Climate Change Risks in Auckland

AUCKLAND COUNCIL TECHNICAL REPORT, TR2019/019

Auckland Council
Te Kaunihera o Tāmaki Makaurau

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Executive Summary

Auckland is being impacted by climate change and projections indicate that impacts will intensify over the next century. **Action is required** to anticipate the effects and adapt to a changing climate.

In response to the threat of climate change, Auckland Council has committed to facilitating the development of Auckland's Climate Action Plan. It will steer the region on a path toward rapidly reducing greenhouse gas emissions and to prepare the city for the impacts of a changing climate. This is in line with the 2015 Paris Agreement to limit global warming to 1.5°C.

As part of developing the evidence-base for the action plan, Auckland Council's Research and Evaluation Unit has produced a Climate Change Risk Assessment technical report series. This assessment aims to provide information about the risks the Auckland Region may face and its impacts on people, society and the environment. This research is underpinned by the *Auckland Region climate change projections and impacts* research undertaken by the National Institute of Water and Atmospheric Research (Pearce et al., 2018).

This document summarises the research, key findings and considerations from the risk assessment to contribute to the development of Auckland's Climate Action Plan.

Climate change in Auckland

The National Institute of Water and Atmospheric Research climate projections (Pearce et al., 2018) provide Auckland with the most robust, localised information on the anticipated changes in climate for the region and is available on Knowledge Auckland. The anticipated changes in the climate in Auckland are changes in sea level rise, temperature, rainfall, storm events, wind and humidity.

Climate Change Risk Assessment

The Climate Change Risk Assessment technical report series were undertaken using the Intergovernmental Panel on Climate Change methodology (IPCC, 2014) to assess impacts on people, the environment and infrastructure. The purpose was to identify which parts of Auckland are the most susceptible to impacts of climate change and also the social and environmental vulnerability. This is understood by evaluating the adaptive capacity of areas to impacts of climate change.

Key findings

Combining the impacts of climate change with relative vulnerability across Auckland suggests that:

The ability of people and households to adapt and respond to the effects of climate change is dependent on many factors.

- Where people live, their socio-economic circumstance, their support networks, their occupations and their ability to have options can impact their vulnerability.
- Children and older people will be more vulnerable than others to some effects, especially related to poor air quality.
- There is some evidence that Māori and Pacific peoples may be more affected than others to some effects, due to their generally younger age structures as well as other factors.

Sea level rise could put infrastructure and ecosystems at risk while flooding poses direct and indirect risks to people, infrastructure and services.

The changing climate will create an environment that allows water and vector-borne diseases to thrive, which will affect people and ecosystems.

Terrestrial, marine and freshwater ecosystems are at risk and face a combination of stressors. The most vulnerable species are those that have limited capacity to migrate and those that will experience a 'coastal squeeze'.

Changes to these ecosystems are likely to impact on human wellbeing and the economy.

Informing Auckland's Climate Action Plan

The Climate Change Risk Assessment identifies areas, sectors and communities at greatest risk from climate impacts. This provides an evidence base to support the development of Auckland's Climate Action Plan.

It is worth remembering that climate change is not happening in isolation and not just in Auckland. Rapid population growth, land use changes, pollution and human induced stressors will compound the effects of climate change for people and the environment.

There is inherent uncertainty in the projections and the magnitude and extent of the effects could vary. Risks will continue to emerge due to the multiple stressors. Continual re-evaluation will need to be undertaken as more data become available.

Implementing precautionary and adaptive measures into decision-making at every level will allow for better response to reduce risks and will help prepare Auckland for climate change.

Contents

Wynyard Quarter © Auckland Council

01/ Introduction

Auckland's Climate Action Plan will set a path to rapidly reduce greenhouse gas emissions to keep within 1.5 degrees of warming while ensuring Auckland is prepared for the impacts of climate change.

Auckland Council is committed to reducing emissions and ensuring resilience for Auckland. In 2016, Auckland Council joined the C40 Cities Climate Leadership Group, a global network of over 90 cities committed to tackling climate change. In renewing C40 membership in November 2018, Auckland Council committed to leading the development of a climate action plan for the region.

Auckland's Climate Action Plan will set a path to rapidly reduce greenhouse gas emissions in line with the 2015 Paris Agreement to keep warming within 1.5 degrees. It will ensure that Auckland is prepared for the impacts of climate change. The plan is being developed in collaboration with businesses, organisations, mana whenua, communities and individuals as well as across all levels of government.

In developing the evidence base for Auckland's Climate Action Plan, Auckland Council's Research and Evaluation Unit has developed a Climate Change Risk Assessment technical report series, using Auckland's Climate Change Projections (Pearce et al., 2018) as a basis. This research aims to provide information about the risks and vulnerabilities that the Auckland region may face under the changing climate.

This document summarises risks identified within the technical report series to understand how the Auckland region will be affected by climate change.

Specifically, the research covers:

- Health effects of extreme heat.
- Climate change, air quality and health impacts.
- Creating conditions for disease vectors.
- Social vulnerability.
- Flooding risk in the built environment.
- Climate change impacts and risks for terrestrial ecosystems.
- Climate change impacts and risks for marine and freshwater ecosystems.
- Effects of sea level rise on Auckland.

Understanding the climate change risks and impacts on vulnerability for Auckland is imperative to both mitigate and adapt to climate change and to inform planning and decision making. This research will help Aucklanders to understand the impacts of climate change on their health, the health of our ecosystems, and the impact on the natural and built environment.

The technical report series will be expanded and built on as data and other resources become available.

Collaborating with Māori

Auckland Council is working to interface Te Ao Māori perspectives, values and ancient ancestral knowledge (Mātauranga Māori) into current and future decision making around climate change.

By working with the Mana Whenua Kaitiaki Forum, kaumatua and Māori experts, the plan seeks to weave the mātauranga of those who have come before us and the voices of mana whenua into solutions around specific climate challenges for Tāmaki Makaurau. It is crucial that these meet the specific needs and interests of our Māori communities, give a voice to our future generations through the work we do today, and give agency to the non-human elements around us that make up the world that we are a part of.

Research across New Zealand highlights that Māori communities, assets and economy are vulnerable to the impacts of our changing climate.

Future research aims to:

Develop a more comprehensive understanding of the specific impacts of climate change on Māori communities, assets and economy across Tāmaki Makaurau.

Provide clarity around how Auckland Council and Council Controlled Organisations can enable and honour our commitment of active protection in relation to climate change under the Treaty of Waitangi.

Climate Change Risk Assessment document map

Auckland Region Climate Change Projections and Impacts
NIWA, 2018

RIMU Risks and Vulnerabilities Research Programme

An assessment of vulnerability to climate change in Auckland	Air quality and societal impacts from predicted climate change in Auckland
Development of the Auckland Heat Vulnerability Index	Creating conditions for disease vectors
Sea Level Rise in Auckland	Flooding risk in the built environment
Climate change impacts and risks for marine and freshwater ecosystems	Climate change impacts and risks for terrestrial ecosystems

Climate Change Risks in Auckland
THIS DOCUMENT

Auckland's Climate Action Plan
TO BE RELEASED 2019

Figure 2: Document map

Manurewa native forest remnants © Auckland Council

02/ Auckland's Changing Climate

The climate in Auckland is changing, with extreme weather events becoming more common and more severe.

The National Institute of Water and Atmospheric Research has undertaken an important research piece – Auckland region climate change projections and impacts (Pearce et al., 2018) – which provides Auckland with the most robust information on the climate projections for the region.

This research has been used to underpin the Climate Change Risk Assessment.

The report

The National Institute of Water and Atmospheric Research reviewed climate change projections in Auckland and modelled expected changes for 21 different climate variables out to 2120. The future changes were assessed by incorporating knowledge of natural variations in the climate and changes that may result from human induced increases in greenhouse gas concentrations.

Future climate scenarios were considered using four Representative Concentration Pathways, 2.6, 4.5, 6.0 and 8.5 for 2040, 2090 and 2110. These indicated the projected greenhouse gas concentrations based on forecast emission trends and were used as inputs to the model to represent different scenarios. The graph below demonstrates the different pathways:

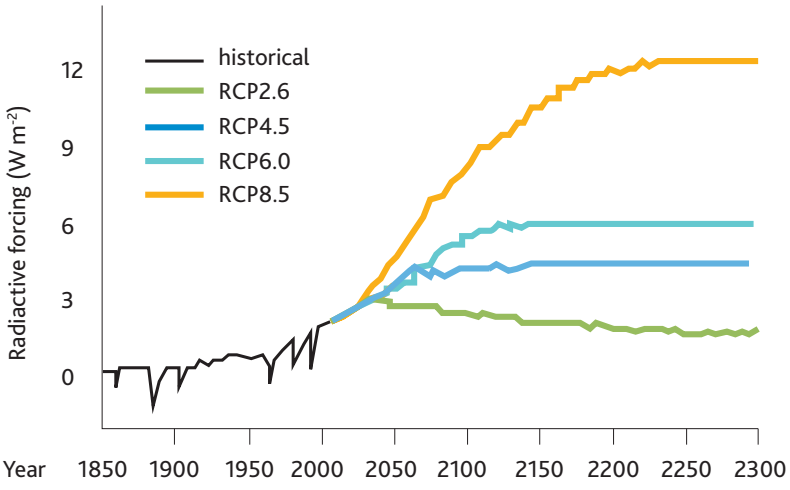


Figure 3: Representative Concentration Pathways

Application to the Climate Change Risk Assessment

The climate change projections have been used as the basis for assessing impact and risk in the Auckland Council Research and Evaluation Unit Climate Change Risk Assessment technical report series for Auckland. The forecasts for Representative Concentration Pathway 8.5 have been used as these are most representative of current emission trends and allow a precautionary approach.

