



Ministry for the
Environment
Manatū Mō Te Taiao

National Climate Change Risk Assessment for New Zealand

Arotakenga Tūraru mō te Huringa
Āhuarangi o Āotearoa

Main report

Pūrongo Whakatōpū

This document may be cited as: Ministry for the Environment. 2020. *National Climate Change Risk Assessment for Aotearoa New Zealand: Main report – Arotakenga Tūraru mō te Huringa Āhuarangi o Aotearoa: Pūrongo whakatōpū*. Wellington: Ministry for the Environment.

Disclaimer

The information in this publication is, according to the Ministry for the Environment's best efforts, accurate at the time of publication. The information provided does not alter the laws of New Zealand and other official guidelines or requirements. Users should take specific advice from qualified professional people before undertaking any action, as a result of information obtained from this publication. The Ministry for the Environment does not accept any responsibility or liability whether in contract, tort, equity or otherwise, for any action taken as a result of reading, or reliance placed on the Ministry for the Environment because of having read any part, or all, of the information in this publication or for any error, or inadequacy, deficiency, flaw in or omission from the information provided in this publication.

Acknowledgements

Prepared for the Ministry for the Environment by a consortium led by AECOM, including Tonkin + Taylor Ltd, NIWA and Latitude and a number of independent contractors.

Published in August 2020 by the
Ministry for the Environment
Manatū Mō Te Taiao
PO Box 10362, Wellington 6143, New Zealand

ISBN: 978-1-98-857993-1 (online)

Publication number: ME 1506

© Crown copyright New Zealand 2020

This document is available on the Ministry for the Environment website: www.mfe.govt.nz.



*Making Aotearoa New Zealand
the most liveable place in the world*

Karakia

Whakataka te hau ki te uru,
Whakataka te hau ki te tonga.
Kia mākinakina ki uta,
Kia mātaratara ki tai.
E hī ake ana te atākura he tio,
he huka, he hauhunga.
Haumi e! Hui e! Tāiki e!

Get ready for the westerly
and be prepared for the southerly.
It will be icy cold inland,
and icy cold on the shore.
May the dawn rise red-tipped on ice,
on snow, on frost.
Join! Gather! Intertwine!

This karakia (prayer) speaks to the great natural forces, which bind us together. It portrays a Māori worldview to help frame our thinking, and our approach to huringa āhuarangi (climate change) in Aotearoa New Zealand. It speaks to the winds from the west (hau ki te uru) and from the south (hau ki te tonga). It acknowledges the growing challenges before us and the preparation needed to respond to them. It expresses the strengthening of our resilience and acknowledges that with unity we can overcome challenges and respond to ongoing changes in our environment.

In the context of te huringa āhuarangi, this narrative emphasises our ties to and reliance on the natural world, and the connection of each generation to those before and after. This includes the connectedness of ecosystems and society, and of actions and consequences across domains.

Contents

Karakia	3
Key messages	7
1 Introduction	17
1.1 Context and audience	17
1.2 Objectives	17
1.3 Structure	18
1.4 Purpose	18
2 Summary of approach	20
2.1 Assessment and engagement method	20
2.2 Limitations	27
2.3 Overview of value domains	28
3 Te Ao Māori and climate change risk	31
3.1 Bringing Māori perspectives to the NCCRA	33
4 Climate change in New Zealand	35
4.1 New Zealand is already experiencing the impacts from a changing climate	35
4.2 Overview of climate change projections and impacts	35
5 Climate change risks and opportunities	40
5.1 Risks by urgency	40
5.2 Significant risks by value domain	43
5.3 Natural environment domain Rohe taiao	48
5.4 Human domain Rohe tangata	60
5.5 Economy domain Rohe ōhanga	68
5.6 Built environment Rohe tūranga tangata	78
5.7 Governance domain Rohe kāwanatanga	90
5.8 Opportunities	98
6 Case studies: cascading impacts and socio-economic projections	102
7 Uncertainty and gaps	106
7.1 Risk and uncertainty	106
7.2 Gaps in knowledge	106
8 Next steps	110

References	111
Appendix A: Glossary	126
Appendix B: Te reo glossary	132

Tables

Table 1:	New Zealand’s 10 most significant climate change risks, based on urgency	9
Table 2:	Overview of NCCRA reports	18
Table 3:	Main report by section	18
Table 4:	Three stages of the NCCRA	20
Table 5:	NCCRA framework: key parameters	22
Table 6:	Description of value domains	29
Table 7:	Elements at risk in each value domain	29
Table 8:	Climate change projections for New Zealand (Ministry for the Environment, 2018)	37
Table 9:	RCP scenarios: Projected mean sea-level rise (metres above 1986–2005 baseline) for the wider New Zealand region (Ministry for the Environment, 2017b)	39
Table 10:	Most significant risks in each domain based on urgency ratings	43
Table 11:	Most significant risks and other priority risks in each domain based on urgency ratings	45
Table 12:	Natural environment domain	48
Table 13:	N1 Risks to coastal ecosystems: Urgency profile	51
Table 14:	N2 Risks to indigenous ecosystems and species: urgency profile	55
Table 15:	Human domain	60
Table 16:	H1 Risks to social cohesion and community wellbeing: Urgency profile	63
Table 17:	H2 Risks of exacerbating existing inequities: Urgency profile	66
Table 18:	Economy domain	68
Table 19:	E1 Public sector fiscal risks : Urgency profile	71
Table 20:	E2 Risks to the financial system from instability : Urgency profile	76
Table 21:	Built environment	78
Table 22:	B1 Risk to potable water supplies: Urgency profile	82
Table 23:	B2 Risks to buildings due to extreme weather events: Urgency profile	87
Table 24:	Governance domain	90
Table 25:	G1 Risk of maladaptation across all domains: Urgency profile	93

Table 26:	G2 Risk that climate change impacts across all domains will be exacerbated: Urgency profile	96
Table 27:	EO1: Opportunity urgency profile	99
Table 28:	EO2: Opportunity urgency profile	100
Table 29:	HO1: Opportunity urgency profile	100
Table 30:	BO1: Opportunity urgency profile	101

Figures

Figure 1:	Relationship between the NCCRA framework, National Climate Change Risk Assessment, and national adaptation plan	7
Figure 2:	NCCRA process	21
Figure 3:	NCCRA urgency categories	26
Figure 4:	Treasury’s Living Standards Framework (LSF) for wellbeing and the He Ara Waiora framework (Ministry for the Environment, 2019)	31
Figure 5:	Global average surface temperature change from 2006 to 2100 as determined by multi-model simulations relative to 1986–2005	36
Figure 6:	Projected global sea-level rise until 2300	37
Figure 7:	NCCRA risks arranged by the ‘more action needed’ category	41
Figure 8:	NCCRA risks arranged by the ‘research priority’ category	42
Figure 9:	A transmission map from a climate hazard to financial sector losses and the macroeconomy (Batten, Sowerbutts, and Tanaka, 2016)	75
Figure 10:	Cascading systems loop – Risks to wastewater and stormwater systems (rainfall only) (Risk B4)	103

Boxes

Box 1:	Representative concentration pathways	23
Box 2:	Abbreviation system for risks and opportunities	25
Box 3:	Climate change scenarios in the NCCRA	36
Box 4:	Case study: Cascading impacts and interdependencies	102
Box 5:	Case study: Socio-economic trends and projections	104

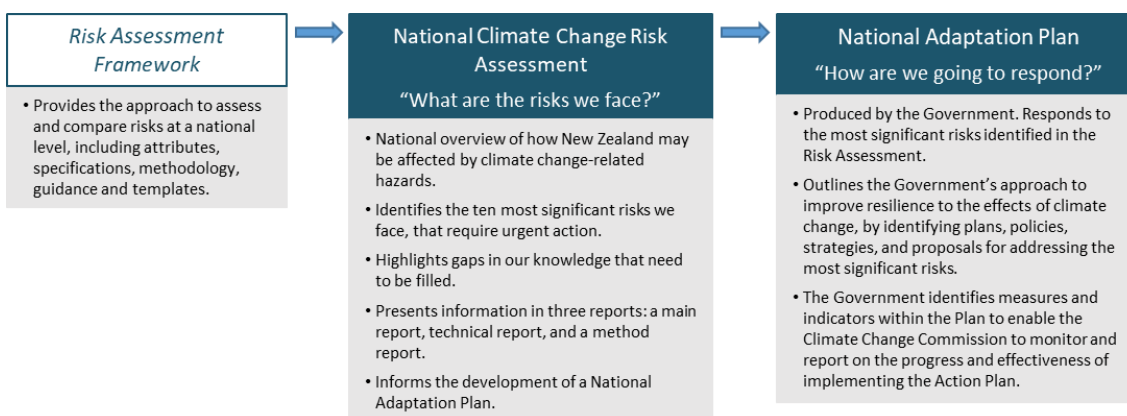
Key messages

Our climate is changing. It is unequivocal that human-induced **greenhouse gas emissions** are warming the global climate system (IPCC, 2019). Climate change is already affecting New Zealand. Over the past century, temperatures have increased, glaciers have melted, and sea levels have risen. Such changes will continue and their impacts increase. This will have far-reaching consequences for people, the natural and built environment, the economy and governance. These ‘value domains’ underpin our wellbeing and provide the structure for this report.

This report presents the findings of New Zealand’s first National Climate Change Risk Assessment (NCCRA). The NCCRA is a national overview of how New Zealand may be affected by climate change-related hazards, and identifies the most significant risks and opportunities. It also highlights gaps in the information and data needed to properly assess and manage the risks and opportunities.

The NCCRA was based on *Arotakenga Huringa Āhuarangi: A Framework for the National Climate Change Risk Assessment for Aotearoa New Zealand* (the NCCRA framework) and was undertaken over nine months by a diverse, multi-disciplinary team of academics and consultants. It combines the outcomes from Māori/iwi and stakeholder engagement with scientific, technical and expert analysis. The findings will be used to develop a national adaptation plan (NAP) that will respond to the most significant risks, opportunities and knowledge gaps.

Figure 1: Relationship between the NCCRA framework, National Climate Change Risk Assessment, and national adaptation plan



New Zealand is committed to adaptation as well as mitigation. The Climate Change Response (Zero Carbon) Amendment Act 2019 (the Act) is a framework for New Zealand to develop and implement clear and stable climate policies to:

- reduce greenhouse gas emissions (ie, ‘mitigation’)
- respond to the changing climate (ie, ‘adaptation’).

The Act commits New Zealand to identify future risks and opportunities by producing an NCCRA every six years. In response to each NCCRA, the Minister for Climate Change must prepare a national adaptation plan.

New Zealand's climate is warming, sea levels are rising, and extreme weather events are becoming more frequent and severe. The National Institute of Water and Atmospheric Research (NIWA) developed the climate change projections used for this risk assessment after the release of the *IPCC Fifth Assessment Report*. They include the following trends:

- In the last 100 years, our climate has warmed by 1°C. If global emissions remain high, temperatures will increase by a further 1.0°C by 2040 and 3.0°C by 2090.
- In the last 60 years, sea levels have risen by 2.44 mm per year. If global emissions remain high, sea levels will increase by a further 0.21 m by 2040 and 0.67 m by 2090.
- Extreme weather events such as storms, heatwaves and heavy rainfall are likely to be more frequent and intense. Large increases in extreme rainfall are expected everywhere in the country, particularly in Northland due to a projected increase in ex-tropical cyclones.
- The number of frost and snow days are projected to decrease, and dry days to increase for much of the North Island and for some parts of the South Island.
- Drought is predicted to increase in frequency and severity, particularly along the eastern side of the Southern Alps.
- Increased northeasterly airflows are projected in summer and stronger westerlies in winter, the latter particularly in the south of the South Island.
- Wildfire risk is predicted to increase in many areas towards the end of the century, due to higher temperatures and wind speeds, and decreased rainfall and relative humidity.

Although there is inherent uncertainty associated with these projections, particularly towards the end of the century, they provide plausible futures resulting from climate change.

The NCCRA identified 43 priority risks across five domains. The five value domains are the human domain, natural environment domain, economy domain, built environment domain and governance domain. Although this NCCRA identifies the 10 most significant risks, all 43 priority risks require action. The report sets out the consequence and urgency ratings, and details research priorities, for all 43 priority risks, so that the developers of the national adaptation plan can properly consider all priority risks.

Consequence ratings

Priority risks have extreme or major consequence ratings in at least one of three assessment timeframes (now, by 2050, by 2100). Consequence ratings reflect the degree to which the assets and values in each domain are exposed and vulnerable to climate hazards. The consequence ratings are: insignificant, minor, moderate, major, extreme.

Urgency ratings

The NCCRA assessed the urgency of taking action to address each risk (the 'adaptation urgency'), to determine the degree to which further action is recommended in the next six years. The urgency ratings in this NCCRA range from 44 to 94 and are based on a number of factors, particularly whether an adequate response is underway or planned.

The NCCRA denotes the two risks from each domain with the highest adaptation urgency rating as being the most significant.

We took this approach, rather than elevating the 10 most urgent risks overall, because the domains are fundamentally different, so consequence and urgency ratings are not directly comparable between domains.

The NCCRA recognises all the priority risks below are important to Māori and will disproportionately affect certain whānau, hapū and iwi, including Māori interests, values, practices and wellbeing. Mātauranga Māori (Māori knowledge) will be critical in developing a greater cultural understanding of these risks, and centring culture in future climate change planning, policy and adaptation. This NCCRA draws attention to specific risks that are highly relevant to Māori. However, all risks that affect New Zealand are relevant to Māori as kaitiaki (custodians) of their ancestral and cultural landscapes.

Table 1: New Zealand’s 10 most significant climate change risks, based on urgency

Domain	Risk	Rating	
		Consequence	Urgency (44–94)
Natural environment	Risks to coastal ecosystems, including the intertidal zone, estuaries, dunes, coastal lakes and wetlands, due to ongoing sea-level rise and extreme weather events.	Major	78
	Risks to indigenous ecosystems and species from the enhanced spread, survival and establishment of invasive species due to climate change.	Major	73
Human	Risks to social cohesion and community wellbeing from displacement of individuals, families and communities due to climate change impacts.	Extreme	88
	Risks of exacerbating existing inequities and creating new and additional inequities due to differential distribution of climate change impacts.	Extreme	85
Economy	Risks to governments from economic costs associated with lost productivity, disaster relief expenditure and unfunded contingent liabilities due to extreme events and ongoing, gradual changes.	Extreme	90
	Risks to the financial system from instability due to extreme weather events and ongoing, gradual changes.	Major	83
Built environment	Risk to potable water supplies (availability and quality) due to changes in rainfall, temperature, drought, extreme weather events and ongoing sea-level rise.	Extreme	93
	Risks to buildings due to extreme weather events, drought, increased fire weather and ongoing sea-level rise.	Extreme	90
Governance	Risk of maladaptation ¹ across all domains due to practices, processes and tools that do not account for uncertainty and change over long timeframes.	Extreme	83
	Risk that climate change impacts across all domains will be exacerbated because current institutional arrangements are not fit for adaptation. Institutional arrangements include legislative and decision-making frameworks, coordination within and across levels of government, and funding mechanisms.	Extreme	80

¹ *Maladaptation* refers to actions that may lead to increased risk of adverse climate-related outcomes, including via increased greenhouse gas emissions, increased vulnerability to climate change, or diminished welfare, now or in the future. Maladaptation is usually an unintended consequence (IPCC, 2018).

The NCCRA domains and risks are highly interconnected. Although some interdependencies are explored, the NCCRA framework did not provide a method for including them in this NCCRA, so they are not rigorously factored into the risk ratings.

To be effective, the adaptation actions that are developed in response to the priority risks will need to recognise these interconnections and be coordinated across risks. Māori consulted as part of this assessment emphasised that recognising interdependencies was fundamental to exploring climate risks from a Māori point of view. The NCCRA framework, particularly the concept of the domains, was considered incompatible with a Māori worldview. There may be an opportunity to explore a Māori national risk assessment, which would include a methodology that emphasises interdependencies and could be underpinned by *tikanga* Māori.

This NCCRA identified four opportunities resulting from climate change. Very few opportunities were identified through literature review, expert elicitation or Māori/iwi and stakeholder consultation. Some opportunities are not well understood and all require further research to ensure responses do not unintentionally worsen climate change impacts. The NCCRA identified opportunities for:

- higher productivity in some primary sectors due to warmer temperatures
- businesses to provide adaptation-related goods and services
- lower cold weather-related mortality due to warmer temperatures
- lower winter heating demand due to warmer temperatures.

There are significant gaps in the knowledge needed to manage climate change risks and opportunities. These gaps reduce New Zealand's ability to assess and manage climate change and should be addressed to inform the NAP and the next NCCRA. They include:

- a lack of coordinated and readily accessible biological inventories and data sets describing the distribution and status of ecosystems and species
- the relationship between social vulnerabilities, cultural heritage and climate change, along with impacts on Māori social, cultural, spiritual and economic wellbeing
- how climate change will affect the banking and insurance sectors, and the flow-on effects on the financial system
- consistent hazard information for assessing the exposure of the built environment at a national scale
- the interdependencies and shared risks between infrastructure sectors
- a coordinated, comprehensive research platform to ensure research is available to inform effective adaptation
- the current and future barriers to adaptation
- the full range of opportunities and better understanding of those already identified.

Mātauranga Māori has an important role to play in climate risk assessments and adaptation planning. Although this knowledge is available, more time and consultation are required to bring it into future NCCRAs. Due to these limitations, some iwi have noted their support for the development of a subsequent, parallel risk assessment for Māori, by Māori. They have indicated the methodology would be underpinned by *kaupapa* and *tikanga* Māori, which may influence the identification, assessment and prioritisation of climate risks.

The NCCRA sought to bring in Māori perspectives by engaging on the risks and opportunities of climate change. Many Māori emphasised that while climate change represents a significant challenge for New Zealand, Māori have lived here for many generations and have survived and prospered by adapting to changes in the climate and the natural world. Many iwi/hapū are already developing their own climate change plans, which set out their values, issues and aspirations in response to climate change.

The NCCRA has factored in diverse Māori views and values in a number of ways, including:

- a set of guiding principles to inform engagement and risk assessment
- recognising the connections and dependencies between domains
- acknowledging key Māori concepts that underpin each domain.

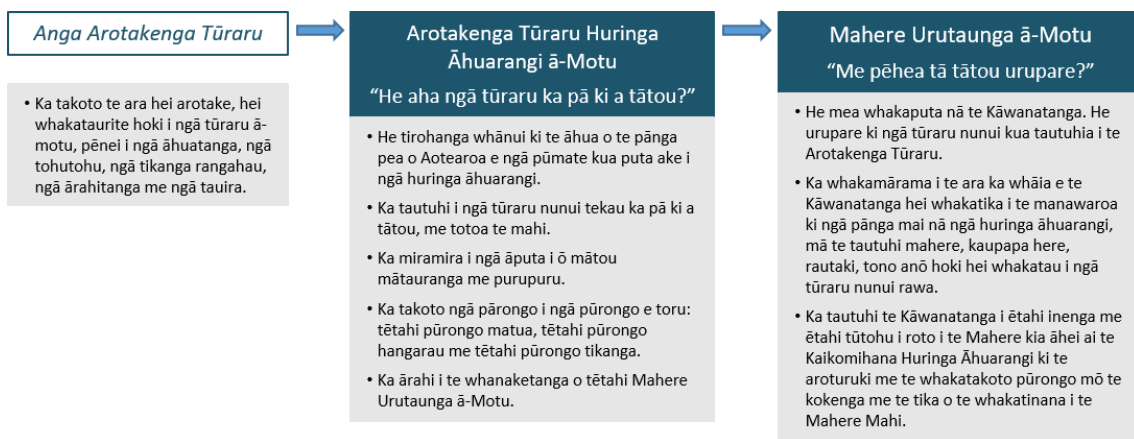
Ngā kupu matua

E huri ana tō tātou āhuarangi. E marama ana te kitea nā ngā tukunga haurehu kati mahana ā-tangata e mahana haere nei te pūnaha āhuarangi o te ao (IPCC, 2019). Kua pāngia kētia a Aotearoa e ngā huringa āhuarangi. I te rautau kua huri, kua piki ngā paemahana, kua rewa ngā awa kōpaka, kua pupuke hoki te pae moana. Ka puta tonu ēnei huringa, ā, ka nui ake ngā pānga. Ka whānui ngā hua i ēnei huringa ki te tangata, te taiao māori me te taiao kua hangaia, te ōhanga me ngā mana whakahaere. Ka noho ēnei 'takiwā uara' hei tūāpapa mō tō tātou oranga, ā, hei tūāpapa hoki mō tēnei pūrongo.

Ko tā tēnei pūrongo, he whakatakoto i ngā kitenga a te Whakahaere Arotakenga Tūraru Huringa Āhuarangi ā-Motu tuatahi mō Aotearoa (NCCRA). He tirohanga whānui te NCCRA ki te āhua o te pānga o Aotearoa e ngā pūmate i ara ake i ngā huringa āhuarangi, ā, e tautuhia ana ngā tūraru me ngā kōwhiringa nunui. E tohua ana hoki ngā āputa i ngā pūrongo me ngā raraunga e matea ana kia tika ai te arotake me te whakahaere i ngā tūraru me ngā kōwhiringa.

Ko te Arotakenga Huringa Āhuarangi: Te Anga Mō Te Whakahaere Arotakenga Tūraru Huringa Āhuarangi ā-Motu mō Aotearoa (te anga o te NCCRA) te tūāpapa o te NCCRA, ā, i pau te iwa marama e mahia ana e tētahi rōpū kanorau, he rerekē nei ngā pūkenga, o ngā tāngata mātauranga me ngā mātanga. Kua huihuia mai ngā putanga i ahu mai i ngā iwi Māori me te torotoro a te hunga whai pānga ki ngā tātaritanga pūtaiao, hangarau, tohunga anō hoki. Ka whakamahia ngā kitenga hei whakawhanake i tētahi Mahere Urutaunga ā-Motu (NAP) hei urupare ki ngā tūraru, ngā kōwhiringa me ngā āputa mātauranga nunui.

Āhua 1: Te hononga i waenga i te anga o NCCRA, te Whakahaere Arotakenga Tūraru Huringa Āhuarangi ā-Motu, me te Mahere Urutaunga ā-Motu.



E ū ana a Aotearoa ki te urutau me te whakamauru. Ko te Pire (te Pire) Whakatikatika mō te Uruparenga Huringa Āhuarangi 2019 (Waro Kore) tētahi anga e whakawhanake ai, e whakatinana ai hoki a Aotearoa i ētahi kaupapa here āhuarangi e marama ana, e pūmau ana hoki ki te:

- whakaiti i ngā tukunga haurehu kati mahana (arā te, 'whakamaurutanga')
- aro atu ki te āhuarangi e huri nei (arā te, 'urutaunga').

Mā te Ture a Aotearoa e here ki te tautuhi i ngā tūraru me ngā kōwhiringa anamata mā te whakaputa i tētahi NCCRA i ia ono tau. Hei urupare ki ia NCCRA, me whakarite te Minita o te Huringa Āhuarangi i tētahi NAP.

Kei te mahana haere te āhuarangi o Aotearoa, kei te pupuke haere te pae moana, ā, kei te auau haere, kei te pākaha haere hoki te putanga mai o ngā pāpono huarere taikaha. I whakawhanake te National Institute of Water and Atmospheric Research (NIWA) i ngā matapae huringa āhuarangi i whakamahia i te arotakenga tūraru i muri mai i te putanga o te Pūrongo Arotakenga Tuarima a *IPCC*. E whai wāhi atu ana ngā take e whai nei:

- I ngā tau 100 kua huri kua 1°C te mahanatanga ake o tō tātou āhuarangi. Ki te kaha tonu ngā tukunga ā-ao, ka 1.0°C anō te pikinga o ngā paemahana hei te tau 2040, ā, ka 3.0°C te pikinga hei te tau 2090.
- I ngā tau e 60 kua huri, kua 2.44 mm te pupuketanga ake o te pae moana i ia tau. Ki te kaha tonu ngā tukunga ā-ao, ka 0.21 m te pupukenga ake o te pae moana hei te tau 2040, ā, ka 0.67 m hei te tau 2090.
- Ka kaha ake, ka auau ake te putanga mai o ngā pāpono huarere taikaha, pēnei i ngā āwhā, ngā hīrangi me ngā ua makerewhatu. Ka kitea te pikinga nui o ngā ua taikaha, puta noa i te motu, ina koa i Te Tai Tokerau nā te pikinga, e matapaetia ana, o ngā huripari nō ngā takiwā pārū.
- E matapaetia ana ka heke te nui o ngā rā e tau mai ai te hauhunga me te huka, ā, ka piki ngā rā maroke i te nuinga o Te Ika-a-Māui me ētahi wāhanga o Te Waipounamu.
- E matapaetia ana ka piki te putanga mai me te kaha o ngā tauraki, ina koa i te taha rāwhiti o Te Tiritiri-o-te-moana.
- E matapaetia ana ka piki te hau whakarua i te raumati, ā, ka piki te hau matatara i te hōtoke, ā, ka kaha tērā i te tonga o Te Waipounamu.
- E matapaetia ana ka piki te tūraru ki ngā ahi mura noa i ētahi takiwā e maha kia tae ki te pito o te rautau, nā te pikinga o ngā paemahana me te tere o te pupuhi o ngā hau, nā te iti haere hoki o te ua me te pikinga o te pārūrū.

Ahako te pūmau o te ngākaurua e pā ana ki ēnei matapae, ina koa ērā e pā ana ki te pito o te rautau, kua takoto mai he whakaahua o tētahi anamata e kaha ana te tūpono ka kitea nā te huringa āhuarangi.

Kua tautuhi te NCCRA i ētahi tūraru e 43 i roto i ngā takiwā e rima. Ko ngā takiwā uara e rima, ko tangata, ko te taiao māori, ko te ōhanga, ko te taiao kua hangaia me ngā mana whakahaere. Ahako kua tautuh tēnei NCCRA i ngā tūraru nunui 10, me whakatau ngā ngā tūraru tōmua katoa e 43. Ka takoto i te pūrongo ngā whakatauranga hua, totoa hoki, ā, ka whakamāramahia hoki ngā take rangahau tōmua mō ngā tūraru tōmua e 43 kia tika ai te whakaaro o ngā kaiwhakawhanake i te NAP ki ngā tūraru tōmua katoa.

Whakatauranga hua

He taikaha, he nui rānei ngā whakataunga hua nō ngā tūraru tōmua i roto i tētahi, neke atu rānei, o ngā anga arotakenga e toru (ināianei, hei te 2050, hei te 2100). E whakaatu ana ngā whakataunga hua i te āhua o te nui o te noho puare, o te noho whakaraerae hoki o ngā rawa me ngā uara i ia takiwā ki ngā pūmate āhuarangi. Ko ngā whakatauranga tukunga iho, ko: te hauiti, te iti, te āhua nui, te nui, me te taikaha

Whakatauranga totoa

I arotake te NCCRA i te totoa o te mahi ki te whakatau i ia tūraru (arā, te 'totoa ā-urutaunga'), kia mōhiotia ai te āhua o te nui o ngā mahi ka whai i tūtohungia ai mō ngā tau e ono kei te tū mai. Kei waenga i te 44 ki te 94 ngā whakatauranga totoa kei roto i tēnei NCCRA, ā, i puta ake hoki i ētahi take, ina koa mehemea rānei kua kōkiritia, kua maheretia kētia rānei tētahi urupare tika.

