom (UK) has been found to be highly predictive of changes in transmission [44, 46].

41 www.who.int/europe/tools-and-toolkits/who-tool-for-behavioural-insights-on-COVID-19

42 www.afro.who.int/publications/social-and-behavioural-insights-COVID-19-data-collection-tool-africa

4.5 Diagnostics

4.5.1 Diagnostic assays

The availability of timely, accurate diagnostic tests is crucial for **diagnosis (for clinical and public health purposes), surveillance and screening**. The sensitivity and specificity of any test for a pandemic pathogen will depend on the following variables: test type, sample type, quality of specimen collected, the transport and storage conditions, the methodological differences in the laboratories performing the test, and the type of test used. **PCR-based methods** are often considered the gold-standard diagnostic assay, with other assays used to complement the findings of PCR testing. PCR-based approaches have a fast turn-around times and the ability to perform at high throughput, which is critical in assisting public health measures. If well-designed, PCR assays also have high sensitivity and specificity and new primers can easily be generated or modified allowing for adaptation of tests, for example if new variants arise. Additionally, the use of PCR-based methodologies reduces the chance of laboratory-acquired infections, as these non-culture-based methods minimise the chance of laboratory staff being exposed to large quantities of viable infectious agent.

Emergence of a new pathogen means that diagnostic assays may not be available and may need to be developed. International and national collaboration is critical in rapidly obtaining new diagnostic protocols and reagents, including positive controls[43], as well as the rapid sharing of alerts regarding emerging pathogenic strains of concern. Where positive controls are not readily available synthetic controls can be rapidly developed. Aotearoa New Zealand has a functional **national laboratory network**, and contacts with international agencies, both of which need to be maintained. For influenza availability of protocols and reagents are coordinated through Global Influenza Surveillance Response System (GISRS) network, public agencies such as the World Health Organization and WHO Collaborating Center for influenza at the United States CDC via the International Reagents Resource (IRR). Similarly, other laboratory networks are available including Australia's Public Health Laboratory Network and the Laboratory Response Network, established by the CDC.

Continued **horizon scanning of advancements in diagnostic capabilities** and test performance for pandemic pathogens will be important to ensure core testing services are available, accessible, of high quality and can be scaled proportionately to the pandemic pathogen(s) of concern. Continual assessment of effective and efficient diagnostic testing service delivery models for different pandemic scenarios will inform and advance commissioning and procurement options/plans for the end-to-end testing process, including innovative ways of working across sectors and within communities. Maintaining and improving established processes to monitor and/or regulate testing products to ensure there is no material risk of harm to a public health response or the public whilst ensuring there is an enabling environment for **scientific innovation and research** within Aotearoa New Zealand during a pandemic.

4.5.2 Delivering diagnostic results

Upscaling diagnostic services takes time. Delays in establishment of new diagnostics service may result in delays in mobilising a diagnostic response. Factors that impact on ability to respond may include the lack of a suitable validated test(s) in a Aotearoa New Zealand laboratory, lack of trained staff (requiring ongoing recruitment, training and retention), testing only being available in limited number of laboratories or with low-throughput, location and capacity of sample collection facilities; disrupted sample transport networks within Aotearoa New Zealand, disruption to testing supply chains and the lack of laboratory resources including trained staff, equipment and

43 For example access to cDNA controls from international reference laboratories such as the Victorian Infectious Diseases Reference Laboratory (VIDRL) https://www.vidrl.org.au/

consumables; time to enable data and digital end to end laboratory solutions (from test ordering to reporting and analysis). **Rapid allocation of funding** is required in the response phase of a pandemic to enable diagnostic laboratories to shift from routine diagnostic testing to testing for a major public health response.

It is essential to **maintain laboratory testing knowledge, capability and capacity that was needed during the COVID-19 pandemic** as well as that established during COVID-19. These skills will be critical for ongoing pandemic surveillance and to support public health responses to cases of concern and outbreaks. Further assessment (using established international assessment tools incorporating the Aotearoa New Zealand context and Te Tiriti o Waitangi) of the existing public health laboratory networks diagnostic capability and capacity for a range of outbreak pathogens at a national, regional, local and community level will identify opportunities to strengthen the diagnostic services preparedness and response. In addition, this assessment should support decisions to ensure right sizing of diagnostic services and supply chains (from test order to result reporting and analysis) for a range of outbreak pathogens enabling timely and equitable access to testing services to support public health decisions and action. **Improved measures and monitoring of laboratory outputs** for public health purposes will support ongoing preparedness and risk assessment.

4.5.3 Digital management

Digital enablers are essential to diagnostic testing, laboratory services and delivery of timely information to inform a response. These systems support the end-to-end testing process and sample tracking (from decision to test, sample collection, sample processing and testing, reporting and data analysis). For example, the availability of electronic test ordering facilitated rapid requesting and paperless collection of samples, quick sample registration in the laboratory that contributed to faster availability of both individual test results and collated data, and national collation of uniform data. Ongoing **horizon scanning of advancements in digital technologies** is essential to ongoing public health surveillance, pandemic preparedness and response. These technologies need to be assessed adherence to laboratory data standards and reporting, development of laboratory and diagnostic digital platforms and repositories for testing data and information, and the ability to provide a coordinated national approach to digital management.

4.5.4 Rapid antigen tests

Rapid Antigen Tests (RAT i.e. point-of-care tests), if sufficiently accurate, may be especially useful to support control measures and case management in moderate or high prevalence situations, because of their very rapid turnaround time. RAT results can be returned within the same clinical encounter or performed at home. This reduces demand for centralised testing facilities, technical expertise and laboratories, which all have limited capacity and may not always be able to meet the needs of patients, caregivers and health workers. When use of RATs is evaluated, consideration also needs to be given to the processing capability of the diagnostic laboratory network together with the strategy that is being considered. The impact on surveillance of the outbreak also needs to be considered as RAT results are less likely to be captured at a national level. During a pandemic multiple different RATs are likely to have been developed in a short period of time. We need a rigorous system to evaluate the available tests to determine which are accurate and appropriate for use in Aotearoa New Zealand.

RATs generally have lower sensitivity and reasonable specificity compared to PCR tests [47]. However, it is essential to recognise the **trade-off between sensitivity and processing time where diagnostics are being used to support a test-trace-isolate-quarantine approach**. For example, a test with 80% sensitivity that returns a result almost immediately may be more effective in reducing transmission than a test with 100% sensitivity but a 1 to 3-day processing time. This is particularly true for pathogens with significant presymptomatic transmission or short generation

intervals, because the first day or two after testing is likely to be the highest risk for onward transmission. Furthermore, RATs are likely to be indicative of the infectious period than PCR tests, which often pick up cases that are no longer infectious and therefore do not need to isolate [48, 49]. Future research on prospective and comparative evaluation of individual tests, either alone or in combination, and in different settings to identify the best way they can be used to develop effective diagnostic/clinical, surveillance/public health management pathways.

4.5.5 Pathogen characterisation

Typing methods discriminate between pathogens of the same species and are used to identify outbreaks and detect changes over time. Phenotypic-based methods have traditionally been used to facilitate pathogen typing although in the last decade **genomic sequencing capability** has become integral to typing of infectious diseases, with international sharing of genomic data, building on the longstanding sharing of other typing results, strengthening surveillance activities. For further information see the genomics section.

4.6 Mathematical Modelling

Mathematical and computational modelling is a key capability in understanding and responding to a pandemic threat. Models are especially valuable in the early stages of a pandemic when important strategic decisions may have to be made quickly, and often in circumstances when uncertainty is high and direct empirical data is limited. This also applies when a new disease strain or variant of concern emerges. Early estimates key epidemiological quantities, such as the basic reproduction number (or transmission advantage over existing variants), generation interval, number of undiagnosed cases, degree of pre-symptomatic transmission, and IFR typically come from the mathematical modelling community internationally [50-52][44].

Developing and maintaining computational mathematical models of infectious disease dynamics that are tailored to the Aotearoa New Zealand population and can be easily applied to a range of different pathogens, including novel or emerging pathogens, is an important component of **pandemic preparedness**. It is essential that high-quality models, and the expertise needed to run them with the appropriate epidemiological inputs and interpret their output, are ready in advance of the emergency. This requires strong, ongoing **communication and relationships between mathematical modellers, policymakers and public health** so that the necessary data is available to use as model inputs, suitable modelling questions are designed, and the limitations and interpretation of the raw data and model outputs are clearly understood [53, 54]. Modelling capability during the COVID-19 pandemic has been provided primarily by the university sector, with support from Crown Research Institutes and the private sector. Enhanced capability to design, develop and/or interpret models of infectious disease dynamics within Aotearoa New Zealand's public service, in partnership with academic researchers, would make for a more robust and sustainable system.

Modelling can help provide an **assessment of the potential impact** of a pandemic in Aotearoa New Zealand before local transmission is established and therefore before any local surveillance data is available. It may also be used to evaluate the potential **effect of different control measures** and contribute to strategy development. It would be valuable to have an interactive model or decision support tool to enable decision makers to explore likely healthcare demand for a novel pathogen, and how this might change under different strategic responses. For example, interactive models such as COVIDSim[45] allow exploration of epidemic dynamics for a range of user-specified parameters representing population

44 www.imperial.ac.uk/mrc-global-infectious-disease-analysis/COVID-19/report-1-case-estimates-of-COVID-19
45 http://COVIDsim.eu

demography, epidemiological characteristics (such as R_0, latent period, infectious period), clinical severity, and various types and timings of intervention. **Decision support tools** are designed to incorporate emerging and uncertain epidemiological information in real-time to provide an impact assessment and an evaluation of the relative cost and benefits of different response options for example, the Australian Health Management Plan for Pandemic Influenza Decision Support Tool [10]. These types of tools could be adapted for to the Aotearoa New Zealand population and context. These should not be framed as decision-making algorithms, nor can they replace context-specific epidemiological advice and modelling and the need to consider other relevant sources of evidence. However, it would be beneficial to have flexible, ready-made tools allowing decision makers to explore potential pandemic impact and alternative responses, as opposed to having to build these from scratch during an emergency.

Once local transmission is established, modelling and data analytical tools provide the capability to **integrate a range of raw epidemiological data streams** to account for known biases, reporting lags and uncertainty to provide real-time situational assessment and forecasting. Scenario models can also be used to compare epidemic trajectories and impact under alternative strategies or policy options over longer periods of time. There would be benefits to incorporating additional factors into epidemiological models. These include quantifying economic impacts or indirect impacts, as well as the direct impacts of the pathogen concerned, and incorporating the effects on transmission of spontaneous behavioural changes in response to the outbreak [55, 56]. Models would benefit from real-time data on behavioural surveillance [44, 46] and regular testing of a representative sample to provide estimates of infection prevalence [57, 58] nationally and in important subgroups, such as Māori and other high-risk groups.

4.7 Genomics

Until the COVID-19 pandemic, genomic studies of viral outbreaks had typically been retrospective (for exceptions see [59-61]), where the evolution and spread of a virus within a population is only realised after the fact. However, recent advances in **next generation sequencing** (i.e. Oxford Nanopore) can generate whole viral genomes directly from patient samples within several hours of the sample being taken. Using these technologies, genomic data were rapidly generated from SARS-CoV-2 samples, enabling **real-time genomic surveillance** during the COVID-19 pandemic.

It is vital to harness genomic data to enable tracking the evolution, molecular epidemiology, population dynamics and transmission chains of an outbreak. These results will assist more effective deployment of responsive practical measures, including targeted public health interventions, and thus enhance Aotearoa New Zealand's response to an infectious disease outbreak. **Phylodynamic** approaches provide a powerful way to accurately estimate key parameters of a viral outbreak. These parameters include: the effective basic reproductive number (R_e) – extending the R_e for individual virus lineages, which is difficult to obtain using incidence data; and the effective population size – which reflects the number of infected individuals. Advanced genomic analyses taken together with clinical data provide a means to identify viral mutations. This allows us to understand the changes that lead to differences in the functional aspects of a virus such as its transmissibility and virulence. When combined with geographical information, it is possible to reveal **pathways of viral spread** (including from the global population), domestically and at the community level (who acquires infection from whom), which can support **contact tracing** efforts in elimination phases. The results can be used to direct public health interventions (e.g. quarantine), highlight transmission hotspots to target community testing, identify super-spreaders and assess the impact of other interventions such as travel restrictions and border closures.

There is an urgent need to ensure Aotearoa New Zealand's capacity and capability for real-time genomics and its integration into public health is maintained and expanded. During the COVID-19 pandemic, sequencing of SARS-CoV-2 was performed at three ESR sites, located throughout the country. Since 2020, ESR have expanded their capability in genomics further. Nevertheless, it is vital that this expertise is maintained and improved, enabling genomic data generation to be more efficient and equitable. For example, there is reliance on individual diagnostic laboratories to send clinical samples to an ESR site. Combined with the resource demands on responding laboratories, this contributed to **regions of the country being underrepresented** or missing from genomic data analysis at times. Building routine and surge capacity to generate pathogen genomics data within diagnostics laboratories, along with IT infrastructure to ensure these data are shared with relevant stakeholders for example, would ensure rapid, genomics-informed surveillance nationwide. Further, the **bioinformatic and genomic epidemiology and modelling expertise** needed to analyse these data are currently very limited to only a small team across ESR and academia – a team which currently lacks gender and ethnic diversity. It is therefore vital to build capability in this area.

4.8 Contact tracing

Contact tracing is a vital part of an infectious disease outbreak response. It is the process used identify potential new cases before they infect others. Traditionally contact tracing has been performed by Aotearoa New Zealand Public Health Units using case interviews, although other agencies including general practice, family planning, youth and student health services, maternity and prison services can conduct contact tracing depending on the outbreak and expertise required. This **manual contact tracing** is widely used, and generally associated with improved control of infectious disease outbreaks.

A **Manaaki approach** was employed across many regions where iwi, marae and community organisations given their knowledge of their respective communities and as trusted, known persons joined the Public Health efforts for contact tracing. This ensured a tikanga and cultural approach was layered into the process for appropriateness and comfort to cases in sharing crucial information.