The future climate is uncertain

Climate change projections are a snapshot in time and are projections based on current models. There is inherent uncertainty in climate change projections and the future changes that will occur as a result. Uncertainty is due to:

- The cumulative impacts of climate change.
- Conflicting impacts of climate change and what this means for the natural and built environment.

Evidence demonstrates that the climate is changing more rapidly than anticipated by climate scientists. Therefore, projections for the next century could very well be accelerated into the latter part of this century.

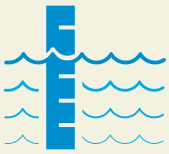
Climate projections

TEMPERATURE

Increasing annual average temperatures and extreme temperatures, and significantly more hot days each year. Plant growing days also increase.

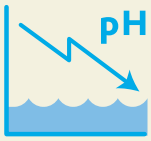
SEA LEVEL

Rising sea level puts coastal communities and infrastructure at risk from inundation and erosion. Under RCP 8.5, 1m sea level rise is projected by the end of this century.



OCEAN ACIDIFICATION

Uptake of atmospheric CO_2 is leading to ocean acidification. Changes in the oceans will adversely impact health of marine life and cause nutrient decline.



HUMIDITY

Annual relative humidity is projected to slightly decrease while absolute humidity is expected to increase.

RAINFALL

Seasonal distribution of rainfall is projected to change with wetter autumns and drier springs. More extreme rainfall events are expected to increase while the number of rain days and soil moisture deficit are set to decline.

WIND

Average wind speed and number of windy days are decreasing and this is projected to continue, while intensity of tropical cyclones is expected to increase.

Auckland skyline © Istock

03/ Climate Change Risk Assessment

Purpose

The Climate Change Risk Assessment technical report series provides a technical, evidence-driven foundation to guide actions for Auckland's Climate Action Plan.

Definitions

This research utilises the Intergovernmental Panel on Climate Change definitions (IPCC, 2014):

RISK

The Intergovernmental Panel on Climate Change defines risk as the likelihood of an event occurring combined with the impacts. Specifically, for climate change, risk is comprised of three components (seen in Figure 4):

- The hazard.
- Exposure of people, infrastructure, economy and natural environment to the hazards.
- Vulnerability to the hazards.

VULNERABILITY

The vulnerability of people, a species or habitat, infrastructure, economy or the natural environment is a component of risk. Vulnerability includes the following:

- Exposure to the hazard.
- Sensitivity.
- Adaptive capacity.

Vulnerability includes the physical, geographic and socio-economic contexts that determine an individual's or group's ability to adapt to change. For species, their ability to migrate would influence their adaptive capacity.

Understanding the most vulnerable areas of Auckland is important to understand how to build resilience and develop targeted actions to prepare Auckland in response to a changing climate.

Risk and vulnerabilities relationships

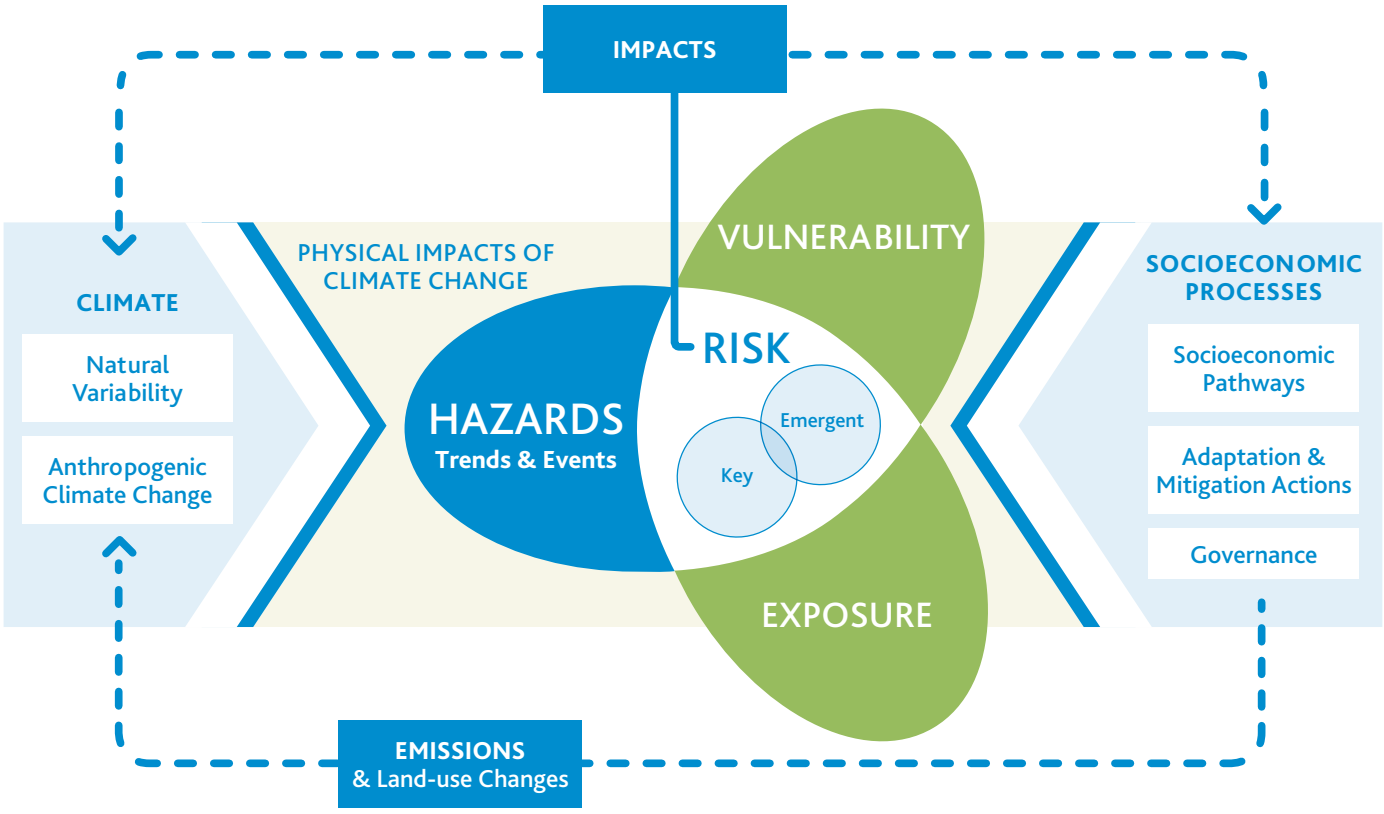


Figure 4: Relationship between vulnerability, risk, exposure and hazards (IPCC, 2014)

Methodology

The Intergovernmental Panel on Climate Change methodology was undertaken for the Climate Change Risk Assessment technical report series. This methodology was applied to people, ecosystems, societal systems, built infrastructure and green and blue infrastructure to understand risks and vulnerabilities.
The methodology included:

1. Understanding stressors on the people, society and environment as a result of climate change.
2. Definition of the spatial scale being assessed – in most 'people specific' cases this was a census area unit – for habitats it was a specific species.
3. Identification of quantifiable indicator variables that cover exposure, sensitivity and adaptive capacity:

   Exposure indicators are variables that measure the region's exposure to climate change.

   Sensitivity indicators illustrate reactiveness to changes in the climate. For people this includes employment status, age, accessibility and underlying health conditions. For species it includes ability to migrate and distance from coastal regions.

   Adaptive capacity covers the ability to react to the changes. For people this includes factors such as socio-economic standing and accessibility to greenspace.
4. Indices: indicators for each spatial unit were scored and weighted to develop index values.
5. Identification of vulnerability hotspots: these were identified based on spatial units with high sensitivity, high exposure and low adaptive capacity.
6. Assessment and discussion: identifying the vulnerability hotspots in Auckland enabled an analysis of the most at risk areas, groups, species, habitats infrastructure.

Climate Change risk assessment methodology

Figure 5: Climate Change risk assessment methodology

Key Messages

Climate change will impact people, societal structures, the natural and built environment, species and habitats.

A few of the key findings from the Auckland's climate change research undertaken include:

Climate change is happening, and effects can already be seen

Climate change is linked to deteriorating air quality which will further impact the health of the population.

Weather patterns will change. Spring rainfall is projected to decline and autumn rainfall is projected to increase across the Auckland Region.

Climate change will increase extreme heat events (hot days) which will likely impact the health of Auckland's communities and environments. There may be further unknown consequences that cannot be projected at this stage, such as the risks associated with the establishment of new disease and disease vector populations such as mosquitos and parasites.

Storm surge and sea level rise are already affecting Auckland's people and infrastructure.

Ocean acidification is already threatening Auckland's marine ecosystems, including culturally, economically and ecologically significant species.