Tohu ai te NCCRA i ngā tūraru e rua i ia takiwā, ā, ko te whakatauranga totoa ā-urutaunga teitei rawa te mea nunui rawa. Koinei te ara i whāia ai, tē whakatauranga kē ai i ngā tūraru tino totoa 10 katoa, nā te mea he rerekē ngā takiwā, nō reira kāore e ōrite ana ngā whakatauranga hua, totoa hoki i roto i ngā takiwā.

Whakaū ai te NCCRA e whai hiranga ana ki te Māori ngā tūraru tōmua katoa kei raro nei, ā, ka pāngia pāhikahikangia ētahi whānau, hapū, iwi anō hoki, tae atu ki ngā pānga Māori, ngā uara, ngā tikanga me te hauora. Ka tino whaitake te **mātauranga Māori** ki te whakawhānui i te māramatanga ā-ahurea ki ēnei tūraru, me te whakanoho i te ahurea ki roto i ngā whakamahere huringa āhuarangi, ngā kaupapa here me ngā urutaunga o anamata. Miramirangia ai i tēnei NCCRA ngā tūraru whāiti e tino hāngai ana ki te Māori. Heoi anō, katoa ngā tūraru ka pā ki Aotearoa, ka hāngai ki te Māori hei kaitiaki i runga i ō rātou whenua tupuna, ahurea anō hoki.

Tūtohi 1: Ngā tūraru huringa āhuarangi nunui rawa 10 o Aotearoa, e takoto nei i runga i te totoa.

Takiwā	Tūraru	Whakatauranga	
		Hua	Totoa (44–94)
Taiao māori	Ngā tūraru ki ngā pūnaha hauropi tahatai, pēnei i te taihua, i ngā wahapū, i ngā tāhuahua, i ngā roto tahatai me ngā repo, nā te pupukenga tonutanga o ngā wai o te moana me ngā pāpono huarere taikaha.	Nui	78
	Ngā tūraru ki ngā pūnaha hauropi me ngā momo taketake nā te pikinga o te horapa, o te ora me te whakanohonga o ngā momo urutomo nā te huringa āhuarangi.	Nui	73
Tangata	Ngā tūraru ki te whakakotahitanga ā-pāpori me te hauora ā-hapori i te peinga o ētahi tāngata takitahi, o ngā whānau me ngā hapori nā ngā pānga o te huringa āhuarangi.	Taikaha	88
	Ngā tūraru ki te whakanui ake i ngā tōkeke koretanga me te whakarite i ētahi tōkeke koretanga hou nā te rerekē o te tohanga o ngā pānga o te huringa āhuarangi.	Taikaha	85
Ōhanga	Ngā tūraru ki ngā kāwanatanga i ngā utu ā-ōhanga e hono ana ki ngā whakaputanga i ngaro, ngā utu whakaora aituā me ngā taumahatanga kore tahua ka pā pea nā ngā pāpono taikaha me ngā huringa tonutanga.	Taikaha	90
	Ngā tūraru ki te pūnaha ahumoni i te pāhekeheke nā ngā pāpono huarere taikaha me ngā huringa tonutanga.	Nui	83
Taiao kua hangaia	Ngā tūraru ki ngā whakaputunga wai inu (te wātea me te kounga o te wai) nā ngā huringa hekenga ua, paemahana, tauraki, pāpono huarere taikaha me te pikinga tonutanga o te pae o te moana.	Taikaha	93

Takiwā	Tūraru	Whakatauranga	
		Hua	Totoa (44–94)
	Ngā tūraru ki ngā whare nā ngā pāpono huarere taikaha, tauraki, te pikinga o ngā huarere e mura ai te ahi me te pikinga tonutanga o te pae o te moana.	Taikaha	90
Mana whakahaere	Ngā tūraru ki te urutaunga koretanga ¹ puta noa i ngā takiwā nā ngā tikanga, ngā tukanga me ngā taputapu kāore nei e whakaaro ana ki ngā ngākauruatanga me ngā huringa tauroa.	Taikaha	83
	Ngā tūraru ki te whakanuitanga o ngā pānga huringa āhuarangi puta noa i ngā takiwā katoa nā te mea kāore e tika ana kia urutautia ngā whakaritenga whakahaere o nāianei. Ko ngā whakaritenga whakahaere ko ngā anga ā-ture, ā-whakatau hoki, ko ngā mahi ruruku i roto, puta noa hoki i ngā pae o te kāwanatanga, me ngā tikanga tahua tautoko.	Taikaha	80

¹ E hāngai ana te *urutaunga koretanga* ki ngā mahi e kaha ake ai pea ngā tūraru ki ngā putanga kōaro e hāngai ana ki te āhuarangi, mā te pikinga o ngā tukunga haurehu kati mahana, te pikinga o te noho whakaraerae ki ngā huringa āhuarangi, ki te hekenga oranga rānei, ināianei, ā anamata rānei. He tukunga iho pokerehū noa iho, i te nuinga o te wā, te urutaunga koretanga (IPCC, 2018).

E kaha ana te hono i waenga i ngā wāhanga NCCRA. Ahakoa rā i tirohia ētahi taupuhipuhitanga, kāore e takoto i te anga o NCCRA tētahi tikanga e uru mai ai ērā ki tēnei NCCRA, nō reira kāore ērā e āta whakaurua ana ki ngā whakatauranga tūraru.

E whaimana ai, me whakaū ngā mahi urutau ka whakaritea hei urupare ki ngā tūraru tōmua i ēnei hononga, ā, me whakataurite i roto i ngā tūraru. I miramira ngā Māori i whai wāhi ki te kōrero tahi mō tēnei arotakenga he wāhanga nui te whakaū i ngā taupuhipuhitanga i te tūhuringa o ngā tūraru āhuarangi i tā te Māori titiro. I whakaarotia ake kāore te anga o NCCRA, ina koa te ariā ki ngā takiwā, i hāngai ki tā te Māori titiro ki te ao. Ka puta pea te kōwhiringa ki te tūhura i tētahi arotakenga tūraru Māori ā-motu, ka whai wāhi atu ki tērā tētahi tikanga rangahau e miramira ana i ngā taupuhipuhitanga, ka noho hoki ko ngā tikanga Māori hei tūāpapa.

E whā ngā kōwhiringa i tautuhia ai e te NCCRA e puta mai ana i ngā huringa āhuarangi. He iti noa iho ngā kōwhiringa i tautuhia ai mā roto mai i ngā arotakenga mātātuhi, i te kōrero ki ngā mātanga, i te kōrero tahi rānei ki ngā iwi Māori me te hunga whai pānga. Kāore i te tino mārāma ētahi o ngā kōwhiringa, ā, me rangahau tonu te katoa kia kore ai ngā urupare e whakakino noa iho i ngā pānga huringa āhuarangi. I tautuhi te NCCRA i ngā kōwhiringa nei:

- ka nui ake te whakaputanga i ētahi rāngai matua nā ngā paemahana mahana ake
- ka whakarato ngā pakihī i ngā rawa me ngā whakarātonga urutaunga
- ka heke te hunga ka mate i te makariri o te huarere nā ngā paemahana mahana ake
- ka iti ake te hiahia ki te whakamahana i te hōtoke nā ngā paemahana mahana ake

Arā ētahi āputa nui kei roto i ngā mātauranga e matea ana hei whakahaere i ngā tūraru huringa āhuarangi me ngā kōwhiringa. E whakaheke ana ēnei āputa i te āheinga o Aotearoa ki te arotake me te whakahaere i te huringa āhuarangi, ā, me whakatau ēnei hei whakamōhio i te NAP me te NCCRA ka whai mai. Koinei ngā āputa:

- he iti ngā rārangi koiora kua rurukutia, e wātea kau ana hoki me ngā huinga raraunga e whakamārama ana i te tohanga me te tū o ngā pūnaha hauropi me ngā momo
- te hononga i waenga i te noho whakaraerae ā-pāpori, ngā tuku ihotanga ā-ahurea me te huringa āhuarangi, tae atu ki ngā pānga ki te hauora Māori ā-pāpori, ā-ahurea, ā-wairua, ā-ōhanga hoki
- ka pēhea te pānga o te huringa āhuarangi ki te rāngai pēke me te rāngai inihua, me ngā pānga ka whai mai ki te pūnaha ahumoni
- ngā mōhiohio pūmate e rite tonu nei te puta mai mō te arotake i te noho puare o te taiao kua hangaia i tētahi korahi ā-motu
- ngā taupuhipuhitanga me ngā tūraru whānui i waenga i ngā rāngai hanganga
- tētahi pae rangahau whānui kua rurukutia kia wātea ai ngā rangahau hei ārahi i urutaunga kia tika ai
- ngā taupā o nāianeī, o anamata hoki ki te urutaunga
- ngā kōwhiringa whānui katoa, ā, kia mārama pai hoki ki ērā kua tautuhia kētia.

He mahi nui tā te [mātauranga Māori](#) i roto i ngā arotakenga tūraru āhuarangi me ngā whakamahere urutaunga. Ahakoa e wātea ana tēnei mātauranga, me nui ake te wā me te kōrero tahi e kawea mai ai ki ngā NCCRA o anamata. Nā ēnei here i kī ai ētahi iwi ka tautoko rātou i te whanaketanga o tētahi arotakenga tūraru ka whai mai, ka noho whakarara hoki mā te Māori, nā te Māori. Kua tohu mai rātou ko te tūāpapa o te tikanga rangahau ko te [kaupapa](#) me ngā [tikanga Māori](#), ā, ka whakaweawe pea tērā i te tatuhinga, i te arotakenga me te raupapatanga o ngā tūraru āhuarangi.

I whai te NCCRA ki te mau mai i ā te Māori titiro mā te whiriwhiri i ngā tūraru me ngā kōwhiringa o te huringa āhuarangi. He tokomaha ngā Māori i miramira i te take ahakoa e tohu ana te huringa āhuarangi i tētahi wero nunui mā Aotearoa, kua noho te Māori i konei i roto i ngā whakatupuranga maha, ā, kua ora, kua tupu mā te urutau ki ngā huringa ā-āhuarangi, ā-taiao anō hoki. He nui ngā iwi me ngā hapū kua huri kē ki te whakawhanake i ā rātou ake mahere huringa āhuarangi, e takoto ana i ērā ō rātou uara, ā rātou take me ō rātou wawata hei urupare ki te huringa āhuarangi.

Arā ētahi tikanga i whakauru ai te NCCRA i ngā tirohanga rerekē me ngā uara rerekē o te Māori, pēnei i:

- tētahi huinga mātaūpono arataki hei ārahi i te torotoro me te arotakenga tūraru
- te whakaū i ngā hononga me ngā whakawhirinakitanga i waenga i ngā takiwā
- te whakamihi i ngā ariā Māori matua kei te tūāpapa o ia takiwā.

1 Introduction

1.1 Context and audience

1.1.1 Context

Climate change is already affecting New Zealand. Temperatures have increased, glaciers are melting and sea levels have risen over the past century. Such changes are expected to continue, with far-reaching consequences across all the [value domains](#) that underpin wellbeing in New Zealand – namely, the natural environment, human capital, the economy, the built environment and governance.

Significant work is underway to better understand and prepare for local, regional and national impacts of climate change. At the local and regional level, this includes risk assessments and adaptation plans by many public and private sector organisations. At a national level, the Ministry for the Environment has released updated climate projections and adaptation guidance. A range of organisations and projects are also focused on enabling New Zealanders to adapt, manage and thrive in a changing climate.

The Climate Change Response (Zero Carbon) Amendment Act 2019 (the Act) passed into legislation in November 2019. The Act forms the framework for New Zealand to:

- develop and implement clear and stable policies to reduce GHG (greenhouse gas) emissions (ie, ‘mitigation’)
- respond to the inevitable impacts of climate change (ie, ‘adaptation’).

It requires the Climate Change Commission to prepare an NCCRA at least once every six years. In response to each assessment, the Minister for Climate Change must prepare a national adaptation plan (NAP).

1.1.2 Audience

The NCCRA will give decision-makers the best available evidence and assessment of risks and opportunities to plan their approach to address the impacts of climate change. The primary audience is central government. It will also be of interest to a broad range of stakeholders, whānau, iwi, hapū and communities.

1.2 Objectives

The NCCRA has the following key objectives:

- provide a national overview of how New Zealand may be affected by various hazards and threats that are caused, exacerbated or influenced by climate change, and the risks and opportunities this brings, as well as any gaps in evidence
- support decision-makers to better understand the wide range of risks that New Zealand will face, and which risks to address most urgently
- provide the best available evidence, information and assessment of risks to inform a NAP directly.

1.1.3 National adaptation plan (NAP)

The NAP will define both the Government’s objectives for adapting to climate change and how the Government will meet those objectives. It will establish a planned approach to adaptation and put in place a forward-looking, holistic plan to respond to the priority risks, opportunities and gaps identified in the NCCRA.

The NCCRA focuses on potential shortfalls in adaptation to the priority risks and opportunities, which could benefit from further action in the NAP. It uses urgency ratings informed by the *2017 UK Climate Change Risk Assessment* (Committee on Climate Change, 2017) to signal the need for adaptation decision-making. Urgency is defined as ‘a measure of the degree to which further action is needed in the next five years to reduce a risk or realise an opportunity from climate change’ (Committee on Climate Change, 2017).

1.3 Structure

The outputs of the NCCRA are in three reports, outlined in table 2.

Table 2: Overview of NCCRA reports

Report	Purpose
Main report (this report)	An overview of the findings, with a focus on the 10 most significant risks.
Technical report	Further detail on the risk assessment findings, including profiles of the risks, opportunities and gaps in each domain and descriptions of exposure, vulnerability, consequence, adaptation and strength of evidence. It provides the evidence base for the assessment findings and is intended as an ongoing resource for the NAP. It is a companion to the main report.
Method report	Details the approach to the risk assessment and engagement methodology, including the results of engagement. It supports national, local and regional risk assessments of organisations that wish to learn and draw from this methodology.

1.4 Purpose

This report is an overview of the findings of the NCCRA, with a focus on the 10 most significant risks. Table 3 sets out the sections of the report.

Table 3: Main report by section

Section	Content
1. Introduction	<ul style="list-style-type: none">• Overview of the context, objectives and structure of the NCCRA.
2. Summary of approach to the NCCRA	<ul style="list-style-type: none">• Brief overview of the approach to the NCCRA. (The method report has further information.)
3. Te ao Māori and climate change risk	<ul style="list-style-type: none">• Portrays a Māori worldview and unique lens to help frame our thinking about, and approach to, te huringa āhuarangi (climate change) in Aotearoa New Zealand.• Identifies specific risks, opportunities and gaps detailed in the report that have particular relevance to Māori rights, values, practices and communities.

Section	Content
4. Climate change in New Zealand	<ul style="list-style-type: none"> Overview of how climate change is affecting and will continue to affect New Zealand, and the hazards considered by the NCCRA. (The technical report has further information.)
5. Climate change risks and opportunities	<ul style="list-style-type: none"> Overview of climate change risks for New Zealand. Describes the two most urgent risks from each domain, with overviews of other priority risks and opportunities. (The technical report has further information on all climate change risks, opportunities and gaps.)
6. Cascading impacts and socio-economic factors	<ul style="list-style-type: none"> Two case studies illustrating: <ul style="list-style-type: none"> the interactions between domains and risks how socio-economic trends will influence the nature and severity of risks in the future.
7. Uncertainty and gaps	<ul style="list-style-type: none"> Summarises priority information gaps identified through the risk assessment, and the inherent uncertainty underlying any risk assessment.
8. Next steps	<ul style="list-style-type: none"> What happens after the completion of the NCCRA.
9. References	<ul style="list-style-type: none"> Citations in this report.

2 Summary of approach

2.1 Assessment and engagement method

This first NCCRA is based on *Arotakenga Huringa Āhuarangi: A Framework for the National Climate Change Risk Assessment for Aotearoa New Zealand* (the NCCRA framework). The framework was developed by an expert panel and sets out guidance on methods for the NCCRA. The NCCRA combined Māori and stakeholder engagement with scientific, technical and expert information to inform the assessment.

The NCCRA was undertaken over three stages by a diverse, multi-disciplinary team of academics and consultants, see table 4 and [figure 2](#). Before Stage 1, a ‘context-setting’ phase set the objectives, scope and method for the assessment.

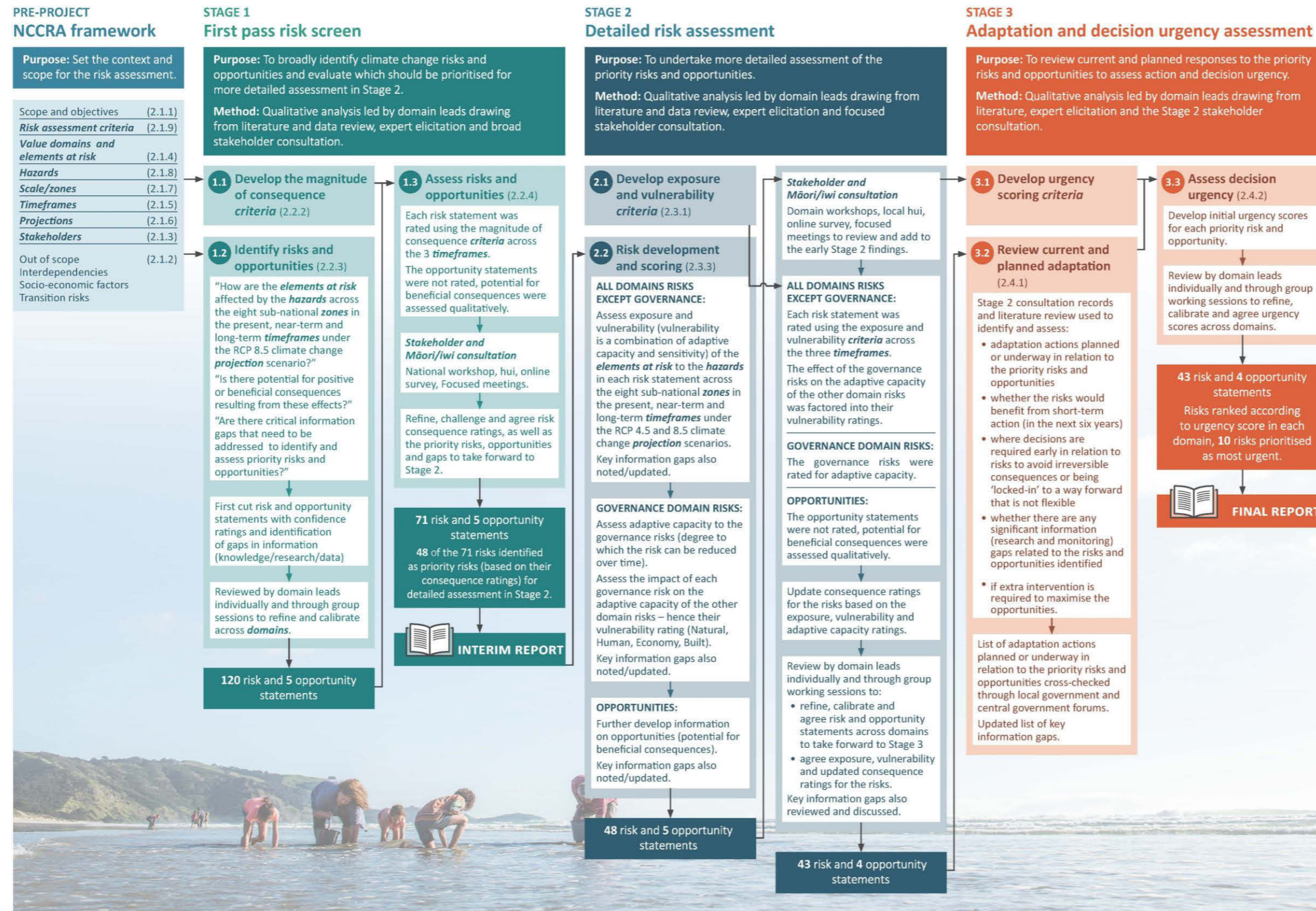
The sections below summarise each stage, followed by an overview of the method and key concepts.

Engagement informed all three stages of the process. The [method report](#) gives more detail about the assessment and engagement method.

Table 4: Three stages of the NCCRA

Stage	Objectives	Output
Stage 1: First-pass risk screen	High-level consideration of climate change risks to New Zealand. Determine national risks to consider in Stage 2.	A set of priority national climate change risks (rated extreme and major in the Stage 1 risk screen) for detailed assessment in Stage 2. Documented in an interim report.
Stage 2: Detailed risk assessment	Examine risks rated extreme and major. Prioritise risks to consider in an NAP.	More detailed assessment of risks to inform the NAP. Identify the 10 most urgent risks, documented in this main report.
Stage 3: Adaptation and decision urgency	Assess current and planned adaptation to identify risks needing the most urgent action.	Contribute to prioritising the 10 most urgent risks to consider in the NAP. Documented in this main report.

Figure 2: NCCRA process



2.1.1 The NCCRA framework

The NCCRA framework formed the basis for the overall objectives, scope and method, including:

- engaging partners, stakeholders and communities
- assessing value domains
- timeframes
- climate projections
- scale
- climate change hazards
- risk assessment criteria
- guiding principles.

Table 5 sets out these parameters. The NCCRA framework and the [method report](#) have further information.

Table 5: NCCRA framework: key parameters

Parameter	Description
Partners, stakeholders and communities	The NCCRA engaged a range of stakeholders and communities along with Māori as Partners with the Crown, who provided input into every stage of the assessment. See section 3 and the method report for further detail.
Value domains	The NCCRA framework outlines five ‘value domains’ for assessing risks and opportunities: natural environment, human, economy, built environment and governance. They represent groups of values, assets and systems that may be at risk from climate-related hazards, or that could benefit. Each domain can be broken down into ‘elements at risk.’ See section 2.3.1 for further detail.
Timeframes for assessing risks	The NCCRA considers risks to New Zealand arising from climate change in the present day (risks already occurring, including those observed over the past 10 to 20 years), near term (projected to manifest around 2050) and long term (projected to manifest around 2100). The Stage 2 assessment also considered risks to coastal hazards and sea-level rise, projected to manifest around 2150.
Climate change projections and RCPS	Risks and opportunities have been analysed for projections of climate change, reflecting different possible futures. The NCCRA considers RCP8.5, a high-emissions pathway, and RCP4.5, a medium-low emissions pathway. See box 1 below.
Scale	The NCCRA is a national-scale assessment. The consultants considered variation in projections across seven sub-national climate zones. See section 2.2.3 and the method report for further discussion.
Climate change hazards	Hazards can be: <ul style="list-style-type: none"> • a change in magnitude, persistence and frequency of natural hazard events, such as more intense short-duration rainfall, or • a ‘stressor’ or ‘trend’ in climatic conditions. NIWA provided information on hazards and their direction of change over the NCCRA timeframe, based on regional projections.
Risk and assessment criteria	Climate change risk assessment requires more emphasis on consequences than on likelihood. Risk is framed using the elements of hazard, exposure and vulnerability, with the overlap defining the risk. Risk is a function of climate hazards, the degree to which values are exposed to the hazard and their vulnerability to its effects (Ministry for the Environment, 2019).

Parameter	Description
	Risks were rated using magnitude of consequence criteria developed for this assessment. Each risk's exposure and vulnerability (sensitivity and adaptive capacity) was also rated using criteria developed for this assessment. Finally, the assessment rates the risks for decision urgency to signal the need for adaptation action, using criteria developed for this assessment.
Urgency	The NCCRA uses the concept of adaptation decision urgency to summarise findings of the analysis and to inform the NAP. The NCCRA framework adopted the urgency categories from the <i>2017 UK Climate Change Risk Assessment (UK CCRA 2)</i> (Committee on Climate Change, 2017). The UK criteria were adapted to the New Zealand context. Section 2.1.4 has further information.

Box 1: Representative concentration pathways

Representative concentration pathways (RCPs)

- The *Intergovernmental Panel on Climate Change (IPCC) Assessment Report 5 (AR5)* set out a range of emission trajectories over the next century called representative concentration pathways (RCPs). The NCCRA considers two RCPs. RCP8.5 was used to screen risks in Stage 1, while Stage 2 considered risks arising under both RCP8.5 and RCP4.5. The RCPs are outlined below:
- RCP8.5, a high concentration pathway characterised by increasing GHG emissions driven by a lack of policy changes to reduce emissions. This pathway represents increased use of land for agriculture, a heavy reliance on fossil fuels and a high-energy intensity with a low rate of technology development (NIWA, 2019).
- RCP4.5, a moderate concentration pathway consistent with low levels of emissions achieved through ambitious emissions reduction strategies. This pathway represents implementation of stringent climate policies, with a lower-energy intensity, strong reforestation and decreased land for agriculture due to improvements in crop yields and dietary changes (NIWA, 2019).

Guiding principles – Ngā mātāpono

The NCCRA framework provides a set of guiding principles, which have informed the risk assessment and engagement work. The mātāpono are based on the principles in the National Disaster Resilience Strategy (Ministry of Civil Defence and Emergency Management, 2019), with the addition of ōhanga (prosperity), from the Living Standards framework (The Treasury, 2018).

The mātāpono, which are additional to the principles of [Te Tiriti o Waitangi](#) (partnership, protection, participation and potential), are:

- manaakitanga (care and reciprocity)
- kaitiakitanga (intergenerational sustainability)
- whanaungatanga (connectedness and relationships)
- ōhanga (prosperity)
- rangatiratanga (leadership and autonomy)
- kia mahi ngātahi (engagement and participation)
- kia āwhina (support).

The [method report](#) outlines how the mātāpono informed the NCCRA. In summary, climate change is an intergenerational issue for all communities in New Zealand (kaitiakitanga and ōhanga). Strong leadership from the Government, its Māori partners, the private sector and communities will be critical in responding to the challenges and opportunities from climate change. The NCCRA aims to begin to identify key national-level risks and opportunities that will manifest over the next 80 years, to support leadership and decision-making (rangatiratanga). The risk assessment method held the natural environment and human domains, rohe taiao and rohe tangata, as a central focus, along with a recognition of the interconnectedness of all the domains (manaakitanga).

The NCCRA approach was grounded in engagement across the five domains, and included national, regional and local agencies, as well as representatives of Māori groups and iwi (kia mahi ngātahi). Participants could contribute in a variety of ways, including workshops, hui, online surveys, focused individual meetings and phone calls (kia āwhina). Over 400 individuals participated throughout the process. The approach emphasised the NCCRA was the beginning of a consultation that would be carried forward into the NAP and future NCCRAs.

Under the guidance of the NCCRA's Kaumātua and Māori engagement advisors, the project team focused the limited time and resources on engaging with Māori leaders directly involved in matters of climate change and decision-making (whanaungatanga). The NCCRA has been informed by existing iwi/hapū climate change strategies and plans. Comprehensive consultation with these groups and consideration of how [mātauranga Māori](#) might inform future climate science and policy-making has been limited. [Section 7.2.3](#) discusses this gap.

2.1.2 Stage 1: First-pass risk screen

The purpose of the first pass risk screen was to:

- examine potential risks and opportunities from the interaction between hazards, exposure and vulnerability across New Zealand
- prioritise risks and opportunities for further assessment.