However, it is **labour intensive** and is reliant on cases to both remember and identify their contacts. Furthermore, during large outbreaks there are likely to be delays following up the contacts of new cases may reduce the efficacy of manual contact tracing.

During the COVID-19 pandemic, widespread use was made internationally of **digital contact tracing** systems, such as smartphone apps using QR location code scanning, Bluetooth proximity technology, or GPS tracking. Access to digital diaries assists contact identification by helping cases remember where they have been while infectious and identify who they have come into contact with. The data collected by these apps can be managed and used in a variety of ways, which prioritised privacy to varying extents. The success of digital contact tracing is dependent on app adoption, which can be used exclusively or in conjunction with manual contact tracing.

In Aotearoa New Zealand, the "**NZ COVID Tracer" app** was developed and deployed in 2020. Initially, this used QR code scanning or manual location entry to create a digital diary, which could be voluntarily shared with health officials following a positive test result. Health authorities would typically publish a list of public exposure locations or follow up with individuals where a location had a known attendance list, as part of a **test-trace-isolate-quarantine** operation.

Later, **Bluetooth proximity functionality** was added to the app. After testing positive for COVID-19, app users could choose to share their anonymised device identification with a central

server, which was checked regularly by other users' devices. Users whose device had logged a contact with the case could then be sent an automatic notification under the Apple-Google Exposure Notification framework. This meant that the contact history of positive cases was not disclosed to health officials, a condition of the Apple-Google framework.

Uptake of the system was reasonably good: at its peak, there were almost **four million QR-code scans in a day**, from almost 1.5 million phones, and around 2.4 million devices exchanging Bluetooth handshakes[46]. There were times during the elimination phase where the system may have prevented major outbreaks and helped avoid the need for more disruptive and costly measures. Digitally supported contact tracing may be an important component of the response to future pandemic threats. Digital contact tracing should not be seen as even a partial replacement for traditional contact tracing carried out by highly trained public health professionals, but rather a **complementary capability** that can improve coverage, speed or scalability [62].

Aotearoa New Zealand would benefit from developing a strategy for digital contact tracing and being prepared to rapidly roll out a well-designed and inclusive system if needed[47]. The system design will depend on various factors, including the epidemiological transmission characteristics and the acceptable level of privacy trade-off, which may depend on the magnitude of the potential pandemic impact. Trust in the system and data confidentiality are paramount for it to be effective. **Scalability** is also an important consideration as some systems, such as location-based contact tracing, may work well at low infection prevalence but become unworkable at higher prevalence.

Figure 9 provides graphical representation of how surveillance, diagnostics, modelling, genomics and contact tracing can be incorporated into an integrated workflow during an outbreak [63].

46 www.auckland.ac.nz/en/news/2021/05/19/lessons-from-our-covid-tracing-app.html and https://github.com/minhealthnz/nzcovidtracer-data/tree/main/usage-data

47 www.auckland.ac.nz/en/news/2021/05/19/lessons-from-our-COVID-tracing-app.html

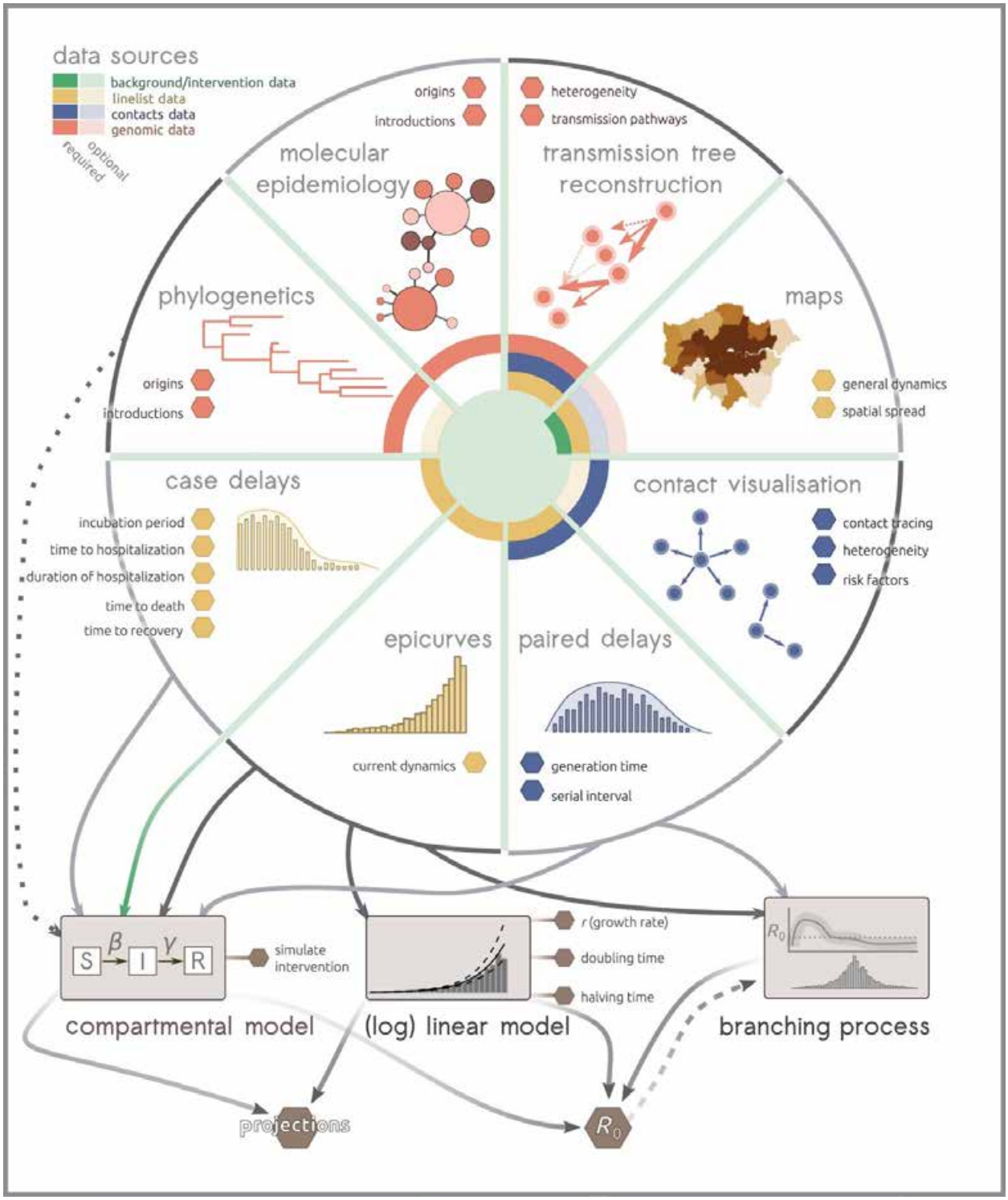


Figure 9. Example of outbreak analytics workflow incorporating surveillance, diagnostics, modelling, genomics and contact tracing. Figure legend in publication: "This schematic represents eight general analyses that can be performed from outbreak data. Outputs containing actionable information for the operations are represented as hexagons. Data needed for each analysis are represented as a different colour in the center, using plain and light shading for mandatory and optional data, respectively." Source: Outbreak analytics: a developing data science for informing the response to emerging pathogens, Volume: 374, Issue: 1776, DOI: (10.1098/rstb.2018.0276). [63].

4.9 Vaccines

In the event of a PHEIC for which there is an internationally available vaccine, the primary focus will be on independently evaluating the efficacy and safety of available vaccines and acquiring them rapidly and in sufficient volume to provide adequate population protection.

At the start of the COVID-19 pandemic in 2020, **Vaccine Alliance Aotearoa New Zealand** – Ohu Kaupare Huaketo (VAANZ) was established. This was part of the Government's COVID-19 vaccine strategy to support research and development, and the establishment of a national COVID-19 vaccine evaluation platform with the aim of developing and delivering domestic vaccine candidates.

In the event of an emergence of a 'disease X' pathogen similar to SARS-CoV-2, Aotearoa New Zealand will be highly unlikely to be able to develop and deliver a vaccine within the timelines achievable by the major international pharmaceutical companies. We will still be heavily dependent on accessing vaccines developed overseas as well as supporting international initiatives aimed at equitable distribution of vaccines[48]. However, developing and maintaining the capability to develop and deliver vaccines in Aotearoa New Zealand may bring the following benefits:

- The ability to manufacture vaccines locally **reduces the dependence on international supply** chains. Having local capability means we are more likely to be included in a **multinational, distributed manufacturing model**, providing greater access to newly developed and approved vaccines.
- If the pandemic persists beyond 2-3 years, we would have the potential to develop vaccines **tailored to the Aotearoa New Zealand population** (e.g. considering subpopulations with a higher prevalence of adverse reactions to globally-available vaccines).
- Enhance our ability to develop and deliver **vaccines for domestic animals and wildlife**. This could be useful for zoonotic diseases which may either be emerging (e.g. H5N1 vaccination of poultry) or to eliminate potential reservoirs of a virus.

Funding for vaccine development in Aotearoa is currently limited, but some resourcing may be available through the MBIE-funded Ribonucleic Acid (RNA) Development Platform[49].

4.10 Therapeutics

The availability of therapeutics that help prevent morbidity and mortality from infectious diseases is important for pandemic preparedness and response[50,51]. Therapeutics can provide critical support in controlling outbreaks by treating infected individuals and reducing transmission. By alleviating symptoms, reducing complications, and shortening the duration of illness, therapeutics help minimise the strain on healthcare systems and resources.

Antiviral medications, for example, can be used to inhibit viral replication and alleviate symptoms in patients already infected. Immunotherapies and monoclonal antibodies can enhance the immune response, neutralise pathogens, and improve patient outcomes. Other agents, such as corticosteroids, can help to reduce clinical severity and the management of severe cases. Monoclonal antibodies may lose their efficacy as a pathogen evolves, and this requires a rapid understanding

48 www.who.int/initiatives/act-accelerator/covax

49 www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/strategic-science-investment-fund/host-ribonucleic-acid-platform

50 www.nationalacademies.org/event/01-10-2023/pandemic-preparedness-accelerating-the-discovery-of-new-therapeutic

51 health.ec.europa.eu/events/broad-spectrum-anti-viral-therapeutics-key-tool-pandemic-preparedness-and-response-2022-11-22_en

of the genomics of new variants as they emerge, and the ability to modify these preventative and therapeutic agents to regain their efficacy.

Antimicrobial resistance is a global public health threat, associated with higher patient morbidity and mortality. This is due factors such as the increased length of time taken to start effective therapy and the higher toxicity of effective antimicrobials. Antimicrobial resistance in Aotearoa New Zealand is generally lower that rates observed overseas although there are several drug-resistant infections identified every year, both from endemic infections and those likely to have been acquired overseas.

Antimicrobials available for use in Aotearoa New Zealand are maintained by Pharmac. The process for adding new antimicrobials to the list is time consuming due to factors including the amount of evidence that is needed and the frequency of review. Pharmac's Named Patient Pharmaceutical Assessment (NPPA) process can be used to consider whether to fund a treatment for an individual patient, although this needs to be repeated for every patient. It would be challenging to navigate the current system if an antimicrobial was needed that was currently available in Aotearoa New Zealand.

Mechanisms must be in place to **identify new drug targets**, optimise existing treatments, and ensure their affordability, accessibility, and availability to vulnerable populations. Collaboration between national and international researchers, healthcare providers, pharmaceutical companies, and policymakers is essential to expedite the development, clinical evaluation, regulatory approval, and distribution of therapeutics in times of crisis.

Rongoa Māori was sourced across many whānau, iwi and Māori organisations and distributed during the Covid-19 pandemic to bring relief from ailments associated with SARS-CoV-2. Such remedies offered a culturally acceptable therapeutic alternative in alignment with and to a degree independent of other treatments and vaccines [64, 65]. Pandemic planning particularly in Te Tiriti o Waitangi when giving consideration to the ability for Māori to exercise their authority over their affairs and further the protection of their right to options should include rongoā Māori, the parameters that should be included and developed in partnership with Māori.

4.11 Primary healthcare and hospitals

Primary healthcare and hospitals play a critical role in managing and mitigating the impact of a pandemic. Primary healthcare serves as the frontline defence, providing primary prevention, early detection, and timely management of cases, as well as helping identify potential risks and educating the population. Hospitals are crucial in providing specialised care for those who are severely affected by the pandemic. They offer advanced medical facilities, specialised equipment, and a skilled workforce to diagnose, treat, and monitor patients with complex symptoms or complications. Hospitals act as a hub for critical care, ensuring that patients receive the necessary interventions and supportive treatments to improve their chances of recovery. They may need specialised equipment and skills, such as wearing PPE to manage infectious cases[52].

Furthermore, primary healthcare and hospitals collaborate closely to coordinate efforts in contact tracing, testing, and monitoring of cases. They work in tandem to identify hotspots, implement quarantine measures, and provide timely healthcare services to affected individuals. The availability of a robust primary healthcare system and well-equipped hospitals significantly contributes to controlling the spread of the disease, reducing the burden on healthcare resources, and ultimately saving lives.