Terrestrial, marine and freshwater ecosystems will change due to the compounding effects and multiple stressors of climate change and other environmental stressors such as pollution.

The current projections may accelerate at an unknown rate, so that effects projected for the next century – such as sea level rise – may take place over a much shorter time frame.

The Climate Change Risk Assessment takes into consideration scientific projections, our current understanding of climate change effects, and Auckland's current environment in order to better understand the key risks and vulnerabilities of Auckland. Some of the key findings include:

The ability of people and households to adapt and respond to the effects of climate change is dependent on many factors.

- Where people live, their socio-economic circumstances, their support networks, their occupations and their ability to have options can impact their vulnerability.
- Children and older people will be more vulnerable than others to some effects, especially related to poor air quality.
- There is some evidence that Māori and Pacific peoples may be more affected than others to some effects, due to their generally younger age structures as well as other factors.

Sea level rise will put infrastructure and ecosystems at risk while flooding poses direct and indirect risks to people, infrastructure and services.

The changing climate will create an environment that allows water and vector-borne diseases to thrive, which will affect people and ecosystems.

Terrestrial, marine and freshwater ecosystems are at risk and face a combination of stressors. The most vulnerable species are those that have limited capacity to migrate and those that will experience a 'coastal squeeze'.

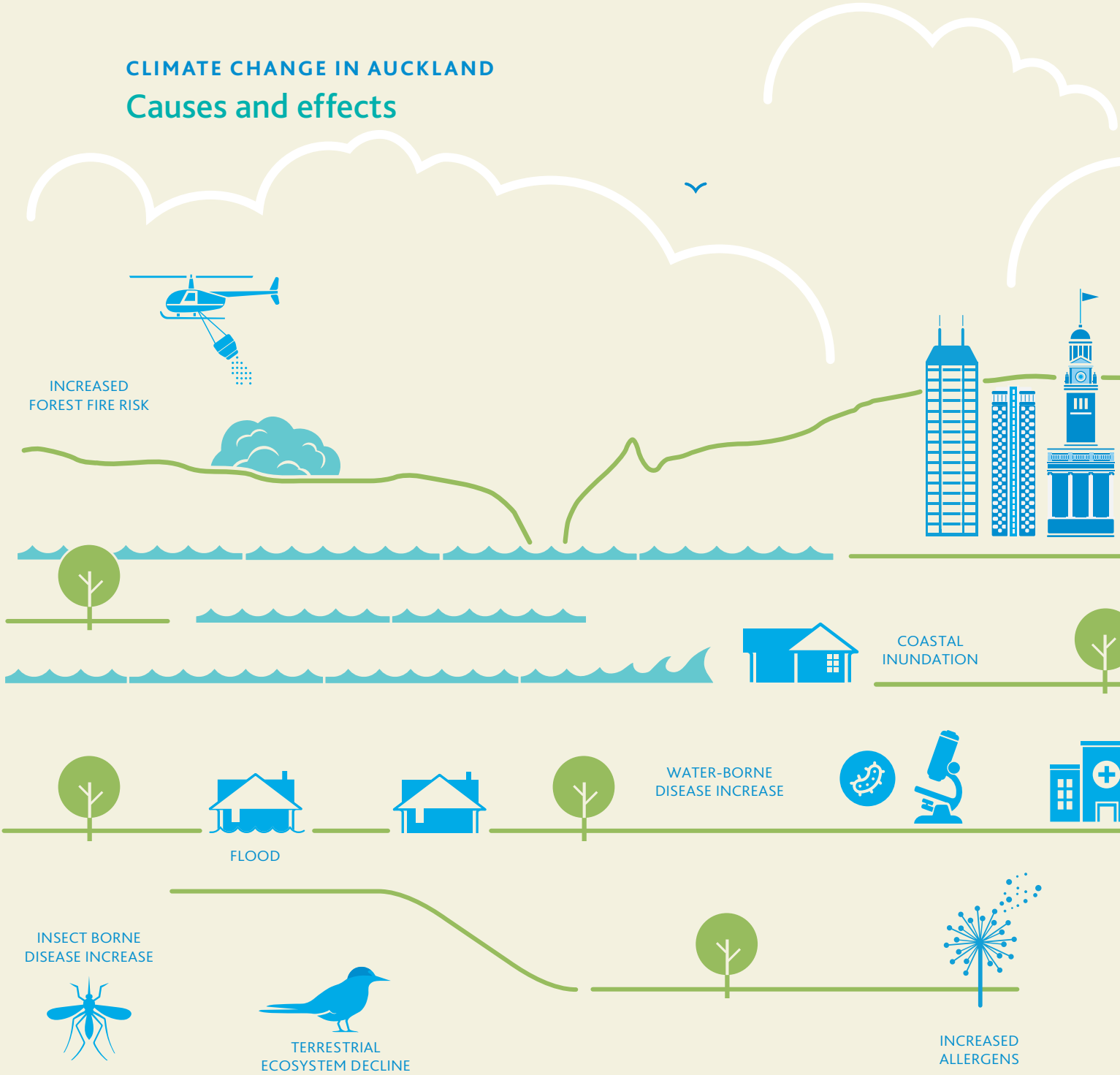
Changes to these ecosystems are likely to impact on human wellbeing and the economy.

The Climate Change Risk Assessment technical report series identifies some evidence-based, targeted considerations for those areas, sectors and communities at greatest risk from climate impacts. These considerations will tie into Auckland's Climate Change Action Plan. The considerations from these risk assessments are not comprehensive and actions identified in Auckland's Climate Change Action Plan will encompass these considerations and more.

The following sections summarise the technical report series and further detail Auckland's climate change impacts and the risks for people, society and the environment.

CLIMATE CHANGE IN AUCKLAND

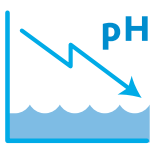
Causes and effects



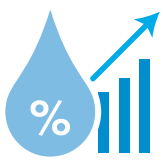
CLIMATE CHANGE IN AUCKLAND

Causes

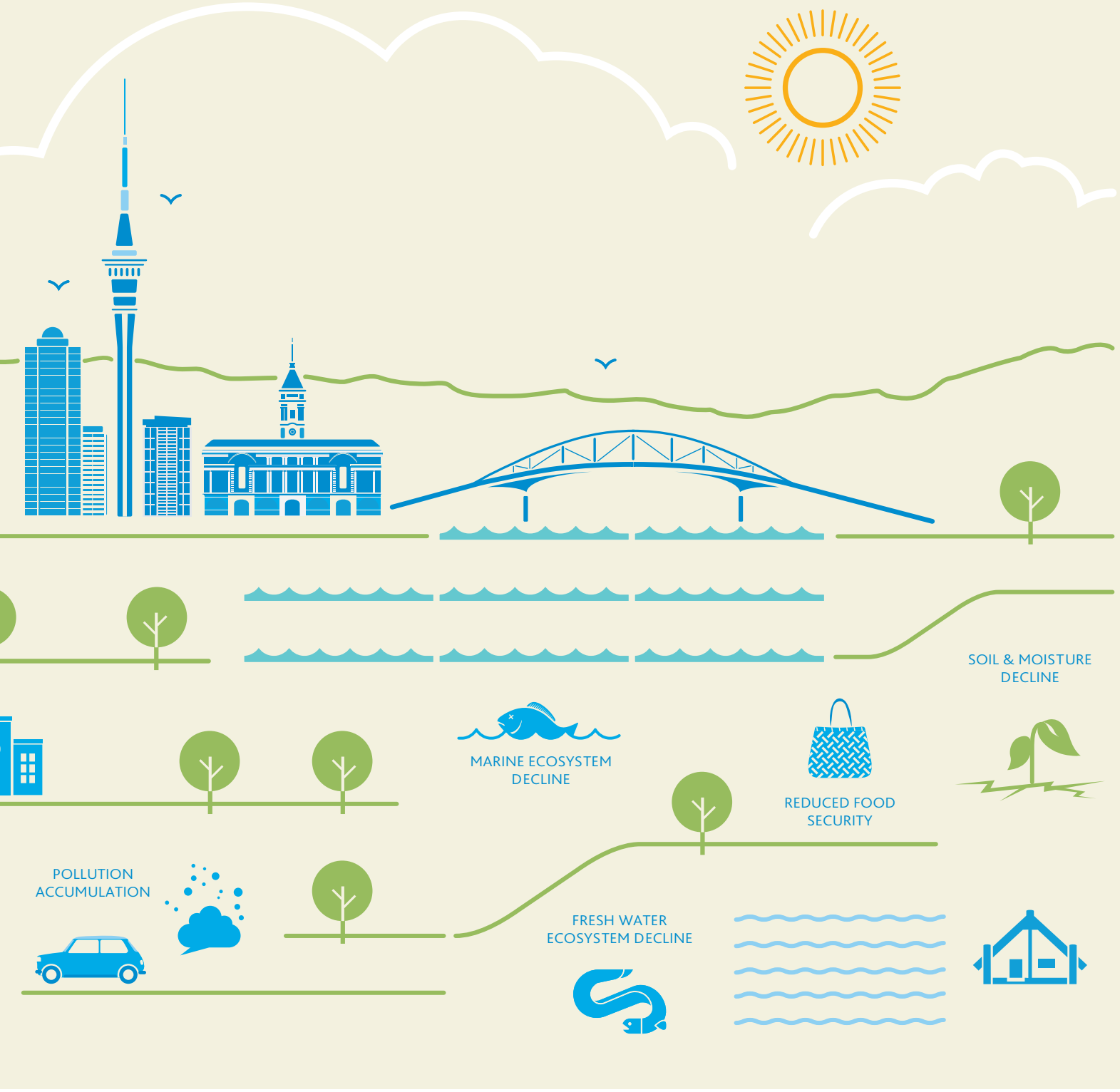
TEMPERATURE INCREASE



OCEAN ACIDIFICATION



ABSOLUTE HUMIDITY INCREASE



STORM INTENSITY INCREASE

DECREASED RAINFALL DAYS

SEA LEVEL RISE

VARIABLE WIND SPEED

The following section summarises the Technical Report series developed by Auckland Council's Research and Evaluation Unit.