The first pass screen considered:

- how elements at risk across the five value domains were affected by hazards across New Zealand at a high level
- the seven sub-national zones, territorial sea and exclusive economic zone (EEZ) in the present, near term and long term under [RCP8.5](#).

This was done through a literature review that generated initial risk and opportunity statements. The consultants then consolidated, analysed and evaluated (rated) these through a series of working meetings, and through the engagement detailed in [section 2.1.5](#).

Stage 1 resulted in a set of 48 priority risks and five opportunities. Priority risks were those rated either extreme or major in the first-pass screen. The consultants took these to Stage 2 and 3 for detailed assessment and consideration of adaptation urgency.

2.1.3 Stage 2: Detailed risk assessment

The detailed risk assessment examined the 48 risks rated extreme and major. Further investigation of vulnerability and exposure supported an understanding of the magnitude of consequence arising from these risks under both RCP4.5 and RCP8.5 (table 9) in the present term, near term and long term.

Further literature review brought better understanding of each risk. The consultants then consolidated, analysed and assessed (rated) the review findings through a series of working meetings of the project team and through the engagement detailed in section 2.1.5.

Stage 2 refined the set of risks to 43 priority risks and four opportunities. The reduction in risks was in large part due to merging similar risks, after further analysis.

Box 2: Abbreviation system for risks and opportunities

Risk and opportunity numbering

Each risk and opportunity in this main report is numbered using a letter and number per the convention outlined below:

- letter denotes the relevant domain the risk applies to: natural environment domain (N), economy domain (E), built environment domain (B) and governance domain (G). For opportunities, the letter O is added
- number, in chronological order, according to the urgency within each domain, one being the most urgent.

2.1.4 Stage 3: Adaptation and decision urgency

Stage 3 assessed existing and planned adaptation and the extent to which priority risks are being addressed as a result of these actions at a high level. This assessment also considered:

- where early action might be needed to avoid being locked in to a current pathway
- actions that will require long lead times to be effective
- actions with long-term implications.

Information about adaptation work either underway or planned was gathered through stakeholder consultation and a review of the *Stocktake Report of Climate Adaptation in New Zealand* and its recommendations report (Climate Change Adaptation Technical Working Group, 2017).

Stage 3 generated adaptation and decision urgency ratings for each of the priority risks and opportunities. Urgency is defined as “a measure of the degree to which further action is needed in the next five years to reduce a risk or realise an opportunity from climate change” (Committee on Climate Change, 2019, p.5). The NCCRA framework adopted the urgency categories from the *2017 UK Climate Change Risk Assessment* (Committee on Climate Change, 2017).

Figure 5: Application of urgency categories in the NCCRA



The way these categories were applied in the NCCRA (figure 5) differed from the method outlined in the NCCRA framework. The framework had categories that are mutually exclusive so that, if this method had been applied, each risk would have fallen into a single urgency category – which is how urgency was defined in the UK assessment. This approach proved inappropriate for the New Zealand NCCRA.

Urgency profiles

Given the breadth of each risk, and that New Zealand is still in the early stages of planning for climate change, a more nuanced application of the urgency categories was adopted. Rather than each risk falling into only one category, the NCCRA developed an ‘urgency profile’ through expert elicitation with the domain leads for each risk.

The profiles rate the applicability of each category to each risk and then use a weighted sum of these rates to assess the overall urgency. The more urgent categories were weighted higher than less urgent categories (the scale on the left of figure 5 indicates the relative urgency). Each risk was assigned:

- an overview of the types of actions required, using the urgency categories
- an overall urgency rating to inform decision-making in each domain.

This involved the following tasks.

1. The RA team and domain leads worked together on initial scoring, based on adaptation information outlined in task 1. They took the following approach to each risk.
 - (a) Domain leads estimated the percentage of total effort required under each of the urgency criteria. For example, a risk may have the following allocation:
 - Watching brief: 10 per cent
 - Sustain current action: 40 per cent
 - Research priority: 20 per cent
 - More action needed: 30 per cent.

- **Laying the groundwork for ongoing engagement** – ensuring at the end of the process, there is a foundation for long-term ties with partners and stakeholders, to be led by the Ministry for future adaptation work.
- **Following a transparent and repeatable process** – as a sound basis for the NAP and future NCCRAs.

The aim was to identify as many potential risks throughout New Zealand as possible and to elicit responses from different regions and disciplines. Stages 2 and 3 were more targeted, focusing on partners and stakeholders with direct responsibility for managing the risks rated as either major or extreme. In total, over 400 individual stakeholders from about 250 organisations were consulted.

Taking place between October 2019 and March 2020, activities included:

- a national multi-stakeholder workshop in November 2019
- a hui in November 2019, with representatives of Māori organisations and iwi/hapū from across New Zealand
- five risk assessment workshops, each focusing on a different value domain
- local hui through invitation from Te Ātiawa, Te Arawa and Waikato-Tainui iwi
- meetings, workshops and teleconferences with target partners and stakeholders, including local and central government
- two web-based surveys (in Stages 1 and 2)
- supplementary engagement at conferences and other forums.

The Ministry also held a series of regional hui in February 2020, which included discussion and feedback about the NCCRA.

The results are set out in the [method report](#).

2.2 Limitations

2.2.1 Socio-economic projections

For this first assessment, the NCCRA framework excluded socio-economic projections, such as future changes in population, gross domestic product and other economic, land use or employment variables.

Socio-economic changes will affect future vulnerability and exposure, and therefore the magnitude of consequence for some risks, particularly in the medium and long term. New Zealand's socio-economic fabric (population, technological change and economic growth) will be very different in 2050 and in 2100. For example, cultural diversity will continue to grow.

This report explores these issues and areas of consideration for future NCCRAs at a high level through a case study in [section 6](#).

2.2.2 Transition risks

Risks may emerge from the transition to a lower-carbon global economy. This may entail extensive policy, legal, technology and market changes to address mitigation and adaptation. Such risks include higher pricing of GHG emissions or costs of transitioning to lower emissions technology (Task Force on Climate-related Financial Disclosures (TCFD), 2017). Transition risks may combine with physical risks to affect different sectors.

The NCCRA framework excluded the consideration of transition risks from this first NCCRA. The Government is currently addressing these risks through other regulatory mechanisms such as the reporting requirements of the Climate Change Response (Zero Carbon) Amendment Act 2019. It is also proposing to require financial firms and listed companies to report on the impacts for their business and investments in a consistent way, in line with guidance from the TCFD.

2.2.3 National assessment

The NCCRA is a national-scale assessment designed to feed into the NAP through a systematic examination of climate risks and opportunities to New Zealand, and the urgency for addressing them. It considers climate impacts on different parts of the country, using seven sub-national zones and two zones for the marine environment (territorial sea and EEZ).

The consultants aggregated the risks to the national scale, with a qualitative description provided where risks may be higher in one or two climate zones. The NCCRA methodology is adaptable to the regional, catchment, district and city scale as part of future assessments. The regional and district assessments would focus more on informing governance and planning by regional, district and city councils (Ministry for the Environment, 2019).

2.2.4 International and transboundary issues

The NCCRA recognises climate change will affect people and economies around the world. This will have flow-on effects for New Zealand. The first NCCRA recognises international and transboundary issues, and discusses those relevant to specific risks. As many international impacts will be inextricably tied to socio-economic projections, future NCCRAs may explore these issues more broadly.

2.3 Overview of value domains

2.3.1 Value domains

The NCCRA framework outlines five 'value domains' for assessing risks and opportunities (table 6). The domains represent groups of values, assets and systems that could be either at risk from climate-related hazards or beneficially affected. They are a hybrid of the New Zealand Treasury's Living Standards Framework and those used in the *National Disaster Resilience Strategy* (The Treasury, 2018; Ministry of Civil Defence and Emergency Management, 2019). The domains are interconnected, apply at individual, community and national levels, and include tangible and intangible values.

Table 6: Description of value domains

Value domain	Description
Human	People’s skills, knowledge and physical and mental health (human); the norms, rules and institutions of society (social); and the knowledge, heritage, beliefs, arts, morals, laws and customs that infuse society, including culturally significant buildings and structures (cultural).
Natural environment	All aspects of the natural environment that support the full range of our indigenous species, he kura taiao (living treasures), and the ecosystems in terrestrial, freshwater and marine environments.
Economy	The set and arrangement of inter-related production, distribution, trade and consumption that allocate scarce resources.
Built environment	The set and configuration of physical infrastructure, transport and buildings.
Governance	The governing architecture and processes in and between governments, and economic and social institutions. Institutions hold the rules and norms that shape interactions and decision-making and the agents that act within their frameworks.

Each value domain consists of a series of ‘elements at risk’. These divide the domains into subcategories that can then be assessed by their exposure and vulnerability to climate hazards. Table 7 sets out examples.

Table 7: Elements at risk in each value domain

Value domain	Elements at risk
Human	Community wellbeing, social cohesion and social welfare (urban, rural and coastal communities); health, education, sports, recreation, cultural heritage (archaeological sites, museums, arts, theatre), ahurea Māori, tikanga Māori – Māori culture, values and principles, cultural taonga .
Natural environment	New Zealand’s indigenous species, including he kura taiao – living treasures, terrestrial ecosystems, freshwater ecosystems, coastal, estuarine and marine ecosystems, biosecurity.
Economy	Primary industries (forestry, agriculture, horticulture, arable land, viticulture, fisheries, aquaculture, marine farming); land use, tourism, technology and business, whakatipu rawa – Māori enterprise, insurance and banking.
Built environment	Built infrastructure across sectors including housing, public amenity, water, wastewater, stormwater, energy, transport, communications, waste and coastal defences.
Governance	Treaty partnerships, adaptive capacity, all governing and institutional systems, all population groups, including vulnerable groups.

2.3.2 Interdependencies, direct indirect and cascading impacts

The NCCRA provides a national overview of how New Zealand may be affected by various hazards and threats that are caused, exacerbated or influenced by climate change, and the resulting risks and opportunities. However, it does not consider cascading impacts, interdependencies and future socio-economic projections.

There has been little research on how the impacts of climate change cascade across human systems, and even less on how to consider such cascades when assessing climate change risk. More studies are needed.

Still, it is recognised the domains and their elements at risk are highly interconnected and interdependent. The NCCRA therefore examined both direct and indirect risks. Most direct risks are in the natural, economy, human and built environment domains, where there is direct

exposure to climate hazards. However, the economy, human and governance domains also include indirect risks because they rely on, or interact with, elements in other domains that are directly exposed to climate hazards.

This assessment recognises the significance of cascading impacts by:

- assessing the effect of priority governance risks on priority risks in other domains. In particular, the impact of governance risks on the ability to adapt to risks in the other value domains. See section 2.3.3 for further information
- illustrating the effect of cascading impacts through a case study in [section 6](#)
- describing dependencies between risks in each profile for the 10 most significant risks (section 5.3.1, Interacting risks). The [technical report](#) includes this description for all priority risks.

2.3.3 Governance domain

Governance-related risks are distinct because they are universally crosscutting and indirect, emerging from other domain risks. They also have the effect of reducing the ability to address risks in the other domains, by lowering adaptive capacity (Lawrence et al, 2018). Although crosscutting and indirect risks were also identified in other domains, governance risks were considered to represent either barriers or enablers to climate action relevant to all domains. The consultants therefore assessed the governance risks differently, using the concept of adaptive capacity (a component of vulnerability) to:

- understand how governance risks affect the risks in other domains and vice versa
- prioritise the governance risks with the greatest effect.

The [method report](#) details how the risks were assessed across domains.

3 Te ao Māori and climate change risk

The Māori worldview (te ao Māori) acknowledges the interconnectedness and interrelationship of all living and non-living things. The karakia at the start of this report speaks to this vital connection with, and reliance on, the natural world, and of each generation to those before and after. This includes the connectedness of ecosystems and society, as well as of actions and consequences across domains. These interconnections are also reflected in the Treasury’s Living Standards Framework (LSF) for wellbeing, which is based on four capitals – natural, human, social, and financial and physical, and particularly its He Ara Waiora framework (see figure 4).

Waiora is a broad conception of human wellbeing, grounded in water (wai) as the source of all life. The foundations for wellbeing include kaitiakitanga (stewardship of all our resources), manaakitanga (care for others), ōhanga (prosperity) and whanaungatanga (the connections between us) (O’Connell et al, 2018, p ii).

Figure 4: Treasury’s Living Standards Framework (LSF) for wellbeing and the He Ara Waiora framework (Ministry for the Environment, 2019)

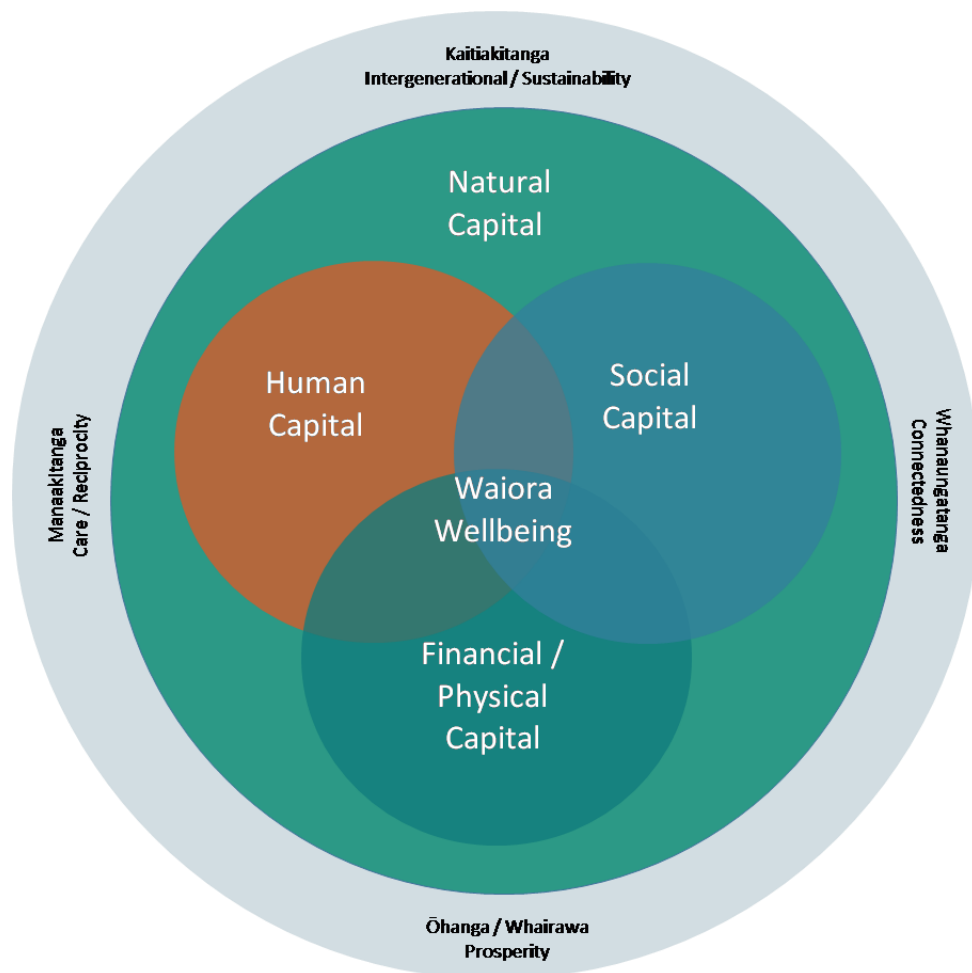


Figure 4 shows that natural capital surrounds all the other capitals in the LSF. Our wellbeing is highly dependent on sustaining natural capital, or ecosystem ‘services’ (Roberts et al 2015).¹ These provide resources, moderate the climate, absorb pollutants, cycle nutrients, and confer cultural and other benefits. They are all supported by biodiversity: the animals, plants and micro-organisms that have adapted to, and interact in, the ecosystem. Ecosystems also include people and are shaped by cultural and social interactions.

The LSF complements Māori views of the world that acknowledge the interconnectedness between the environment and people, where the health and wellbeing of all, are intertwined and deeply connected. In Māori customary contexts, *whakapapa* is the essential expression of these relationships and helps to generate meaning for human behaviour and understanding in the world. These complementary frameworks are a useful starting point for assessing climate change risk.

The LSF is applied in the context of the values and principles of *manaakitanga* (care and reciprocity), *kaitiakitanga* (intergenerational sustainability), *whanaungatanga* (connectedness and relationships), *ōhanga* (prosperity), *kia mahi ngātahi* (engagement and participation) and *kia āwhina* (support). A further principle, included for consideration in the NCCRA, is *rangatiratanga* (leadership and autonomy). The NCCRA framework summarises these values as *ngā mātāpono* – guiding principles (see [section 2.1.1](#) for more on how the principles were applied in the NCCRA).

As [section 2.3.1](#) explains, the approach to identifying elements at risk for the first NCCRA draws on and aligns with the Treasury’s LSF. The NCCRA framework also draws on the recent National Disaster Resilience Strategy (NDRS), which details priorities and objectives for increasing New Zealand’s resilience to disasters. The LSF’s four capitals contribute to wellbeing at the individual, community or national level. Similarly, the NDRS categorises elements and assets (also termed capitals) under broad categories of social, cultural, economic, built environment, natural environment, and governance. This provides a structure for the NCCRA framework to gain an understanding of risk in terms of the value domains – groups of things we value as a society – that align with the NDRS and LSF. The domains defined by the NCCRA framework are:

- natural environment – *rohe taiao*
- human environment – *rohe tangata*
- built environment – *rohe tūranga rangata*
- economy – *rohe ōhanga*
- governance – *rohe kāwanatanga*.

¹ Ecosystem services are the processes by which people benefit from ecosystems, such as clean air, fresh water and the pollination of crops. These are commonly classified as four types: provisioning (eg, food, fibre, water, fuel, genetic resources); regulating (eg, air quality, climate, water flow, pollination, erosion control, pest and disease control); cultural (eg, spiritual, aesthetic, recreational, educational); and supporting (eg, photosynthesis, soil formation, nutrient cycling) (Roberts et al, 2015).

3.1 Bringing Māori perspectives to the NCCRA

The NCCRA had to balance the challenge of using risk assessment methodology with factoring in diverse Māori views and values. A risk assessment is a reductive analytical exercise, simplifying complex systems (the natural environment, society, economy) into discrete parts and potential future events (risks), and then attempting to assess and prioritise these risks.

Clear connections and interdependencies of risks arise across the five domains. For Māori who were consulted, exploring these links was felt to provide a more complete understanding of how climate change will affect the wellbeing of Aotearoa New Zealand. However, the framework identifies there is currently no rigorous method for factoring interdependencies into risk assessment and rating. It is therefore beyond the scope of this first NCCRA.

Due to these limitations, some iwi, including Te Urunga O Kea – the Te Arawa Climate Change Working Group, have noted their support for the development of a subsequent, parallel risk assessment for Māori, by Māori. They note the methodology for such a parallel process would emphasise interdependencies and be underpinned by *kaupapa* and *tikanga* Māori, which may influence the identification, assessment and prioritisation of climate risks.

The risk assessment sought to recognise interdependencies and Māori perspectives in the following ways:

1. **Interconnectedness of domains:** [Section 5](#) describes the interdependencies for each of the 10 most significant risks. This report also includes a case study on interdependencies and cascading effects ([section 6](#)). Interdependencies between domains and risks have not affected the risk ratings, except for the governance risks. [Section 2.3.3](#) has more detail about the risk assessment method. The [technical report](#) sets out all the priority risks.
2. **Ngā mātāpono:** These are the guiding principles of this report, informing engagement and the risk assessment. [Section 2.1.1](#) describes how the principles informed the work of the NCCRA. The [method report](#) gives more detail on how the NCCRA sought to apply these principles within the limitations of the project scope and timeframe.
3. **Māori perspective on each domain:** In the [technical report](#), the sections that present the risks, opportunities and knowledge gaps in each domain include an overview of relevant Māori concepts and values.
4. **Risks and opportunities of particular relevance to Māori:** While acknowledging that all the risks are relevant to Māori, the NCCRA also identifies risks that particularly relate to Māori interests, values and practices. These are listed in [section 3.1.1](#) and described in [section 5](#).

3.1.1 Risks and opportunities of particular significance to Māori

Risks

The following risks have been identified as being of particular significance to Māori. These risks could affect Māori interests, kawa (protocols) and tikanga (correct procedures, lore, practices) as well as diverse expressions of mana (authority, dignity, control, governance, power) and kaitiakitanga (intergenerational sustainability):

- H5 – Risks to Māori social, cultural, spiritual and economic wellbeing from loss and degradation of lands and waters, as well as cultural assets such as marae, due to ongoing sea-level rise, changes in rainfall and drought.

- H6 – Risks to Māori social, cultural, spiritual and economic wellbeing from loss of species and biodiversity due to greater climate variability and ongoing sea-level rise.
- H8 – Risks to Māori and European cultural heritage sites due to ongoing sea-level rise, extreme weather events and increasing fire weather.
- G4 – Risk of a breach of Treaty obligations from a failure to engage adequately with and protect current and future generations of Māori from the impacts of climate change.

Some risks will have a disproportionate impact on Māori or certain Māori groups:

- H1 – Risks to social cohesion and community wellbeing from displacement of individuals, families, and communities due to climate change impacts.
- H2 – Risks of exacerbating existing inequities and creating new and additional inequities due to differential distribution of climate change impacts.
- H4 – Risks of conflict, disruption, and loss of trust in government from changing patterns in the value of assets and competition for access to scarce resources primarily due to extreme weather events and ongoing sea-level rise.
- H7 – Risks to mental health, identity, autonomy and sense of belonging and wellbeing from trauma due to ongoing sea-level rise, extreme weather events and drought.
- B1 – Risk to potable water supplies (availability and quality) due to changes in rainfall, temperature, drought, extreme weather events and ongoing sea-level rise.
- B2 – Risks to buildings due to extreme weather events, drought, increased fire weather and ongoing sea-level rise.
- B4 – Risk to wastewater and stormwater systems (and levels of service) due to extreme weather events and ongoing sea-level rise.
- B6 – Risks to linear transport networks due to changes in temperature, extreme weather events and ongoing sea-level rise.
- G6 – Risks to the ability of the emergency management system to respond to an increasing frequency and scale of compounding and cascading climate change impacts in New Zealand and the Pacific region.
- G8 – Risk to the ability of democratic institutions to follow due democratic decision-making processes under pressure from an increasing frequency and scale of compounding and cascading climate change impacts.

These risks are described in [section 5](#), and in more detail in the [technical report](#).

Opportunities

The opportunities in [section 5.8](#) are relevant to Māori business, particularly the primary sector (EO1), which is a strong focus for the Māori economy, whakatipu rawa (Māori enterprise) (EO2), and mahinga kai (food provisioning) (EO1). The health and financial opportunities of warmer winters are of particular significance to vulnerable groups such as low-income families, in which Māori are disproportionately represented (HO1 and BO1).

4 Climate change in New Zealand

4.1 New Zealand is already experiencing the impacts from a changing climate

Natural variations have always played a part in our climate, and will continue to do so. Climate change is expected to shift the range and the pattern of this variability. New Zealand is observing gradual changes such as sea-level rise and higher average temperatures, and more frequent and severe extreme weather events such as heatwaves, coastal flooding and changing seasonality (Ministry for the Environment, 2018). Climate change poses additional risks to New Zealand's communities and environment (natural and built), and will require adaptive responses to build resilience.

Due to past emissions, the climate will continue to change well into the future. Global surface temperatures have warmed, on average, by about 1°C on average since the late 19th century (Met Office, 2015). In New Zealand, a warming of 1°C was also recorded between 1909 and 2018. On the basis of monthly mean temperatures relative to the 1981–2010 average temperature, the five warmest years were: 2016 (+0.8°C), 2018 and 1998 (tied on +0.8°C), 1999 (+0.7°C), and 2013 (+0.7°C) (NIWA, 2019).

The oceans have already warmed and the amounts of snow and ice have diminished (IPCC, 2013).

The global average sea level rose about 19 cm between 1901 and 2010, at an average rate of 1.7 mm per year. The global average sea level rose at an average rate of about 3.4 mm per year between 1993 to 2016 (MfE, 2017a).

Due to the influence of regional climate trends and gravitational effects, the sea level does not rise uniformly around the globe. Between 1961 and 2018, a mean rate of sea-level rise of 2.44 mm per year was recorded across the four long-term monitoring sites across New Zealand. This rate is more than double the mean rate of 1.22 mm per year for the same sites between the start of our records and 1960 (MfE, 2017a).

4.2 Overview of climate change projections and impacts

Warming of the climate system, driven by anthropogenic (caused by human activity) greenhouse gas emissions, is unequivocal (IPCC, 2019). Risks identified in the NCCRA are likely to be sensitive to the degree of climate change. This section provides an overview of climate change projections for New Zealand. Risks identified in the NCCRA are likely to be sensitive to the degree of climate change, outlined below. The world has already experienced significant climatic changes due to emissions from the combustion of fossil fuels and changes in land use. The volume and rate of emissions will depend on climate policies, resource availability and demographic, economic and technological change, all of which are uncertain.

4.2.1 Representative concentration pathways (RCPs)

To consider this uncertainty, the IPCC developed four future emission scenarios, called representative concentration pathways (RCPs), to model future climate change for a range of climate variables. See [box 1](#).

Risks identified in the NCCRA are likely to be sensitive to the degree of climate change, outlined below.

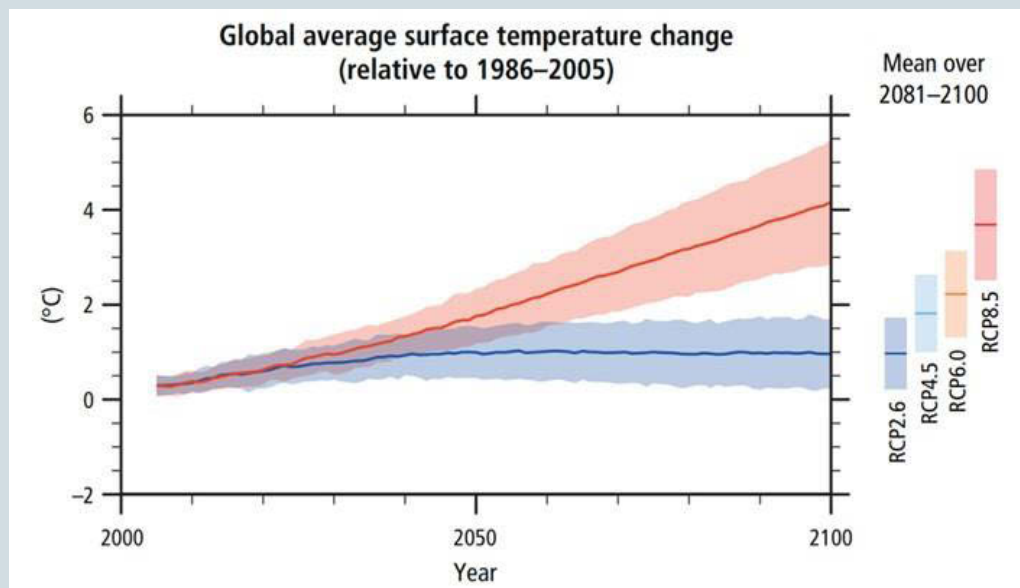
Box 3: Climate change scenarios in the NCCRA

The RCPs are possible future emissions trajectories that could result from a range of climate policies. They include a time series of emissions and concentrations of greenhouse gases, aerosols and chemically active gases, as well as land use and land cover. RCPs are only one set of many scenarios that would lead to different levels of global warming (IPCC, 2019).