52 www.cdc.gov/vhf/ebola/clinicians/index.html

The capacity of **the healthcare system is critical to responding to an infectious disease outbreak.** This is a large topic, and healthcare systems are complex, and a fuller evaluation of capacities in these areas is warranted. Considerations will include:

- For an effective response, it is critical to have a highly trained healthcare workforce. **This will require long-term investment in training, recruitment, and retention of workers.**
- **Capacity for continuing routine healthcare** services during a pandemic needs to be in place. This will require sufficient frontline staff, whānau connectors and liaisons, nurses, doctors, hospital beds, medical personnel, equipment, and supplies to be available to deliver routine healthcare effectively.
- Capacity needs to be available for treating **severe cases of pandemic disease**, including those requiring intensive care. Additionally, this is likely to be in the context of transmission control measures, requiring effective separation (depending on the pathogen this might require physical separation, separate healthcare teams, the ability to isolate ventilation systems between wards etc).
- Capacity needs to available for activities to **aid disease control**. This includes the collection samples for infection testing, and distribution of any treatments that may reduce transmission (e.g. antivirals).
- An effective "**care in the community**" service needs to be available those isolating in the community (i.e. not in a healthcare or quarantine facility). This will need to effectively deliver treatments and monitor patient health in order to support people isolating and aid to control transmission in the community.
- **Healthcare workers** (and their families) need to be protected from infection with the pandemic agent (PPE, training), as well as from burn-out and other mental health issues.
- Building confidence in the healthcare system and its resilience to increased workload is important, but also challenging.
- The community workforce in the form of **Kaimanaaki** lifted the overall response during the Covid-19 Pandemic from training as vaccinators, point of care diagnostics and contact tracing to bring a culturally responsive and delivered approach to Māori, Pacific Peoples and whānau living in lower deciles, rural and isolated communities.
- All health services have a **duty of care** whether interfacing or not to whānau and communities to be effective, safe and appropriate. In particular, effective healthcare delivery for Māori and Pacific people and other populations that are under-served by the current system needs to be improved and maintained to eliminate inequities of care and access that were highlighted throughout and following the COVID-19 pandemic.

4.12 Communication

Effective communication of reliable information between subject experts, decision makers, trusted advisors, the media and the general public is essential to ensure sound **evidence-informed decisions** are made, and that these result in good compliance with public health measures and alleviate anxiety. Strong, well-informed **communication networks** also help to counter the spread of **mis- and dis-information**[53].

Future pandemic preparedness and planning needs to consider the characteristics of effective communication during all phases of a pandemic/PHEIC, including the interpandemic period. This includes:

- Determining **who is responsible for communication** and who has the authority to deliver information at national and local/community levels. Identifying the trusted

53 https://thedisinfoproject.org

voices within communities, and how can they be empowered to deliver the most timely and appropriate advice.

- Identifying the most **reliable and trusted sources of information**, and the most appropriate way to deliver the information.
- Identifying where the **subject expertise** lies in Aotearoa New Zealand and internationally, and how can it be accessed rapidly.
- Developing and drawing on extant, **effective communication networks**. Local examples of infectious disease expert networks include the New Zealand Microbiology Network[54] and One Health Aotearoa[55]. Community networks are described in the sections on Māori and Pacific considerations.
- **Messaging within communities** during the COVID-19 pandemic was repackaged to fit with the language, age target and context of those communities. Ensuring that communities are provided with messages that are adaptable and clear is crucial for bottom-up communications.
- Rangatahi and young people delivered messages across a range of **media platforms** and were able to gain "viral" status faster at times due to their level of "influence". It is important to **develop a network of young people** to champion correct information during a pandemic.
- Ensuring there are **systems and structures** in place that could be activated in the event of a new pandemic, and that they are flexible enough to respond to different agents, syndromes and pathways.
- Working with **news media**, including the Science Media Centre (SMC)[56], to ensure accurate, evidence-based reporting. The SMC coordinated a network of infectious disease experts during the COVID-19 pandemic, providing mentorship and guidance particularly during the first two years of the pandemic.
- Providing additional **training for media-based analysts** to ensure information is correctly interpreted (e.g. denominator-based and stratified to adjust for confounding).

"Effective communication of reliable information between subject experts, decision makers, trusted advisors, the media and the general public is essential to ensure sound evidence-informed decisions are made, and that these result in good compliance with public health measures and alleviate anxiety."

54 www.nzmn.org.nz
55 https://onehealth.org.nz
56 www.sciencemediacentre.co.nz

4.13 Leadership and decision making

Effective leadership of pandemic planning, preparedness and response requires proactivity, anticipation, agility, accountability and authority for decision making at community and national levels. It requires credibility and experience and the ability to operate in a multi-agency environment with structures in place for interagency decision making.

4.13.1 Overview of the Coordinated Incident Management System (CIMS), the National Security System (NSS)

The following has been adapted from the **CIMS** and **NSS** handbooks. A summary is included here for convenience, and to highlight the importance of the '**All of Government' (AoG)** approach, but the reader is referred to the documents themselves for more detail.

- The following gives a high-level overview of the CIMS, and NSS – both of which are emergency agnostic – and a brief characterisation of how these might be applied to a health-related emergency such as an epidemic with national impact or a pandemic. Manatū Hauora would be the lead agency, with other agencies supporting as needed.
- Much of the description is taken or adapted from the CIMS handbook (3rd edition)[57] and the NSS Handbook. More detail can be found in those documents.
- This section also briefly describes some of the processes within health that are stood up in order to immediately triage any potential health-related incident, such as the initial assessment team (IAT) and the incident management team (IMT), and the public health risk assessments (PHRA).
- In practice, the application of the processes and guidelines needs to be flexible in order to adapt to the situation at the time and as it evolves.

4.13.2 CIMS

- Emergency management in Aotearoa New Zealand operates on an **all hazards, all risks basis** across the outcomes of the "4 R's": risk reduction, readiness, response, and recovery. The CIMS is the New Zealand government's chosen framework for responding to multi-agency incidents, at any scale, and designed for the Aotearoa New Zealand context (Figure 10).
- CIMS is the equivalent of AIIMS in Australia, or NIMS[58] in the United States, and has been customised for use in Aotearoa New Zealand. CIMS is inherently flexible and scalable and at its simplest, provides structure, co-ordination mechanisms and organisation to different work streams and activities.
- The CIMS framework is guided by principles and characteristics that allow it to be **adapted to any type of response** while providing consistency and managing expectations of roles and responsibilities.

57 Coordinated Incident Management System (CIMS) third edition, National Emergency Management Agency – Te Rākau Whakamarumaru, https://www.civildefence.govt.nz/resources/coordinated-incident-management-system-cims-third-edition [Accessed: 16 June 2023]

58 AIIMS – Australasian Inter-Service Incident Management System. NIMS – National Incident Management System.

Figure 10. A high-level overview of the CIMS structure and defined roles. Source: CIMS 3rd edition[59]

When a large or complex coordinated response is required, the National Security System (NSS) may be activated. This provides the highest level of governance for response.

4.13.3 National Security System (NSS)

- The NSS[60] (now called the **ODESC System, or Officials Domestic and External Security Coordination System**) is part of the national security architecture for strategic crisis management, i.e., the sum of activities and functions that allow government agencies to plan for, prepare for, respond to, and learn lessons from nationally significant crises.

Strategic crisis management is inextricably connected to emergency management. Governance is supported by Strategic Communications and Policy functions.

- The ODESC System enables all-of-government support to decision makers and policy at the strategic level and focuses on the national interest. It coordinates the activities of government agencies in support of a lead agency[61].
- The ODESC System is activated for events that are nationally significant or complex enough to warrant a coordinated strategic response at the

59 Coordinated Incident Management System (CIMS) third edition, National Emergency Management Agency – Te Rākau Whakamarumaru, https://www.civildefence.govt.nz/resources/coordinated-incident-management-system-cims-third-edition [Accessed: 16 June 2023]

60 National Security Systems Handbook https://www.dpmc.govt.nz/our-programmes/national-security/new-zealands-national-security-system/national-security-systems [Accessed: 16 June 2023]

61 A lead agency is one mandated through legislation or sector expertise for managing a particular hazard or an aspect of a hazard that results in an incident. While some hazards or risks are managed by the lead agency alone, many require the support and expertise of other agencies or organisations

national level. This ensures strategic resource and task allocation in response and recovery, particularly when gaps are encountered. These structures also allow increased and timely information flows.

- The ODESC System operates at three levels: **Watch Group, the Officials' Committee ODESC and Ministers**. The NSS structure was updated in October 2021 (see Figure 11).
- The Watch Group comprises Tier 3 and Tier 2 senior officials from relevant organisations, including the lead agency's National Controller. The Watch Group delivers assessments and advice to ODESC. The ODESC provides all-of-government coordination at the Tier 1 (Chief Executive) level and provides a link to Cabinet via the Chair of ODESC.

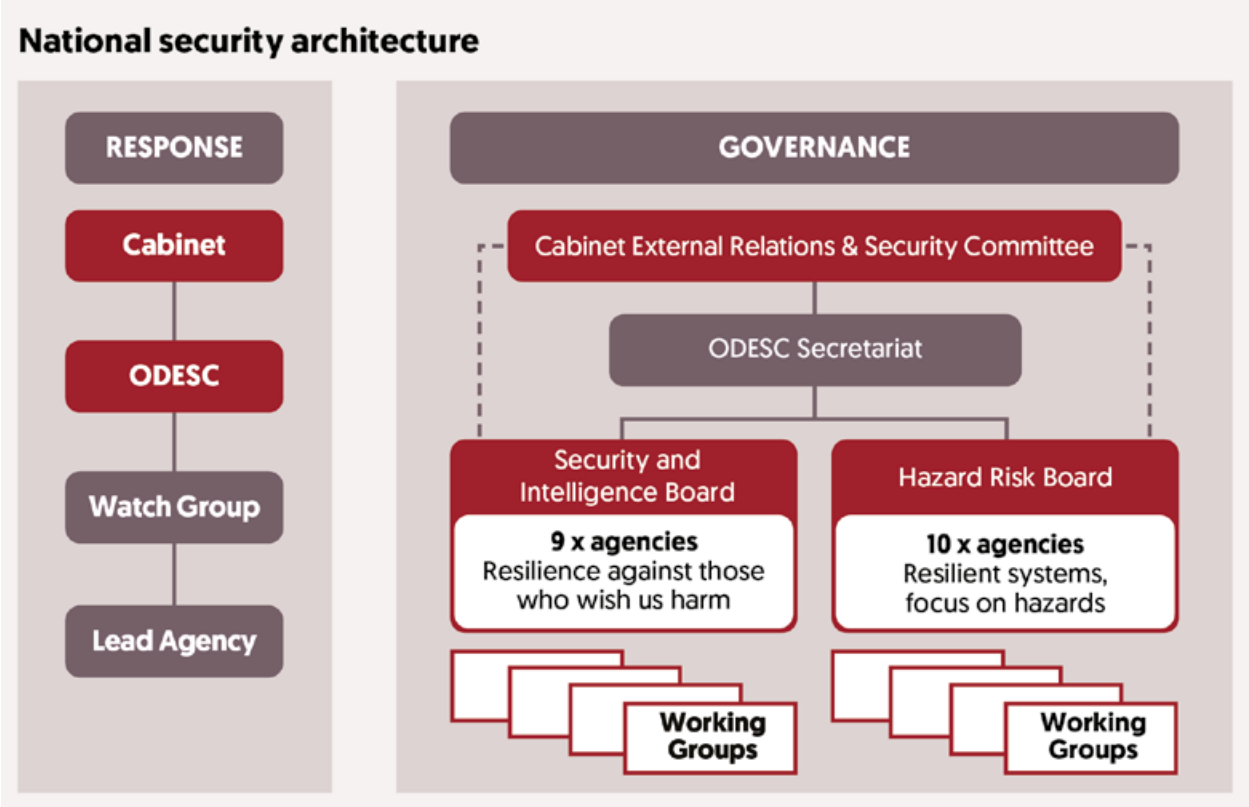


Figure 11. The current structure of the National Security System. Updated October 2021. Includes a tiered approach to a response to a national security event

4.13.4 Health-specific mechanisms

On the notification of a potential or actual emergency event, the **Ministry Emergency Management Team** (as a component of strategic crisis management) may convene an **initial assessment team (IAT)** meeting depending on the nature and extent of the event. The IAT provides initial identification and triaging of the issues and evaluates the need for escalation. There are no pre-determined thresholds or metrics for setting up an IAT, which is typically a small, agile group that is likely to include public health expertise, intelligence, and affected leads from health, as appropriate. One of the main outputs of the IAT is to determine if the situation warrants escalation through the convening of an IMT or requesting a an ODESC System Watch Group. An IMT often involves a broader group of stakeholders. In some cases, depending on the situation the process could immediately move to an IMT without IAT.

At this point, if the event needs to be escalated further -- because it may involve national action or is otherwise complex – further specific assessments may be called for. For example, a **PHRA meeting** may be required to provide specific public health advice, involving senior health leaders and subject matter experts. In parallel, if the ODESC System is to be activated (usually one of several outcomes from a Watch Group), then those processes will confirm a **lead agency** and the **appropriate AoG supporting responses and coordination**.

4.14 Borders and quarantine

A pandemic response may include measures designed to **prevent, reduce or delay importation of the pathogen** across Aotearoa New Zealand's international border, including the maritime and air border. This is likely to depend on a coordinated response between **multiple government agencies and private sector organisations**, such as Manatū Hauora, New Zealand Customs Service, New Zealand Immigration, ports, airports, and commercial airlines. **Testing of international arrivals and collection of appropriate metadata on travel history** could be an important surveillance activity in the early stages of a pandemic or PHEIC, providing key information on undetected transmission, and global patterns of spread.

Pandemic response may also involve the use of privately owned accommodation as quarantine facilities. The ability to **rapidly stand up managed isolation and quarantine facilities**, with effective infection prevention and control procedures, could be an essential component of an elimination strategy. In the event isolation and quarantine facilities are needed, they are unlikely to be bespoke or designed for infection control. As such, special attention needs to be paid to the risk of within-facility transmission and transmission from the facility, e.g., with a focus on ventilation and the ability to follow necessary infection prevention and control procedures. **At home isolation or quarantine may be appropriate** depending on transmissibility and the likely consequences of community transmission. Mandatory managed isolation and quarantine is a costly and disruptive option that requires **significant legal and equity considerations**, for example regarding challenges for marginalised groups and extended families entering Managed Isolation and Quarantine (MIQ).

A High Court ruling[62] during the COVID-19 pandemic found that the requirement to enter MIQ was reasonable and proportionate as part of the public health response but did not sufficiently allow individual circumstances to be considered and prioritised where necessary. Consideration of how long a border closure or MIQ system is likely to be needed to support response objectives is important. This is likely to depend on anticipated availability of vaccines or therapeutics.

The border response might also involve **routine testing** of people working at the maritime or air border, which will comprise a mixture of public sector workers, private sector employees and contractors. The ability to establish a **national cross-sector register of border workers** would enhance the effectiveness of a border testing programme and support outbreak investigation and contact tracing in the community.