Whangaparoa Peninsula © Istock

04/ Technical Report Series

4.1 Health effects of extreme heat

Based on: Joynt, J. L. R. and Golubiewski, N. E. (2019). Development of the Auckland Heat Vulnerability Index. Auckland Council technical report, TR2019/013

The Auckland Heat Vulnerability Index identifies the areas and populations more sensitive to the effects of extreme heat. Vulnerability to extreme heat is influenced by socio-economic, health and environmental factors. Ten representative indicators derived from census and land cover data for Auckland are combined and mapped (overleaf) to indicate areas of greater sensitivity and reduced adaptive capacity to hot days.

Vulnerability to extreme heat is not the same across Auckland – heat related impacts are closely related to both social vulnerability and the local environment. Evidence from the literature indicates that heat related mortality and morbidity is more common in certain groups, including: female householders, the socially isolated, the elderly and the young, those with language barriers, ethnic minorities, low income households, renter households, and those with pre-existing mental and chronic health conditions. According to the index the most vulnerable populations are in South and West Auckland. The cause of the vulnerability in each area varies but includes limited adaptive capacity because of high socio-economic deprivation, tenure type and limited transport access, as well as increased sensitivity to extreme heat due to the prevalence in the population of either old or young, underlying health conditions, single occupant households as well as the effects of limited greenspace.

Social infrastructure, such as community centres, can increase social cohesion and reduce isolation and vulnerability to extreme heat. Although not factored into the Heat Vulnerability Index, the considerable community cohesion evident in many parts of South and West Auckland enabled through existing social infrastructure is likely, in part, to mitigate the risk for some communities. Measuring and including social infrastructure in the Heat Vulnerability Index represents a future research development opportunity.

Increasing access to social and green infrastructure, like community cool spaces, can help reduce heat stress for those most vulnerable.

People working in heat sensitive occupations including construction and labour activities may be subject to negative outcomes. There is evidence to suggest this may affect some groups such as Māori and Pacific peoples more than others.

Social infrastructure can increase social cohesion and **reduce isolation and vulnerability** to extreme heat.

Reducing the effects of extreme heat

Examples of effective heat mitigation actions include:

- Heat management plans and warning systems.
- Inventories of social infrastructure.
- Establishment of 'buddy systems' to check on isolated and high risk community members.

Natural and built environment investment and intervention can have a significant effect on reducing the severity of heat events, for example:

- Cooling can be achieved through increasing green-infrastructure design, such as increased tree canopy and green space and green warrants of fitness on buildings. Many of the areas identified as high risk in the Heat Vulnerability Index have proportionally less green space.
- Further, the provision of improved social infrastructure can create greater community cohesion, which reduces social isolation, as well as provide for community 'cool spaces', particularly in low socio-economic communities for the population to evacuate to during extreme heat days.
- The Heat Vulnerability Index highlights the importance of green space, and addressing underlying deprivation and health issues in the community.

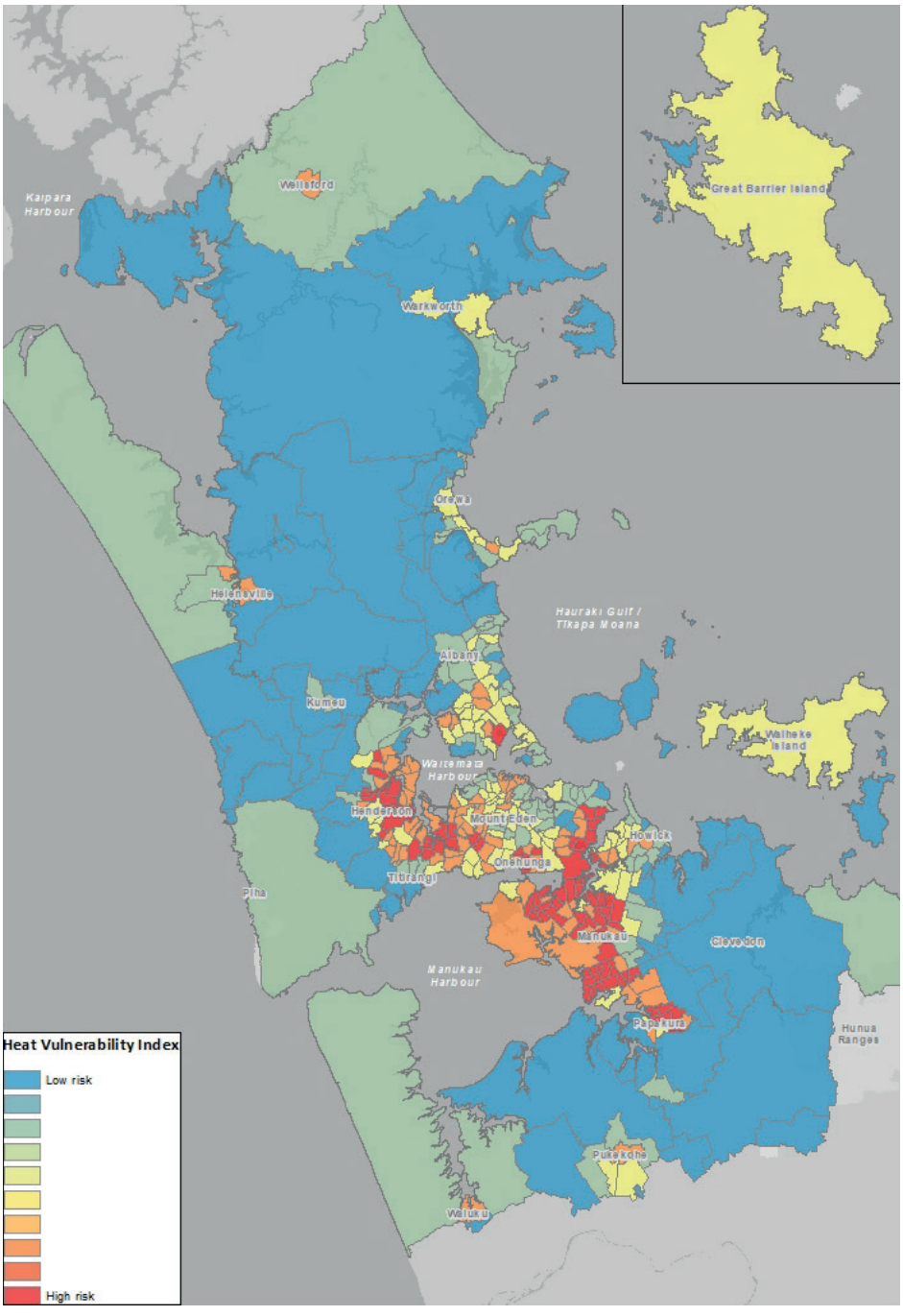


Figure 6: Heat vulnerability index for Auckland

4.2 Connecting climate change to reduced air quality

Based on: Talbot, N. (2019). Air quality and societal impacts from predicted climate change in Auckland. Auckland Council technical report, TR2019/012

The impact of climate change has strong implications on air quality across Auckland.

Health implications from climate forecasts

Air quality is highly susceptible to other changes that result from climate change, such as increased temperature, decreased humidity and rainfall and changes in wind speed and direction.

TEMPERATURE

Heat stress makes people more susceptible to acute health problems. High temperatures also tend to occur during periods of reduced airflow, resulting in a 'pooling' of air, increasing pollutant concentrations through chemical processes. This is most likely to occur in densely populated urban street canyons surrounded by tall buildings and along heavily-trafficked roads.

Increased air temperature results in a longer growing season for plants, increasing pollen in the atmosphere. Once mixed with airborne pollutants, the allergenic properties can be enhanced – if inhaled, it can trigger asthma attacks and other acute respiratory disease symptoms.

HUMIDITY

Humidity can make pollen more problematic by causing spores to split and allowing them to infiltrate further into the lungs. Humidity levels also change the nature of particulate matter in the atmosphere. Low and high humidity favour transmission and survival of influenza virus and increased humidity can impact indoor air quality, potentially increasing mould growth.

RAINFALL

Fewer rainy days will lower the efficiency of the removal of atmospheric pollutants and may allow accumulation of pollutants on road surfaces which could remain suspended within road dust. Drier conditions increase the chance of wildfires, for example, in the Waitakere Ranges, which would reduce air quality.