Stage 1 of this NCCRA used projections based on **RCP8.5, a high greenhouse gas emissions scenario**. This is assumed to be a plausible upper level of risk. It supports the identification of the most significant climate-related risks, analysed in Stage 2 of the assessment. However, more extreme scenarios are possible, and the sensitivity of the climate system remains uncertain.

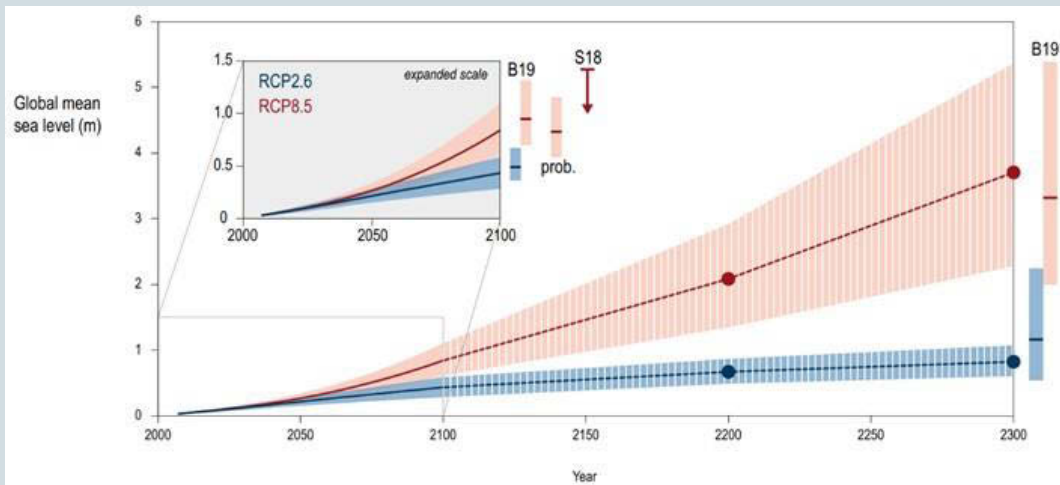
Stage 2 also used **RCP4.5, a relatively lower greenhouse gas emissions scenario**. It was used to consider climate risks associated with trajectories involving greater mitigation of emissions. This involves a sharp reduction in emissions in the second half of the century, but importantly it does not achieve the Paris Agreement goal of limiting warming to 2°C.

Figure 5: Global average surface temperature change from 2006 to 2100 as determined by multi-model simulations relative to 1986–2005



Note: Time series of projections and a measure of uncertainty (shading) are shown for scenarios RCP2.6 (blue) and RCP8.5 (red). The mean and associated uncertainties averaged over 2081–2100 are the coloured vertical bars at the right of each panel (IPCC, 2019).

Figure 6: Projected global sea-level rise until 2300



Note: The inset shows an assessment of the likely range of the global projections for RCP2.6 and RCP8.5 up to 2100. Projections for longer time scales are highly uncertain but a range is provided (5th–95th percentiles) (Oppenheimer et al, 2019).

NIWA developed the projections that form a basis of this report after the release of the *IPCC Fifth Assessment Report*. Projections were sourced from *Climate Change Projections for New Zealand* (Ministry for the Environment, 2018) and *Our Future Climate New Zealand* (NIWA, 2016). Climate projections represent the average climatic conditions over a 20-year period, centred on either 2040 (‘near future’) or 2090 (‘far future’). Unless otherwise specified, all projections are based on RCP8.5 (and refer to a baseline period of 1996–2005). A summary of projected changes to New Zealand’s climate is shown in table 8, and the projected mean sea-level rise is shown in table 9. See the [technical report](#) for further information on these projections.

Table 8: Climate change projections for New Zealand (Ministry for the Environment, 2018)

Climate variable	Description of change	Change in 2040	Change in 2090
Temperature			
Mean	Overall increasing, with greatest changes at higher elevations. Warming greatest in summer and autumn, and least in winter and spring.	+1.0°C	+3.0°C
Minimum and maximum	Overall increasing, with greatest changes at higher elevations, particularly for maximum temperature.	Not available	Daily range increases by up to 2°C
Number of cold nights (<0°C)	Overall decrease.	Average 50% decrease	Average 90% decrease
Number of hot days (>25°C)	Increase, particularly in already warm regions.	Average 100% increase	Average 300% increase
Rainfall			
Average rainfall	Regional and seasonal variation. Generally an annual pattern of	Substantial variation around the country, increasing in magnitude with increasing emissions.	

Climate variable	Description of change	Change in 2040	Change in 2090
	increases in west and south, and decreases in north and east.		
Number of dry days	More dry days throughout North Island, and in inland South Island.	Not available	Up to 10 or more dry days per year (~5% increase).
Extreme rainfall events	Increase everywhere.	The 1 in 10-year event up +11% for 1-hour duration, up +5% for 5-day	The 1 in 10-year event up +34% for 1-hour duration, up +15% for 5-day
Snow	Large decreases confined to high altitude or southern regions of the South Island.	Not available	Snow days per year reduce by 30 days or more
Drought	Increase in severity and frequency, especially in already dry areas.	Not available	Up to 50 mm or more increase per year, on average, in July–June (PED)
Other variables			
Pressure and wind	Varies with season, on average more northeast airflow in summer. Strengthened westerlies in winter.	Generally, the changes in pressure are only a few hectopascals ² but the spatial pattern matters for mean wind changes.	
Extreme wind speeds	General increase. Most robust increases in southern half of North Island, and throughout the South Island.	Up to 10% or more in parts of the country.	
Storms	Likely poleward shift of mid-latitude cyclones and possibly a small drop in frequency.	Specific projections are not available for storms in New Zealand.	
Solar radiation	Varies around the country and with season. West Coast shows the largest changes by 2090: summer increase (~5%) and winter decrease (5%).	Seasonal changes generally lie between –5% and +5%.	
Relative humidity	Overall decreasing, with largest decreases in South Island in spring and summer.	Not available	Up to 5% or more, especially in the South Island.

Note: Where numbers are provided, they are the mean change for the country, averaged over all 41 models for the 20 years, centred on 2040 or 2090. PED is the measure for lack of soil moisture, a major source of plant stress.

² A unit for measuring atmospheric or barometric pressure.

Table 9: RCP scenarios: Projected mean sea-level rise (metres above 1986–2005 baseline) for the wider New Zealand region (Ministry for the Environment, 2017b)

RCP scenario	Mid-century (30 years)	End of century (80 years)
RCP8.5: Higher greenhouse gas emissions		
Sea-level rise projections from the Coastal Hazards and Climate Change guidance: median and (H ⁺) ³	0.28 m (0.37 m) [2050]	0.79 m (1.05 m) [2100]
Updated sea-level rise projections including offsets from IPCC Special Report: median and (H ⁺) ⁴	0.33 m (0.42 m) [2050]	0.89 m (1.15 m) [2100]
RCP4.5: Lower greenhouse gases		
Sea-level rise projections from the Coastal Hazards and Climate Change guidance: median ⁵	0.24 m [2050]	0.55 m [2100]
Updated sea-level rise projections including offsets from IPCC Special Report: median ⁶	0.26 m [2050]	0.58 m [2100]

³ *Coastal Hazards and Climate Change: Guidance for Local Government* (Ministry for the Environment, 2017b).

⁴ *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* (Oppenheimer et al, 2019).

⁵ *Coastal Hazards and Climate Change: Guidance for Local Government* (Ministry for the Environment, 2017b).

⁶ *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* (Oppenheimer et al, 2019).

5 Climate change risks and opportunities

5.1 Risks by urgency

This section outlines the priority risks by their urgency category. As described in [section 2.1](#), in Stages 2 and 3 all risks were considered to have the potential for major or extreme consequence for New Zealand. However, the urgency and the type of adaptation response needed vary.

To support the NAP, the NCCRA developed an urgency profile for each risk. These describe the degree of action required under four different categories of action: more action needed, research priority, sustain current action, and maintain a watching brief. More urgent risks had higher ratings for 'more action needed' or 'research priority'; less urgent risks had higher ratings in 'sustain current action' or 'watching brief'. [Figure 7](#) sets out risks by 'more action needed', and [figure 8](#) by 'research priority'.

The urgent risks below represent a broad range of issues. Some risks, like those to the human, built and natural environment domains, are driven by vulnerabilities. In some cases, particularly in the natural environment, more research is urgently needed to understand the risks better before they can be properly managed. Other risks, for instance in governance and the economy, require urgent action to enable effective adaptation across all domains.

Figure 7: NCCRA risks arranged by the 'more action needed' category

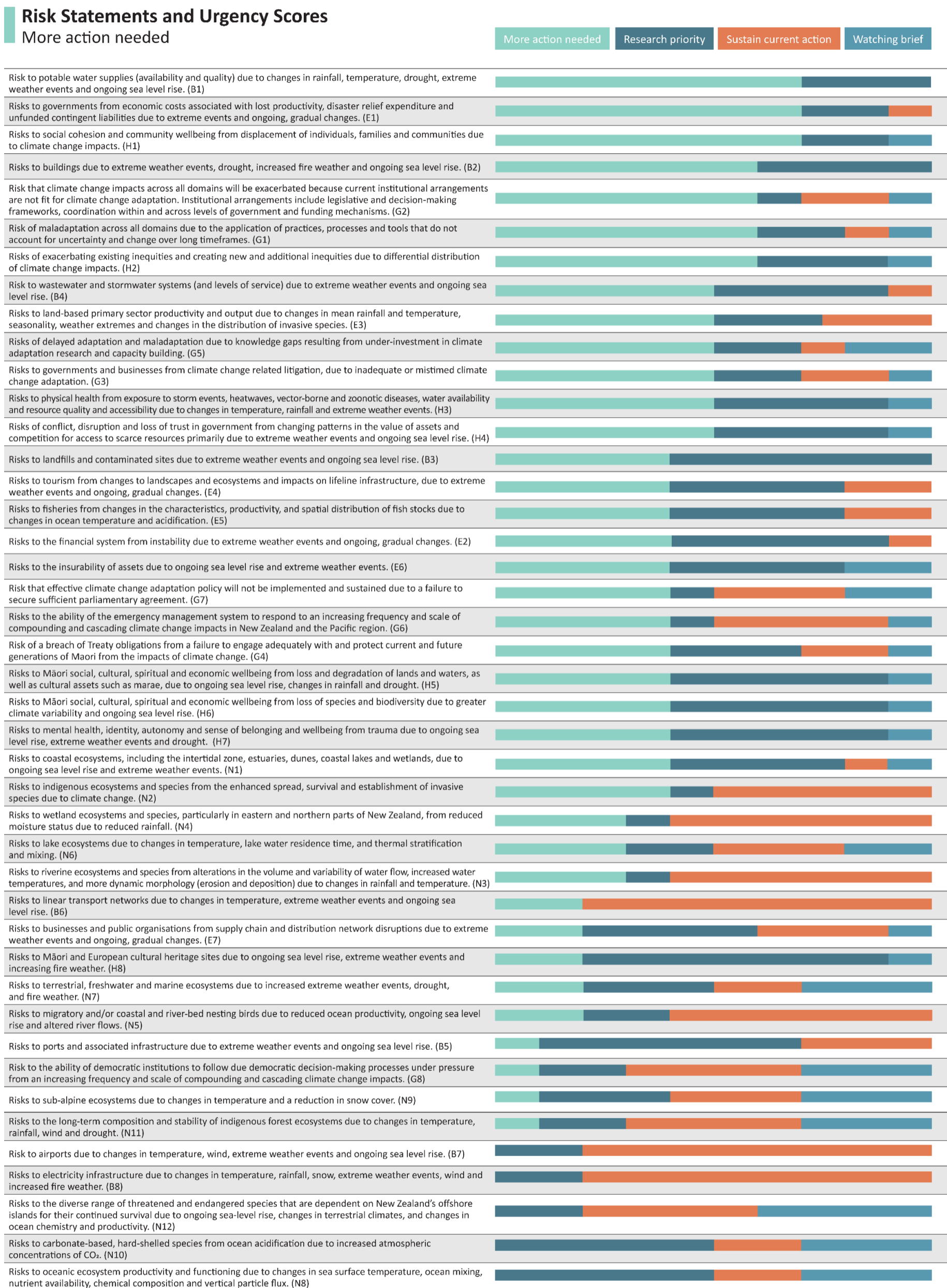
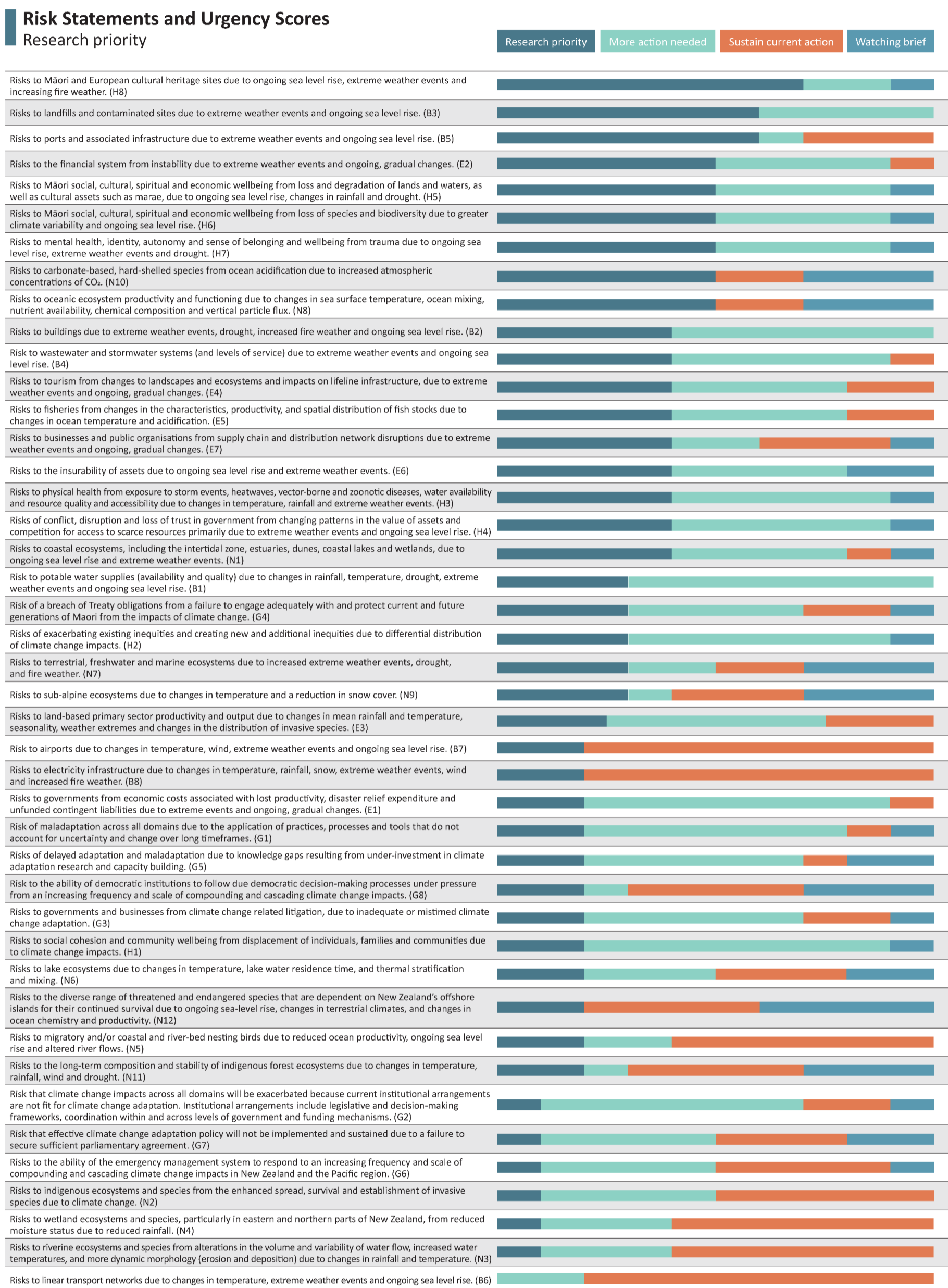


Figure 8: NCCRA risks arranged by the 'research priority' category



5.2 Significant risks by value domain

This section describes the two most significant risks in each domain, with a summary of the other priority risks. For detailed profiles of all the priority risks in Stage 2 and 3, see the [technical report](#).

Table 10 shows the two most urgent, hence most significant, risks in each domain.

Table 11 shows all risks and their urgency ratings. For each risk, an overall urgency rating has been provided which allows the NAP developers to compare the urgency of risks within each domain (see [section 5.1](#)). This comparison should only be made within each domain and not between domains. The domains are fundamentally different and their ratings are not easily comparable. For example, the risks to the natural environment require more research before adaptation actions can be identified. In comparison, the built environment risks are better understood, so it is easier to identify immediate and urgent actions.

The domains and their elements at risk are highly interconnected. Climate hazards affect many elements at risk individually, but these in turn affect one another across domains ([section 2.3.2](#)). This is also the case for adaptation. To be effective, adaptation actions should be coordinated. As much as possible, they should address multiple risks.

Adaptation efforts will need to be spread across all the domains rather than simply focusing on risks with the highest urgency ratings. For this reason, the 10 most significant risks here are taken to be the two most urgent risks in each domain (table 10), rather than the risks with the highest urgency scores overall.

Table 10: Most significant risks in each domain based on urgency ratings

Risk	Ratings	
	Urgency	Consequence
Natural environment (N)		
N1 Risks to coastal ecosystems, including the intertidal zone, estuaries, dunes, coastal lakes and wetlands, due to ongoing sea-level rise and extreme weather events.	78	Major
N2 Risks to indigenous ecosystems and species from the enhanced spread, survival and establishment of invasive species due to climate change.	73	Major
Human (H)		
H1 Risks to social cohesion and community wellbeing from displacement of individuals, families and communities due to climate change impacts.	88	Extreme
H2 Risks of exacerbating existing inequities and creating new and additional inequities due to differential distribution of climate change impacts.	85	Extreme
Economy (E)		
E1 Risks to governments from economic costs associated with lost productivity, disaster relief expenditure and unfunded contingent liabilities due to extreme events and ongoing, gradual changes.	90	Extreme
E2 Risks to the financial system from instability due to extreme weather events and ongoing, gradual changes.	83	Major

Built environment (B)		
B1 Risk to potable water supplies (availability and quality) due to changes in rainfall, temperature, drought, extreme weather events and ongoing sea-level rise.	93	Extreme
B2 Risks to buildings due to extreme weather events, drought, increased fire weather and ongoing sea-level rise.	90	Extreme
Governance (G)		
G1 Risk of maladaptation across all domains due to the application of practices, processes and tools that do not account for uncertainty and change over long timeframes.	83	Extreme
G2 Risk that climate change impacts across all domains will be exacerbated because current institutional arrangements are not fit for climate change adaptation. Institutional arrangements include legislative and decision-making frameworks, coordination within and across levels of government and funding mechanisms.	80	Extreme

* Urgency rating: the adaptation and decision urgency rating for this risk.

**Consequence rating: the highest consequence rating for this risk out of all three periods (now, 2050, 2100). The [technical report](#) provides the consequence rating for each risk and period.

Table 11: Most significant risks and other priority risks in each domain based on urgency ratings

Natural environment				Human			Economy			Built environment			Governance									
10 most significant risks																						
Risk	Ratings			Risk	Ratings			Risk	Ratings			Risk	Ratings									
N1 Risks to coastal ecosystems, including the intertidal zone, estuaries, dunes, coastal lakes and wetlands, due to ongoing sea-level rise and extreme weather events.	Urgency	78		H1 Risks to social cohesion and community wellbeing from displacement of individuals, families and communities due to climate change impacts.	Urgency	88		E1 Risks to governments from economic costs associated with lost productivity, disaster relief expenditure and unfunded contingent liabilities due to extreme events and ongoing, gradual changes.	Urgency	90		B1 Risk to potable water supplies (availability and quality) due to changes in rainfall, temperature, drought, extreme weather events and ongoing sea-level rise.	Urgency	93		G1 Risk of maladaptation across all domains due to the application of practices, processes and tools that do not account for uncertainty and change over long timeframes.	Urgency	83				
	Consequence*	Now	Min		Consequence	Now	Min		Consequence	Now	Min		Consequence	Now	Major		Consequence	Now	Major	Consequence	Now	Major
		2050	Mod			2050	Ext			2050	Major			2050	Major			2050	Ext			
		2100	Major			2100	Ext			2100	Ext			2100	Ext			2100	Ext			
N2 Risks to indigenous ecosystems and species from the enhanced spread, survival and establishment of invasive species due to climate change.	Urgency	73		H2 Risks of exacerbating existing inequities and creating new and additional inequities due to differential distribution of climate change impacts.	Urgency	85		E2 Risks to the financial system from instability due to extreme weather events and ongoing, gradual changes.	Urgency	83		B2 Risks to buildings due to extreme weather events, drought, increased fire weather and ongoing sea-level rise.	Urgency	90		G2 Risk that climate change impacts across all domains will be exacerbated because current institutional arrangements are not fit for climate change adaptation. Institutional arrangements include legislative and decision-making frameworks, coordination within and across levels of government, and funding mechanisms.	Urgency	80				
	Consequence	Now	Mod		Consequence	Now	Major		Consequence	Now	Min		Consequence	Now	Major		Consequence	Now	Major	Consequence	Now	Major
		2050	Mod			2050	Ext			2050	Mod			2050	Ext			2050	Ext			
		2100	Major			2100	Ext			2100	Major			2100	Ext			2100	Ext			
Other priority risks																						
Risk	Ratings			Risk	Ratings			Risk	Ratings			Risk	Ratings									
N3 Risks to riverine ecosystems and species from alterations in the volume and variability of water flow, increased water temperatures, and more dynamic morphology (erosion and deposition), due to changes in rainfall and temperature.	Urgency	68		H3 Risks to physical health from exposure to storm events, heatwaves, vector-borne and zoonotic diseases, water availability and resource quality and accessibility, due to changes in temperature, rainfall and extreme weather events.	Urgency	83		E3 Risks to land-based primary sector productivity and output due to changes in mean rainfall and temperature, seasonality, weather extremes and changes in the distribution of invasive species.	Urgency	81		B3 Risks to landfills and contaminated sites due to extreme weather events and ongoing sea-level rise.	Urgency	85		G3 Risks to governments and businesses from climate change-related litigation, due to inadequate or mistimed climate change adaptation.	Urgency	78				
	Consequence	Now	Mod		Consequence	Now	Min		Consequence	Now	Min		Consequence	Now	Mod		Consequence	Now	Mod	Consequence	Now	Mod
		2050	Mod			2050	Mod			2050	Major			2050	Major			2050	Major			
		2100	Major			2100	Major			2100	Major			2100	Major			2100	Major			
N4 Risks to wetland ecosystems and species, particularly in eastern and northern parts of New Zealand, from reduced moisture status due to reduced rainfall.	Urgency	68		H4 Risks of conflict, disruption and loss of trust in government, from changing patterns in the value of assets and competition for access to scarce resources, primarily due to extreme weather events and ongoing sea-level rise.	Urgency	83		E4 Risks to tourism from changes to landscapes and ecosystems and impacts on lifeline infrastructure, due to extreme weather events and ongoing, gradual changes.	Urgency	80		B4 Risk to wastewater and stormwater systems (and levels of service) due to extreme weather events and ongoing sea-level rise.	Urgency	85		G4 Risk of a breach of Treaty obligations from a failure to engage adequately with and protect current and future generations of Māori from the impacts of climate change.	Urgency	75				
	Consequence	Now	Min		Consequence	Now	Mod		Consequence	Now	Min		Consequence	Now	Major		Consequence	Now	Major	Consequence	Now	Mod
		2050	Mod			2050	Major			2050	Mod			2050	Ext			2050	Major			
		2100	Major			2100	Major			2100	Major			2100	Ext			2100	Major			

Natural environment			Human			Economy			Built environment			Governance							
N5 Risks to migratory and/or coastal and river-bed nesting birds due to reduced ocean productivity, ongoing sea-level rise and altered river flows.	Urgency		65	H5 Risks to Māori social, cultural, spiritual and economic wellbeing from loss and degradation of lands and waters, as well as cultural assets such as marae, due to ongoing sea-level rise, changes in rainfall and drought.	Urgency		80	E5 Risks to fisheries from changes in the characteristics, productivity, and spatial distribution of fish stocks, due to changes in ocean temperature and acidification.	Urgency		80	B5 Risks to ports and associated infrastructure, due to extreme weather events and ongoing sea-level rise.	Urgency		70	G5 Risks of delayed adaptation and maladaptation, due to knowledge gaps resulting from under-investment in climate adaptation research and capacity building.	Urgency		75
	Consequence	Now	Min		Consequence	Now	Major		Consequence	Now	Min		Consequence	Now	Min		Consequence	Now	Major
		2050	Mod			2050	Ext			2050	Mod			2050	Major				
2100	Major	2100	Ext	2100	Major	2100	Major	2100	Major	2100	Major	2100	Major						
N6 Risks to lake ecosystems due to changes in temperature, lake-water residence time, and thermal stratification and mixing.	Urgency		65	H6 Risks to Māori social, cultural, spiritual and economic wellbeing from loss of species and biodiversity, due to greater climate variability and ongoing sea-level rise.	Urgency		80	E6 Risks to the insurability of assets, due to ongoing sea-level rise and extreme weather events.	Urgency		75	B6 Risks to linear transport networks, due to changes in temperature, extreme weather events and ongoing sea-level rise.	Urgency		60	G6 Risks to the ability of the emergency management system to respond to an increasing frequency and scale of compounding and cascading climate change impacts in New Zealand and the Pacific region.	Urgency		70
	Consequence	Now	Min		Consequence	Now	Major		Consequence	Now	Insig		Consequence	Now	Major		Consequence	Now	Major
		2050	Mod			2050	Ext			2050	Mod			2050	Major				
2100	Major	2100	Ext	2100	Ext	2100	Major	2100	Major	2100	Ext	2100	Major						
N7 Risks to terrestrial, freshwater and marine ecosystems, due to increased extreme weather events, drought, and fire weather.	Urgency		60	H7 Risks to mental health, identity, autonomy and sense of belonging and wellbeing from trauma, due to ongoing sea-level rise, extreme weather events and drought.	Urgency		80	E7 Risks to businesses and public organisations from supply chain and distribution network disruptions, due to extreme weather events and ongoing, gradual changes.	Urgency		68	B7 Risk to airports, due to changes in temperature, wind, extreme weather events and ongoing sea-level rise.	Urgency		55	G7 Risk that effective climate change adaptation policy will not be implemented and sustained, due to a failure to secure sufficient parliamentary agreement.	Urgency		68
	Consequence	Now	Min		Consequence	Now	Ma		Consequence	Now	Insig		Consequence	Now	Major		Consequence	Now	Major
		2050	Mod			2050	Major			2050	Mod			2050	Major				
2100	Major	2100	Major	2100	Major	2100	Major	2100	Major	2100	Ext	2100	Ext						
N8 Risks to oceanic ecosystem productivity and functioning, due to changes in sea-surface temperature, ocean mixing, nutrient availability, chemical composition and vertical particle flux.	Urgency		55	H8 Risks to Māori and European cultural heritage sites, due to ongoing sea-level rise, extreme weather events and increasing fire weather.	Urgency		75		Urgency			B8 Risks to electricity infrastructure, due to changes in temperature, rainfall, snow, extreme weather events, wind and increased fire weather.	Urgency		55	G8 Risk to the ability of democratic institutions to follow due democratic processes under pressure from an increasing frequency and scale of compounding and cascading climate change impacts.	Urgency		53
	Consequence	Now	Min		Consequence	Now	Ma		Consequence	Now	Mod		Consequence	Now	Mod		Consequence	Now	Mod
		2050	Mod			2050	Major			2050	Mod			2050	Major				
2100	Major	2100	Major	2100	Major	2100	Major	2100	Major	2100	Major	2100	Major						
N9 Risks to sub-alpine ecosystems, due to changes in temperature and a reduction in snow cover.	Urgency		55		Urgency				Urgency				Urgency				Urgency		
	Consequence	Now	Min		Consequence	Now			Consequence	Now			Consequence	Now			Consequence	Now	
		2050	Mod			2050				2050				2050					
2100	Major	2100	Major	2100		2100		2100		2100		2100							
N10 Risks to carbonate-based, hard-shelled species from ocean acidification, due to increased atmospheric concentrations of CO ₂ .	Urgency		55		Urgency				Urgency				Urgency				Urgency		
	Consequence	Now	Min		Consequence	Now			Consequence	Now			Consequence	Now			Consequence	Now	
		2050	Mod			2050				2050				2050					
2100	Major	2100	Major	2100		2100		2100		2100		2100							