62 www.courtsofnz.govt.nz/assets/Uploads/Judgments-online/MR-2022-NZHC-832.pdf

4.15 Legal framework

The following legal instruments are of relevance to the prevention and control of existing and future pandemics:

- Health Act 1956 (last major reform in 2016).
- Civil Defence Emergency Management Act 2002.
- Employment Relations Act 2000 and the Health and Safety at Work Act 2015.
- Privacy Act 2020.
- New Zealand Bill of Rights Act 1990.
- Epidemic Preparedness Act 2006.
- COVID-19 Public Health Response Act 2020.

A detailed review of the legal framework relating to pandemic response is beyond the scope of this document. The reader is referred to the **Law Commission report on the Legal Framework for Emergencies in Aotearoa New Zealand**[63]. This study paper, published in November 2022, "undertakes a preliminary evaluation of how well Aotearoa New Zealand's laws and legal institutions anticipated the challenges presented by COVID-19, and identifies any questions that ought to be considered to ensure readiness for future emergencies". The report made a series of recommendations about the legal framework as it relates to emergency preparation, emergency legislation and emergency response and recovery. These include recommendations to ensure that tikanga Māori, Māori rights and Crown obligations under Te Tiriti o Waitangi are upheld.

The reader is also referred to the **New Zealand Parliament Inquiry into COVID-19 Secondary Legislation**[64], a Report of the Regulations Review Select Committee published in January 2023. This report scrutinised the extensive secondary legislation passed by the executive branch of government under powers delegated to it by Parliament under the COVID-19 Public Health Response Act 2020. This provides important commentary of relevance to pandemic preparedness and the development of a pandemic plan. The current legal framework has evolved and been implemented in response to a series of emergencies, including the Canterbury earthquakes in 2011, COVID-19 and Cyclone Gabrielle in 2023. Although Section 70 of the Health Act was used as the primary means of enacting COVID-19 orders early in the pandemic, bespoke emergency legislation was also required to manage the response. Due to the uncertain nature of any future events further bespoke legislation may be required. **Consideration of a range of likely scenarios, alongside a review of the current legislation**, would help the preparation of relevant material that could form the basis of future legislation. Such an approach, conducted during the interpandemic period as part of pandemic planning and preparedness, would expedite the preparation and passage of new bespoke legislation through Parliament when the need arises, and avoid attempting to design general legislation for national emergencies that may not be suitable for particular situations. This **hybrid approach, combining existing legislation dealing with national emergencies, with bespoke legislation**, is considered a "a sensible and pragmatic response that could be applied for other future emergencies"[65].

> **"Consideration of a range of likely scenarios, alongside a review of the current legislation, would help the preparation of relevant material that could form the basis of future legislation."**

63 www.lawcom.govt.nz/our-projects/emergency-powers-pandemics-and-other-threats
64 https://selectcommittees.parliament.nz/v/6/598a07f5-0ea1-49f1-8949-08db6d443690
65 https://selectcommittees.parliament.nz/v/6/598a07f5-0ea1-49f1-8949-08db6d443690

4.16 One Health responses to zoonotic agents

One Health has a broad definition as an **integrated, unifying approach that aims to sustainably balance and optimise the health of people, animals, and ecosystems** with a recent definition being endorsed by the Quadripartite of the Food and Agriculture Organisation (FAO), World Organisation for Animal Health (WOAH), WHO and United Nations Environment Program (UNEP) [66].

Every year millions of people and animals around the world are affected by **zoonotic diseases**[66] . Collaboration between multiple sectors is needed to address national and international zoonotic infectious disease threats, due to the connectivity between people, animals, and their shared environments. This One Health collaborative approach has become more important in recent years due to the changes in interactions between people, animals, and their environment. For example, human population growth is driving expansion into new geographic areas resulting in environmental changes and closer contact between people and wild animal populations.

COVID-19 is a reminder of the importance of the One Health approach. SARS-CoV-2, the cause of COVID-19 emerged from an animal source in Asia and, through human-to-human transmission and adaptation, resulted in a pandemic, with subsequent host-switches back into animal populations, ranging from farmed mink in Europe to white-tailed deer in the Americas.

Other current examples include **highly pathogenic avian influenza (HPAI) H5N1**, which likely emerged following selection for pathogenicity in domestic poultry preceding an infection with low pathogenic viruses circulating in wild birds [67]. HPAI H5N1 now circulates globally among wild birds, killing them and poultry and, occasionally, mammalian species [68]. While geographically isolated, these types of infection pose significant threats to Aotearoa New Zealand species and complicate infection control as infections can switch hosts and establish reservoirs in wild, feral, peri-domestic and domestic species [68].

4.16.1 Prevention of zoonotic infections

A key role that One Health approaches should take is to focus on **prevention of pathogen spillover from animals to humans**; so shifting the infectious disease control paradigm from reactive to proactive. Prevention includes addressing the drivers of disease emergence, namely ecological, meteorological and anthropogenic factors and activities that increase spillover risk, in order to reduce the risk of human infection. It is informed by, amongst other actions, **biosurveillance** in natural hosts, people and the environment, **understanding pathogen infection dynamics** and **implementing intervention activities**[67]. This incorporates some aspects typically classified as public health when applied to vector-, food- and waterborne diseases.

4.16.2 Surveillance of zoonotic infections

There have been several recent assessments of global mechanisms for early warning and One Health surveillance, including by the **One Health High Level Expert Panel (OHHLEP)** and **Quadripartite One Health Intelligence Scoping Study**[68], at the request of the Quadripartite.

For a One Health surveillance system, there are current gaps and challenges, which include agreement on the scope for One Health surveillance; defining what data are required; developing integrated systems that are flexible, but coordinated, recording timely and standardised data, that can accommodate technological advances and big data (e.g., whole genome sequencing, citizen science-based

66 www.who.int/initiatives/tripartite-zoonosis-guide

67 www.who.int/publications/m/item/prevention-of-zoonotic-spillover

68 www.who.int/publications/m/item/quadripartite-one-health-intelligence-scoping-study

surveillance); developing governance systems that overcome political, ethical, administrative, regulatory and legal (PEARL) barriers; developing protocols for surveillance overviews and outputs, including the implications for reporting results that lead to equitable and appropriate responses; and developing implementation plans that account for current capacities.

There are components of such systems that have been developed or are in development, including the **Joint FAO–OIE–WHO Global Early Warning System** for health threats and emerging risks at the human–animal–ecosystems interface [GLEWS], the **WHO Global Antimicrobial Resistance and Use Surveillance System (GLASS)**, the **WHO Global Outbreak And Response Network (GOARN)**, **FAO's Global Animal Diseases Surveillance and Early Warning System**.

There are systems in place for data sharing for some necessary aspects, such as viral genomes via the **Global Initiative on Sharing All Influenza Data (GISAID)**, but there are numerous challenges and gaps.

4.16.3 Responses to zoonotic infections

Preparing and planning for **incursions of zoonotic agents with pandemic potential**, particularly those with sustained transmission in humans and animals, requires additional considerations over and above those for pathogens primarily transmitted between humans. These include the need to **identify and assign roles and responsibilities** for logistics (e.g. mobilising the veterinary workforce), communication, technical support and the management of diseased and healthy animals. The **health and safety** of those in occupations which involve close contact with domestic animals (e.g. veterinarians, farmers and abattoir workers) and wildlife (e.g. Department of Conservation (DoC) workers and conservationists) will need to be safeguarded. There are also important **animal and human welfare considerations**: animals may need to be euthanised/culled; there may be disruptions to the food supply chain and animal husbandry; and considerable psychological impacts on communities, farmers, pet owners and conservationists. **Taonga and endangered species may need to be protected**, and conservation efforts continued. **Economic impacts** on the agriculture sector and potential environmental impacts will need to be planned for. A programme of **vector control** may also be needed [42].

As part of preparedness and pandemic planning consideration should be given to the organising of regular **simulation exercises**, **scenario planning** and a **review** of zoonotic disease management and response coordination systems. This will evaluate needs for logistical support for activities such as animal vaccination, depopulation and repopulation. It will also highlight the need for **formal structures, accountabilities and responsibilities** to be established across Manatū Hauora|MoH, Manatū Ahu Matua|MPI and Te Papa Atawahi|DoC and not be heavily dependent on informal relationships between individuals. Such systems and structures need to be resourced, developed and maintained during interpandemic period.

4.16.4 Response to a pandemic / PHEIC involving sustained transmission in both humans and animals

The formal AoG, interagency process is through the **national security system**. This is convened by the **Department of the Prime Minister and Cabinet (DPMC)**. It includes the **Hazard and Risk Board** and the **ODESC**[69]. These groups lead the interagency work required and form the watch groups in the event of a potential, emerging, or ongoing threats. A **lead agency** is identified. They also initiate other escalation pathways as required.

In addition, there are several **interagency groups with a One Health focus**, that Manatū Hauora | MoH works with to assist with a range of activities, from horizon scanning through to action plans. For example:

69 ODESC www.dpmc.govt.nz/our-programmes/national-security-and-intelligence/new-zealands-national-security-system-during-a-crisis/governance-during-crisis/odesc

- Manatū Hauora|MoH and Manatū Ahu Matua|MPI conduct a **weekly intelligence sharing meeting** on topics such as zoonoses.
- Domestically, Manatū Hauora|MoH coordinates the **food safety protocol** with Manatū Ahu Matua|MPI. Globally, Manatū Hauora|MoH is connected via **INFOSAN with WHO and Manatū Ahu Matua|MPI** for global food safety events.
- Manatū Hauora|MoH, Tumata Arowai and the Ministry for the Environment all have roles in **protecting the nation's drinking water**. The Ministry for the Environment is responsible for protecting the water sources and Taumata Arowai is the regulator for the water services. Manatū Hauora including the Public Health Agency, are responsible for reviewing the scientific evidence and providing advice to the other two groups. Manatū Hauora|MoH drafted a working document that describes guidelines for water safety plans, including the management of incidents and emergencies, such as epidemics caused by water-borne pathogens[70].
- Nonetheless, given the recent changes to the way Aotearoa regulates and oversees the drinking water supply, there is the **potential for gaps in the system**, including in the event of a pandemic. It is noted that, for example, in May 2023[71], in order to address gaps identified with regard to nitrates and drinking water across regulatory regimes, government agencies and local authorities, an inter-agency group chaired by the PHA was established.
- Manatū Hauora|MoH have an memorandum of understanding (MoU) for coordination with **Taumata Arowai**, the regulator of drinking water.
- There exists a coordination arrangement for **chemicals and radiation events** with the Te Mana Ruahī Taiao|Environmental Protection Authority, Fire and Emergency New Zealand and others.

Border Executive Board meets regularly and is a forum for connecting Manatū Hauora | MoH, Customs, Civil Aviation Authority, Maritime New Zealand, Manatū Ahu Matua|MPI, and Immigration.

4.17 Bioterrorism

Bioterrorism is the **deliberate release of pathogenic microorganisms** such as bacteria, viruses, or their toxins to cause illness or death in people, animals, or plants [69]. The pathogens are typically found in nature, but it is possible that **additional virulence factors** and/or weaponisation of the agent could be incorporated to increase their ability to cause disease. There have been **a number of documented cases** of bioterrorism events, with recent events involving *Bacillus anthracis* and *Salmonella* Typhimurium [69].

The CDC have categorised biological agents with potential for bioterrorism into **three distinct groups**, depending on public health impact (severity of illness and mortality), dissemination potential, public perception, and the easiness of preparation[72] [70].

4.17.1 Category A

High-priority agents include organisms that **pose a risk to national security** because they can be easily disseminated or transmitted from person to person, result in high mortality rates, and have the potential for major public health impact. Diseases and their agents include anthrax (*Bacillus anthracis*), botulism (*Clostridium botulinum* toxin), plague (*Yersinia pestis*), smallpox (*Variola major*), tularemia (*Francisella tularensis*), and viral hemorrhagic fevers [filoviruses (e.g. Ebola, Marburg) and arenaviruses (e.g. Lassa, Machupo)].

70 https://environment.govt.nz/publications/addressing-risks-associated-with-nitrates-in-drinking-water

71 www.taumataarowai.govt.nz/assets/Uploads/Guidance/Handbook-Preparing-water-safety-plan-May-2019.docx

72 www.niaid.nih.gov/research/emerging-infectious-diseases-pathogens

4.17.2 Category B

The second highest priority agents include those that are moderately easy to disseminate, result in moderate morbidity rates and low mortality rates, and **require specific enhancements of CDC's diagnostic capacity and enhanced disease surveillance**. Diseases and their agents include brucellosis (*Brucella* species), epsilon toxin of *Clostridium perfringens*, food safety threats (e.g., *Salmonella* species, *Escherichia coli* O157:H7, Shigella), glanders (*Burkholderia mallei*), melioidosis (*Burkholderia pseudomallei*), psittacosis (*Chlamydia psittaci*), Q fever (*Coxiella burnetii*), ricin toxin from *Ricinus communis* (castor beans), Staphylococcal enterotoxin B, typhus fever (*Rickettsia prowazekii*), viral encephalitis [alphaviruses (e.g. Venezuelan equine encephalitis, eastern equine encephalitis, western equine encephalitis)], and water safety threats (e.g. *Vibrio cholerae*, *Cryptosporidium parvum*).

4.17.3 Category C

The third highest priority agents include emerging pathogens that could be **engineered for mass dissemination in the future** because of availability, ease of production and dissemination, and potential for high morbidity and mortality rates and major health impact. Agents include emerging viruses such as Nipah virus and Hanta virus.

Preparedness for intentional outbreaks have a lot in common with preparedness for naturally occurring public health emergencies [69]. However intentional events may involve **agents that are not endemic to a region**, meaning that regions may lack diagnostic tests and therapeutics. The ability to establish diagnostic tests for key biological agents with potential for bioterrorism is hampered by the **lack of freely-available information**, as this information is frequently classified to prevent it being used inappropriately. If Aotearoa New Zealand wants to prepare for the arrival of these agents we need:

- People with both the appropriate **security clearance** and knowledge to receive documentation and attend meetings.
- To consider **joining an existing network**, such as the CDC's Laboratory Response Network, or partnering with a current member country. This would require a ministerial request, but would give access to information and resources currently not available.
- Permission to **import positive control material** for diagnostic assays, which may be nucleic acid and/or live agent, and/or the capacity to develop or import non-infectious synthetic controls, such as has been used for high consequence pathogens [71].