Drought could also result in plant stress. Through a complex process, plant stress could result in increased ozone and nitrogen dioxide with organic compounds released by plants mixing with vehicle exhaust and sunlight.

WIND

Changes in wind speed and direction will alter how pollutants are carried to and dispersed around the city. The wind speed and direction regulate aerosol loading as well as brown haze events. Changing wind directions may also increase contribution of shipping emissions over Auckland from the Port.

Impact on community

There are poor health outcomes from reduced air quality due to a number of factors. Health conditions such as respiratory illness and asthma are exacerbated by worsened air quality.

The built-up city centre could be an area of high exposure due to the condensed architecture of tall buildings and high vehicle traffic volumes.

Dispersion of particulate matter is reduced at ground level which affects those who live and work in built-up urban centres.

Research identified that certain communities are disproportionately vulnerable to health impacts from air pollutants in Auckland. Vulnerable populations are:

- Communities with elderly or young populations as relatively small increases in air pollutants disproportionately impact them.
- Māori and Pacific peoples may be disproportionately affected by adverse social and economic circumstances, as well as higher rates of diseases and chronic illness, making them more vulnerable to reduced air quality.
- Communities with low income and employment are less likely to have capacity to protect themselves against air pollution impacts.

Air quality will be negatively impacted by climate change. We must focus efforts to increase resilience for those that are most vulnerable to the changes.

How Auckland can adapt

Several considerations are recommended to improve air quality and limit the impact on populations:

Air quality can be improved by reducing the wood-burning emissions from domestic heating and industrial emissions across Auckland.

Green infrastructure can improve air quality as natural vegetation can act as a filter to remove or divert air pollutants from the atmosphere.

Target areas of high density living near busy roads for air quality improvement measures. This would build on the Fossil Fuel Free Streets initiative and include procuring zero-emission public transport.

Technology can be developed to target specific vulnerable populations such as those with pre-existing health conditions to provide alerts and advice in real-time. This could include pollen or particulate matter warnings and encourage people to stay inside or limit exposure during periods of poor air quality.

This research will enable Auckland Council to better mitigate and adapt to climate change and to focus efforts on specific key vulnerable groups.

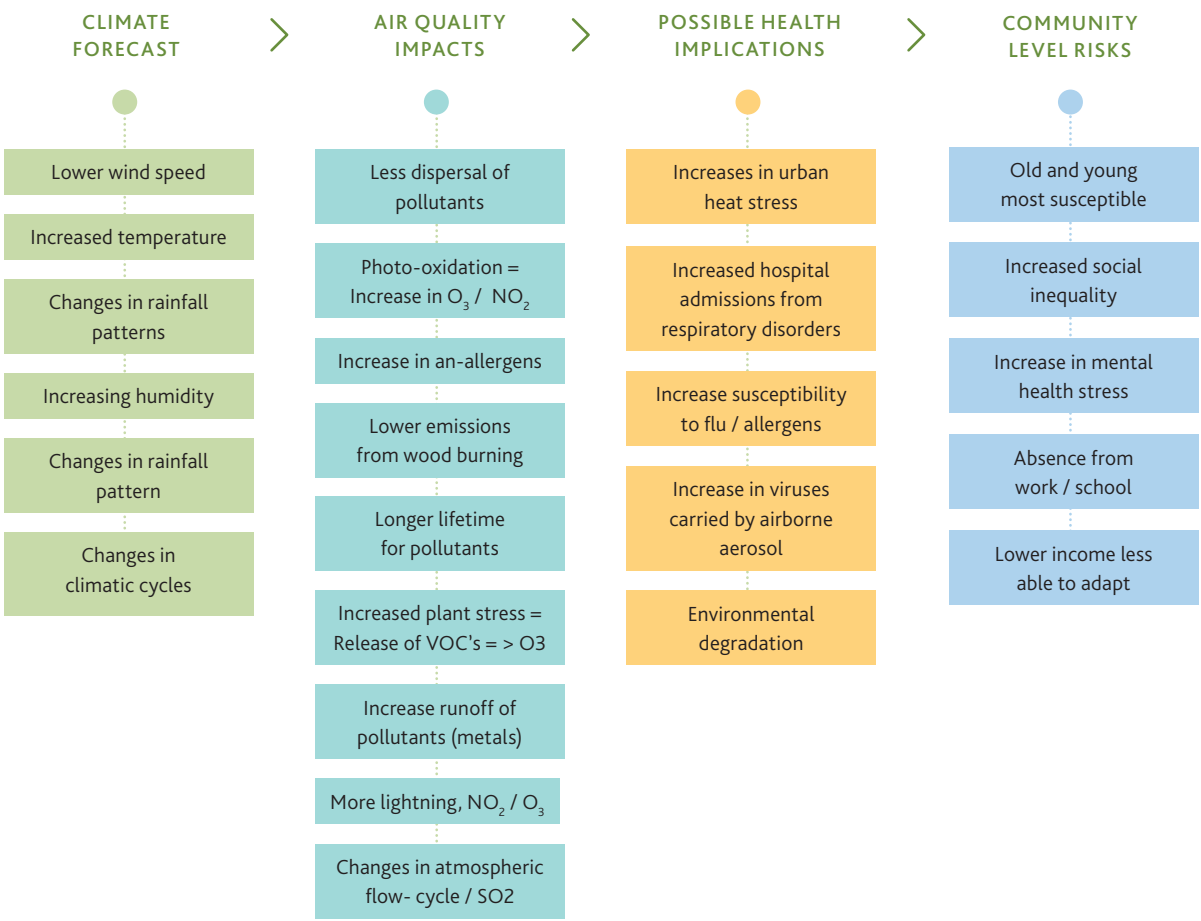


Figure 7: Connceting climate change, air quality and its impacts

4.3 Creating conditions for disease vectors

By: Joynt, J. L. R

Auckland is at risk of being exposed to new diseases as a result of climate change.

Increased temperature, humidity and rainfall can all facilitate the spread of disease and allow conditions for disease to thrive and establish in the community. Water and vector-borne diseases – those carried by mosquitoes and parasites – are of particular concern.

As Auckland's climate becomes more tropical, conditions grow more favourable for the establishment of mosquito and other vector species populations.

Mosquito borne diseases

New Zealand has 16 species of mosquito, and several others have been intercepted at its borders. For disease to establish in the community, both the vector and the disease need to be present.

To date there has never been a confirmed case of a human acquiring a mosquito-borne disease in New Zealand. However, there are established species already which are capable of being vectors for diseases such as West Nile Virus, if it were to enter New Zealand. The Malarial parasite is carried by the anopheline mosquito which is endemic in Australia and South East Asia and has been previously intercepted at New Zealand's borders.

Other vector-borne diseases that could become established in New Zealand include Murray Valley Encephalitis, Japanese Encephalitis and dengue fever, which has already had previous outbreaks in New Zealand with Pacific Island origin.

Climate change and disease

Climate change will make conditions more favourable for a population to become established and highlights a significant threat to public health. Flooding events can create breeding grounds, particularly in increasingly warm conditions and lead to increased vector establishment. Waterborne disease outbreaks are closely correlated with extreme weather events which are projected to increase in intensity and frequency in Auckland with climate change.

Other health risks

Other health risks include contamination of drinking water supply and waterways in flooding events from sewage overflow. Parasites such as giardia and the Escherichia coli (E.coli) bacteria can cause illness when contaminated waterways are used for recreation such as swimming and fishing. Cyanobacteria and avian botulism in reservoirs also pose a risk as dry conditions with low water levels can result in their establishment in drinking water reservoirs.

The changing climate could create an environment that allows water and vector borne diseases to thrive as well as the introduction of new diseases to the Auckland Region.

How Auckland can adapt

Regular surveillance and monitoring of disease outbreaks, as well as disease vectors, will help assess and forecast changes.

4.4 Social vulnerability to climate change impacts

Based on: Fernandez, M. A. and Golubiewski, N. E. (2019). An assessment of vulnerability to climate change in Auckland. Auckland Council technical report, TR2019/011

Vulnerability has been assessed across the census area units of Auckland based on the degree to which geophysical, biological, and socio-economic systems are susceptible to, and unable to cope with, adverse impacts of climate change. The assessment combines multiple factors in order to stress test areas of Auckland and identify which will be the most vulnerable to climate change.

Vulnerability is characterised by the potential impact (comprising exposure and sensitivity) and adaptive capacity of each census area unit. Indicators used for characterisation are shown in Table 1. Vulnerable areas are those that suffer potentially high impact (high exposure and sensitivity) and have a low adaptive capacity.

Assessment results show the impact and adaptive capacity across the Auckland region, with hotspots located in southern and western areas of Auckland. Factors that characterise vulnerable hotspots are: a low share of green space such as cropland, grassland or tree cover, high rates of single-person households, low average household income, high housing stress, low levels of house ownership and high deprivation levels. Some of these stressors correspond to the physical and geographical environment, while others are characterised by socio-economic context and social preferences.

How Auckland can adapt

This assessment improves the understanding of what drives vulnerability in Auckland and informs development of adaptation options and priorities for intervention.