Natural environment			Human	Economy	Built environment	Governance
N11 Risks to the long-term composition and stability of indigenous forest ecosystems due to changes in temperature, rainfall, wind and drought.	Urgency	53				
	Consequence	Now	Insig			
		2050	Min			
		2100	Major			
N12 Risks to the diverse range of threatened and endangered species that are dependent on New Zealand's offshore islands for their continued survival due to ongoing sea-level rise, changes in terrestrial climates, and changes in ocean chemistry and productivity.	Urgency	45				
	Consequence	Now	Min			
		2050	Mod			
		2100	Major			

Consequence rating key:

Insig Insignificant
 Min Minor
 Mod Moderate
 Major Major
 Ext Extreme

5.3 Natural environment domain | Rohe taiao

Table 12: Natural environment domain

Natural environment		
Most significant risks	Ratings	
	Urgency	Consequence
N1 Risks to coastal ecosystems, including the intertidal zone, estuaries, dunes, coastal lakes and wetlands, due to ongoing sea-level rise and extreme weather events.	78*	Major**
N2 Risks to indigenous ecosystems and species from the enhanced spread, survival and establishment of invasive species, due to climate change.	73	Major
Other priority risks (Stage 2)		
N3 Risks to riverine ecosystems and species from alterations in the volume and variability of water flow, increased water temperatures, and more dynamic morphology (erosion and deposition), due to changes in rainfall and temperature.	68	Major
N4 Risks to wetland ecosystems and species, particularly in eastern and northern parts of New Zealand, from reduced moisture status, due to reduced rainfall.	68	Major
N5 Risks to migratory and/or coastal and river-bed nesting birds, due to reduced ocean productivity, ongoing sea-level rise and altered river flows.	65	Major
N6 Risks to lake ecosystems, due to changes in temperature, lake-water residence time, and thermal stratification and mixing.	65	Major
N7 Risks to terrestrial, freshwater and marine ecosystems, due to increased extreme weather events, drought, and fire weather.	60	Major
N8 Risks to oceanic ecosystem productivity and functioning, due to changes in sea surface temperature, ocean mixing, nutrient availability, chemical composition and vertical particle flux.	55	Major
N9 Risks to sub-alpine ecosystems, due to changes in temperature and a reduction in snow cover.	55	Major
N10 Risks to carbonate-based, hard-shelled species from ocean acidification, due to increased atmospheric concentrations of CO ₂ .	55	Major
N11 Risks to the long-term composition and stability of indigenous forest ecosystems, due to changes in temperature, rainfall, wind and drought.	53	Major
N12 Risks to the diverse range of threatened and endangered species that are dependent on New Zealand's offshore islands for their continued survival, due to ongoing sea-level rise, changes in terrestrial climates, and changes in ocean chemistry and productivity.	45	Major

* Urgency rating: the adaptation and decision urgency rating for this risk.

**Consequence rating: the highest consequence rating for this risk out of all three periods (now, 2050, 2100). The [technical report](#) provides the consequence rating for each risk and period.

5.3.1 Most significant risks

N1 Risks to coastal ecosystems, including the intertidal zone, estuaries, dunes, coastal lakes and wetlands, due to ongoing sea-level rise and extreme weather events

Risk summary

Climate change will affect coastal ecosystems in various ways, with a strong potential for wider effects on the more inland ecosystems to which they are connected (O'Meara, Hillman, and Thrush, 2017). Sea-level rise, mainly expressed as ongoing gradual change, can be expected to affect coastal ecosystems in various ways and is likely to be exacerbated by discrete but sporadic extreme storm events. Moderate storm and flooding events are also likely to increase in frequency and sequencing, causing recurring stress on coastal ecosystems.

This combination of gradual change and episodic extreme events can be expected to become more severe over time and profoundly affect indigenous ecosystems of the intertidal zone, estuaries, dune systems, coastal wetlands, and coastal rivers, streams and lakes, along with the species they support. Existing human-induced pressures will intensify these effects. This includes direct effects such as coastal development and other land-use changes that result in sediment runoff and lower water quality, and the more indirect effect of physical occupation of coastal sites. The latter reduces the availability of sites for landward migration by ecosystems and species as sea levels rise. This phenomenon is known as coastal squeeze (Rouse et al, 2017).

Exposure

Extreme storm events and the ongoing gradual threat of sea-level rise are projected to become more frequent and severe towards the end of the century. Rising sea levels will affect coastal areas throughout New Zealand, adding to the increase of 20 cm that has already occurred since 1900 (Ministry for the Environment, 2017b). See [section 4](#) for more detail. More frequent storm events will pose a significant risk to ecosystems and species through direct physical damage (eg, wave surge), and increased sediment deposition.

Sea-level rise, coupled with more frequent, extreme storm events, will pose direct and major risks to the integrity of a diverse range of coastal ecosystems, including mangroves, dunes, estuaries, salt marsh, coastal turfs, boulder beaches and coastal cliffs. This will threaten the survival of many species that are restricted to the coastal zone, for example, the many threatened plant species in coastal turfs (Johnson and Rogers, 2003).

As sea levels rise, the zone of influence of tides will extend further inland, affecting lowland rivers, coastal lakes and wetlands. Inundation of low-lying areas from tides, storm surges and waves surpassing natural or human barriers, will become more frequent and widespread (Rouse et al, 2017). For example, a 1 m sea-level rise will result in salinity intrusion extending up to 5 km further inland up the Waihou River on the Hauraki Plains (McBride et al, 2016).

Sensitivity

A recent national analysis of the susceptibility of New Zealand's shoreline (Rouse et al, 2017) concluded the east coasts of the North and South Islands are likely to be more sensitive to climate change-induced coastal inundation and erosion, reflecting their currently low-wave exposure, low-tidal range, and deficits in sediments near tidal inlets. By contrast, the west coasts of both islands have a lower sensitivity due to their exposure to high-wave energy (Rouse et al, 2017).

Natural responses to these risks will be impeded in many locations by existing high-intensity human use and development in the coastal zone, particularly where there is coastal squeeze (Rouse et al, 2017).

Adaptive capacity

In the absence of human-induced pressures, many coastal ecosystems and species would be able to adapt in some way. However, most are exposed to the effects of introduced species, inputs of nutrients and sediments (eg, from agricultural practices, see Wilcock et al, 2011), and direct disturbance from activities such as subdivisions and the construction of buildings, roads, marinas and other structures. This is likely to reduce their adaptive capacity substantially, particularly where there is intensive human activity such as around towns and cities. Ecosystems and species that are more tolerant of periodic exposure to saline waters are likely to have a greater adaptive capacity, as well as those having some degree of dispersal ability.

The adaptive capacity of coastal ecosystems will rely somewhat on effective management, rather than on their own characteristics.

Consequence

Sea-level rise, coupled with more frequent, extreme storms, will pose risks to a broad range of coastal ecosystems and threaten many species, including many found only in coastal environments. This includes highly productive coastal ecosystems with important breeding, roosting and foraging habitat for indigenous bird species. Some, including Kaipara Harbour, the Firth of Thames and Farewell Spit, provide crucial habitat for internationally significant migratory bird species (McGlone and Walker, 2011). Others provide important nursery habitat for juvenile fish (Francis et al, 2011).

Salinity intrusions into currently freshwater ecosystems will lead to changes in the distribution of species. For example, Lake Waiholo is predicted to shift progressively to a greater dominance by estuarine and marine species. Although this will increase the richness of salt-tolerant species, it is likely to be offset by losses of indigenous freshwater species (Schallenberg, Hall, and Burns, 2003). Risks of invasion by more salt-tolerant, introduced species will increase where these changes trigger mortality events among indigenous species.

More frequent storm events pose a risk to ecosystems and species through direct physical damage (eg, wave surge), and increased sedimentation. The latter is likely to have negative impacts on inshore and estuarine marine ecosystems by reducing light, increasing turbidity and reducing primary productivity (Thrush et al, 2004). Changes in sediment size can also reduce habitat suitability for current species, in some cases directly causing mortality – for example, when fine silt covers coarser sandy sediments (Rouse et al, 2017).

High human use and development in the coastal zone will hamper responses to these risks.

Interacting risks

Impacts on coastal ecosystems will interact with oceanic productivity and functioning (N8) and will have cascading impacts on reliant bird species (N5). Freshwater ecosystems (N3, N4 and N6) may be affected through saline intrusion due to coastal inundation.

Coastal environments are innately connected with social and economic systems. Disruption of coastal ecosystems will have cascading impacts on these systems as well. Impacts on coastal ecosystems will affect the tourism sector (E4) as well as fisheries and aquaculture (E5).

Ongoing sea-level rise and extreme storm events will also pose a threat to New Zealand’s coastal development (B2), which is likely to displace coastal communities (H1), and to Māori social, economic, cultural capital, cultural heritage values, and spiritual wellbeing where this is strongly connected to coastal ecosystems (H5, H6 and H8).

There is a risk that uncoordinated governance will result in inadequate or maladaptive actions to protect coastal ecosystems and manage retreat. This will have significant consequences for coastal ecosystems, as well as social and economic systems (G1). Effective governance will be key in building adaptive capacity for coastal environments. However, there is a risk in our ability to understand, predict and respond to climate change impacts on biodiversity, due to under-investment in biodiversity science (G5). There is also a risk of failing to allocate timely and effective funding for conservation management (G2).

Confidence: High agreement, medium evidence

There is a high level of agreement that ongoing sea-level rise and extreme storm events will result in coastal inundation and salinity intrusion. This, in turn, will degrade a wide range of coastal ecosystems and species. Although there is very strong agreement on the mechanisms driving this risk, and reasonable knowledge about impact pathways, there are still extensive knowledge gaps in how these effects will manifest for particular ecosystems and species, and in different locations.

Adaptation

Current action to manage the risk to coastal ecosystems due to sea-level rise is being driven by regional councils and local community groups. However, this is mostly focused on protecting human infrastructure rather than biodiversity. Actions include the development of frameworks, implementation plans and community engagement.

Regions that are highly exposed, such as Hawke’s Bay, have coastal hazard strategies that define the problem, and a framework for decision-making. They apply this to hazard risk response, and outline actions (Hawke’s Bay Regional Council, 2016; Bendall, 2018). The Takutai Kapiti Project and Makara Beach Project are examples of community-led, collaborative projects that are developing action plans. The Makara Beach Project has put forward a series of community-endorsed recommendations to the Wellington City Council for how the wider community should prepare for and adapt to sea-level rise and extreme weather events (The Makara Beach Project, nd).

Table 13: N1 Risks to coastal ecosystems: Urgency profile

N1 Risks to coastal ecosystems: Urgency profile		
Urgency category	Proportion of urgency out of 100	Description of actions
More action needed	40	Active adaptive management to avoid and reduce coastal squeeze, particularly by regional/unitary authorities. These should focus on management of the impacts of human development and maladaptations on environments of high biodiversity value, while taking account of likely changes in sea level.
Research priority	40	Research required to identify most vulnerable types of hydro-systems, how they will respond and change their bio-physical functioning, eg, supporting significant biodiversity values, on exposed coasts, coastal lakes, lowland rivers, or with current or projected high levels

N1 Risks to coastal ecosystems: Urgency profile

Urgency category	Proportion of urgency out of 100		Description of actions			
			of human development and land use, and how to manage adaptation.			
Sustain current action	10		Continue current management of coastal ecosystems and species to maintain their resilience and maximise their ability to adjust naturally to sea-level changes.			
Watching brief	10		Monitor representative high-value coastal ecosystems for evidence of change.			
Adaptation urgency	78		Confidence	High agreement, medium evidence		
Consequence	Now	Minor	2050	Moderate	2100	Major

N2 Risks to indigenous ecosystems and species from the enhanced spread, survival and establishment of invasive species due to climate change

Risk summary

New Zealand is recognised as a globally significant biodiversity hotspot. It has very high levels of endemism, including more than 80 per cent of all vascular plants, 90 per cent of insects, all reptiles, a quarter of birds, and all terrestrial mammals, namely several species of bats/pekapeka (Department of Conservation, 2020). A significant number of endemic species are vulnerable to extinction (Macinnis-Ng et al, nd).

New Zealand's indigenous ecosystems and taonga species are already under considerable pressure from introduced pests. The country is described as one of the most invaded places on earth (Mooney and Hobbs, 2000). As temperatures warm, climatic conditions are likely to:

- favour existing introduced species that are more adapted to, or have a higher tolerance of, warmer conditions (Thuiller, Richardson, and Midgley, 2007)
- facilitate expansion of the problematic, introduced species and the establishment of new ones.

These factors combine to increase pressures on indigenous ecosystems and species. The impacts are often challenging to predict, with complex effects across different trophic levels (Tompkins, Byrom, and Pech, 2013; Macinnis-Ng et al, nd). Further complications arise from interactions with other human-induced pressures such as habitat fragmentation and harvesting.

Exposure

Ongoing gradual changes in climate and extreme weather events will exacerbate the threat of invasive or exotic species. Projections show an increase in severity and frequency towards the end of the century, with the greatest increases under RCP8.5. Key hazards include warming temperatures, changes in rainfall, drought and heatwaves, and floods. [Section 4](#) details these hazards.

Most sub-national climate zones will experience some degree of climatic change. Predictions include:

- generally uniform increases in average temperatures, with slightly higher increases in the northeast than in the southwest
- slightly greater warming in the North Island than the South Island

- less frequent frosts, with much of the northern North Island expected to become largely frost-free by 2100.

The predicted changes are expected to foster expansion of many invasive species, likely southwards and to higher elevations (McGlone and Walker, 2011). Many have traits that help them invade new habitats, including wide dispersal of propagules, fast reproductive or growth rates, and the ability to establish or persist in harsh environments.

Additions to the pool of invasive species are also likely to arise from species that are already established in New Zealand, but not currently considered problematic. This is likely as changing climates enable them to reproduce or alter their competitive advantage over indigenous species facing increasing stress (Thuiller, Richardson and Midgley, 2007).

Higher temperatures will also favour new, warm-climate invasive species. Human transport will bring some (eg, plant or insect species accidentally carried with imported goods or products, marine invertebrates in ship ballast water). Others are likely to establish through natural dispersal (eg, wind-borne plant pathogens, or marine species moving south in response to warmer ocean temperatures).

Sensitivity

Many of New Zealand's indigenous ecosystems and taonga species already face high pressure from introduced species, including plants, vertebrates, invertebrates and pathogens. Impacts include predation, competition and, in some cases, mortality. These combine to reduce both native dominance in ecosystems, and the abundance of vulnerable species, in some cases leading to endangerment or even extinction.

Climate change will exacerbate these pressures by enabling invasive species to expand. For example, rodents may extend their altitudinal ranges, and freshwater pest fish in warmer northern lakes and rivers are more likely to spread southwards and to higher elevations. Some non-problematic species could become invasive, and novel species from warm locations outside New Zealand are more likely to become established and invade indigenous ecosystems. By contrast, higher temperatures in some waters may reduce the abundance of introduced salmonids, increasing the survival of indigenous fish (Robertson et al, 2016).

Humans will facilitate the invasion of introduced species. The greatest numbers of weeds are near population centres, which are reservoirs for spread into surrounding landscapes (Timmins and Williams 1991). Humans have also introduced freshwater pest fish, particularly in northern waters, through accidental and deliberate release (Hamilton et al, 2013).

Fragmentation increases the vulnerability of many lowland, terrestrial indigenous ecosystems. It increases the ratio of edge-to-core habitats (edge effects are changes in population or community structures that occur at the boundary of two or more habitats), providing more opportunities for invasion from surrounding exotic-dominated landscapes (McGlone and Walker, 2011). Indigenous landscapes in drier environments, where human firing has replaced woody cover with tussock grasslands, are particularly vulnerable to invasion by wilding conifers. Some of these can survive at higher elevations than indigenous species that normally occur at treeline, allowing them to invade subalpine ecosystems.

Predicting the overall impacts of invasive species is difficult, given the complex relationships between invasive and indigenous species, and between invasive species (Tompkins, Byrom, and Pech, 2013). More frequent events, such as droughts or heatwaves, may enable invasive species to expand their range, eg, when formerly dominant indigenous species are lost through stress-induced mortality (Thomsen et al, 2019).

Adaptive capacity

Many indigenous ecosystems and taonga species (indigenous) exhibit a low adaptive capacity in the face of human-induced pressures such as introducing alien species, clearing and fragmentation of habitat, discharging nutrients and sediments into waterbodies, and harvesting marine fish. This is a common feature of island biotas, and particularly those with long genetic isolation (Frankham, 1997; Williams, Shoo, Isaac, Hoffmann and Langham, 2008). Most indigenous bird species have declined in the face of predation by introduced mammals (Innes et al, 2010), many of our forests have been changed significantly by introduced mammalian browsers (eg, Wardle et al, 2001), and the numbers of distinctive freshwater galaxiids have declined because of predatory salmon (McDowall, 2003; McIntosh et al, 2010).

Site-specific studies are generally lacking, but it is crucial to continue managing introduced species with the aim of keeping diverse ecosystems as healthy as possible, and maintaining populations of species at particular risk of decline.

Adaptive capacity of species and natural ecosystems is somewhat limited without effective governance. Interventions to reduce the impact of invasive species may help, at least in the short-to medium-term. Conservation management to eradicate invasive species and protect taonga and indigenous species has had some success in New Zealand. However, there are major knowledge gaps and challenges in eradicating invasive predators in the long term (Macinnis-Ng et al, nd).

Consequence

Expanding and new pest species are likely to compromise our ability to maintain the integrity and functioning of our indigenous ecosystems, and to increase the challenge of protecting our at-risk and threatened species. These risks are also likely to interact with, and be compounded by, all the other natural environment risks identified by this assessment.

A number of taonga species are already under threat, including the brown kiwi, kākā, mohua, whio, *Powelliphanta* snails, and the North Island kokako (Department of Conservation, 2019). Without continued effective conservation management, higher temperatures may add pressure, as invasive species spread.

Interacting risks

The disruption of natural ecosystems by invasive species would affect sectors that rely on indigenous species and natural landscapes, particularly tourism (E4), the land-based primary sector (E3), fisheries and aquaculture (E5). Conversely, changes in land use could render existing uses unsustainable, creating cascading impacts on the natural environment.

Invasive species pose a threat to indigenous species and ecosystems that are fundamental to Māori social, economic, cultural capital, cultural heritage values, and spiritual wellbeing (H6 and H8). With the invasion of exotic species comes the threat of vector-borne diseases and associated health implications (H3).

Confidence: High agreement, medium evidence

There is a high level of agreement that changing climatic conditions will likely enable the spread of existing and novel introduced species, with a likely change in ecosystem composition and loss of taonga and indigenous species. However, evidence of the impacts is limited largely to a few well-studied systems. Further research is needed to identify the specific vulnerabilities of a wider range of indigenous ecosystems and species.

Adaptation

Adaptation action to reduce establishment, spread and survival of exotic or invasive species is largely driven by the Department of Conservation (DOC), the Ministry for Primary Industries (MPI) and regional councils. Non-government organisations (NGOs) and community groups also contribute. For example, Predator Free 2050 is supported by NGOs such as WWF, Kiwis for Kiwi, Forest and Bird, and Sanctuaries of New Zealand (Predator Free NZ, nd).

Adaptive management includes risk assessments (including anticipation of emerging risks), early detection/rapid response (EDRR), border management, marine biosecurity, pest management, eradication of predators and assisted migration (translocation) (Champion, 2018; Department of Conservation, nd).

MPI is accountable for the end-to-end management of the biosecurity system under the Biosecurity Act (1993). Under this, regional councils for example, are driving action by updating and implementing regional pest management plans, providing a framework for the efficient and effective management or eradication of specific species (Auckland Council, 2019).

Other examples include Predator Free 2050, War on Weeds, The Kauri Dieback Program, Myrtle Rust Strategy, and Land Information New Zealand control programmes.

Table 14: N2 Risks to indigenous ecosystems and species: urgency profile

N2 Risks to indigenous ecosystems and species: urgency profile						
Urgency category	Proportion of urgency out of 100		Description of actions			
More action needed	40		Proactively detect and manage existing and new pests as they become established. Reduce the impacts of species that induce major changes in ecosystem structure, including those that become invasive after disturbance events such as fire or marine heatwaves.			
Research priority	10		Research required to: <ul style="list-style-type: none"> identify new and emerging risks from invasive species across terrestrial, freshwater and marine domains develop effective ways to manage these risks. 			
Sustain current action	50		Aggressively continue pre-border, border and post-border biosecurity and control of problematic species.			
Watching brief	0		Proactively detect and manage existing and new pest species as they become established. Reduce the impacts of species that induce major changes in ecosystem structure, including those that become invasive after disturbance events such as fire or marine heatwaves.			
Adaptation urgency	73		Confidence	High agreement, medium evidence		
Consequence	Now	Minor	2050	Moderate	2100	Major

5.3.2 Other priority risks for the natural environment

The remaining 10 priority risks in the natural environment domain are listed in order of urgency. For more information, see the [technical report](#) (table 1, section 3.4).

N3 Risks to riverine ecosystems and species from alterations in the volume and variability of water flow, increased water temperatures, and more dynamic morphology (erosion and deposition), due to changes in rainfall and temperature

New Zealand's freshwater riverine ecosystems support a diverse array of animal and plant life, including fish, invertebrates, plants, birds and microorganisms, many of which are endemic (Weeks et al, 2016; Robertson, Bowie, Death and Collins, 2013).

Up to 74 per cent of indigenous freshwater fish species are listed as endangered or at risk, making these among the most threatened in the world (Weeks et al, 2016). In riverine ecosystems, disturbance by high river and stream flows plays an important role in structuring invertebrate communities and broader ecosystem function (Townsend et al, 1997; Death et al, 2015).

However, there is already significant pressure from human activities such as hydro-power generation, agricultural intensification and urbanisation. These impede the movement of migratory species, reduce river flows and their variability, and increase inputs of sediments, nutrients and other contaminants (Weeks et al, 2016). There are also 21 introduced freshwater fish species and over 70 introduced aquatic plant species in our rivers and streams, reducing the abundance of indigenous fish by competition, predation, and alteration of biodiversity and habitat (Weeks et al, 2016).

N4 Risks to wetland ecosystems and species, particularly in eastern and northern parts of New Zealand from reduced moisture status, due to reduced rainfall

New Zealand's wetland ecosystems and species are already vulnerable because of widespread changes in land use. About 90 per cent of their former cover has been lost since European settlement in the 1840s, most notably in lowland environments (Robertson, Ausseil, Rance, Betts, and Pomeroy, 2019). Despite this, wetlands still support a high proportion of the country's threatened plant species, many surviving in ephemeral wetlands (Holdaway, Wiser, and Williams, 2012).

Climate change is predicted to alter the distribution of annual and seasonal rainfall. This, combined with higher temperatures and more wind, will inevitably affect the moisture status of many freshwater wetland ecosystems and species. The greatest impact will likely be in drier (mainly eastern) environments, where wetland loss has generally been greater than in high rainfall (mainly western) environments.

Many wetlands surviving in drier environments have high conservation values because they are irreplaceable; they are likely to continue to decline, given the expected deterioration in their moisture status. More indigenous species will likely be lost, and invasion by introduced species will increase.

N5 Risks to migratory and/or coastal and river-bed nesting birds, due to reduced ocean productivity, ongoing sea-level rise and altered river flows

New Zealand supports an abundance of marine and coastal bird species, making it one of the world's most significant regions for seabird diversity. About 80 seabird species breed here (McGlone and Walker, 2011). A number of other riverine and coastal bird species that

are endemic, permanently reside in New Zealand, but undertake annual migrations from summer breeding grounds on braided rivers to coastal sites for overwintering.

Changing climatic conditions, such as altered river flows and flood frequencies, extreme weather events, sea-level rise, warming ocean temperatures and drought, will likely affect migratory, coastal and river-bed nesting birds in many ways. The impacts are likely to include availability of food and coastal habitats, and breeding success (Robertson, Bowie, Death and Collins, 2013; Law et al, 2018).

N6 Risks to lake ecosystems, due to changes in temperature, lake-water residence time, and thermal stratification and mixing

New Zealand's 3820 lakes with a surface area of more than 1 hectare account for 1.3 per cent of the country's land area (Hamilton et al, 2013). These lakes are already degrading significantly due to altered inflows and outflows, invasive species (algae, fish and macrophytes) and increased nutrient inputs from land-use changes, including agricultural intensification.

Climate change poses diverse risks, several interacting with existing pressures (Hamilton et al, 2013). Periodic or permanent increases in salinity are likely in coastal lakes because of sea-level rise, changing ecosystem composition and structure.

Rising temperatures, coupled with more frequent strong winds, will likely alter mixing and thermal regimes in many deeper lakes, extending the period over which stratification is maintained. Warmer temperatures are also predicted to raise the risk of:

- deoxygenation of bottom waters and altered nutrient status through the release of phosphorus and ammonium
- shifts from macrophyte to algal dominance in shallow lowland lakes
- the spread of problematic, introduced plant and fish species that are presently most widespread in warmer northern lakes
- the loss of New Zealand's highly distinctive, but little studied sub-alpine lake ecosystems.

N7 Risks to terrestrial, freshwater and marine ecosystems, due to increased extreme weather events, drought and fire weather

Natural disturbance has long been recognised as important in many of New Zealand's terrestrial indigenous ecosystems. These are adapted to, and in many cases structured by, disturbances such as earthquakes and extreme weather events that cause mortality through wind, drought, heatwaves, hail and frost (eg, Ogden, Stewart, and Allen, 1996).

Projections are for more frequent extreme and moderate climatic events, as well as changes in their sequence and seasonal timing. This is likely to affect our indigenous ecosystems and species.