Wāhanga C | Part C: Pandemic response: Impact assessment, strategy development and control measures

The aim of this part of the document is to provide a narrative to accompany parts A and B, describing the **dynamic response to an unfolding pandemic threat** in relation to the typology of pandemic scenarios and pandemic agents described in Part B.

Section 5 describes the dynamic nature of a pandemic and how this means that the response cannot be fixed but needs to be flexible and capable of being iteratively refined over time.

Sections 6 to 8 describe three key interacting elements of a pandemic response: impact assessment; strategy development; and control measure implementation.

5. Dynamic nature of a pandemic

Epidemics and pandemics are highly dynamic events (Figure 12a). This means that actions taken at one point in time can have a major effect on the future trajectory, and similarly the best course of action depends on previous decisions and on likely future outcomes. The success or failure of control measures to achieve strategic aims can depend crucially on their timing.

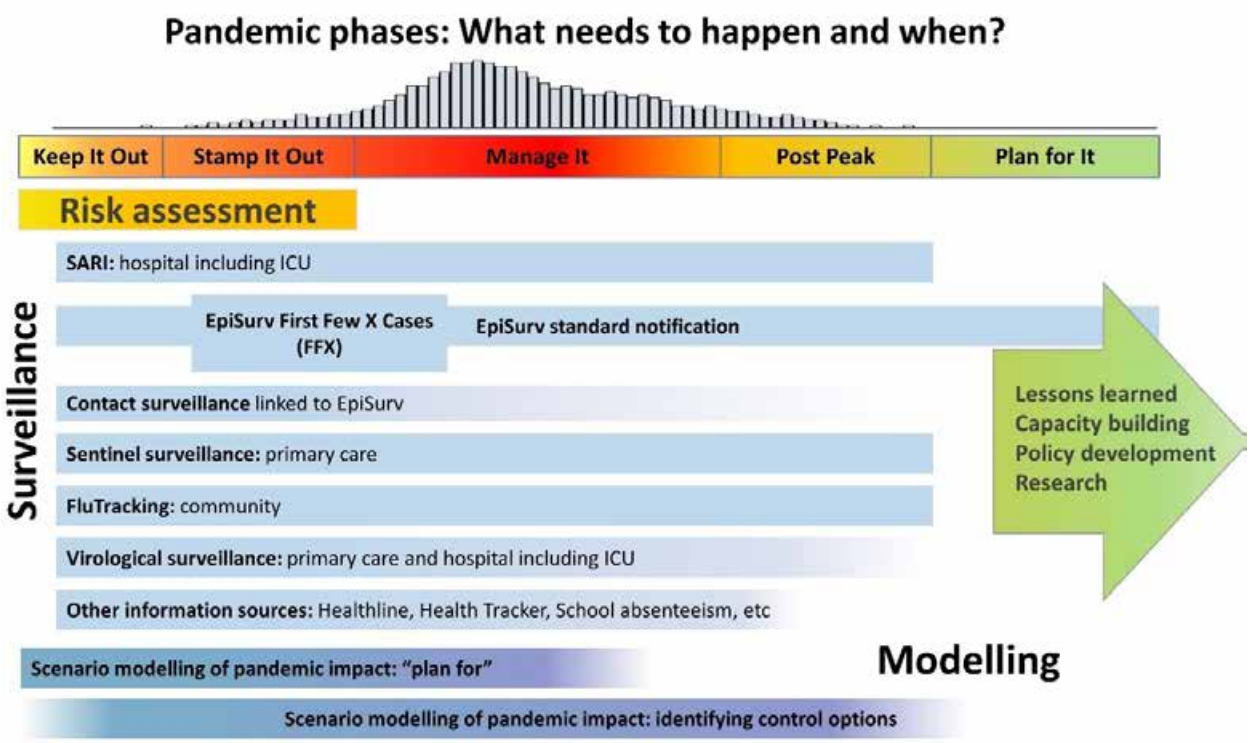
A pandemic response needs to be sensitive to the dynamic nature of the situation and, once determined, is not fixed. Although the **goal** of the response and the **principles** that guide it should remain consistent, the **strategy** may shift over the course of the pandemic as circumstances change, whilst **control measures** may change rapidly as the epidemiological situation changes, new interventions become available, or new systems become operational [1].

For example, it may be desirable in some circumstances to enact stringent public health measures when prevalence is very low in order to prevent a much larger outbreak or to avoid healthcare capacity being exceeded. Conversely, the effect on future transmission dynamics needs to be considered. There may be little point in taking costly action to eliminate an outbreak if future reintroductions are inevitable and there is little prospect of improved interventions becoming available. **Mathematical modelling** is an essential tool as it provides a systematic way of testing assumptions against surveillance data and comparing alternative strategic choices while accounting for the dynamic nature of the situation and the interdependency between decisions and outcomes at different times.

A pandemic plan needs to be a living document in which key evidence is regularly re-evaluated, particularly evidence about transmission, impact, equity, and intervention effectiveness as these key features of a pandemic can change rapidly over time and a shift is likely to require prompt policy action. Barriers and enablers of outbreak control are also likely to change over time. For example, adherence with infection control measures may increase or decrease, altering the feasibility of a chosen strategy.

Three key components of a response to a pandemic threat are: (i) impact assessment; (ii) strategy development and (iii) selection and implementation of control measures. These components are described in the following sections and are supported by the generic capabilities described in Part B. However, these are not standalone components to be carried out one after the other, but rather part of an iterative process as more information becomes available about the nature of the threat and about the effectiveness of the control measures so far in achieving strategic objectives (see Figure 12b).

A.



B.

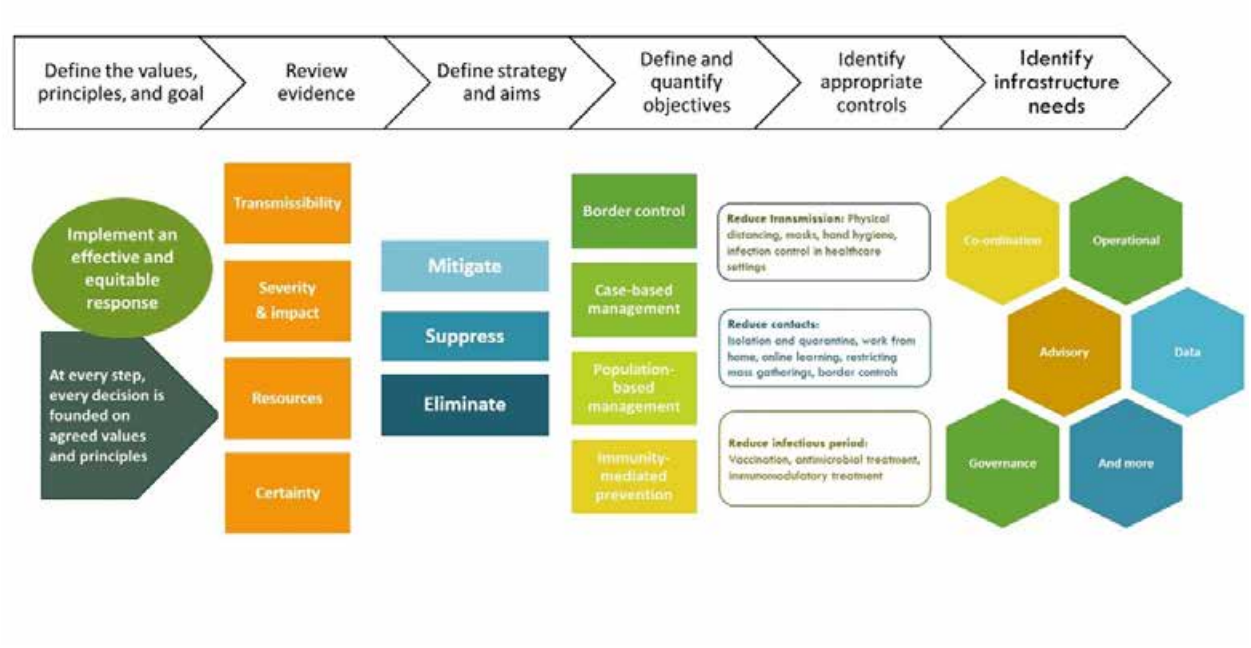


Figure 12. Pandemic phases (a) and strategy decision framework (b): overview of the key elements. Adapted from Polonksy *et al* 2019 [63], Kvalsvig *et al.* (2020) [72] and Kvalsvig and Baker (2021) [1]. It is likely that these elements will need to be iteratively updated as more information becomes available.

6. Impact assessment

One of the first activities conducted in the face of a pandemic threat is to **assess the likely impact of the disease on the population**. This is an essential first step to informing a proportionate response. Aotearoa New Zealand would benefit from an **impact assessment tool** that reflects unique aspects of our situation and capabilities, ensuring consideration of key principles such as **the need to uphold Te Tiriti o Waitangi in health policy**.

Questions to guide development of an impact assessment tool include:

- What types of impact can be expected from a pandemic disease?
- Will their duration be short- or long-term?
- What is their likely magnitude?
- Who are the populations of interest?
- What information is needed to assess and quantify impact, and how will this evidence be generated?

Information on the impacts can guide **selection of a pandemic strategy** and determines the **stringency of control measures**, so it is important to consider **impacts of the response as well as impacts of the disease**.

Early assessment of impact is particularly important to **evaluate exclusion or elimination** as strategic options for an emerging pandemic because the success of these strategies depends on early, high-stringency action, whereas mitigation or suppression strategies are more likely to step up or step down in response to observed or near-future predictions about changes in the outbreak.

Assessment of impact includes consideration of both relative and absolute measures of risk and impact:

- **Relative measures** such as CFR, IFR and R_0 are a useful guide for assessing a new pandemic disease by comparing it with other infectious diseases, positioning it within a typological mapping such as Figure 1, and identifying gradients of risk between populations, age groups and other factors.
- However, impact is experienced in **absolute numbers** (e.g. cases, disability, deaths, health impacts from unmet healthcare need, and costs). A common misconception is that small percentage impacts indicate mild disease, but high transmissibility in a population **multiplies small risks into large numbers** (e.g. see Figure 2). This can have significant consequences, including threshold effects on services with capacity limits.

Pandemic impacts are not limited solely to fatalities or acute illness, but include **long-term impacts in survivors**, which may be transient or decades-long (e.g., lifecourse impacts seen from 1918 influenza). In a low-mortality, highly-transmissible infection

pandemic, post-acute impacts may become important determinants of impact on health and functioning of society. For example, many of the deaths attributable to measles virus are caused by secondary infections because the Measles virus diminishes previously acquired immune memory to other infections, leaving individuals at risk for infection by other pathogens [73] (These adverse effects on the immune system were not seen in vaccinated children). Impact assessments early in the pandemic need to take these longer-term health impacts into account, which can be challenging.

In the following sections we present some examples of impacts that need to be considered and, as far as possible, quantified, to guide pandemic decisions. With further consultation, key impacts could be identified and **presented in a systemised way as an impact assessment tool** to enable a rapid and comprehensive understanding of potential impacts.

6.1 Types of impact: direct, indirect, short- and long-term

The impacts of a pandemic or other significant disease outbreak can include a range of direct, indirect, short-term, and long-term impacts on various aspects of society. The specific impacts and their magnitude vary depending on the nature of the disease, its transmission characteristics, the affected population(s), and the response measures implemented.

6.1.1 Direct impacts

Direct impacts are typically the **immediate consequences of a disease outbreak**, primarily affecting individuals who become infected and their families. Direct impacts include illness, hospitalisation, and in severe cases, loss of life. The clinical severity and IFR of the disease play a crucial role in determining the direct impact. These impacts and their assessment are further described in the surveillance section.

Recent epidemics, such as those caused by Zika virus, Mpox, and SARS-CoV-2, highlight the importance of assessing the **health impact of post-acute conditions** caused by these pathogens (including mortality, impact on healthcare, and community attack rates leading to short- or long-term illness and disability).

There needs to be consideration of how to assess the potential type and magnitude of longer-term impacts before they are playing out in the population. Advances in immunology have enabled a more detailed understanding of immunopathogenesis of infectious diseases than was possible in the past. Indicators could include the:

- **Severity profile of acute illness** as this may predict post-traumatic stress disorder (PTSD) and other mental distress following intensive care management, and lasting organ damage, such as acute respiratory distress syndrome (ARDS) leading to lung fibrosis, as seen following SARS and MERS outbreaks [74].
- **Tropism for specific organs**, e.g., brain, heart or tissue, e.g. vascular endothelium (predicts multi-organ dysfunction), pancreatic beta cells (predicts diabetes), etc.
- **Immune dysregulation**, as the patterns of immune responses to infection can signal potential future sequelae of autoimmunity, susceptibility to other infections, and/or oncogenesis.

Further research is needed to develop a **rapid assessment approach for a new pandemic pathogen** to gauge its potential to cause longer-term morbidity and mortality, as far as that can be ascertained, before widespread transmission within Aotearoa New Zealand.

It is important to document patient experiences as early as possible: the **'First Few X cases' (FFX)** protocol was not implemented in Aotearoa New Zealand in response to COVID-19, but creating a cohort of early cases that are followed up very closely and continue to be followed up past the acute phase of the pandemic identifies early signals of emerging health problems, as well as contributing essential information on acute severity and transmission characteristics.

6.1.2 Indirect impacts

Indirect impacts often affect broader aspects of society. The impact of the pandemic response on individuals and populations may include the following:

- Pressure on health services can lead to **unmet healthcare needs** for non-pandemic conditions.
- Control measures that aim to reduce human-human transmission by reducing in-person interactions have multiple adverse **impacts on societal functioning and wellbeing** including workplaces, education, the economy, social connectedness and mental health.
- Border closures have significant impacts on **individuals, businesses and trade**.