Exposure to climate change effects combined with socio-economic vulnerability results improves our understanding of who climate change will impact the most severely.

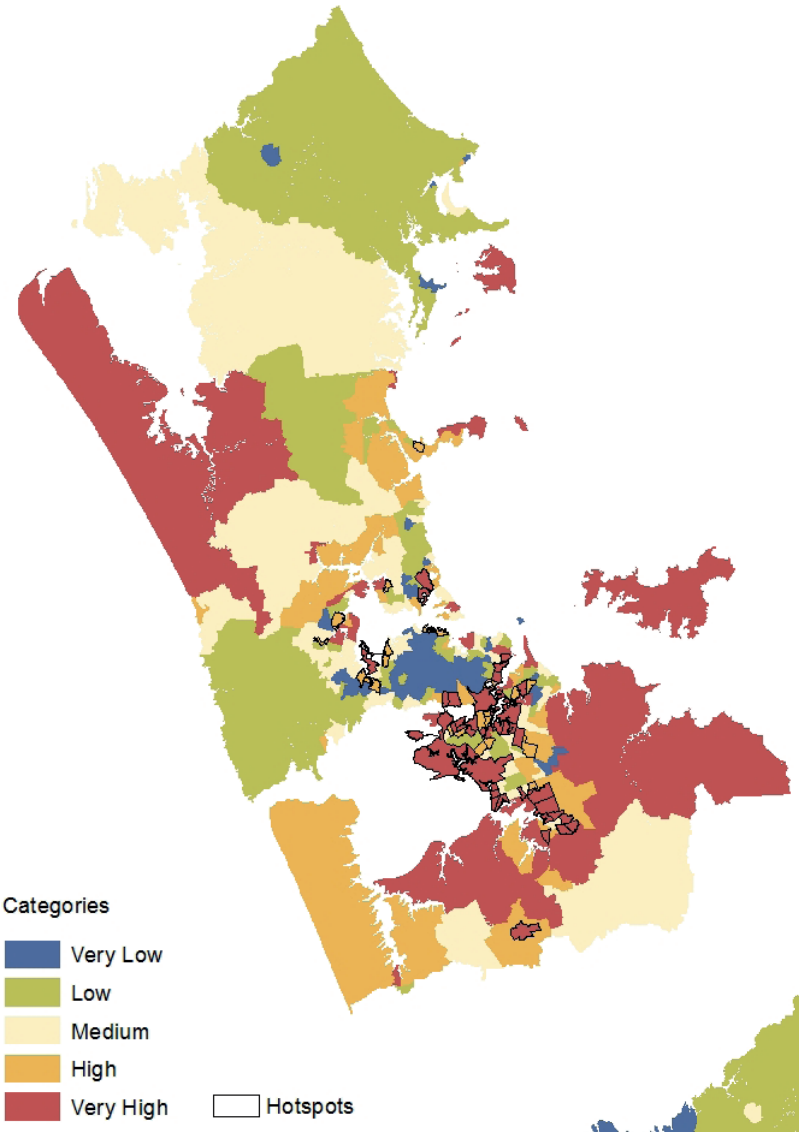


Figure 8: Vulnerability assessment and hotspots: Impact (sensitivity and exposure)

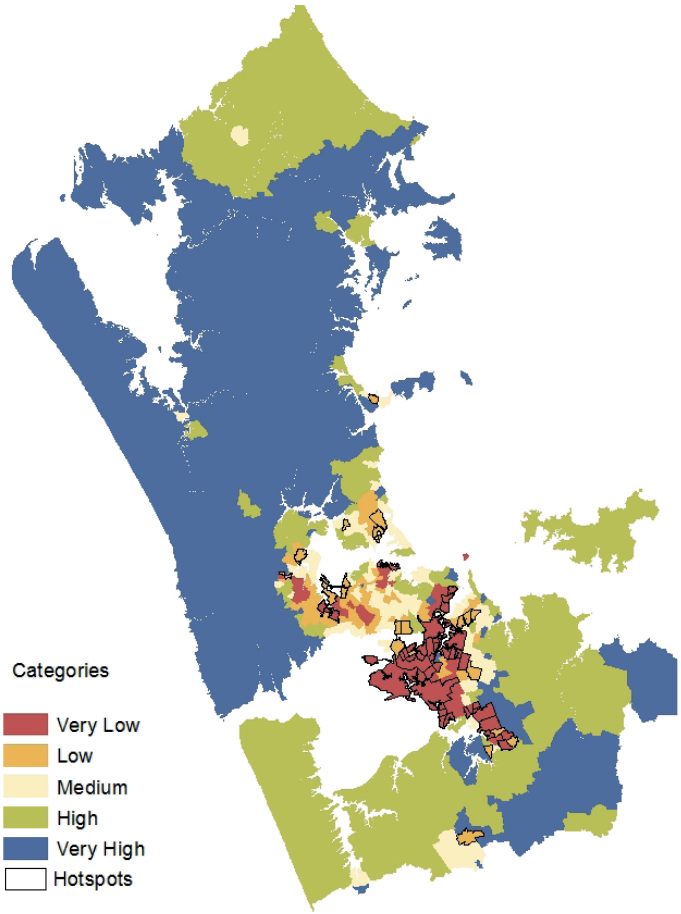


Figure 9: Vulnerability assessment and hotspots: Adaptive capacity

TABLE 1 INDICATORS USED TO MEASURE VULNERABILITY COMPONENTS

INDEX	INDICATORS	FUNCTIONAL RELATIONSHIP
Exposure	Coastal inundation – 50 years return 1 metre sea level rise	Vulnerability ↑ as indicator ↑
	Dry days < 1 mm	Vulnerability ↑ as indicator ↑
	Total precipitation percentage change	Vulnerability ↑ as indicator ↑
	Heavy rainfall days > 25 mm	Vulnerability ↑ as indicator ↑
	Hot days > 25	Vulnerability ↑ as indicator ↑
	Mean temperature	Vulnerability ↑ as indicator ↑
	Mean wind speed	Vulnerability ↑ as indicator ↑
	Relative humidity	Vulnerability ↑ as indicator ↑
Sensitivity	Deprivation Index	Vulnerability ↑ as deprivation index ↑
	Unemployment rate*	Vulnerability ↑ as unemployment ↑
	Ratio of population under 15 and over 65 to 19 – 64 *	Vulnerability ↑ as rate of dependency ↑
	Percentage of populated area relative to CAU area	Vulnerability ↓ as % populated area ↑
	Percentage of single-headed households*	Vulnerability ↑ as % of single-headed households ↑
	Road density (ratio of km of road per km^2 of populated area)	Vulnerability ↑ as ratio ↑
Adaptive Capacity	Average household income*	Vulnerability ↓ as income ↑
	Housing stress (ratio of rent payments to household income)*	Vulnerability ↑ as housing stress ↑
	Percentage of population that are owner-occupiers of house*	Vulnerability ↓ as % owning house ↑
	Percentage of area in cropland**	Vulnerability ↓ as % on crops production ↑
	Percentage of area in grassland**	Vulnerability ↓ as % on grass production ↑
	Percentage of area in forest**	Vulnerability ↓ as % of forest cover ↑

NOTE

* Data at census area unit level, extracted from Census 2013.

** Data extracted from LUCAS NZ land use map 2012. Climatic (exposure) data extracted from Pearce et al. (2017)

4.5 Flooding risk in the built environment

Based on: Golubiewski, N. E., J. L. R. Joynt and K. Balderston, (Forthcoming). Flood risk in a changing climate... Auckland Council technical report, TR2019/016

Flooding is the most common natural hazard in Auckland. With its many harbours, inland watercourses and tributaries, there is no part of the region that is not close to and intimately related with water.

Auckland's sub-tropical climate means that high humidity and heavy rainfall events are not uncommon year-round. Further, there is a risk of tropical storms from the Pacific.

Climate change will increase the severity and frequency of flooding across the city, particularly in winter and autumn.

Auckland's urban area has large amounts of impervious surfaces. These surfaces can alter the volume, speed and path of rainfall runoff.

Almost one quarter (23%) of Aucklands buildings are exposed to flood hazards. It is estimated that that 16,000 buildings are at risk of floor flooding in a 100 year flood event.

Impacts

Flood events damage property and endanger the population directly through debris fields, high velocities and increased risk of drowning. Secondary effects include but are not limited to increased risks of vector and water-borne diseases following flood events and contamination from wastewater overflows.

Infrastructure failure, displacement, disruption and insurance costs all have further impact on society and have long lasting impacts. Increased risk of Post-Traumatic Stress Disorder can result from extreme natural disasters such as flooding

Improving green infrastructure and having less paved surfaces can help absorb some of the impacts of flooding and protect infrastructure.

TABLE2 FLOOD HAZARDS

FLOOD HAZARD	NUMBER OF BUILDINGS*	PERCENTAGE OF TOTAL BUILDINGS[6]
Floodplain (FP)	64,064	12%
Flood prone area (FPA)	22,798	4%
Overland	80,244	15%
Total	127,593	23%

NOTE

* Buildings are defined as structures greater than or equal to 60m^2 in area, many small structures such as garden sheds would not be included in this estimate.

Vulnerability

Current and future flooding exposure and risk is core council information. How exposure translates into vulnerability is necessary to understand the impact of flood events on different communities.