Although specific evidence from New Zealand studies is largely lacking, it has been argued that extreme climate events are likely to affect ecosystems and species more than the more gradual shifts in mean temperature and rainfall expected under climate change (Jentsch and Beierkuhnlein, 2008). In particular, species that can persist under stable conditions may not be able to reproduce in a more disturbance-prone environment. Disruptions to ecosystem structure and composition are likely to provide greater opportunities for the establishment of competing introduced species (Thuiller, Richardson and Midgley, 2007). Compounding these pressures are existing habitat loss and fragmentation, and competition with or predation by established introduced species (Macinnis-Ng et al, nd).

N8 Risks to oceanic ecosystem productivity and functioning, due to changes in sea-surface temperature, ocean mixing, nutrient availability, chemical composition and vertical particle flux

New Zealand lies across a zone of enhanced ocean productivity along the subtropical front. This is an important boundary between warmer northern (subtropical) waters with low nutrients and productivity, and colder southern (subantarctic) waters with higher nutrient levels and generally greater phytoplankton productivity (Bradford-Grieve et al, 2006).

Projected increases in ocean temperatures and windiness will alter physical and biogeochemical processes, particularly at the ocean surface (Law et al, 2018). Ocean productivity and function will be altered mostly through changes in the depth of the surface mixed layer, affecting light penetration and the exchange of nutrients across the mixed layer boundary. This is expected to reduce primary productivity. Effects will likely flow on to the functioning of broader marine food webs and ecosystems through reductions in the vertical flux of organic particles to the sea floor (Law et al, 2018). This, in turn, may see regional shifts in ecosystem composition, and in the distribution and abundance of marine species.

These changes will most likely occur via a process of ongoing, gradual change. Changes in ocean temperature and chemistry are expected to increase gradually towards the end of the century. Human activities have already extensively affected our marine environment, including from bottom trawling, land-based discharge of sediments, nutrients and pollutants, and the introduction of invasive species. These impacts are likely to interact with the effects of climate change by reducing the resilience of ecosystems and species.

N9 Risks to sub-alpine ecosystems, due to changes in temperature and a reduction in snow cover

New Zealand's sub-alpine ecosystems support a diverse array of indigenous species. About 93 per cent of vascular, alpine plant species are endemic (Halloy and Mark, 2003). Many are relatively isolated populations in habitat 'islands' on range crests that are often separated from similar habitats. This isolation is often compounded by clearance and fragmentation of surrounding lower-elevation habitats. With limited potential to migrate southwards or up-slope in the face of rising temperatures, these ecosystems and their distinctive species could become significantly vulnerable (Macinnis-Ng et al, nd).

One study identified around 40–70 alpine species at risk of extinction from higher temperatures (Halloy and Mark, 2003).

Temperatures predicted under RCP8.5 (about 2.8–3.1°C by 2100 (Ministry for the Environment, 2018, Pearce et al, 2018) will likely:

- cause the loss of 200–300 indigenous, vascular plant species, equating to about half our total alpine flora (Halloy and Mark, 2003)
- increase risks of invasion by introduced species such as *Pinus contorta* and *Calluna vulgaris* L. (Tomiolo, Harsch, Duncan and Hulme, 2016; Giejsztowt, Classen and Deslippe, 2019)
- increase the suitability of sub-alpine environments for introduced vertebrate predators such as ship rats, and predation on subalpine birds, lizards and invertebrates by stoats, mice and hedgehogs.

N10 Risks to carbonate-based, hard-shelled species from ocean acidification, due to increased atmospheric concentrations of CO₂

Increasing atmospheric CO₂ (carbon dioxide) concentrations are acidifying the oceans, in turn creating conditions that threaten the survival of a broad range of species with carbonate-based exoskeletons. These include molluscs, some plankton, echinoderms and corals (Law et al, 2017; Rouse et al, 2017).

The likely result is lower developmental rates, impaired shell forming and maintenance, and reduced survival of larvae (Rouse et al, 2017). Many of these hard-shelled species play important roles in controlling ecosystem structure or function. For example, phytoplankton are critical to ocean productivity and provide food for marine food webs (Law et al, 2017). Similarly, many New Zealand mollusc species, including pāua, cockles and flat oysters, play complex and important roles in maintaining healthy ecosystem function and structure, through biogeochemical processing, nutrient recycling, controlling phytoplankton biomass, and providing food and habitat for benthic (deep-sea) organisms (Gazeau et al, 2013; Law et al, 2017). Some of these species are also of economic importance.

N11 Risks to the long-term composition and stability of indigenous forest ecosystems, due to changes in temperature, rainfall, wind and drought

Indigenous forests once formed the dominant land cover across New Zealand. Substantial clearance since human settlement has reduced their extent by about 75 per cent, to a current area of about 6.4 million hectares (Forestry New Zealand, 2020). Forest loss has been greatest in lowlands, where many surviving forests are highly fragmented.

Analysis of the historic and current distributions of dominant forest species (eg, McGlone et al, 1993; Leathwick, 1995), shows a high degree of landscape-scale sorting of ecosystems and species in relation to climate parameters such as temperature and moisture stress. This might suggest future climate changes will alter the distribution of forest ecosystems and species. However, there is only very limited evidence for this (McGlone and Walker, 2011), suggesting a degree of stasis in distribution. Such changes may be slowed down by lower abundance of avian dispersers, and fragmentation in many lowland environments. A likely complication in detection is the pervasive effects of introduced browsers.

N12 Risks to the diverse range of threatened and endangered species that are dependent on New Zealand's offshore islands for their continued survival, due to ongoing sea-level rise, changes in terrestrial climates, and changes in ocean chemistry and productivity

New Zealand's offshore islands play a critical role in the conservation of many of its at-risk and threatened indigenous species. They provide vital refuge from introduced vertebrate pests including rodents, mustelids and feral cats, which have severely reduced or eliminated a significant number of vulnerable indigenous species from the mainland (Mortimer, Sharp, and Craig, 1996).

These islands now provide critical habitat for around 6 per cent of indigenous, vascular plant species, 25 per cent of indigenous reptiles and frogs, and around 50 per cent of breeding seabird species (Bellingham et al, 2010) (Mortimer, Sharp, and Craig, 1996). Many support more than one threatened species; the Chatham Island group alone supports 20 per cent of New Zealand's threatened bird species (Aikman, Davis, Miskelly, O'Connor, and Taylor, 2001).

Gradual sea-level rise and reduced ocean productivity (N8), coupled with more frequent extreme storm events, will likely pose a serious long-term threat to species dependent on our offshore islands for survival. Although most of the islands are nature reserves with restricted public access, the threat will likely intensify with other human-mediated threats to these species (Bellingham et al, 2010; Mortimer, Sharp and Craig, 1996). For example, lower ocean productivity is likely to further compromise species such as albatross (*Diomedea exulans*), which already suffer high levels of mortality from long-line ocean fishing (Pryde, 1997).

5.4 Human domain | Rohe tangata

Table 15: Human domain

Human		
Most significant risks	Ratings	
	Urgency	Consequence
H1 Risks to social cohesion and community wellbeing from displacement of individuals, families and communities, due to climate change impacts.	88*	Extreme**
H2 Risks of exacerbating existing inequities and creating new and additional inequities, due to differential distribution of climate change impacts.	85	Extreme
Other priority risks (Stage 2)		
H3 Risks to physical health from exposure to storm events, heatwaves, vector-borne and zoonotic diseases, water availability and resource quality and accessibility, due to changes in temperature, rainfall and extreme weather events.	83	Major
H4 Risks of conflict, disruption and loss of trust in government from changing patterns in the value of assets and competition for access to scarce resources, primarily due to extreme weather events and ongoing sea-level rise.	83	Major
H5 Risks to Māori social, cultural, spiritual and economic wellbeing from loss and degradation of lands and waters, as well as cultural assets such as marae, due to ongoing sea-level rise, changes in rainfall and drought.	80	Extreme
H6 Risks to Māori social, cultural, spiritual and economic wellbeing from loss of species and biodiversity, due to greater climate variability and ongoing sea-level rise.	80	Extreme
H7 Risks to mental health, identity, autonomy and sense of belonging and wellbeing from trauma, due to ongoing sea-level rise, extreme weather events and drought.	80	Major
H8 Risks to Māori and European cultural heritage sites, due to ongoing sea-level rise, extreme weather events and increasing fire weather.	75	Major
Opportunity		
HO1 Opportunity for reduction in cold weather-related mortality.	45	n/a

* Urgency rating: the adaptation and decision urgency rating for this risk.

**Consequence rating: the highest consequence rating assigned to this risk out of all three periods (now, 2050, 2100). The [technical report](#) provides the consequence rating for each risk and period.

5.4.1 Most significant risks

H1 Risks to social cohesion and community wellbeing from displacement of individuals, families and communities, due to climate change impacts

Risk summary

Extreme events such as flash floods, more frequent coastal flooding and erosion or landslides, or gradual, accumulating changes (particularly rising sea levels), may render some locations uninhabitable. When people are **displaced**, they can suffer trauma from leaving familiar surroundings, breaking social and cultural bonds, and the challenges of resettlement. There are two sides to the risk: the impact on those who move away, and the impact on the community left behind.

Mobilised populations, whether moving internally or across borders, will change the composition of communities, affect housing and labour markets, require changes to regional development planning, and alter the demand for social services and other resources. Those who remain may experience a sense of loss and abandonment as the community diminishes, and from broken family, social and cultural bonds. As a community shrinks, essential services may be eroded – for example, education facilities, job opportunities or community services. This has been reported in rural New Zealand communities over the last 30 years as a result of government reform in the mid-1980s. These risks to social cohesion and community wellbeing increase over time and are greater under RCP8.5 than RCP4.5.

Exposure

New Zealand's low-lying coastal areas are exposed to ongoing sea-level rise and associated pressures such as rising groundwater and salinisation, and extreme events. Intensified development along coastal areas and urbanisation are increasing the number of people exposed to extreme weather events, landslides and coastal flooding (Glavovic, Saunders and Becker, 2010). About 675,500 people live in areas currently prone to flooding. A further 72,065 people live in areas that are subject to 1 per cent AEP (annual exceedance probability) extreme sea-level elevation (Paulik, 2019). Inland communities are exposed to extreme events and gradual changes, which may alter the viability of crucial economic enterprises.

Sea levels are projected to rise by up to 0.90 m by 2100 under RCP8.5 for all zones, resulting in coastal flooding and salinisation of groundwater (Ministry for the Environment, 2017b). Extreme storm tides, winds and rainfall are projected to increase in frequency and magnitude in all regions for 2050 and 2100 under RCP8.5. The intensity of tropical cyclones in the North Island and northern South Island is also projected to increase (Pearce et al, 2018). This will result in flooding, landslides and erosion that can have immediate and long-term implications, due to damage to belongings and households, displacement and trauma (Stephenson et al, 2018). Some areas are already very exposed to flooding. For example, 4.3 per cent of Westport will be inundated by a 1-in-50-year flood. By 2080, this could rise to 80 per cent (Hennessy et al, 2007).

Sensitivity

Networks and relationships are particularly important in communities before, during and in recovery after extreme events and disasters (Jakes and Langer, 2012). Any erosion of these networks (as the community shrinks) can increase communities' sensitivity and decrease their ability to respond to future events.

The communities most likely to be sensitive include those where livelihoods depend on the natural environment. Farming communities are highly sensitive to events that can disrupt farming, causing financial losses, and affecting mental health, social cohesion and community wellbeing (Krishnamurthy, 2012). In this case, the risk may cascade through the natural and economic domain rather than directly from exposure to a hazard.

Other examples of communities that are likely to be sensitive include:

1. Low-lying areas facing the impacts of coastal erosion and ongoing sea-level rise. These hazards increase the risk of disruption to livelihoods and communities in the short and long term (Stephenson et al, 2018). As the disruptions increase, so does the likelihood that those who can move will move (Lawrence et al, 2018).
2. Flood plains, or areas potentially affected by waterlogging (due to groundwater changes), which may cause parts or all of the community to be relocated.
3. Ethnically and culturally homogeneous communities, where social cohesion generally declines as diversity increases (Laurence and Bentley, 2016).

Individuals who rely on strong social networks for support (eg, the elderly) are more sensitive to loss of social cohesion (Wistow, Dominelli, Oven, Dunn and Curtis, 2015) and connectedness.

Adaptive capacity

A sense of community, social cohesion and community wellbeing is paramount for resilience and adaptive capacity (Jakes and Langer, 2012; Tompkins and Adger, 2004). If this is eroded, by definition, that capacity lessens. For Māori, culture forms the basis of social cohesiveness, which in turn contributes wellbeing and resilience including the adaptive capacity of the collective.

This is apparent in community responses to historical events. When Mt Ruapehu erupted in 1995–1996, a sense of community and self-efficacy were important predictors of people’s resilience and the capacity to respond (Tompkins and Adger, 2004). The ability to cope would have been compromised without connections and cohesion.

Maintaining social cohesion and community wellbeing in the face of displacement and movement of people requires a recognition that adaptation in other domains will affect this risk. For example, good governance and inclusive decision-making are required to develop acceptable adaptation options for communities, and minimise risks to cohesion and wellbeing.

Anticipatory governance and effective decision-making in the context of uncertainty is necessary to reduce exposure to this risk, by ensuring communities do not develop in areas prone to climate change hazards that may lead to displacement.

Consequence

Populations displaced by disasters and climate change will change the composition of communities, affect housing and labour markets, require changes to regional development planning, and alter the demand for social services. Displaced people may also lose their local support networks, and communities receiving them might be unwelcoming, contributing to or causing tension and conflict (Campbell, 2019; Boege, 2018).

Kelso was a small Otago town of 200 residents that experienced severe floods in 1978, and again 15 months later. Works to increase flood protection were deemed unaffordable and individual residents moved, depending on the perceived risk to households (Glavovic,

Saunders, and Becker, 2010). This led to the closure of community amenities and the eventual relocation of remaining residents to neighbouring towns (Glavovic, Saunders, and Becker, 2010). The townspeople have held reunions but the social bonds within the community were ultimately broken.

It is likely that cultural, economic and social capital as well as spiritual wellbeing will be adversely affected if Māori are forced to relocate from tribal lands and territories.

Interacting risks

The interaction between climate hazards, social cohesion and community wellbeing could amplify the vulnerability of individuals and communities to climate change. Loss of land and households will exacerbate physical and mental health issues (H3 and H7), affect a sense of belonging and identity (H7) and perpetuate inequity (H2), adversely impacting social cohesion. Loss or damage to cultural heritage sites (H8) may also reduce social cohesion and community wellbeing. Risks to lifeline infrastructures, such as energy networks (B8), transport networks (B6) and water (B1 and B4) can increase pressures on populations and communities. Climate change-related economic pressures, particularly in agricultural communities (E3), will also interact with displacement and community cohesion.

Confidence: High agreement, moderate evidence

There is high agreement that climate will expose community wellbeing and social cohesion to risks. However, the way and extent to which communities will be affected, and the range of impacts, is not well understood.

Adaptation

There were no discoverable adaptation actions for this risk from either the literature review or the consultation process.

Table 16: H1 Risks to social cohesion and community wellbeing: Urgency profile

H1 Risks to social cohesion and community wellbeing: Urgency profile						
Urgency category	Proportion of urgency out of 100		Description of actions			
More action needed	70		Action needed on how communities might relocate away from risk areas in an agreed and fair way. Consider policy and funding first.			
Research priority	20		Further research to understand how to relocate affected individuals and communities successfully.			
Sustain current action	0					
Watching brief	10		Establish monitoring process to ensure actions are effective.			
Adaptation urgency	88		Confidence	High agreement, moderate evidence		
Consequence	Now	Minor	2050	Extreme	2100	Extreme

H2 Risks of exacerbating existing inequities and creating new and additional inequities, due to differential distribution of climate change impacts

Risk summary

Exposure to extreme weather events such as flooding or heatwaves, or to gradual changes such as inundation of low-lying areas, will be the same for communities and individuals in affected areas. However, the ability to respond, adapt or cope with these risks is uneven, due to existing inequalities (Ellis, 2018). Those marginalised by age, race, ethnicity, socioeconomic status, gender, literacy or health may be unable to access resources to respond to climate risks (Ton, Gaillard, Adamason, Akgungor and Ho, 2019). An inability to convert resources to action can create and worsen inequity (Ton, Gaillard, Adamason, Akgungor and Ho, 2019).

New inequities may appear, especially due to slowly emerging risks such as sea-level rise. Exacerbation of existing inequalities and creation of new inequalities can have cascading implications for livelihoods and wellbeing.

Exposure

Extreme events and ongoing gradual changes will take place across all regions of New Zealand and may intersect with existing social vulnerability and inequality. For example, flooding and waterlogging often occur in the low-lying areas of South Dunedin. A significant proportion of the community there have social deprivation scores of between 8 and 10 (Stephenson et al, 2018). Conversely, changing exposure may create new inequities as new groups of people and communities are affected as the hazards increase. Exposure to this risk will be greater under RCP8.5 than RCP4.5 and will increase over time, potentially compounded by inequalities from other domains.

Sensitivity

Sensitivity is influenced by social, cultural, political and economic processes (Adger et al, 2004). Sensitivity and adaptive capacity are place-dependent; they vary according to the climate hazard, and over time (Cutter and Finch, 2008). For example, Oppenheimer et al (2014) differentiate vulnerability before a crisis or disaster (eg, drought, flood), and in the recovery.

The following are understood to be key sources of sensitivity to extreme climate events:

- Socio-economic disparities between Māori and non-Māori communities: These increase sensitivity to climate change impacts and risks for Māori society (Manning, Lawrence, Ngaru King and Chapman, 2015). Māori communities are more sensitive to climate impacts on ecological systems, due to dependence on primary industries for livelihoods, and the impacts of climate change on cultural and spiritual wellbeing (H5, H6), as well as on coastal [mahinga kai](#) and proximity of housing and infrastructure (Stephenson et al, 2018).
- Socioeconomic status: In general, people living in poverty are more sensitive to the impacts of climate change hazards (Fothergill and Peek, 2004).
- Ethnicity: Ethnic communities are often geographically and economically isolated from jobs, services and institutions. Discrimination also plays a major role in increasing their sensitivity (Fothergill, Maestras and Darlington, 1999). Where minorities are immigrants from non-English-speaking countries, language barriers can greatly increase vulnerability to a disaster (Trujillo-Pagan, 2007).

- **Gender:** After disasters, women and children are often vulnerable. Evidence shows that lower-income women experience ongoing job and house displacement, increased domestic violence and reduced access to education and childcare for children after extreme events (Freudenburg, Gramling, Laska and Erikson, 2008). Unequal participation in labour markets and decision-making compound inequalities (Enarson, 2007). Research also shows domestic violence increases after extreme events, such as fires (Parkinson and Zara, 2013).
- **Age:** Disruptions from a disaster can have significant psychological and physical effects on children. The elderly are likely to suffer health problems and recover more slowly, and tend to be more reluctant to evacuate their homes (Ton, Gaillard, Adamason, Akgungor and Ho, 2019).
- **Disability:** People with mental or physical disabilities are less able to respond effectively to disasters and require additional help to prepare for and recover from disasters (McGuire, Ford and Okoro, 2007).
- **Other factors** such as perceived risk, previous experiences and trauma, social networks and informed climate change knowledge influence sensitivity to risks (Freudenburg, Gramling, Laska and Erikson, 2008).

Sensitivity to gradual, ongoing change is less well known, but it is becoming apparent the distribution of climate change risk is changing across society. For example, wealthy asset owners of coastal properties, who may have large mortgages, could face more precarious situations if they experience insurance retreat and are affected by an extreme event.

Adaptive capacity

Inequity and adaptive capacity are related. Inequity can hinder adaptive capacity and a lack of adaptive capacity can intensify social vulnerability (Fisher, 2011). Community members most likely to be affected are the least empowered or accustomed to contributing to decision-making (Barnett and O’Neill, 2010). Decisions can lead to inequitable outcomes or maladaptation that entrenches inequity (Barnett and O’Neill, 2010; Guerin, 2007).

The ability to adapt is affected by socio-economic factors such as age, gender, social networks and social capital in conjunction with past experiences, perceived risk and informed knowledge.

Limited knowledge or understanding of climate change risks (potentially a consequence of limited access to information) can result in maladaptation and path dependency as well as constrain adaptive capacity, further exacerbating inequity. For example, developing coastal areas and low-lying land exposed to flooding, or relying on hard protection measures such as structural flood controls to mitigate risk, can lead communities to believe they are adequately protected (Manning, Lawrence, King and Chapman, 2015). Inclusive decision-making and adaptation strategies that help to increase self-efficacy and empower individuals to participate may help to address existing inequities and limit future ones (Stephenson et al, 2018; Tompkins and Adger, 2004).

Consequence

Access to resources for individual, family and community wants and needs is already unequal across society, with some groups experiencing marginalisation and poor social outcomes (eg, health, employment, access to education or welfare and support services). Climate change is likely to exacerbate these existing inequities and generate new ones.

There is also the question of who will fund a response, particularly for managed retreat (Boston and Lawrence, 2018). Financial assistance after natural disasters for affected communities and households is currently ad hoc (Boston and Lawrence, 2018). For example, the Government announced in 2017 after severe flooding in Edgecumbe that it would fund the clean-up and repair of all affected properties, including those uninsured or unable to afford repairs (Boston and Lawrence, 2018). However, many other communities affected by similar extensive flooding have not received such funding.

Changing climate conditions are also likely to exacerbate many of the health inequalities already faced by Māori. This will demand careful societal responses that do not exacerbate these (Manning, Lawrence, King and Chapman, 2015). Many Māori communities are concentrated around coastal areas, which are particularly vulnerable to rising sea levels.

Interacting risks

Inequity is both exacerbated by and produced by a changing climate, which increases the sensitivity of vulnerable individuals and communities to risk. Increased inequity will likely exacerbate physical and mental health issues (H3 and H7), affect a sense of identity and belonging (H7), and may even lead to social conflict or disruption (H4) as a result of inadequate adaptation and action (G5 and G1). Climate hazards that damage or limit access to infrastructure such as homes, transport networks (B6), energy (B8) and telecommunications have the greatest impact on marginalised persons.

Confidence: High agreement, medium evidence

There is high agreement that climate hazards will worsen existing inequity and create new inequities. What is needed is greater understanding of community vulnerability to local impacts, together with governance that includes marginalised people.

Adaptation

Although efforts are under way to address social inequities in a more general sense, few, if any have a climate change adaptation component.

Efforts are usually targeted to a vulnerable group such as rural populations or Māori groups, and address access to resources rather than climate change and potential and emerging inequities. There are limited, if any, actions to address this risk in a holistic and integrated manner. Climate change will likely create new groups of vulnerable people – an issue which has not been explored.

Table 17: H2 Risks of exacerbating existing inequities: Urgency profile

H2 Risks of exacerbating existing inequities: Urgency profile			
Urgency category	Proportion of urgency out of 100	Description of actions	
More action needed	60	Early policies, principles and practices are likely needed to ensure that inequity (current and intergenerational) is considered in all future actions.	
Research priority	30	Further research would be useful; however, some actions should and can be taken regardless.	
Sustain current action	0		
Watching brief	10		
Adaptation urgency	85	Confidence	High agreement, medium evidence.

Consequence	Now	Major	2050	Extreme	2100	Extreme 150
-------------	-----	-------	------	---------	------	-------------

5.4.2 Other priority risks for the human domain

H3 Risks to physical health from exposure to storm events, heatwaves, vector-borne and zoonotic diseases, water availability and resource quality and accessibility, due to changes in temperature, rainfall and extreme weather events

New Zealanders' physical health is already affected by impacts from climate hazards such as wildfire, floods, heatwaves, droughts and storms (Jones, Bennett et al, 2014). These hazards are projected to increase in frequency and severity. New Zealanders will also be exposed to zoonotic and water-borne diseases, due to changes in the distribution of species and in hydrological systems (Cann et al, 2013; Derraik and Slaney, 2007).

Human health will be indirectly affected by drought and heavy rainfall events affecting water availability and quality (McBride et al, 2014; Woodward et al, 2001). Climate change will also alter the quality of and access to resources that support human health and wellbeing, such as food, water, outside space and clean air (Royal Society | Te Apārangi, 2017). These climate changes will impact the physical health, safety and wellbeing of New Zealanders.

H4 Risks of conflict, disruption and loss of trust in government from the changing patterns in the value of assets and competition for access to scarce resources, primarily due to extreme weather events and ongoing sea-level rise

Climate change is likely to exacerbate stressors that give rise to conflict and disruption, particularly as the value of assets changes and competition for resources intensifies. Gradual, ongoing change, and the growing magnitude and frequency of extreme events is likely to affect the value of assets (eg, property) and decrease the availability of some resources (eg, land, water, safe building sites), while increasing the demand for the resources and the value of other unaffected assets. Conflict is therefore likely to arise over competition for increasingly scarce resources such as water and arable land, and from relocation and displacement (Boege, 2018).

Gradual changes may also aggravate existing environmental, economic and societal stressors such as water supply and food security, resulting in increased tension (Weir and Virani, 2011) and may exacerbate socio-economic vulnerability. Conversely, new tensions may emerge, if powerful groups have their interests affected and their wealth reduced.

Perceptions of unfairness and opacity in processes could also lead to tensions, particularly over adaptation funding. Competition for adaptation resources is likely to emerge rapidly. Conflict may arise from land-use changes driven by climate events such as coastal inundation, but also in response to changes in regulations and financial priorities. Inadequate government response or maladaptation pathways may also amplify tension and reduce trust in governments.

H5 Risks to Māori social, cultural, spiritual and economic wellbeing from loss and degradation of lands and waters, as well as cultural assets such as marae, due to ongoing sea-level rise, changes in rainfall and drought

Māori have unique spiritual, cultural and economic ties with the environment and [mana whenua](#). Degradation and loss of land and waters is likely to increase over time. This will affect cultural wellbeing and spiritual health, identity and livelihoods. Many Māori communities live

in exposed areas, and climate change-induced pressures will challenge the capacities of some Māori to cope and adapt (King et al, 2012).

H6 Risks to Māori social, cultural, spiritual and economic wellbeing from loss of species and biodiversity, due to greater climate variability and ongoing sea-level rise

Human pressures are already affecting New Zealand’s biodiversity, and climate change is expected to further change the abundance and distribution of indigenous flora and fauna. Loss of species and biodiversity is very likely to increase over time, with greater impacts under RCP8.5 than under RCP4.5 (see [box 1](#)). Loss of species is expected to have adverse consequences for Māori, impacting cultural practices, health and economic opportunity.

H7 Risks to mental health, identity, autonomy and sense of belonging and wellbeing from trauma, due to ongoing sea-level rise, extreme weather events and drought

Climate change has several implications for the mental health and wellbeing of New Zealanders. The harm experienced or witnessed when exposed to extreme events can cause trauma (Berry et al, 2010). Mental health risks range from minor stress and distress to clinically recognised disorders such as anxiety and post-traumatic stress (Royal Society | Te Apārangi, 2017). Communities may also experience disruptions to environmental and social determinants of health. For example, disruption of the relationship between individuals and their environment can cause risks to mental health (Royal Society | Te Apārangi, 2017), as can the loss of livelihoods, poverty and displacement (Berry et al, 2010). Loss of autonomy and feelings of helplessness (eg, from being unable to stop the beach in front of your property eroding) can also affect mental health. Finally, fear and grief associated with climate change and expected loss itself can cause trauma (Jones, Keating et al, 2014; Cunsolo and Ellis, 2018).