Specific impacts that a risk assessment tool could monitor would include:

- **Stress or overwhelming of healthcare systems** resulting in lack of capacity to treat other acute illness, increased emergency response times, and delays or cancellations to routine healthcare and screening.
- **Economic impacts** as illness and potentially control measures impact economic activities, leading to job losses, reduced productivity, disruption to supply chains and economic downturns. Industries such as travel, tourism, hospitality, and retail are particularly vulnerable. Government spending and therefore debt may also increase due to healthcare expenses and emergency response measures.
- **Social impacts** as the above health and economic impacts lead to social disruption and strain on healthcare systems. Public health measures such as quarantine, social distancing, and travel restrictions can result in social isolation, reduced access to essential services, and psychological distress.
- **Education** may be impacted by ill health and control measures, such as school closures, affecting the learning outcomes of students. Remote learning may be implemented, but it can exacerbate inequalities, as not all students have equal access to technology or resources.

The above indirect impacts may be short term. Many are likely to be transient, resolving as soon as the emergency phase has passed. Such impacts include panic buying, shortages of essential supplies, and increased demand for medical resources. However, there may be long-term indirect impacts. These are the enduring consequences that can persist after the immediate crisis subsides. Regular, comprehensive impact assessments can enable timely policy action to mitigate adverse effects while ensuring that infrastructure and other improvements are sustained into the post-pandemic phase.

These longer-term impacts include:

- **Long-term disabilities and health issues**, impacting people's health and financial situation and their family's wellbeing.
- **Healthcare system changes** as outbreaks often expose weaknesses in healthcare systems, leading to reforms and improvements in healthcare infrastructure, emergency preparedness, and disease surveillance, but they might also cause significant negative impacts, such as the loss of healthcare workers through disease [75] or leaving the sector[73].
- **Economic restructuring** can occur if outbreaks trigger changes in industries and global supply chains, with a potential shift towards more resilient and sustainable practices. Investments in healthcare research and development may increase, leading to medical advancements and innovations.

73 www.cdc.gov/vhf/ebola/pdf/impact-ebola-healthcare.pdf

- **Social and behavioural changes**, for example an increased emphasis on hygiene practices, adoption of telemedicine, and a greater focus on public health education and awareness. Social and behavioural changes may be enduring or they may be subject to 'pandemic fatigue' and disinformation campaigns.
- **Political and policy changes** as governments have gained or lost public trust, and outbreaks may shape policies related to healthcare, public health, emergency response, and international cooperation. Governments may establish or strengthen institutions and regulations to prevent and manage future outbreaks.

6.2 Distribution of impact

Assessment of the distribution of infectious disease impact includes, but is not limited to, the following populations of interest:

- The base assumption should be that **a pandemic infectious disease will worsen health equity** in Aotearoa New Zealand and that both incidence and severity are likely to be higher for Māori and Pacific Peoples and other groups with high levels of socioeconomic deprivation. These populations experience higher incidence of a range of infectious diseases [76] through mechanisms that increase the number of contacts (e.g. 'essential worker' occupations that cannot be conducted remotely) or the risk of close-contact transmission (e.g. families sleeping in one room to reduce heating costs) [77]. Similarly, clinical severity may be exacerbated by the high prevalence of multimorbidity in Māori and Pacific populations [78] or by structural racism in the healthcare system leading to delayed care [79]. Over the last century of pandemics in Aotearoa New Zealand, Māori have consistently experienced higher mortality than non-Māori[74][24, 27]. There is no justification for a 'wait and see' approach: the starting assumption for any pandemic disease should be that Māori and Pacific Peoples will be disproportionately affected. Identification of important risk factors for severe disease may further help identify high-risk groups.
- Many infectious diseases have a significant **age-dependence in severity**. It is important to assess significant early life risks (stillbirth, preterm birth, and hospitalisation/mortality) in infants and vulnerability of older adults via immune senescence and higher prevalence of comorbidities, factors that can increase both incidence and clinical severity. The needs of tamariki and rangatahi have not always been adequately considered in pandemic policy. We note that the New Zealand Government has a duty of care under the **United Nations Convention on the Rights of the Child** (the Children's Convention) to uphold human rights standards for the treatment of children and young people.
- **Pregnant people** are a particularly neglected group in infectious disease control:
  - Immune adaptations to pregnancy mean increased health risks of infections.
  - Pregnant people are often excluded from vaccine and treatment trials.
  - The pregnant person, the fetus/es, and/or future pregnancies may be at risk in each instance of infection during pregnancy.
- Persons with **underlying conditions and disability** are highly likely to experience severe and inequitable impacts.

A key point of pandemic strategy is that those who are most at risk (as above, and any additional populations) need to have **autonomy in risk assessment and risk management** in a pandemic. Measures that reduce these risk factors are likely to have many socioeconomic benefits.

74 www.tewhatuora.govt.nz/assets/Our-health-system/Data-and-statistics/Covid-19/Covid-trends/COVID-19-Trends-and-Insights-Report-23-December-2022-PDF-2.0-MB.pdf

7. Strategy development

An effective pandemic response requires clearly defined strategic aims and objectives to ensure that agencies and the population as a whole have a shared understanding of what needs to be done and why, and whether the strategy is working.

A pandemic strategy is a high-level approach that **defines the aims of the response**, whereas control measures are the **actions taken to implement the response** [1].

Types of outbreak strategy that may be used in a pandemic include [1]:

1. **Mitigation**, a form of control that accepts transmission at a predetermined, manageable level, e.g., to avoid overwhelming the health system in an influenza pandemic;
2. **Suppression**, a form of control that aims to keep transmission at a low level to minimise adverse health effects, as for HIV/AIDS;
3. **Elimination**, which aims for zero community transmission of a pathogen. This strategy includes **'exclusion'**, where border controls are applied so effectively that the pathogen never transmits within a particular jurisdiction, and can become **eradication** if extended to the global level [80]. If global eradication is not possible, elimination may be a temporary strategy that is later switched to mitigation or suppression.

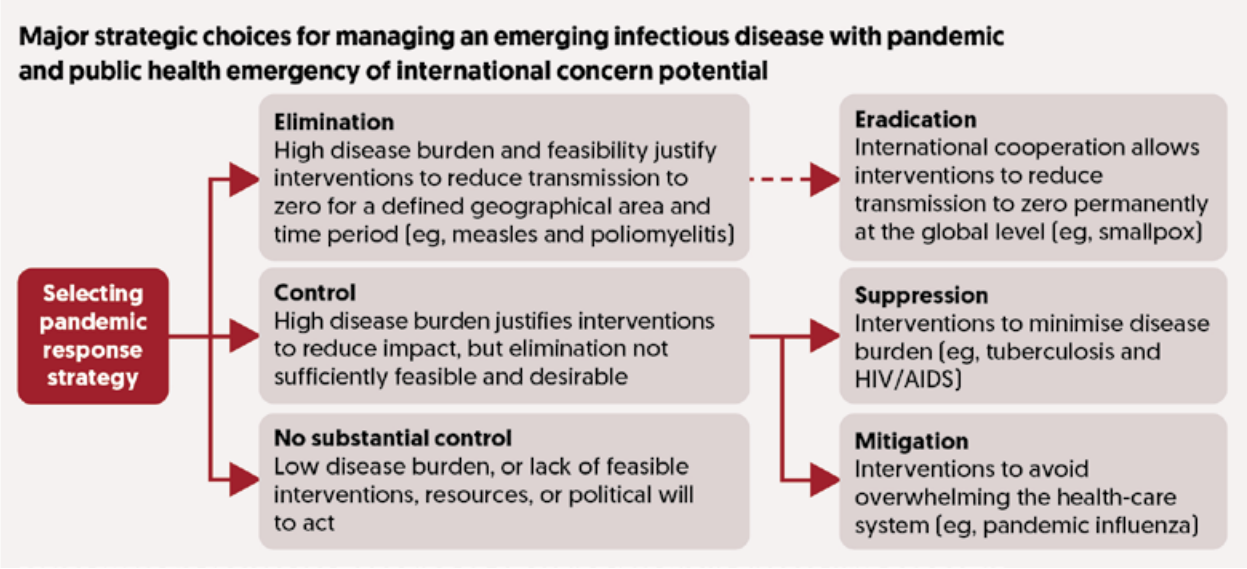


Figure 13. Pandemic response strategic choices. Source: Baker 2023 [81].

These three strategies respectively share some similarities with the "Keep it out", "Stamp it out", "Manage it" stages described in Aotearoa New Zealand's (and other countries') **Influenza Pandemic Plan**.[75] However, while there may be changes in strategy over time, these will not necessarily be a simple linear progression and varying amounts of time might be spent under different strategic settings.

The **distinction between strategy and control measures** can be seen in the example of elimination, a well-established strategy that is used for a range of infectious diseases:

- Measles elimination strategies use **vaccination** as their principal control measure;
- SARS-CoV-2 transmission was eliminated within Aotearoa New Zealand by **non-pharmaceutical interventions** early in the pandemic before vaccines were available;
- Yaws disease is eliminated from geographical regions using **mass treatment**, with an ultimate aim of global eradication [82].

Conversely, pandemic responses are based on a **relatively small set of control measures** (see Section 8) such as isolation and quarantine, contact tracing, border controls, personal protection equipment (PPE), and vaccination that may be used to give effect to an elimination, mitigation, or suppression approach.

All types of pandemic strategy are likely to include the following objectives, implemented by different actors:

1. To **identify and extinguish transmission chains** (public health);
2. To **prevent undetected transmission** (multiple actors, including Government e.g., air quality standards and the public, e.g., staying home when unwell);
3. To **prevent or reduce seeding of new clusters** into the area (border control);
4. To **reduce the pool of susceptible individuals** in the population (health services via vaccines and antimicrobial treatment).

However, **the chosen strategy will determine the intensity and timing of the objectives**, and hence the implementation of control measures. For example, an elimination strategy for a highly transmissible pathogen typically requires control measures to be applied at a high level of intensity early in an outbreak, but once elimination is achieved some types of control can be de-escalated or removed. By contrast, mitigation and suppression strategies require a lower level of peak intensity of the response but are likely to need continuous application of control measures to maintain R_e at the desired level.

75 www.health.govt.nz/your-health/healthy-living/emergency-management/pandemic-planning-and-response/influenza-pandemic-plan

7.1 Determining the appropriate strategy for an emerging pandemic

The default strategy in Aotearoa New Zealand's 2017 New Zealand Influenza Pandemic Plan[76] was a mitigation approach, i.e., aiming to reduce cases, slow transmission and spread the epidemic wave out over time sufficiently to protect health systems. This strategy was embedded in the plan as the default approach because of implicit assumptions 1) that the next pandemic would be caused by influenza and 2) that influenza could not be eliminated.

This approach needs re-evaluation in the light of Aotearoa New Zealand's experience during winter 2020 when stringent border and respiratory controls eliminated transmission of seasonal influenza as well as SARS-CoV-2 [83]. More broadly, **the COVID-19 pandemic highlighted the fact that Aotearoa New Zealand did not have a generic country-level pandemic plan that could guide an appropriate response to a range of potential pandemic pathogens**. Future generations of pandemic plan need to account for the fact that, in some scenarios, an **effective public health response, combined with spontaneous behavioural change in response to the threat, can drastically alter the course of the epidemic**. This can be beneficial, as seen during the COVID-19 pandemic when elimination bought valuable time for vaccine development, but it also brings challenges because eliminating the pathogen does not eliminate the threat.

Baker *et al.* have proposed that elimination may be the optimum initial strategy for a novel and potentially severe pandemic pathogen [84]. An initial elimination approach could buy time 1) to evaluate emerging evidence about transmission and severity and 2) to protect population health in the short- and medium-term until effective vaccines and treatments become available.

On the other hand, a mitigation approach may be more suitable for a pathogen with sufficiently low severity, for example the swine flu pandemic of 2009.

Unless transmission is globally eradicated or lasting herd immunity can be achieved through mass vaccination (e.g., as for measles), **elimination is likely to be temporary**. In these situations, an elimination strategy needs to be accompanied by an **"exit plan"** for when and how to shift to a suppression or mitigation strategy. Barring global eradication, all pandemics end with the accumulation of sufficient population immunity to reduce the effective reproduction number below 1 in the absence of other control measures. This means that continued transmission can only be sustained by susceptible replenishment (through population turnover and/or waning immunity). Immunity can be infection-derived or vaccine-derived, but infection-derived immunity typically carries much higher risk of acute illness, long-term sequelae and death. A key advantage of an elimination strategy at the start of a pandemic is the possibility of delaying transmission until a vaccine or effective treatment is available.

Initial impact assessment and strategy development may need to be done in the absence of any local surveillance data if, for example, early outbreaks of an emergent pathogen occur overseas before transmission becomes established in Aotearoa New Zealand, as occurred with SARS and COVID-19. **Strategy development is likely to be an iterative process** as more information becomes available to inform the impact assessment (particularly on transmissibility and clinical severity), including Aotearoa New Zealand surveillance data as and when this becomes available.

76 www.health.govt.nz/system/files/documents/publications/influenza-pandemic-plan-framework-action-2nd-edn-aug17.pdf

8. Control measures

This section outlines some of the **main control measures** that may be considered as part of the pandemic response strategy and how their **effectiveness relates to the pathogen typology** described in Part B.

Blanket lockdowns were effective in reducing transmission during the COVID-19 pandemic but are an **extremely costly and blunt instrument**. The exact combination of control measures implemented varied between jurisdictions. Over time efforts were made to ease the most restrictive measures while retaining sufficient control of the epidemic. Despite some efforts to quantify the impact of individual control measures on transmission (via estimates of the effective reproduction number) [85, 86], the international evidence base in this area remains patchy. Control measures frequently have synergistic effects: for example, restrictions on large gatherings enhance the feasibility and effectiveness of contact tracing. Moreover, the **effectiveness of specific control measures will be situation-specific** and will depend, for example, on variable levels of adherence and the broader epidemiological situation and public health response. Quantification of the direct and indirect costs of control measures is even less developed. As a result, we lack a clear picture of the relative costs and benefits of specific control measures in given situations.