As with all climate related risks, the effects of flooding will be influenced by a range of factors. These factors can include things such as household income, housing tenure or personal mobility. More information is needed to understand the level of flood vulnerability that Auckland communities in different locations experience now and may in the future.

Responding to climate change requires fundamental changes in how we think about and plan for the future of our catchments, coastlines and communities. Some hard decisions will be required about the acceptability and affordability of sustaining human habitation and infrastructure in some areas. We need to change how we use land and waterways, and design, construct, and manage buildings and infrastructure to reduce the risk. We need to consider the whole of life risks and costs of future investments in land and infrastructure development, and engage the community in open and honest conversations.

How Auckland can adapt

Reduce the effect of impervious surfaces in new developments, utilising green infrastructure to decrease runoff.

Locating new development appropriately, outside floodplains.

Work across Council to create future focussed policy, planning, development and asset management that is informed by the long-term consolidated risk to human life, property and infrastructure from all natural hazards and future climate change.

Flooding is the **most common** natural hazard in Auckland.

4.6 Auckland's exposure to sea level rise

Based on: Golubiewski, N. E., Balderston, K; Hu, C. and Boyle, J. (2019) Auckland's exposure to sea level rise: part 1 – regional inventory. Auckland Council technical report, TR2019/017

And Boyle, J. Golubiewski, N. E., Balderston and K; Hu, C. (2019). Auckland's exposure to sea level rise: part 2 – local inventory. Auckland Council technical report, TR2019/018 (forthcoming)

Auckland will experience sea-level rise and coastal inundation, with significant impacts on people, the environment, land, buildings and infrastructure.

Over this century approximately 1.5-2.5% of Auckland's land area could be exposed to sea level rise. This encompasses 0.3% of buildings, 80% of coastal ecosystems and 6% of dairy land.

Outside of these potentially exposed areas, there are other areas across Auckland that are predicted to become exposed to coastal inundation in extreme weather events.

Scenarios

The following scenarios were assessed for sea level rise, and for coastal inundation to understand Auckland's exposure impacts over time.

SEA LEVEL RISE

- 0.25 metre sea level rise
- 0.5 metre sea level rise
- 1 metre sea level rise
- 2 metre sea level rise

COASTAL INUNDATION

- 1 in 100-year average return interval (ARI)
- 1 in 100-year ARI + 1 metre sea level rise
- 1 in 100-year ARI + 2 metre sea level rise

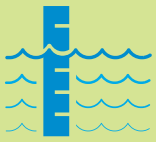
Coastal inundation and sea level rise are already affecting Aucklanders. We need to prepare our infrastructure now and understand limitations to areas available for future infrastructure.

Exposure

- A substantial proportion of coastal ecosystems would be exposed with projected sea level rise. Some coastal and scrub forests exposed to sea level rise and inundation, with mangroves and saltwater wetlands being the most exposed*.
- Some unitary plan zones are exposed in long-term sea level rise scenarios, particularly coastal zones, port zone and the central business district.
- Buildings have been constructed in zones that are now known to be exposed to sea level rise, although planning regulations require habitable floors to be above the 100 year storm inundation level including 1 metre sea level rise.
- Some residential land is exposed (the most exposed being Rural and Coastal Settlement zones), and less than 1% of the future urban zone is exposed across sea level rise scenarios investigated here.
- Many parks lie along shores and coastal margins, with between 1% and 7.5% of Council-owned green space exposed to sea level rise, including sports fields, parks and cemeteries.
- Utilities and transport have high proportional exposure as they are more likely to be below sea level and may be exposed to salt intrusion, as well as utility assets on the coast being more directly exposed, due to their location.
- Livestock farms including sheep, beef and dairy comprise most of the agricultural production land in the Auckland region and have the greatest area of land exposed to sea level rise.
- Further industries that will be affected include: fisheries, hatcheries and other marine aquaculture.

How Auckland can adapt

Understanding the specific areas that are exposed to sea level rise and coastal inundation will enable a targeted focus to assist building capacity and preparation. These specific areas identified will inform additional actions for Auckland's Climate Action Plan to build resilience, planning and regulations and to mitigate the impacts of climate change as much as possible.



1.5-2.5%
of Auckland's land area could be exposed to sea level rise this century.

NOTE

* Vulnerability is not known e.g. there may be room for these to move/adapt with SLR.

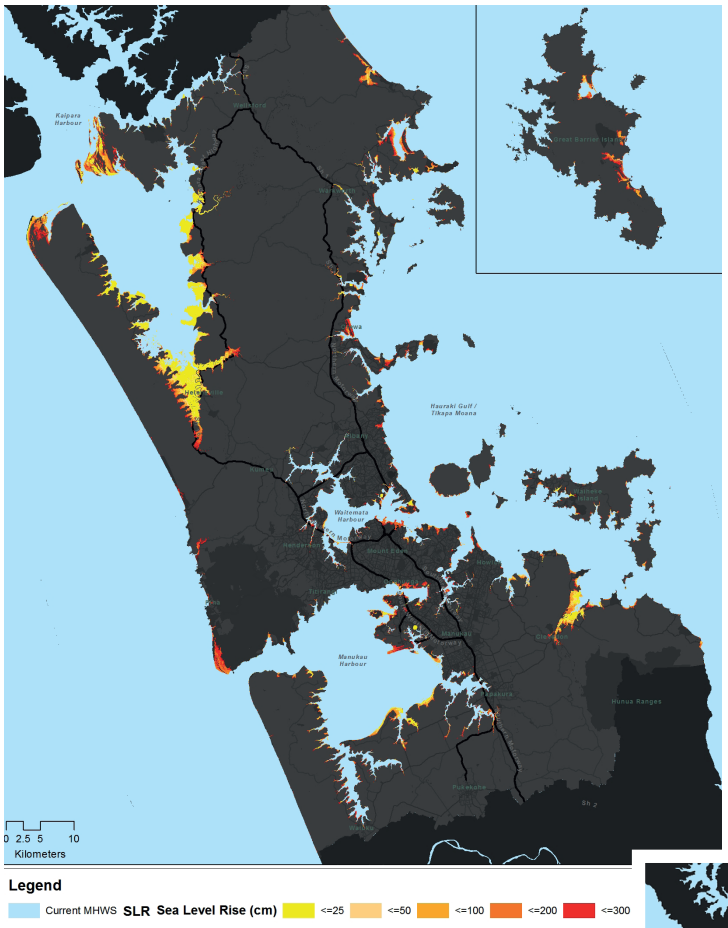


Figure 10: Exposure of Auckland to possible sea level rise scenarios

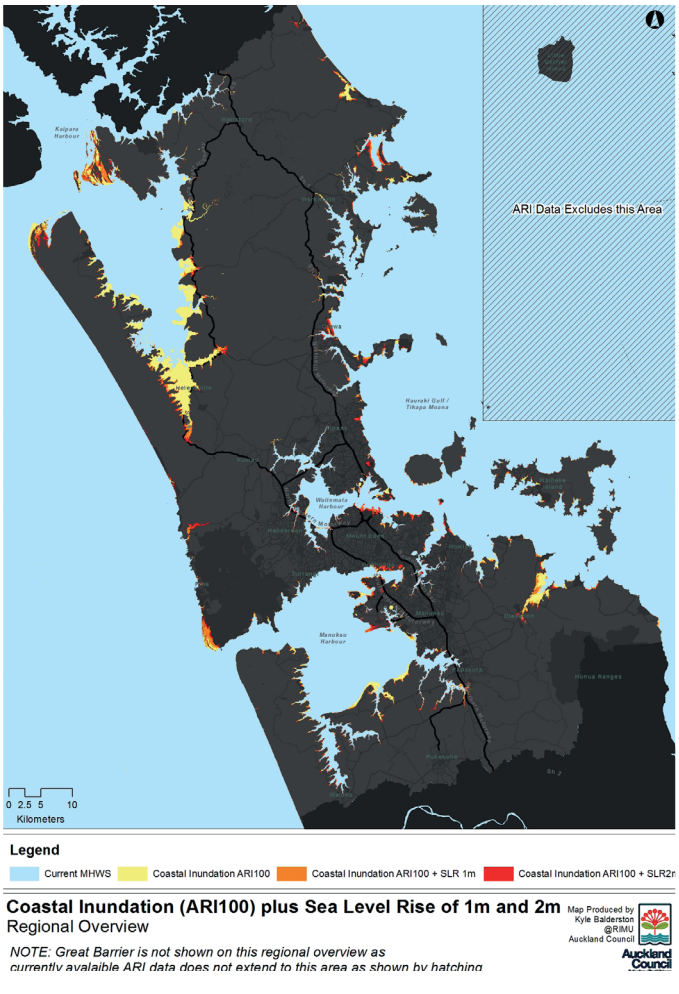


Figure 11: Exposure of Auckland to coastal inundation coupled with sea level rise

4.7 Climate change impacts and risks for terrestrial ecosystems

Based on: Bishop, C. D. and Landers, T. J. (2019). Climate change risk assessment for terrestrial species and ecosystems in the Auckland region. Auckland Council technical report, TR2019/015

Auckland's current climate is classified as sub-tropical with warm humid summers, mild winters and plentiful rainfall.