H8 Risks to Māori and European cultural heritage sites, due to ongoing sea-level rise, extreme weather events and increasing fire weather

New Zealand’s cultural heritage includes places of significance to Māori, archaeological sites, historic buildings and structures, and cultural landscapes (Parliamentary Commissioner for the Environment, 1996). Heritage, in all its forms, is already exposed and vulnerable to climate hazards. Rising sea levels, increased intensity of extreme weather events and changes in humidity are expected to have significant implications for cultural heritage (Reisinger et al, 2014). Exposure to acute events and ongoing gradual change is projected to increase, and to be greater under RCP8.5 than RCP4.5 (see [box 1](#)).

5.5 Economy domain | Rohe ōhanga

Table 18: Economy domain

Economy		
Most significant risks	Ratings	
	Urgency	Consequence
E1 Risks to governments from economic costs associated with lost productivity, disaster relief expenditure and unfunded contingent liabilities due to extreme events and ongoing, gradual changes.	90*	Extreme**
E2 Risks to the financial system from instability due to extreme weather events and ongoing, gradual changes.	83	Major
Other priority risks (Stage 2)		

Economy		
E3 Risks to land-based primary sector productivity and output due to changing precipitation and water availability, temperature, seasonality, climate extremes and the distribution of invasive species.	81	Major
E4 Risks to tourism from changes to landscapes and ecosystems and impacts on lifeline infrastructure, due to extreme weather events and ongoing, gradual changes.	80	Major
E5 Risks to fisheries from changes in the characteristics, productivity, and spatial distribution of fish stocks due to changes in ocean temperature and acidification.	80	Major
E6 Risks to the insurability of assets due to ongoing sea-level rise and extreme weather events.	75	Major
E7 Risks to businesses and public organisations from supply chain and distribution network disruptions due to extreme weather events and ongoing, gradual changes.	68	Major
Opportunities		
EO1 Opportunities for increased primary sector productivity due to warmer temperatures	80	n/a
EO2 Opportunity for businesses to provide adaptation-related goods and services	80	n/a

* Urgency rating: the adaptation and decision urgency rating for this risk.

**Consequence rating: the highest consequence rating for this risk out of all three periods (now, 2050, 2100). The [technical report](#) provides this rating for each risk and period.

5.5.1 Most significant risks

E1 Risks to governments from economic costs associated with lost productivity, disaster relief expenditure and unfunded contingent liabilities due to extreme events and ongoing, gradual changes.

Risk summary

The costs of climate change in New Zealand are already significant (Frame et al, 2018), and will only increase over time. Almost all risks detailed in this report impact on the economy and the Government's fiscal position, whether from loss of revenue or additional spending to adapt infrastructure, respond to health needs or recover from extreme events. The damages from, and costs of adapting to climate change will likely place a significant and growing financial burden on public authorities, who will be tasked with funding investments in adaptation, providing post-event relief and responding to health impacts.

Exposure

The public sector and the Government's fiscal position are exposed to the consequences of climate change across the domains. The damage from climate-change hazards will place a growing financial burden on citizens, businesses and public authorities. Central and local government, on behalf of communities, manage risks to public goods and assets (including the environment) and create an institutional, market and regulatory context that promotes resilience and action (Ministry for the Environment, 2017c).

Research by Frame et al (2018) investigated the scale of the economic impact of climate-related floods and drought in New Zealand between mid-2007 and mid-2017. They conservatively estimate that flood and drought costs attributable to anthropogenic influence on climate are already somewhere near \$120 million per decade for insured damages from floods, and \$720 million per decade for economic losses from droughts. They

warn these costs will “almost certainly” (p9) increase over time. Already the annual cost of repairing land transport networks damaged by weather-related events (B6) has more than quadrupled over the past decade (Boston and Lawrence, 2018). The Government may be exposed to compensation for homeowners and commercial buildings, due to managed retreat from landslide areas and coastal or river flood plains.

Ecosystem services provided by the natural environment are significant and, in some cases, irreplaceable. Examples include nutrient cycling, soil provision, water and air purification, carbon sequestration, food and resource provision, and cultural services and experiences. Their loss, as well as diminishing the welfare of all New Zealanders, may also burden the Government by impacting on key sectors of the economy, such as primary industries (E3, E5) and tourism (E4). The impacts of climate change on people also manifest in the economy, through declining productivity in hot weather, the direct health risks from disease and exposure to extreme events (H3), the indirect costs of trauma (H1), and exacerbation of persistent inequalities (H2).

A review of recent research related to climate change risks in New Zealand by McKim (2016) identified only two pieces of (grey) literature on finance (including banking and insurance) and climate change. It concluded that “a general lack of published research in this area, at least in the New Zealand context, is evident” (p15).

Sensitivity

New Zealand governments are sensitive to the financial risks from climate change. Already local governments are struggling to finance infrastructure for housing, tourism and regional development, provide safe drinking water, and develop resilient infrastructure (DIA 2017). For some councils, further investment is constrained because they are approaching covenanted debt limits (New Zealand Productivity Commission, 2019).

Local governments rely on rates for more than 50 per cent of their income, which are generally based on the land, capital or rental value of property in the government area (LGNZ, 2019). This situation increases the sensitivity of local governments to climate change impacts that influence property values, for example insurance sector retreat (E6). Also, rates that are linked to land, capital or rental values may fail to keep pace with the costs of adaptation, particularly those projected to occur under RCP8.5 (see [box 1](#)).

Central government finances are relatively strong, but fiscal pressures are projected to increase as an ageing population slows revenue growth and increases expenses (Treasury, 2019). The Treasury (2016) also warns that “[i]n the future, we may also see threats to our natural resources (eg, climate change, water quality and natural disasters) as a fiscal pressure” (p6).

Adaptive capacity

Local governments currently have varying, but generally limited, capacity to respond to economic risks. Some councils have indicated they could meet additional costs through general or targeted rates (James et al, 2019). However, on average, growth in council rates has outstripped common economic indicators, and continuing rates increases may make council rates less affordable for households (DIA, 2017). Other councils have disaster relief funds or have already budgeted for higher infrastructure costs. Many councils remain unsure of what the costs would be and how they would meet them (James et al, 2019).

Central government is better able to adapt by preparing for a changed climatic future and funding efforts to ensure New Zealanders can prosper socially, economically and culturally. Central government sets the domestic regulatory framework for considering adaptation. Among other roles, it provides robust information on how New Zealand’s environment may change and makes this information accessible to other sectors (Ministry for the Environment, 2017c).

Consequence

There have been numerous attempts to calculate the economic cost of climate change, notably the Stern Review (Stern, 2006). This estimated that, without action, climate change might lead to costs equivalent to losing at least 5 per cent of global gross domestic product (GDP) each year. More recently, Hinkel et al (2014) estimated that if the sea level rises by 1.23 m by 2100,⁷ frequent floods alone would cause losses of over 9 per cent of global GDP each year. A decline in economic output of this magnitude would have significant consequences for the New Zealand Government’s ability to deliver services to support communities.

Confidence: High agreement, medium evidence

There is high agreement that climate change is likely to have adverse consequences for the economy, but limited agreement on their extent. There is robust evidence of the economic costs of climate change in other global regions, but very little research has explored this risk in the New Zealand context.

Adaptation

All levels of government are taking actions that indirectly manage public sector fiscal risk. Efforts of central government and its departments include tax policies, adverse events policies, transport resilience strategies, capacity building and engagement with other levels of government. These efforts are not necessarily targeted directly at Risk E1 as it relates to climate change, but serve to reduce the risk regardless. Local and regional governments have also progressed actions related to infrastructure strategies, adaptation pathway development, establishing community resilience groups, and emergency management. Adaptation to address the other risks in this report will also contribute to reducing this risk.

Table 19: E1 Public sector fiscal risks: Urgency profile

E1 Public sector fiscal risks : Urgency profile		
Urgency category	Proportion of urgency out of 100	Description of actions
More action needed	70	Planning and budgeting for the growing financial burden is critical at all levels of the public sector. Adequate resourcing between different levels of government is essential.
Research priority	20	Develop credible estimates of future financial impacts of climate change over time across sectors.
Sustain current action	10	Taking adaptation action in other areas will reduce this risk. Continue to monitor risk reduction efforts.
Watching brief	0	

⁷ The highest projected global mean sea-level rise across all models and emission scenarios (95th percentile of MIROC ESM CHEM).

Adaptation urgency	90		Confidence	High agreement, medium evidence.		
Consequence	Now	Minor	2050	Major	2100	Extreme

E2 Risks to the financial system from instability, due to extreme weather events and ongoing, gradual changes

Risk summary

Financial instability affects livelihoods, socio-economic inequality and the economy. The fundamental changes projected for the climate system are likely to have severe implications for the stability of the global financial system (Dafermos, Nikolaidi and Galanis, 2018). New Zealand is exposed to climate change impacts in financial markets globally as well as locally. Climate-related hazards could severely and abruptly damage the balance sheets of households, corporations, banks and insurers, triggering financial and macroeconomic instability (Batten, Sowerbutts and Tanaka, 2016).

Exposure

New Zealand's financial system is highly exposed to climate change through local changes and international markets. The global financial system is an extremely complex network of tightly linked financial institutions and markets. As the global fallout from the implosion of the United States' sub-prime mortgage market in 2008 showed, this complexity and interconnectedness can transmit and amplify disruption across the globe.

The stability of New Zealand's financial system is therefore influenced by climate-related hazards occurring globally, as well as the behaviour of foreign governments, regulatory bodies and financial institutions (Batten, Sowerbutts and Tanaka, 2016). The system could be affected by any single acute event or a series of events – such as hurricanes or cyclones, fires or floods – that precipitate rapid reappraisals of asset values in major financial hubs such as New York, Tokyo, Shanghai, Shenzhen, Hong Kong or London. The pricing of ongoing, gradual events – particularly sea-level rise – could also trigger rapid reappraisal and disruption. Vulnerability of supply and distribution systems (E7) may also expose the financial system to disruption (Hong, Li and Xu, 2019).

Small and medium enterprises (SMEs), which account for 97 per cent of all New Zealand businesses and 29 per cent of employment (New Zealand Foreign Affairs and Trade, nd), are particularly sensitive to such disruption, and could function as a source of financial system instability.

Extreme events and ongoing gradual changes could contribute to this financial instability in New Zealand. Sea-level rise, or change in climatic means, could over the long-term stress businesses, governments, bank balance sheets, and economic activity. Extreme events in areas where valuable assets are concentrated, such as cities, could also lead to disproportionate instability.

Sensitivity

New Zealand's financial system is resilient to a broad range of economic risks (Reserve Bank of New Zealand, 2019). Many factors affect its sensitivity to climate change, including debt, capitalisation and the ability to price risk.

New Zealand's AAA credit rating is justified by its 'very high economic resilience', a strong fiscal position and effective institutions and policies, which mitigate our vulnerability to financial shocks (Fyers, 2016). However, a large external or domestic shock, such as a natural disaster, could result in a credit downgrade, which would undermine the banking system by raising the cost of funding (Moody's, 2017). This would be particularly severe if some of New Zealand's many highly indebted households and dairy farms had to default (Reserve Bank of New Zealand, 2019).

The Reserve Bank of New Zealand has recognised the costs of bank failures are higher than previously understood. It has proposed to reduce the sensitivity of the banking system by gradually raising bank capital requirements. However, some insurers and non-bank deposit takers have capital buffers that would absorb only relatively small losses, rendering them sensitive to disruption (Reserve Bank of New Zealand, 2019).

The insurance sector is highly sensitive to changes in climate hazards and may be underestimating the impact of climate change on catastrophe risks. For example, reinsurers could be underestimating their exposure to 1-in-10-year and 1-in-250-year catastrophe losses by an average of about 50 per cent (Standard and Poor's, 2014). Catastrophe models, used by insurers, reinsurers, governments, capital markets and other financial entities, also tend to rely on historical data and do not necessarily incorporate climate change trends (Lloyd's, 2014).

Adaptive capacity

The *Reserve Bank of New Zealand Climate Change Strategy* acknowledges the need to consider climate change risk in setting monetary policy (which controls either monetary supply or the interest rate payable on short-term borrowing), monitoring financial stability risks and financial markets, and identifying appropriate prudential requirements (Reserve Bank of New Zealand, 2020). However, historically low interest rates limit the ability to stimulate the economy in the event of a demand-side shock (Reserve Bank of New Zealand, 2019). Monetary policy instruments are also limited in addressing supply-side shocks.

Actions by the financial sector influence the size and allocation of damages from a hazard (Batten, Sowerbutts, and Tanaka, 2016). For example, the amount of insurance and credit available for construction in flood-prone areas will determine the size of the eventual financial losses from flooding in these areas, as well as the allocation of these losses. The inherent uncertainty in future concentrations of greenhouse gas, corresponding climate change, and the reactions of humans hinder accurate and efficient pricing of risk (Aglietta and Espanage, 2016). Importantly, the 'long tails' of probability distributions (unlikely but extreme events) that grow 'thicker' (ie, more likely) with climate change inaction cannot be ruled out as they are crucial for accurate pricing of uncertainty (Weitzman, 2009).

There is an international movement towards disclosure of climate change risks such as the Carbon Standards Disclosure Board, the UN Principles for Responsible Investment, the Task Force on Climate-related Financial Disclosures, and the Network for Greening the Financial System, of which New Zealand is a member. The intention is to mobilise mainstream financial flows towards investments that are not exposed to climate risk. Thus far, disclosure by the Task Force on Climate-related Financial Disclosure (TCFD) is minimal, and capital flows generally still fail to consider climate risk. The market, in general, under-reacts to many types of value-relevant information (Weitzman, 2009) such as industry news, demographic shifts and upstream-downstream relationships (Hong, Torous and Valkanov, 2007; Cohen and Frazzini, 2008).

Research also suggests that stock markets are inefficient in responding to information about drought trends (Hong, Li and Xu, 2019). The reasons require further research but may include inattention, home country equity bias, or other institutional investor frictions. Whatever the reason, the inability to price climate change risk adequately reduces adaptive capacity (Hong, Li and Xu, 2019). Government proposals to introduce TCFD-aligned disclosures may help reduce sensitivity to this risk by enabling more accurate pricing.

Consequence

Climate change presents a systemic risk to the financial system, with severe impacts on the real economy. Extreme events, such as flooding or fire, along with ongoing gradual changes, like soil erosion or sea-level rise, can have several impacts. These could be intensified through interactions between the financial system and other parts of the economy as well as government policies and regulations. Financial instability could have a range of economic effects, including greater income inequality (Domanski and Zabai, 2016) and reinforcing the adverse effects of climate change on economic activity (Dafermos, Nikolaidi and Galanis, 2018).

Climate change poses a potential risk to financial systems by disrupting both supply and demand.

Demand-side disruptions affect consumption, investment and international trade. Climate change-induced losses could reduce household wealth and therefore private consumption. Business investments could be reduced by uncertainty and damage to physical and financial assets. Climate hazards can also have significant effects on domestic and international trade (Gassenher, Keck and The, 2010; Oh and Reuveny, 2010).

Supply-side disruptions affect productive capacity. These disruptions could include loss in worker productivity in hot weather, impacts on production facilities and the transport networks, or shortages in commodities reducing the supply of goods.

Climate change could cause permanent or long-term damage to capital and land (Stern, 2013), and increase the rate of capital depreciation (Fankhauser and Tol, 2005). Both can reduce profitability and gradually diminish the liquidity of firms. Extreme events undermine the financial robustness of banks (Klomp, 2014). In extreme cases, capital reserves become too low to cover regulatory requirements, necessitating a government response, which may include a bailout. This would adversely affect the public debt-to-output ratio (Dafermos, Nikolaidi and Galanis, 2018).

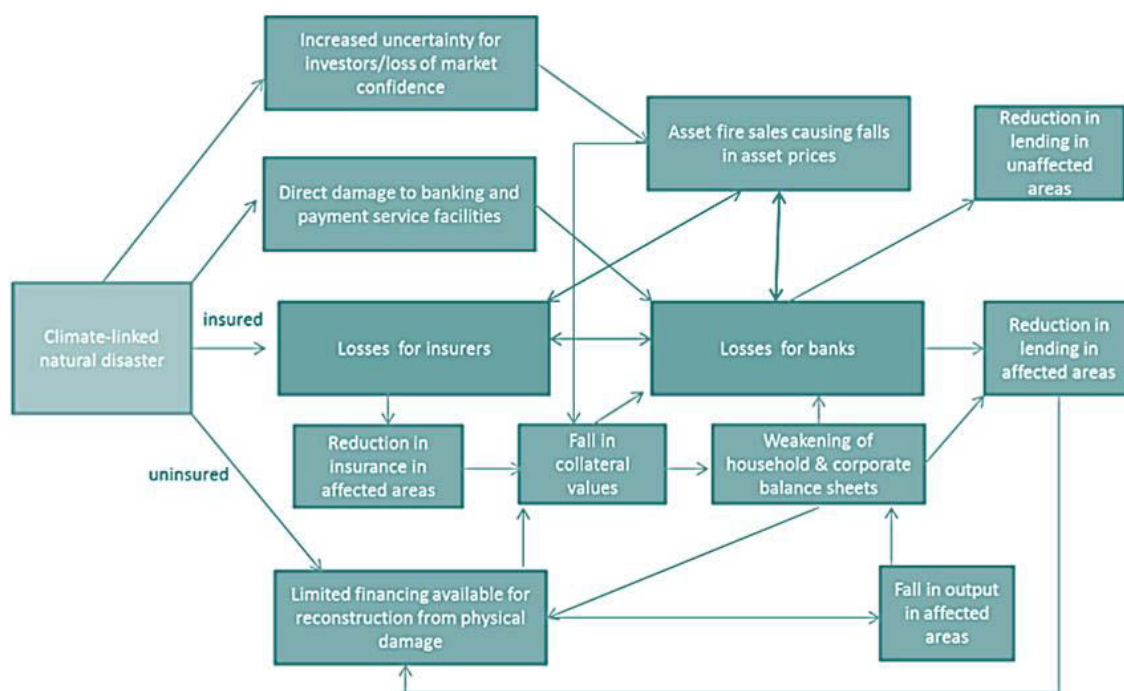
If banks suffer losses on their capital because of a climate hazard and cannot raise new capital immediately, they may reduce lending to both affected and unaffected areas to improve their regulatory capital ratios. The resulting reduction in credit supply could in turn exacerbate a fall in the value of assets used to secure loans, and further affect the balance sheets of households and businesses, potentially deepening the inevitable economic downturn (Batten, Sowerbutts and Tanaka, 2016).

An extreme event could also undermine business confidence and trigger a sharp sell-off in financial markets. This could result in an increase in the cost of funding new investments and thus reduce investment demand. Climate change may also influence how households allocate capital. In response to declining corporate profitability and increases in risk, households may reallocate financial wealth from corporate bonds towards term deposits and government securities, which are perceived to be less risky. This reallocation of investment portfolios can cause a gradual decline in the price of corporate bonds, which would reduce economic growth

from wealth-related consumption and firms' ability to fund investment, thereby constraining economic growth (Dafermos, Nikolaidi and Galanis, 2018). These impacts are expected to become more severe if global warming passes a 2.5°C threshold (Dafermos, Nikolaidi and Galanis, 2018).

Climate change can also affect the stability of the financial system through the insurance sector. Increasingly frequent and severe extreme events, such as fires, floods and storm surges, could have a direct effect on the insurers that cover them. If insured losses from an event or a series of events are sufficiently large and concentrated, they could lead to distress or failure of insurance companies. This, in turn, could affect financial stability if it disrupted critical insurance services and systemically important financial markets, such as securities lending and funding transactions (French, Vital and Minot, 2015). Large-scale fire sales of assets by distressed insurers could reduce asset prices, which could adversely affect the balance sheets of other financial institutions like banks. If these risks are uninsured, the deterioration of the balance sheets of affected households and corporates could lead to losses for their lender banks (Campiglio et al, 2018). Figure 9 illustrates some of these relationships.

Figure 9: A transmission map from a climate hazard to financial sector losses and the macro economy (Batten, Sowerbutts and Tanaka, 2016)



Interacting risks

Financial system instability will affect the Government's fiscal position (E1), other economic sectors (E3, E4 and E5) and the ability to fund adaptation (G2). Emergency government responses may occur in the context of a major financial system disruption, posing risks to democratic decision-making (G8). Financial crises also tend to exacerbate inequities (H2) and cause health problems (H3).

Confidence: high agreement, medium evidence

There is a reasonably high degree of agreement on the impacts of climate change on financial system stability, and a large, growing body of academic and grey literature to substantiate

this consensus. However, this research area is in its infancy, and there is little data for the New Zealand context.

Adaptation

Some adaptation efforts, both planned and under way, explicitly target financial system stability in the context of climate change. The Reserve Bank of New Zealand (RBNZ) has developed a climate change strategy and takes other regulatory actions to support financial system stability. The finance and insurance sectors are working with governments on policy frameworks to enable proactive risk reduction, and some banks are starting to factor climate change risk into lending decisions. Adaptation to address other risks in New Zealand will also contribute to reducing this risk.

Table 20: E2 Risks to the financial system from instability: Urgency profile

E2 Risks to the financial system from instability: Urgency profile						
Urgency category	Proportion of urgency out of 100		Description of actions			
More action needed	40		Coordinate a long-term plan integrating climate risk across relevant sectors. Build resilience into the financial system, including climate-related financial disclosure and banking regulations (particularly for lending). Mobilise climate finance for adaptation. Build the resilience of New Zealand’s SMEs.			
Research priority	50		Develop an improve understanding of the potential disruption from shocks due to ongoing climate change. Identify and implement mechanisms to reduce disruption.			
Sustain current action	10		The Reserve Bank of New Zealand has research programmes and a climate change strategy and the Council of Financial Regulators has established a climate work stream, which are good foundations to build on. Existing monetary policy mechanisms have some capacity to manage shocks.			
Watching brief	0					
Adaptation urgency	83		Confidence	High agreement, medium evidence		
Consequence	Now	Minor	2050	Moderate	2100	Major

5.5.2 Other priority risks for the economy domain

E3 Risks to land-based primary sector productivity and output due to changing precipitation and water availability, temperature, seasonality, climate extremes and the distribution of invasive species.

The primary sector faces risks from extreme events and ongoing, gradual changes. Climate change will reduce the quality and quantity of output across many areas including horticulture (Cradock-Henry, 2017), viticulture (Sturman et al, 2017), agriculture and forestry (Wakelin 2018; Lake et al, nd; Ausseil et al, 2019). Changes in temperature and seasonality influence maturation (Salinger et al, 2019), length of growing season and the quality (size, shape, taste) of horticulture products (Cradock-Henry, 2017; Salinger, 1987); the distribution of pests and

diseases (Watt et al, 2019; Wakelin et al, 2018) and the efficacy of some pest control agents (Gerard et al, 2013).

The amount of land suitable for primary industries will decrease as sea levels rise and low-lying coastal areas become affected by inundation and groundwater salinisation (Lake et al, nd). The impacts will increase over time and be greater under RCP8.5 than RCP4.5. Some impacts are already being felt by the sector, for example, pressure on water availability (Frame et al, in press). The Māori economy is focused on primary production industries like dairy, horticulture (especially kiwifruit) and forestry. Reduced production and profitability would have a significant impact on economic return to Māori landowners and Māori working in those businesses.

E4 Risks to tourism from changes to landscapes and ecosystems and impacts on lifeline infrastructure, due to extreme weather events and ongoing, gradual changes

Natural environments have supported New Zealand's tourism industry, but they and the infrastructure that allows us to access and enjoy them are at risk from climate change hazards. Changes to the number of snow days and peak snow elevation affect skiing and other snow activities (Hopkins, 2013), and warmer temperatures may lead to glacier retreat (Espiner and Becken, 2014). Rising sea levels and other climate hazards may damage infrastructure including rail, roads and airports, which provide access for tourism (Paulik et al, 2019). Rising sea levels can also alter coastal ecosystems that attract visitors. Many tourist activities are affected by weather, and therefore wherever climate change exacerbates precipitation, wind and other extreme weather events there could be negative impacts. For example, an interplay of climate factors that degrade wildlife ecosystems may disrupt ventures such as birdwatching tours (Kutzner, 2019). The risk to the tourism industry is expected to intensify over time under projected climate scenarios.

E5 Risks to fisheries from changes in the characteristics, productivity, and spatial distribution of fish stocks, due to changes in ocean temperature and acidification

Primary production in coastal waters may be vulnerable to ocean warming, acidification and sedimentation (The Royal Society of New Zealand, 2016). As fish physiology is directly linked to temperature, rising sea-surface temperatures under both RCP4.5 and RCP8.5 may alter growth, metabolism, reproductive success and food consumption (Flicke et al, 2007). This is most likely at a species level, disrupting and creating additional pressures for aquatic communities (Flicke et al, 2017).

Increasing ocean acidification may damage carbonate-forming species, including molluscs such as pāua, cockles and flay oysters that have significant economic value (Rouse et al, 2017; Law et al, 2017), although the evidence is mixed (Cross et al, 2016; Cornwall et al, 2016). Sea-level rise and ocean acidification are gradual and will increase over time under both RCPs.

The transmission of some diseases is temperature dependent, increasing in rate and prevalence at higher temperatures (Sweet, 2016). Other anthropogenic stressors, such as disturbance of habitat from commercial fishing and overexploitation, can significantly lower productivity (Parsons et al, 2014).

E6 Risks to the insurability of assets, due to ongoing sea-level rise and extreme weather events

Projected changes in the frequency and intensity of acute hazards that we insure against, such as flood, fire, storm-surge, landslide, hailstorm and tsunami, are causing the insurance industry to change premiums, develop new offerings and adjust availability. These changes are likely to affect many insurance markets, most significantly home insurance.

Changes to insurance could add to hardships after extreme events, with significant flow-on effects for New Zealand society including loss of peace of mind, the displacement of communities, changes in business investment and household consumption, fiscal risks to the Government and financial system instability.

E7 Risks to businesses and public organisations from supply chain and distribution network disruptions, due to extreme weather events and ongoing, gradual changes

Supply chains are comprised of local and global networks of infrastructure, people, information, materials and capital. They are subject to climate-related disruptions at many scales and in many geographies. Supply chains are likely to be affected adversely by acute hazards such as flooding, fire or landslides, or gradual changes such as sea-level rise, changes in seasonality, drought and erosion. Adverse weather and transport network disruption (B6) are already increasingly cited as reasons for supply chain disruption (Business Continuity Institute, 2019).

Due to its geographical separation from global markets, New Zealand is particularly prone to disruption to supply and distribution (Basnet, Childerhouse, Foulds and Martin, 2006). This can lead to losses in productivity, share price movements, damage to brand and reputation, loss of customers, and increased regulatory scrutiny. The sensitivity and vulnerability of supply chains is influenced by many factors including the resilience of physical infrastructure, industry profitability, the material characteristics of products, and regulatory frameworks. It therefore differs between geographies, economic sectors, and the actors within each sector. Supply chains are already vulnerable to climate-related hazards; their exposure is likely to be greater under RCP8.5 than RCP4.5 and increase over time.