One distinction that can be made in assigning social and economic costs, is the difference between control measures that reduce transmission by reducing contacts and control measures that reduce the probability of transmission given contact (see Section 8.2). The first group tend to be highly disruptive; examples include stay-at-home orders, movement restrictions, and limitations on gathering size. The second group are more sustainable because they allow normal life to continue, enabling safe access to healthcare, education, workplaces, and social gatherings. Examples in this second group include vaccines, use of face masks in high-risk crowded spaces, and high indoor air quality [87].

Control measures typically fall into one of two areas: **border measures**, which aim to prevent or reduce the arrival of infectious individuals into the community from outside Aotearoa New Zealand; and **community measures**, which aim to reduce transmission within Aotearoa New Zealand's population. Table 5 provides a summary of key control measures and the factors that are likely to increase or decrease their effectiveness.

8.1 Border measures

Border measures may be applied to all international arrivals, or only to those arriving from or transiting through specified jurisdictions or ports. These measures include:

- **Screening of passengers** (e.g., based on symptoms, diagnostic testing or contact history) to prevent infected individuals from travelling.
- **Quarantine of international arrivals** to prevent transmission from infected individuals to the Aotearoa New Zealand community.
- **Restricted eligibility to enter Aotearoa New Zealand**.

The **effectiveness of border measures** is influenced by the incubation period, infectious period, degree of presymptomatic/asymptomatic transmission, and availability of high-sensitivity, high-specificity diagnostic testing. If the incubation period is long, this means screening is less likely to be effective as passengers are more likely to be incubating the pathogen at the time of travel and less likely to be picked up by testing. If the incubation period is long (or if the infectious period is long and there are significant levels of asymptomatic transmission), this makes quarantine more challenging as individuals either need to quarantine for a longer period or are more likely to be infectious after their quarantine period ends.

Effectiveness of border measures also depends on the prevalence of infection (or of a specific subtype such as a variant of concern) within the Aotearoa New Zealand community. If community prevalence is similar to or higher than prevalence among arriving travellers, border measures are likely to be of limited use. In some situations, border measures may only marginally delay the establishment of community transmission, for example if prevalence in arriving travellers is growing exponentially due to epidemic dynamics overseas, and/or if quarantine measures only reduce the risk of onward transmission rather than prevent it entirely [88]. In other situations, highly stringent border measures may be an important component of an elimination strategy (see strategy development), as they can potentially allow costly community measures to be relaxed if community transmission can be prevented or eliminated.

8.2 Community measures

Community control measures aim to **reduce transmission of the pathogen** within Aotearoa New Zealand's population. A useful way to conceptualise the effect of control measures is via their action on the effective reproduction number R_e expressed as [89]:

$$R_e = D \times O \times T \times S$$

where:

- D = duration of infectiousness
- O = opportunities for transmission
- T = transmission probability per opportunity
- S = susceptibility of population

Case-targeted measures, aiming to test and isolate active cases and to trace and quarantine contacts, effectively **reduce the duration of infectiousness** (D) by isolating individuals from the community before or part-way through their infectious period. Antimicrobial treatments may also reduce people's infectious period where available and appropriate. Broadly, effectiveness of case-targeted measures will be correlated with the visibility of the epidemic. Measures to find and isolate or treat cases will be more effective if pre-symptomatic/asymptomatic transmission is relatively rare. If pre-symptomatic/asymptomatic transmission is common, finding cases before they transmit is more difficult. Contact tracing and quarantine will be more effective if the generation interval is relatively long. If the generation interval is short, there is less time available to identify contacts and quarantine them before they become infectious. Effectiveness will also depend on the mode of transmission. For pathogens that transmit largely

through direct contact, identifying contacts will be usually easier than for pathogens with airborne or vector-borne transmission. Individual variability in transmission also matters: for example, superspreading is a feature of some pathogens, where the majority of transmission occurs from a minority of infected individuals. In situations where there is a high degree of superspreading and a relatively long generation interval, source investigations can be more effective as they enable superspreaders to be identified and their contacts to be traced and quarantined. Case-targeted measures have limited scalability to situations with high infection prevalence. Some aspects may be scalable, for example use of self-administered rapid diagnostic tests, home isolation and household quarantine, supported by digital tools. However, interventions that require a highly trained public health workforce, such as traditional contact tracing and source investigation, or laboratory capacity, such as PCR testing and whole genome sequencing, will typically only be able to deal with a certain number of new cases per day. Some deterioration in the effectiveness of case-targeted measure in reducing onward transmission should therefore be expected as prevalence increases.

Physical distancing measures, such as workplace or business closures, school closures, work-from-home recommendations, and restrictions on gatherings or events, act to reduce opportunities for transmission (O). These interventions are likely to be highly costly, as they are blanket as opposed to targeted measures. However, their effectiveness is less sensitive to epidemic visibility and characteristics such as incubation period, generation interval and presymptomatic/asymptomatic transmission, and they are typically scalable to high infection prevalence.

Measures designed to **reduce the probability of transmission** per opportunity (T) include the use of PPE such as face masks, and hygiene interventions, such as handwashing and surface cleaning.

Reducing population susceptibility (S) is possible through vaccination where available. In the event of a limited vaccine supply or limited delivery capacity, it will be necessary to prioritise vaccination. Equity and the principles of Te Tiriti o Waitangi must be paramount in any prioritisation scheme. It may also be affected by epidemiological characteristics. Prioritisation schemes can broadly be categorised as having one of two aims: reducing clinical disease (direct protection); or reducing transmission (indirect protection) [53]. Factors that favour a direct protection strategy include: large differences in risk of severe disease between identifiable groups; evidence of high vaccine effectiveness against severe disease in high-risk groups; limited vaccine availability; widespread transmission has already occurred, meaning high-transmission groups already have some immunity from prior infection. Factors that favour an indirect protection strategy include: large-scale availability of vaccine before widespread transmission; high-risk groups are unknown or have limited vaccine effectiveness (VE); high-transmission groups can be identified; high vaccine effectiveness against transmission.

General health issues can significantly impact an individual's susceptibility to infectious diseases. A person's overall well-being, including factors such as nutrition, immune system function, and underlying medical conditions, plays a crucial role in determining their ability to fight off infections. Poor nutrition, weakened immune systems, chronic stress and pre-existing health conditions can all compromise the body's defence mechanisms, making individuals more vulnerable to infectious agents. Therefore, **maintaining good general health is essential in bolstering our resistance** to infectious diseases and promoting overall well-being. Given these factors are closely correlated to social inequity, reducing inequity is likely to reduce the impact of infectious diseases.

> **“Equity and the principles of Te Tiriti o Waitangi must be paramount in any prioritisation scheme.”**

Table 5. List of potential strategies and control measures together with epidemiological factors that are likely to favour or to work against the adoption of those strategies or measures.

Strategy	Factors in favour	Factors against
Elimination	Potential for high impact Favourable conditions for effective border measures (see below) Possibility of vaccine availability within a reasonable timeframe	Uncontrolled transmission globally and/or border measures less effective or too costly No realistic prospect of vaccines or improved treatment
Suppression	Difficult to prevent introductions but case-targeted measures highly effective	High case burden makes case-targeted measures unfeasible, requiring either an elimination or mitigation approach
Mitigation	High transmissibility coupled with low clinical severity	High case burden resulting in pressure on healthcare or other services, requiring an alternative strategy to achieve more stringent control

Control measure	Factors that increase effectiveness	Factors that decrease effectiveness
Border measures	Short incubation period Low/zero prevalence in the community Ability to quarantine inbound travellers	Long incubation period Long infectious period combined with high rates of asymptomatic transmission Established transmission in the community Significant fomite transmission
Case isolation	High sensitivity and specificity diagnostic available Test results returned quickly Low levels of pre/asymptomatic transmission Social support mechanisms to enable isolation	Diagnostic has low specificity to infectious period High prevalence combined with limited testing capacity Long infectious period High rates of mild disease or non-specific symptom profile

Control measure	Factors that increase effectiveness	Factors that decrease effectiveness
Traditional contact tracing and quarantine	Long latent period Low prevalence Well defined transmission routes High variability in transmission (superspreading) Social support mechanisms to enable quarantine Good outbreak investigation capacity High levels of trust in health authorities Effective and inclusive digital technologies	Short latent period High prevalence
Antimicrobials	Multiple antimicrobials effective Effective antimicrobials available in Aotearoa New Zealand Oral antibiotics effective	Limited antimicrobials effective Effective antimicrobials not in Aotearoa New Zealand or in limited supply Concerns about antimicrobial resistance Need for intravenous antibiotics would increase demands on hospital services
Remote working / education / healthcare and other measures to reduce contact between infectious and susceptible persons, e.g., restrictions on mass gatherings	Airborne/droplet or direct contact transmission High transmissibility Social support for those who cannot work remotely	Populations at risk are well-defined (e.g. by age group) or transmission is not occurring in public settings (e.g. STIs) High social or economic costs are making these measures unsustainable

Control measure	Factors that increase effectiveness	Factors that decrease effectiveness
Measures that directly interrupt human-to-human or vector-to human transmission	Outbreaks with widespread and/or asymptomatic transmission or absence of a diagnostic test as these measures do not require case ascertainment Highly cost-effective when embedded as long-term infrastructure (e.g., wastewater systems to reduce enteric transmission)	Some measures require a high level of agency / adherence / costs to individuals, e.g. masks, bed nets, barrier methods against STIs Absence of relevant public health infrastructure, requiring time and investment to implement effectively
Vaccination (direct protection priority)	Identified groups with elevated risk High VE against severe disease in high-risk groups Limited vaccine availability	High-risk groups poorly defined or have poor immunogenicity
Vaccination (indirect protection priority)	High-transmission groups can be identified High VE against transmission Vaccine available before widespread transmission	Widespread transmission has already occurred

9. Pandemic preparedness: Modifying the controllability and impact of future pandemics

9.1 Reactive and proactive pandemic preparedness

The pandemic agents and typologies presented in earlier sections of this document encompass a range of scenarios that are likely to require a pandemic response. This framework is in part an **assessment of controllability**: the selected scenarios would require measures over and above routine infectious disease prevention and management. It is also **an assessment of impact**: the severity of an emerging outbreak must be sufficient to justify the use of additional measures.

In earlier sections we discussed analysis of key characteristics and transmission dynamics to enable rapid assessment of an emerging pandemic. This type of pandemic preparedness is in essence reactive, **reflecting the need to implement an appropriate and timely response to a new public health emergency**. We now consider controllability and impact themselves as modifiable factors. In this more proactive framing, pandemic preparedness can be seen as an ongoing, purposeful activity of setting resources in place to maximise the controllability and minimise the impact of a range of infectious diseases with pandemic potential.

9.2 Pandemic controllability and impact as a consequence of resource availability

The predominant cause of death from the 1918 influenza pandemic was severe secondary pneumonia [90] due to coinfection by a range of bacterial pathogens. The severity of such a pandemic today is likely to be substantially reduced by the availability of antimicrobial treatment and high-dependency care. In addition, there were no influenza vaccines or diagnostic tests in 1918 to aid control of community transmission [91].

Lack of treatment and control modalities were not the only determinant of severity in that pandemic, disease outcomes were strongly shaped by structural factors including poverty and racism. Population mortality varied over 30-fold across jurisdictions, and a large proportion of the variation could be attributed to differences in per-capita income [92]. In Aotearoa New Zealand, mortality among Māori during the 1918 pandemic is estimated to have been seven times higher than that experienced by non-Māori [27]. These examples illustrate the inequitable distribution of resources that lead to differential impacts in populations; they also highlight the preventability of such impacts when communities have appropriate access to resources.

Major shifts in controllability in the past can offer some indication of what might be possible in the future. Poliovirus, a highly transmissible pathogen that has severe impacts on population health, became very rapidly controllable with the advent of effective vaccines. Likewise, development and rollout of an effective pan-coronavirus vaccine could substantially reduce the likelihood of future coronavirus pandemics [93]. Because of its wastewater and drinking water infrastructure, Aotearoa New Zealand no longer experiences cholera outbreaks; a cholera pandemic is unlikely to require a large-scale pandemic response within this country. The same is likely true of many other waterborne pathogens. But as evidenced by Aotearoa New Zealand's high rates of seasonal respiratory infections, housing and indoor air quality remain poor, exposing the population to risk during future pandemics spread by airborne transmission.

9.3 Scenario-based pandemic planning: resource allocation for maximal controllability

Our existing infectious disease infrastructure is already sufficiently strong that several potential or existing PHEIC scenarios (e.g., poliomyelitis) would not require a pandemic response in Aotearoa New Zealand because the infections in question are highly controllable with current resources. Further evaluation might identify other agents or scenarios where it would be both feasible and desirable to put additional resources in place to elevate controllability to this optimal level.

For most scenarios a pandemic response will be necessary. Planning for these scenarios requires consideration of both **reactive preparedness** (capacity to stand up an effective pandemic response very rapidly if need be) and **proactive preparedness** (resources already embedded in day-to-day operation that prevent the spread of infectious diseases). Proactive preparedness has specific benefits, in particular efficiency: the resources needed to prevent pandemic transmission overlap strongly with public health measures used to control endemic and epidemic infections. If these resources are in place for endemic pathogens, they will be in place for an emerging pandemic. Examples include indoor air quality as above, Māori- and Pacific-led community vaccination infrastructure and an equitable and well-resourced system for paid sick leave to enable effective isolation and quarantine. These and other generic infectious disease control measures have potential for long-term cost-effectiveness because they reduce disease burden between pandemics as well as during them.

Infectious disease **infrastructure designed to interrupt transmission routes** (via air, water, food, vectors, or direct contact including sexual transmission) **represents a highly efficient form of pandemic preparedness** because it protects against multiple pathogens including emerging outbreaks or pandemics before they are detected and characterised. This type of infectious disease control is also relatively unaffected by large case numbers compared with case-based measures such as contact tracing and clinical management that can experience capacity limitations during outbreaks.