Climate change will result in changed weather patterns and conditions, with accumulating impacts, as well as increased risk of extreme events that damage ecosystems.

Rainfall is projected to increase in intensity and decrease overall which will have a direct effect on ecosystems that will be subject to drought and flood conditions more frequently.

The varied ecosystems across Auckland will be affected differently, for example taraire and rimu forests are more susceptible to drought stress. Changes in the pattern of drought conditions have the potential to alter Auckland's ecosystems.

Additionally many ecosystems have restricted spatial distribution that make them more vulnerable to regional extinction from changed environmental conditions or extreme events.

Ecosystem assessment

Ten regional ecosystems are classified as having severely restricted spatial distribution, six of which are critically endangered. These are mostly coastal and therefore are most vulnerable to severe weather events, flooding, erosion and changed weather patterns.

Native ecosystem maps were overlain with projected sea level rise and inundation scenarios to understand the effects on these habitats. Ten ecosystems were identified as being at risk, where more than 10% of their area is vulnerable to a storm surge event. Of those, nine are native ecosystems that are classified as endangered or critically endangered.

Most of Auckland's indigenous ecosystems are already under threat from introduced animal or plant pests, and clearance and fragmentation as a result of development and agriculture. Climate change has the potential to exacerbate these effects.

There are several ecosystems that have highly localised or restricted distributions and so are more vulnerable to regional extinction or severe reduction of their range from a random physical disturbance event. With the increasing frequency and severity of extreme weather events due to climate change, events such as landslides, flooding or erosion can severely impact the health of ecosystems. In the worst-case scenarios, ecosystems can be completely inundated or destroyed.

Coastal areas are particularly prone to the effects of climate change due to their exposure to storm events, salt deposition and rising sea levels.

Species most at risk include bats, reptiles and amphibians, invertebrates, birds and plants with restricted or exclusively coastal distributions. Many already vulnerable or endangered species will experience greater stresses from climate change.

Seabirds are particularly at risk as they are most affected by sea level rise, storm events and destruction of their habitats and nesting colonies.

How Auckland can adapt

Further research is recommended to understand different ecosystems. Currently there is a lack of detailed knowledge on how different ecosystems and their species components react to climate change and so future predictions cannot be accurately made, particularly as accumulating impacts of climate change will impact species uniquely.

The compounding cumulative effects of climate change will affect our native ecosystems.

Auckland is a seabird hotspot with 24 species breeding in the region.

Seabirds are at risk as they are most affected by sea level rise.

4.8 Climate change risks for marine and freshwater ecosystems

Based on: Foley, M.M. and Carbines, M. (2019). Climate change risk and vulnerability assessment for marine and freshwater ecosystems. Auckland Council technical report, TR2019/014

Aquatic ecosystems are highly susceptible to the projected effects of climate change. Increases in air temperature and water temperature, ocean acidification, sea level rise and changes in circulation and storm intensity can all affect marine and freshwater ecosystems.

Whilst the National Institute of Water and Atmospheric Research projections illustrate individual variables, it is difficult to model how changes in multiple variables will cumulatively affect aquatic ecosystems. In addition, the projected climate-related changes are occurring within the broader context of environmental change and human-induced stressors, including sedimentation, pollution, disturbance, and harvesting.

Understanding the interplay between climate change impacts and other human-induced stressors is paramount to protecting culturally, economically, and ecologically important species.

Assessment undertaken

The sensitivity of specific aquatic species and habitats in the Auckland region to potential climate change stressors was assessed and results indicate:

STRESSORS ON MARINE ECOSYSTEMS

- Increasing water and air temperatures in freshwater streams and marine habitats affect reproduction and growth rates. This can also result in a shift in species distributions and create conditions that allow for invasive species to establish new populations in New Zealand. Intertidal mud flats and rocky reefs are highly sensitive to both water and air temperature.
- Ocean acidification affects the condition and survival of marine species, particularly those that have hard, carbonate structures, such as shellfish, urchins (kina), marine snails and plankton, all of which are important components of Auckland's marine ecosystems, and a food source for many as well as important aquaculture species like mussels.
- Lower nutrient concentrations could result in fewer primary producers, such as phytoplankton and macroalgae which form the base of the marine food web and underpin the stability of marine ecosystems.
- Increasing sea level rise reduces the viability of some marine habitats, particularly intertidal habitats and coastal vegetation that are at the edge of the coastal margin and those species that rely on exposure to air throughout the tidal cycle.
- Changes to rainfall and storm patterns may cause declines in water quality due to increased sediment and other contaminant runoff.

Aquatic ecosystems are affected by the accumulating impacts of climate change. The health of these aquatic ecosystems is fundamental to human wellbeing.

STRESSORS ON FRESHWATER ECOSYSTEMS

- Increases in air temperature may result in increased stream temperature, particularly in places where there is little riparian vegetation for shade and in shallow streams characteristic of Auckland.
- Decreased rainfall will result in decreased stream flow, reducing the amount of in-water stream habitat available for fish and macroinvertebrates.
- Heavy rain events can result in increased sediment runoff from the land, stream bank erosion, and stream habitat scouring.
- Reduced wind speed will affect mixing dynamics in the surface of lakes, altering the physical and chemical conditions of the water column. Less ability for freshwater species to migrate also increases their vulnerability if their habitat degrades or is damaged.

The results of the assessment can be seen in Table 3 overleaf.

These changes also need to be considered with natural variability including long term climate cycles.

Intact aquatic ecosystems provide a range of ecosystem services that Auckland relies on every day, including oxygen production, climate regulation, and food and clean water provision. Changing ecosystems will impact our ability to adapt. The health of these aquatic ecosystems is fundamental to human wellbeing.

Rising temperatures will **increasingly stress** marine and freshwater ecosystems.

TABLE 3 CLIMATE CHANGE SENSITIVITY MATRIX FOR KEY AQUATIC SPECIES AND HABITATS

HABITAT/SPECIES	WATER TEMPERATURE	EXTREME RAINFALL	NUTRIENTS	OCEAN ACIDIFICATION	SEA LEVEL RISE	WATER CIRCULATION
Intertidal mud flats	High	High	Low	Moderate	High	Moderate
Intertidal rocky reef	High	High	Moderate	High	High	Moderate
Mangroves	Low	Low	Low	Low	High	Low
Kelp forests	High	Moderate	Moderate	Moderate	Moderate	High
Seagrass	Moderate	Moderate	Low	Low	Moderate	High
Subtidal rocky reef	High	Moderate	Moderate	High	Low	Moderate
Subtidal soft bottom	Moderate	High	Low	Low	Low	Low
Freshwater hard bottom	Low	High	Moderate			
Freshwater soft bottom	Low	High	Moderate			
Marine shellfish	Moderate	High	Low	High	Moderate	Low
Marine fish	Moderate	Low	Low	Moderate	Low	Low
Freshwater fish	High	Low	Low			
Freshwater invertebrates	Moderate	High	Low			

How Auckland can adapt

Understanding the impacts of climate change and interactions with other multiple stressors on the aquatic ecosystems is imperative to planning for a more resilient Auckland.

Taking action to manage other ecosystem stresses such as habitat loss, sedimentation and pollution that will be exacerbated by climate change effects and reduce ecosystem resilience

Restoration of natural ecosystems to increase resilience

Undertaking ongoing New Zealand based studies to assess ecosystem risk.

Devonport © Istock

05/ Additional and emerging risks

In addition to the risks already identified, there are other factors – known and emerging – that may compound with the effects of climate change and potentially exacerbate them.

These could include land use change, increasing population and climate migrants, food and energy security, pollution, global economy, and human induced stressors. There is uncertainty as to how exactly these effects may compound or interact.

A rapidly growing population puts pressure on the environment through sprawl and urbanisation that inevitably encroaches on the environment. Climate migrants are likely to come to New Zealand from the Pacific Islands due to rising sea levels. This will place further pressure on the country's resources.

Food security is a broader issue than merely considering available land allocated to agriculture. A changing climate will alter crop production and increase the risk of drought or flood, as well as increasing the risk of new disease. New Zealand's economy is heavily dependent upon agriculture, which may be affected by the exacerbated effects of climate change on the land.

The magnitude of health consequences from climate change is unknown. There is increased risk of extreme weather events that could cause injury or damage to key infrastructure. New diseases and vectors may become established in New Zealand and events such as extreme heat may cause acute health problems and exacerbate chronic illness, particularly in vulnerable populations.

Saltwater intrusion will increase with rising sea levels and affect a greater area surrounding Auckland. This can pose risks to buried infrastructure such as utilities and transport tunnels, as well as agricultural land. It can also pose risk to artesian water supplies.

The cumulative effect of multiple stressors will also pose emerging risks. While National Institute of Water and Atmospheric Research predictions provide an idea of the effects of individual variables, it is unclear what the effect of multiple variables will be on the ecosystem and Auckland. In the absence of this information, it is critical that precautionary and adaptive measures be taken in decision-making at every level.

It is imperative to keep researching, monitoring and reviewing the impacts of climate change to continue filling in the gaps and prepare. Collaboration is the way forward for Auckland to create resilience amongst our communities.

Ponga, silver fern © Auckland Council

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