These considerations can provide a framework for evaluating pandemic preparedness that includes evaluation of each individual scenario and the resources required for an effective response, but also identifies efficiencies across scenarios and across pandemic and endemic infections. Key protections could be embedded as infrastructure that reduces the high burden of endemic infections while enhancing the controllability of a range of pandemic scenarios.

“For most scenarios a pandemic response will be necessary. Planning for these scenarios requires consideration of both reactive preparedness (capacity to stand up an effective pandemic response very rapidly if need be) and proactive preparedness (resources already embedded in day-to-day operation that prevent the spread of infectious diseases).”

10. Glossary of terms

AIDS: Acquired immunodeficiency syndrome

CDC: Centers for Disease Control and Prevention

CFR: Case fatality ratio (rate)

COVID-19: Coronavirus disease 2019

Disease X: previously unknown human pathogen (see Appendix B)

EARS: Early Aberrant Reporting system

FAO: Food and Agriculture Organisation

FFX: First Few X case studies

Generation interval: time between infection and onward transmission

GISRS: Global Influenza Surveillance Response System

GP: general practitioner

H1N1/H5NI: influenza A virus subtypes defined by two proteins: H = hemagglutinin; N = neuraminidase.

HIV: Human immunodeficiency virus

HPAI: Highly Pathogenic Avian Influenza

ICU: intensive care unit

ID: Infectious disease

IFR: Infection fatality ratio (rate)

ILI: influenza-like illness

IRR: International Reagents Resource

MDSov: Māori data sovereignty

MERS: Middle East respiratory syndrome

Morbidity: the state of having a specific illness or condition

Mpox: formerly monkeypox disease, an *Orthopox* virus similar to smallpox

MDR: multidrug-resistant

nvCJD: new variant Creutzfeldt-Jakob disease

Pandemic: an infectious disease epidemic occurring worldwide, or over a very wide area, crossing international boundaries, and usually affecting a large number of people (see Appendix B)

PHEIC: public health emergency of international concern (see Appendix B)

PISA: pandemic influenza severity assessment

R_{eff}: Effective reproduction number

R_0: Basic reproduction number

SARI: severe acute respiratory infection

SARS: severe acute respiratory syndrome

SARS-CoV-2: severe acute respiratory syndrome coronavirus 2

SHIVERS: Southern Hemisphere Influenza and Vaccine Effectiveness Research and Surveillance

TDR: Totally drug-resistant

UNEP: United Nations Environment Program

VAANZ: Vaccine Alliance Aotearoa New Zealand – Ohu Kaupare Huaketo

WHO: World Health Organization

WOAH: World Organisation for Animal Health

XDR: Extensively drug-resistant

11. Appendix B: Definitions

11.1 Public Health Emergency of International Concern (PHEIC)

A PHEIC is defined in the International Health Regulations IHR (2005) as, "an extraordinary event which is determined to constitute a public health risk to other States through the international spread of disease and to potentially require a coordinated international response"[77].

11.1.1 Declaration of a PHEIC

Under the IHR (2005) a PHEIC is declared by the World Health Organization if the situation meets two of four criteria:

- Is the public health impact of the event serious?
- Is the event unusual or unexpected?
- Is there a significant risk of international spread?
- Is there a significant risk of international travel or trade restrictions?

There have been seven PHEIC declarations since 2005, one of which (poliomyelitis) is still in effect (Table 6).

Table 6. Infectious diseases that have been declared a PHEIC by IHR Emergency Committees.

Disease	Duration of PHEIC
H1N1	2009 – 2010
Poliomyelitis	2014 ongoing
Ebola Virus Disease	2014 – 2016 and 2019 – 2020
Zika Virus	2016 – 2016
COVID-19	2020 – 2023
Mpox	2022 – 2023

77 www.who.int/news-room/questions-and-answers/itememergencies-international-health-regulations-and-emergency-committees

An outbreak can be serious without being declared a PHEIC. WHO reports that "the IHR Emergency Committee concerning Middle East respiratory syndrome coronavirus (MERS-CoV) met on 10 occasions from July 2013 to July 2015. At no time did the Committee conclude that the conditions for a Public Health Emergency of International Concern had been met."[78]

Similarly, in 2016 yellow fever was assessed by the IHR Emergency Committee as being of great concern but it did not meet criteria for a PHEIC. Wilder-Smith and Osman noted that lack of potential to disrupt trade is a common reason for diseases failing to meet the criteria despite presenting a serious health risk to populations [94]. Measles falls in this category, because another reason PHEIC may not called is if an effective vaccine is available. Wilder-Smith and Osman proposed that a PHEIC would not be the appropriate platform to support action on antimicrobial resistance (AMR), although this assessment could change in the event of a rapidly spreading, multi-drug-resistant pathogen. It is likely that the HIV pandemic would have been declared a PHEIC had it occurred after the introduction of the IHR (2005) regulations.

11.2 Pandemic definitions

A pandemic has been defined as "*an epidemic occurring worldwide, or over a very wide area, crossing international boundaries, and usually affecting a large number of people*".

In their 2009 commentary 'What is a pandemic?', Morens, Folkers, and Fauci highlighted the contested nature of this term and listed several key characteristics of a pandemic disease: wide geographic extension, disease movement, high attack rates and explosiveness, minimal population immunity, novelty, infectiousness, contagiousness (i.e., human-to-human transmission), and severity [95].

11.3 Identifying emerging pandemics and PHEICS: implications for Aotearoa New Zealand

Pandemic and PHEIC definitions attempt to capture:

- **Emerging nature**: unexpected, unusual, and/or rapid spread of an outbreak
- **Impact**: to be in scope, there need to be indications of high impact on population health
- **Wide geographical spread,** indicating**:**
  - potential for high impact
  - need for international co-operation.

There are competing risks in declaring a pandemic or PHEIC that need to be weighed up. A declaration facilitates international co-operation and enables rapid and early action including the use of emergency measures for diagnosis, vaccines, and treatment. But both control measures and the declaration itself may be disruptive to normal functioning of societies at an international or national level.

Some commentators [94, 96] state that the current binary nature of PHEIC declaration is unhelpful and that a tiered approach is needed to support action at an early enough stage to prevent a localised outbreak from becoming a pandemic. A key lesson from both the Ebola virus disease outbreak of 2018 and the SARS-CoV-2 pandemic was that delays in

78 www.who.int/groups/mers-cov-ihr-emergency-committee

declaring a PHEIC impeded international efforts to control these serious public health threats. A lesson that had not been learned after the much larger 2013-2016 Ebola virus disease outbreak in West Africa, for which the PHEIC declaration was similarly delayed [97].

Durrheim et al. [96] have proposed a multilevel system for PHEIC declaration: Level 1 would indicate a high-risk outbreak in a single country, requiring action to prevent international spread; Level 2 would indicate that multiple countries have had importations and there is limited spread; and Level 3 would indicate large clusters in multiple countries with ongoing local transmission.

A similarly nuanced assessment may be required by Aotearoa New Zealand to ensure a proactive rather than reactive response to an emerging pandemic. Severe threats to population health may only be declared a PHEIC or pandemic once there is widespread infection, reducing opportunities for effective border control in Aotearoa New Zealand; and a very large outbreak may never be declared a PHEIC if criteria such as disruption of international trade are not met.

11.4 Disease X

"Disease X" was included in the WHO R&D Blueprint list of priority diseases in February 2018[79]. It is an attempt to capture pathogens that are currently unknown to cause human disease but have the potential to cause a pandemic. What "Disease X" is or where it is likely to emerge is, by definition, not possible to determine. However, new diseases are continually emerging in multiple locations, and developing countries are considered to be at higher risk; particularly those with high biodiversity and limited surveillance and response capacity.

COVID-19 caused by SARS-CoV-2 is an example of a Disease X, underlining the need to consider currently unknown human pathogens in pandemic preparedness. International efforts are focused on developing vaccine technologies that can be rapidly deployed to tackle diseases for which no licensed vaccines are currently available, including an emerging Disease X[80].

79 https://cdn.who.int/media/docs/default-source/blue-print/rd-blueprint_prioritization-2022_concept-note_v.1.pdf?sfvrsn=260e4e8f_3

80 https://cepi.net/about/whyweexist

12. Appendix C: Additional insights from the project workshop held on the 16th May

The project team took the opportunity to hold a workshop after a Te Niwha Commissioning workshop on Prevention held in Wellington on the 16th May. Many of the attendees also participated in the project workshop and a number of additional experts attended in person and online.

The three-hour meeting was attended by over 40 individuals with diverse backgrounds including Māori Health, Pacific Health, epidemiology, community health providers, hospital and community-based infectious disease clinicians, public health physicians, paediatricians, modellers, immunisation experts, genomics experts, surveillance experts and policy makers.

Four high level questions were posed:

- What are the key lessons learned from the COVID-19 pandemic and other infectious disease outbreaks that need to be addressed in a future pandemic plan?
- What community-led initiatives worked well?
- How can a future strategy for responding to pandemics be more equitable and give effect to Te Tiriti o Waitangi?
- How can we ensure that Aotearoa New Zealand has the scientific capacity and expertise to respond to future pandemics?

These were followed by the following more detailed questions:

Vaccination rollout

Many elements of the vaccine rollout did not work well for Māori and Pacific people – including the age-group based availability, inadequate resourcing and a top-down rather than ground-up approach.

- What is the best resourcing model (funding, infrastructure, materials, and people) to enable all community providers to rollout vaccinations? What resources are needed upfront in the face of a vaccine preventable pandemic?
- Who are the best communicators to convey key messages to communities? How do we design effective health messages?
- What would an improved vaccine rollout look like on the ground? How would that vary for different communities? E.g., urban, rural, and isolated communities and marginalised groups?

- What are critical steps in the vaccination rollout journey – who comes in where and when? (Key actors). How do we ensure things are done in partnership?

Public health prevention and control measures

This includes measures such as mask wearing, contact tracing, restrictions on gatherings, isolation, and border closures.

- What is the best resourcing model (funding, infrastructure, materials, and people) to enable community providers to implement the use of these measures? What resources are needed upfront in the face of a pandemic? (e.g., trained personnel, materials, and financial support/sick leave – related to isolation/quarantine).
- What would that look like on the ground? How would that vary for different communities? E.g., urban, rural, and isolated communities and marginalised groups.
- How do we develop a shared language concerning control measures? i.e., a 'Pandemic language' using terms consistently across all communities.
- Who are the best communicators to convey key messages concerning the implementation of these measures in communities?
- Which non-pharmaceutical interventions were considered to be most effective in the community and what were the main barriers to their adoption and uptake?

Diagnostic availability

This includes a discussion of what measures could have been taken to achieve a more equitable availability of diagnostic tests and how this would affect surveillance national and regionally.

- What approach to the delivery of diagnostics worked for your whānau and community? (Considering urban, rural, isolated communities). How did this align with regional and national initiatives?
- What was your community infrastructure for the delivery of diagnostics? (e.g., home, community, lab). What were the barriers to delivery?

Surveillance

This includes the use of genomics and wastewater testing and a discussion of what information is needed to mobilise communities.

- How best can we communicate what is being done, and why, at the community level? (Including the role and processes of surveillance). What issues need to be considered with respect to data use, access, and storage in the face of a new pandemic?
- How can communities be better informed and more engaged?
- How do we ensure we have the data access and analytical tools to make sure decision making is informed by the best possible evidence?

Decision making

Key decisions are made during the time course of a pandemic, including whether to step up or down a pandemic response.

- Who makes these decisions, and how can the decision-making process be more effectively communicated at the community-level?
- How can we ensure we have the right people engaged in decision making (including strategic decisions and control measures in the face of a pandemic) that involve/include all relevant people in the community.

Responses were summarised on a whiteboard and transcribed. By agreement with participants:

- The goal was to capture the main themes, rather than detailed comments.
- All participants and their comments will remain anonymous.
- All detailed information derived and gathered from the workshop will securely remain with Massey/ Te Niwha.

The transcribed outputs from the workshop have therefore been used to inform a number of key inputs into the above narrative, rather than provided as a standalone document.

13. Appendix D: Lead Agency and Support Agency (extract from CIMS 3rd edition, Section 2.3)

13.1 Lead Agency

A lead agency is the agency mandated through legislation or expertise for managing a particular hazard that results in an incident. While some hazards or risks are managed by the lead agency alone, many require the support of other organisations.

The lead agency's role is to:

- monitor and assess the situation
- plan for and coordinate the response
- report to Governance
- coordinate the dissemination of public information.

A lead agency should develop and maintain capability and capacity to ensure it is able to perform its role, and may draw on the advice and expertise of others in doing so.

Where activities are required at national, regional and/or local levels, a devolved accountability model is used. For example, Manatū Hauora is the strategic lead for infectious human disease nationally, whilst Te Whatu Ora are the regional leads. Maritime New Zealand is the national lead for a marine oil spill, while the regional lead is the affected Regional Council.

In response, the lead agency establishes control to coordinate the overall response to the incident; however this does not limit, is not a substitution for and does not affect the functions, duties or powers that other agencies may have in support of the management of an incident.

The lead agency may change as the incident evolves and the required authority or expertise changes. The lead agency may also change between [risk] reduction, readiness, response and recovery.

13.2 Support agency

Organisations supporting the lead agency are known as support agencies. Support agencies are required to develop and maintain capability and capacity to ensure that they are able to perform their role. Support agencies may have statutory responsibilities and/or specific objectives of their own, which they may need to pursue in addition to, or as part of, the support that they provide to the lead agency.

Integration of support agencies into the response is a responsibility of the lead agency Controller. While the lead agency Controller may task and coordinate support agencies' resources and actions, they must recognise and accommodate support agencies' statutory responsibilities and/or specific objectives. Sometimes a support agency might support the lead agency by repurposing an existing capability.

The type of incident, response requirements, and consequences being managed determine which support agencies are involved, and these agencies may change as the response changes. Besides government agencies, support agencies may also include entities such as Civil Defence Emergency Management (CDEM) Groups, iwi/Māori, communities/volunteers, private sector organisations such as lifeline utilities, and non-government organisations.

Support agencies must assist the lead agency in the development of Action Plans.

13.3 Lead and support agency references

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