5.6 Built environment | Rohe tūrangā tangata

Table 21: Built environment

Built environment		
Most significant risks	Ratings	
	Urgency	Consequence
B1 Risk to potable water supplies (availability and quality) due to changes in rainfall, temperature, drought, extreme weather events and ongoing sea-level rise.	93*	Extreme**
B2 Risks to buildings due to extreme weather events, drought, increased fire weather and ongoing sea-level rise.	90	Extreme
Other priority risks (Stage 2)		
B3 Risks to landfills and contaminated sites due to extreme weather events and ongoing sea-level rise.	85	Major
B4 Risk to wastewater and stormwater systems (and levels of service) due to extreme weather events and ongoing sea-level rise.	85	Extreme
B5 Risks to ports and associated infrastructure due to extreme weather events and ongoing sea-level rise.	70	Major
B6 Risks to linear transport networks due to changes in temperature, extreme weather events and ongoing sea-level rise.	60	Extreme
B7 Risk to airports due to changes in temperature, wind, extreme weather events and ongoing sea-level rise.	55	Extreme
B8 Risks to electricity infrastructure due to changes in temperature, rainfall, snow, extreme weather events, wind and increased fire weather.	55	Extreme

Built environment		
Opportunities		
BO1 Opportunity for reduction in winter heating demand due to warmer temperatures.	65	n/a

* Urgency rating: the adaptation and decision urgency rating for this risk.

**Consequence rating: the highest consequence rating for this risk out of all three periods (now, 2050, 2100). The [technical report](#) provides the consequence rating for each risk and period.

5.6.1 Most significant risks

B1 Risk to potable water supplies (availability and quality) due to changes in rainfall, temperature, drought, extreme weather events and ongoing sea-level rise

Risk summary

All towns, cities and sectors of our economy rely on a safe and secure water supply. Many water supplies are at risk from drought, changes in mean annual rainfall, extreme weather events (including heavy rainfall) and sea-level rise. This risk is likely to increase in the future.

Drought severity will increase in most regions. As well as reducing water availability, drought and higher temperatures can lead to higher demand, which can exacerbate supply issues. Population growth is projected to increase, adding pressure on water supplies. High growth regions include Auckland, Bay of Plenty, Northland, Waikato, Greater Wellington, Hawke’s Bay and Otago.

Sea-level rise (leading to salinity stress) and increases in heavy rainfall (leading to flooding and sedimentation of water sources) are already affecting water quality around New Zealand, and this will likely increase.

For Māori, water is seen as the essence of all life; impacts on water are a significant cultural issue. Some Māori communities also rely on non-reticulated water systems, making them vulnerable to drought and water contamination.

Exposure

Potable water supplies are exposed to drought, changes in mean annual rainfall, heavy rainfall, rising sea levels and salinity stress. Exposure can reduce water availability and quality.

Projections show that droughts will be more severe in most regions except Taranaki-Manawatu, West Coast and Southland. Droughts are likely to be more frequent and intense in already drought-prone areas (Ministry for the Environment, 2018).

While some areas will have less water available annually, others may experience a lack of water during times of need, or seasonally. Since 2014, the number of councils that have set water restrictions has ranged from 44 to 66 per cent annually (WaterNZ, 2015, 2016, 2017, 2018). This is a significant number and, without intervention, will likely increase. Recent droughts have caused significant, recorded decreases in water supplies around New Zealand. In 2010, Northland had the worst drought in 60 years, with record low rainfall causing significant water shortages for rural and urban populations (Northland Regional Council, 2011). Wellington also had a drought in 2013, when the region came close to running out of drinking water (Harrington et al, 2016). During the 2019–2020 summer, Northland had the driest summer on record, causing water shortages throughout the region, as well as in Waikato and Auckland (RNZ, 2020).

Heavy rainfall can lead to the contamination of water supplies that rely on freshwater rivers and lakes. In March 2017, Auckland had three short, intense rainstorms (the ‘Tasman Tempest’). These caused sedimentation of water reservoirs, which led to the contamination of a number of dams supplying Auckland’s water (Urich, Li and Burton, 2017).

New Zealand has nearly 150 mapped aquifers that provide roughly one-third of its daily supply. Many of these are located along the coast (Pattle Delamore Partners Ltd, 2011). As sea levels rise, coastal aquifers will become increasingly vulnerable to saltwater contamination. Salinisation of coastal aquifers is already occurring in Northland, Auckland, Waikato, Bay of Plenty, Taranaki, Wellington, Tasman, Marlborough, Canterbury and Dunedin (Pattle Delamore Partners Ltd, 2011). Salinity stress and wider groundwater changes will increase the pressure on water security, affecting both water availability and quality (Thorburn et al, 2013).

Sensitivity

Water supplies are sensitive to climate change impacts due to the design, condition and location of infrastructure as well as changes in water availability and demand.

Rising temperatures and drought can increase water demand, both average and peak, as people use more water outdoors. This exacerbates shortages from lower rainfall and higher evapotranspiration (LGNZ, 2019; Paulik et al, 2019a; Paulik et al, 2019b; Hendy et al, 2018; Thorburn et al, 2013). A number of towns in New Zealand do not have water meters or are only partially metered. Managing demand in these towns is therefore more difficult (WaterNZ, 2018). Higher temperatures and drought can also lead to algal blooms, which can contaminate drinking water sources (Ministry for the Environment, Stats NZ, 2020).

Water supplies are generally more sensitive where there is a single source of water, rather than several sources as in Auckland, which has access to dams in the Hunua and Waitākere Ranges, the Onehunga Aquifer and the Waikato River (Watercare, nd).

Rural water supplies are also sensitive to climate change hazards, particularly where reticulated systems are limited or absent (Woodward, Hales and de Wet, 2001). Rural and Māori communities, as well as communities with inadequate resources to import water or pay for private treatment facilities, will be more sensitive to increasing drought (Woodward, Hales and de Wet, 2001).

The potential for water insecurity to affect communities with social inequities or health issues adversely is not well understood in New Zealand. The inquiry into the Havelock North campylobacteriosis outbreak in 2016 illustrates this point, noting that: “unlike in areas where consumers can make their own assessment of risk, drinking water risks are effectively imposed on all consumers by suppliers. The consumer base will include many people who are vulnerable for various reasons, including old age, youth and those who are immunocompromised or suffering from ill health” (DIA, 2017).

Adaptive capacity

In terms of water availability, the adaptive capacity of systems will largely depend on the ability to maintain or enhance supplies and storage, and to manage and reduce per capita demand. Overseas experience has shown that demand can be reduced through interventions such as water efficiency, metering, pricing and behaviour change (Tortajada and Joshi, 2013).

In New Zealand, water is mostly supplied to cities and towns by local authorities (city or district councils), or in some cases, council-controlled organisations. As management of supply is fragmented, improvements in adaptive capacity may continue to be ad hoc around New

Zealand. However, central government is undertaking a Three Waters Review (DIA, 2018) and establishing a new regulatory body (to be called Taumata Arowai), to administer and enforce a new drinking-water regulatory system, including managing the risks to sources of drinking water. This may bring much-needed oversight and consistency in adapting to climate risks.

Adaptive capacity is considered lower in smaller communities where infrastructure is already under pressure due to low investment. Climate change will exacerbate these pressures. The cost to upgrade water and wastewater infrastructure to meet current drinking-water standards is estimated at \$8 billion (BECA, 2019; GHD et al, 2019).

Consequence

Given the importance of water supplies for communities and business, consequences from impaired supply can be significant, and could arise from a range of climate hazards.

The 'Tasman Tempest' (see above) affected water supply in Auckland and thousands of people across the city. It caused very poor, raw water quality, compromised treatment facilities, and reduced throughput. Watercare called for voluntary water savings of 20 litres per day for residential customers, and ran an engagement campaign with all large commercial users to inform them of issues and encourage voluntary reductions and contingency planning. Through these actions, severe commercial losses and impacts on public health were avoided.

Recent droughts have caused water shortages throughout Waikato, Auckland and Northland, resulting in numerous water reduction advisories and waiting lists for water tank refills of up to five weeks (RNZ, 2020). Water reductions are generally staged, with initial restrictions on public outdoor water use (eg, public parks, sports fields), followed by private outdoor use (eg, gardens) and finally more restrictions on residential and commercial use. The increasing restrictions will have corresponding levels of consequence for community health and wellbeing, and for business operations.

Droughts can also lead to more favourable conditions for algal blooms (influenced by high water temperatures, long residence times and high nutrient concentrations) and poorer water quality particularly in non-reticulated systems (van Vliet and Zwolsman, 2008), as well as in reticulated systems where treatment may be inadequate. This can in turn lead to significant health impacts. While not directly climate change related, the Havelock North event illustrates the potentially severe social consequences of water contamination (DIA, 2017).

Interacting risks

Changes in water availability from drought and lower rainfall will have consequences for all domains. They may contribute to a rise in diseases due to water-borne pathogens or a lack of hygiene (H3) (Hendy et al, 2018). More frequent watering bans and higher prices for water (or the imposition of water prices) and wide-scale shortages in drinking water could exacerbate inequities and create new ones (H2).

Increased human use may degrade rivers, lakes and streams (and associated ecosystems) (N3, N6). However, mitigating impacts on rivers, lakes and streams could also help to reduce the risks to potable water in some areas (N3, N6). The management of water resources could be further challenged by uncoordinated and inconsistent governance between and within levels and agencies of government and private property owners, and the possibility of maladaptive actions (G1, G2). Lower capacity of amenity spaces will compromise human health and wellbeing.

Confidence: High agreement, medium evidence

Overall, there is high agreement that climate change will impact urban and rural water security. There is strong evidence on hazard exposure to water systems. In general, there is strong evidence on the vulnerabilities to water security from climate change, but further research is required to understand community vulnerability to changes in water quality.

Adaptation

Adaptation is variable among the various councils and water supply authorities. Watercare has a climate change strategy, which includes a focus on climate resilience for its network. All authorities actively monitor water availability, demand and quality, and most have prepared demand management plans and drought management plans.

Table 22: B1 Risk to potable water supplies: Urgency profile

B1 Risk to potable water supplies: Urgency profile						
Urgency category	Proportion of urgency out of 100		Description of actions			
More action needed	70		Urgent action to best manage urban and rural water security now and in the near future, given this current and pressing risk.			
Research priority	30		Urgent research to fill the considerable knowledge gap on the impacts of drought on water supply, availability, quality and demand.			
Sustain current action						
Watching brief						
Adaptation urgency	93		Confidence	High agreement, medium evidence		
Consequence	Now	Major	2050	Extreme	2100	Extreme

B2 Risks to buildings due to extreme weather events, drought, increased fire weather and ongoing sea-level rise

Risk summary

Many buildings in New Zealand (both residential, non-residential and cultural heritage) are at risk from climate change, mainly from extreme weather events, drought, increased fire weather and rising sea levels. Buildings are also at risk from associated natural hazards like inland and coastal flooding, landslides, groundwater rise and wildfire, all of which are projected to become more frequent and severe.

These risks could cause temporary damage and destruction of buildings, and make it necessary for them to be relocated. The failure of urban drainage systems (due to capacities being exceeded), as well as the potential overtopping and breach of stopbanks and other flood defences, could also result in significant impacts to buildings. The increased risk from flood defence is poorly understood, but the consequences are likely to be significant.

There is limited ability to adapt buildings in a cost-effective manner, given that buildings are generally designed as permanent structures, served by complex infrastructure. Buildings with suspended timber floors are considered to have higher adaptive capacity than buildings with concrete floor slabs, as they can, in some cases, be relocated. Similarly, new buildings

can be located away from risk areas or be designed to accommodate projected changes to the climate.

For Māori, this risk may affect connectivity to [whenua](#), the foundation of [tūrangawaewae](#). This includes direct impacts of climate hazards and natural hazards on Māori land, communities and cultural buildings (including marae), along with impacts from adaptation responses such as relocating buildings (King, Penny and Severne, 2010; Smith et al, 2014; Stephenson et al, 2018). This poses a risk to the cultural functioning capacity of Māori. See risk H5 in [section 5.4.2](#) for more about risk to cultural assets.

Exposure

Buildings are exposed to inland flooding, sea-level rise (and associated groundwater rise), coastal flooding, extreme weather events, wildfires and drought. These events disrupt communities and temporarily or permanently damage buildings. The number of buildings exposed is projected to increase under RCP4.5 and RCP8.5 (see [Box 1](#)) with greater exposure under RCP8.5.

In New Zealand, many communities live on the coast where rising sea levels will exacerbate exposure of buildings to coastal flooding and erosion. At present, there are over 72,000 people and 49,700 buildings exposed to coastal flooding (Paulik et al, 2019b).⁸ For example, in 2015, 800 homes were flooded in South Dunedin from a high tide coinciding with extreme rainfall. This gave rise to over \$28 million in insurance claims (Insurance Council of New Zealand, 2017; Stephenson et al, 2018). Exposure of buildings to coastal flooding will increase this century under both RCP4.5 and RCP8.5. Under RCP8.5, at 2100, about 117,900 buildings would be exposed to coastal flooding (Paulik et al, 2019b).

Exposure to inland flooding is high at present, with about 675,000 people living in flood hazard areas and an estimated 411,500 buildings exposed (Paulik et al, 2019a).⁹ Overtopping and breaching of stopbanks and flood defences, and failure of pumped stormwater systems, are already resulting in exposure. For example, in April 2017, Cyclone Debbie hit the Bay of Plenty coast bringing rainfall and flooding of the Rangitaiki River. The aging Rangitaiki stopbank was breached, causing catastrophic flooding in Edgecumbe with \$72 million in insurance claims from damaged and destroyed housing (Rangitaiki River Scheme Review Panel, 2017; Stephenson et al, 2018). A full evacuation of Edgecumbe's 2000 residents was maintained for eight days (Stephenson et al, 2018). Communities protected by flood defences could be more exposed to increased flooding, as flood defence schemes have a finite design capacity and often no secondary stormwater systems. Future exposure of buildings is likely to increase under RCP4.5, with greater exposure projected under RCP8.5.

Extreme weather events (strong wind and heavy rainfall) currently affect buildings across New Zealand. The data on insurance payments shows the magnitude of loss from storms has increased over the past decade (Insurance Council of New Zealand, 2020). The future exposure

⁸ Paulik et al (2019b) undertook a high-level study on New Zealand's exposure to 1 per cent annual exceedance probability (AEP) coastal flood inundation under present-day and future higher sea levels.

⁹ Paulik et al (2019a) undertook a high-level study to enumerate New Zealand's asset exposure in inland (fluvial and pluvial) flood plains. In the absence of a national flood hazard map, exposed areas were identified by creating a 'composite' flood hazard area map from modelled and historic flood hazard maps and flood prone soil maps. The analysis provides a representative sample of built assets exposed in New Zealand's fluvial and pluvial floodplains. It is noted the analysis cannot be attributed to a particular return period flood event at the present time, nor in the future with climate change.

of buildings and people is likely to increase under both RCP4.5 and RCP8.5 (Ministry for the Environment, 2018).

Groundwater rise is poorly understood in New Zealand. However, it is recognised as an emerging issue in many coastal communities. For example, the suburb of South Dunedin (about 4800 homes) is known to have high groundwater levels, which are tidally influenced. These contribute to surface flooding after heavy rain, especially in winter when groundwater is naturally closer to the surface (Otago Regional Council, 2016).

Erosion, including landslides, is frequent in New Zealand. Climate change may accelerate erosion, through extreme rainfall and sea-level rise, resulting in increased exposure of buildings (Rosser et al, 2017; Basher et al, 2012). Rising sea levels may also expose buildings to soils with higher liquefaction susceptibility, due to rising groundwater in coastal plains and reclaimed areas (Ministry for the Environment, 2017c; Quilter et al, 2015). Drought may also increasingly affect expansive soils, which can dry and shrink (BRANZ, 2008).

New Zealand has a history of wildfires, and exposure is projected to increase (Pearce et al, 2018). Buildings will be exposed to wildfire through direct impacts on structures, and the characteristics of vegetation surrounding buildings. Under RCP4.5 and RCP8.5, it is likely this exposure, particularly in rural areas, will increase throughout this century (Pearce et al, 2018).

Sensitivity

Buildings around New Zealand are currently sensitive to coastal inundation, flooding, extreme weather events, fire weather, and soil changes and movements, such as liquefaction, landslides and soil shrinkage and swelling. Sensitivity to climate and natural hazards is driven by a range of factors, including the design, age and condition of buildings.

Our building stock is largely comprised of wooden and masonry houses, and houses with reinforced-concrete frames (Uma et al, 2008). The average age of residential dwellings is about 50 years (Jaques et al, 2015). Dwelling condition is directly related to age and therefore informs sensitivity to damage. Older buildings (including cultural heritage buildings) are likely to be more badly damaged (Buckett et al, 2010).

Many buildings in New Zealand are sensitive to floods, which can cause structural damage, particularly if the floods reach or exceed floor level (Reese and Ramsay, 2010). The degree of damage depends on various factors, the most important being the flood characteristics (depth, velocity, duration), and the type of building (including structure and material) (Reese and Ramsay, 2010).

Rising groundwater could also impact buildings, leading to the risk of rising damp and impaired stormwater drainage (Tauranga City Council, 2019). Buildings in areas of high groundwater may experience prolonged exposure to floodwaters, with worse damage.

Historically, extreme weather events have caused damage, disruption and financial cost throughout New Zealand (Cenek et al, 2019). While there is limited information in New Zealand on the sensitivity of buildings to wind and weather-related damages, a number of events have caused significant damage over the past decade (Cenek et al, 2019). For example, in April 2014, when ex-tropical cyclone Ita struck the West Coast of the South Island, more than 60 houses in Greymouth lost their roofs (Cenek et al, 2019).

Prolonged periods of extreme rain can also damage buildings through moisture penetration in walls and damp conditions indoors, which can, in turn, degrade interiors (Department of Building and Housing, 2006). This has been linked to health consequences for occupants

(Department of Building and Housing, 2006). Extreme wind can exacerbate the impact of rainfall on buildings by increasing moisture penetration and destroying buildings, including roofing being blown off, broken windows, and other flying debris (Department of Building and Housing, 2006).

Knowledge of stopbank design, age and condition (which informs sensitivity to flood damage) remains sparse across New Zealand. This is exacerbated by inconsistency between formal and informal stopbanks (Crawford-Flett et al, 2018), which reduces the effectiveness of monitoring and maintenance.

Many types of buildings are also sensitive to wildfires. The level of sensitivity depends on a number of factors, which include density per hectare of buildings, the size and shape of groups of buildings, the type and amount of vegetation nearby, the distance between structures, the width and layout of roads and reserves, the climate zone, and the materials used (Opie et al, 2014).

Buildings in New Zealand can also be sensitive to liquefaction, which, as shown by the Christchurch earthquake sequence, is driven by a range of factors including land characteristics (soil type), groundwater levels and building design (MBIE, 2017). Buildings are sensitive to landslides, which are caused by factors including rainfall, soil stability, structural building type (including foundations), and intensity of land development (Guillard-Goncalves et al, 2016; Lin et al, 2017). Buildings are also sensitive to drought-induced soil movements, which can cause certain types of soil to dry and shrink (Corti et al, 2011). As buildings shift and subside, this can result in structural damages to foundations and cracked walls and ceilings (Kovats and Osborn, 2016).

Adaptive capacity

Existing residential and commercial buildings inherently have low adaptive capacity. They are built as permanent structures, which are served by complex, centralised infrastructure that requires large capital and ongoing expenditure. Buildings with a concrete floor slab are harder to relocate and repair, and would have lower adaptive capacity than older buildings with a suspended timber floor.

New buildings and settlements can be built with a much higher adaptive capacity, tolerant of a wider range of climate and weather extremes; there are many good local and international examples of this. For example, the Urban Growth Partnership approach to spatial planning includes climate resilience, and protecting and enhancing the natural environment as a key objective. This is a partnership between central government agencies, local government and iwi and is focused on urban growth areas around New Zealand.

Improving adaptive capacity would require funding, which has financial implications for households, communities, local and central government. Further research is needed to determine how financial institutions and government authorities can support the financing of adaptation measures. Ultimately, enhancing adaptive capacity will require strong leadership, governance, funding mechanisms and community engagement.

Consequence

Climate change impacts on buildings will have economic, social, cultural and public health consequences. Major floods can put financial pressure on individuals and households, for instance by lowering house and land prices. This could be compounded by insurance retreat from high-risk areas.

For coastal communities – such as Haumoana, Granity, Waitara and Urenui, where homes are being undermined or swamped by wave action – the consequences will increase. Other low-lying settlements could also face growing social and economic impacts, including South Dunedin, Edgecumbe, Lower Hutt and Petone, which are already prone to major flooding (Stephenson et al, 2018). These consequences are far reaching across all domains.

The impact of flooding, sea-level rise and extreme weather on buildings could also result in loss of access to valued places, and in turn, impact physical and mental health, identity and sense of belonging (Stephenson et al, 2018). Many communities have social and economic vulnerabilities, including poor health, lack of social connections and financial distress. These can reduce the capacity of people and communities to recover from shocks, such as the damage from floods and extreme weather events. The consequences may become more severe over time (Stephenson et al, 2018).

Increased moisture in buildings due to extreme weather events and flooding could also lead to poor public health and a range of economic and social consequences. At present, mould is visible to some extent in an estimated half of all houses in New Zealand, with a slightly higher prevalence in rental properties (White et al, 2017a). Mould is a key indicator of indoor air quality and is potentially harmful to the health of household occupants (Chang-Richards et al, 2018).

The failure of flood management and protection schemes could also have extreme consequences, given the number of people living in areas with these schemes.

Interacting risks

There are interacting risks to buildings due to transport connections (B6) and essential community infrastructure (B1, B4, B8). The climate change impacts on these supporting services could directly affect the utility of buildings and the viability of communities.

The risks to buildings will also flow on to people, the economy and governance. The risk to residential housing could exacerbate existing inequities (H2) and result in impacts on social cohesion and community welfare (H1). Risks to buildings (B2) may also affect cultural heritage sites (H8).

Impacts on residential and non-residential buildings may cascade into the economy, such as public sector fiscal risks from growing financial burdens and unfunded contingent liabilities (E1), risks to financial system stability and economic development (E2), and to the insurance sector (E6). The exposure and sensitivity of buildings to climate hazards could be compounded by uncoordinated and inconsistent governance between and within levels and agencies of government and private property owners (G2). There could also be maladaptive actions, such as supporting property owners with adaptation in high-risk locations that could create moral hazard problems (G1). Finally, hardening coastal environments (eg, sea walls) to defend settlements against erosion and flooding can lead to coastal squeeze and impacts on coastal ecosystems (N1).

Confidence: High agreement, medium evidence

There is high agreement that buildings are exposed and sensitive to climate and natural hazards. Further research is required to understand the level of exposure of buildings, particularly those defended by flood schemes (including stopbanks). Overall, the research on sensitivity is robust, with considerable evidence in New Zealand and globally.

Adaptation

A number of initiatives are under way at the community, local government and central government levels to progress adaptation for buildings and broader settlements. Community (council-funded) coastal restoration projects are under way through Coast Care and the Coastal Restoration Trust of New Zealand, and the Ministry for the Environment is setting up community resilience groups to build resilience to flood risk. Regional councils monitor and manage flood protection schemes (including stopbanks), and many are actively assessing these in relation to climate change.

More broadly, most regional and district councils regularly plan for hazards. This includes mapping and monitoring flood risk, improving consent requirements for river and coastal flooding, and in some cases setting rules to allow for relocatable houses. Central government also has a number of planned and ongoing initiatives, including a project led by the Ministry of Business, Innovation and Employment (MBIE) to review the evidence on how the building regulations could support the Government’s climate change objectives. Heritage New Zealand Pouhere Taonga is also supporting marae communities with advice and specialist services to manage their own buildings and cultural practice.

Table 23: B2 Risks to buildings due to extreme weather events: Urgency profile

B2 Risks to buildings due to extreme weather events: Urgency profile						
Urgency category	Proportion of urgency out of 100		Description of actions			
More action needed	60		This is a current and pressing risk, affecting buildings in coastal and flood prone areas. It will increase with time and requires an urgent, joined-up and effective response across all levels of government.			
Research priority	40		Further knowledge is required on numerous hazards, including a nationally consistent approach to floods and associated exposure assessments.			
Sustain current action	0		Current actions are deemed adequate for a small subset of risks: fire weather and extreme weather events over the next five years.			
Watching brief						
Adaptation urgency	90		Confidence	High agreement, medium evidence		
Consequence	Now	Major	2050	Extreme	2100	Extreme

5.6.2 Other priority risks for the built environment domain

B3 Risks to landfills and contaminated sites, due to extreme weather events and ongoing sea-level rise

Active and closed landfills and contaminated sites across New Zealand are currently at risk from extreme weather events and sea-level rise, as well as coastal and inland flooding, erosion and rising groundwater.

Closed landfills are likely to be more exposed, as more recent landfills are sited in lower-risk areas (Ministry for the Environment, 2001). Landfills and contaminated sites can be sensitive to erosion, damage and contaminant washout from flooding and extreme weather events. Site failure can cause pollutants to mobilise, with potentially cascading consequences for public health, ecosystems and the economy.

Although modern landfills are subject to strict resource consent conditions and monitoring to reduce the risk of failures, there is a limited understanding of the location and characteristics (including design, extent, type of waste) of closed landfills. The adaptive capacity of landfills and contaminated sites are likely to vary around New Zealand due to gaps in the understanding of sites, and different regional funding availability.

For Māori, the potential for landfill damage to contaminate mahinga kai (food-gathering areas) and affect taonga species is likely to have consequences for cultural practices.

Risks to landfills and contaminated sites are moderate at present and will likely increase.

B4 Risk to wastewater and stormwater systems (and levels of service), due to extreme weather events and ongoing sea-level rise

Wastewater and stormwater infrastructure is currently at risk from extreme weather events (including heavy rainfall), ongoing sea-level rise and drought. Other risks include inland and coastal flooding, coastal erosion and rising groundwater, all of which are projected to become more frequent and severe due to climate change.

Impacts could include more wastewater overflows to waterways and harbours, reduced service levels for stormwater networks due to higher rainfall, and urban pollutants entering downstream environments. Coastal flooding and erosion are a direct risk to nearby infrastructure, such as low-gradient pipes and wastewater treatment plants. These impacts will likely affect both urban and rural settlements throughout New Zealand.

The adaptive capacity of wastewater and stormwater systems varies, based on factors such as funding, age and the condition of infrastructure. Typically, for large wastewater treatment plants it is relatively low, whereas for networks it is higher. In New Zealand, a range of climate-resilient approaches for networks are considered best practice. Many councils and water authorities are aware of these, and some have started using them.

For Māori, water is seen as the essence of all life, and the potential for these impacts (such as contamination) to reduce mauri (life force) of waterbodies is likely to be of concern.

B5 Risks to ports and associated infrastructure, due to extreme weather events and ongoing sea-level rise

Our ports are currently at low risk from extreme weather events and ongoing sea-level rise. However, these risks are likely to increase – in particular, from coastal flooding, strong winds and extreme weather events, which could damage port infrastructure and impact the operational capability of ports. Associated infrastructure, such as petroleum storage in coastal areas, could also be at risk.

Exposure varies according to factors such as geographic setting, wharf heights, tidal ranges, channel depths, and operating ranges for cranes and machinery. Sensitivity is also driven by operational characteristics, and the design, condition and age of structures, buildings and equipment. Internationally, there is a good understanding of the general sensitivity of ports, but there is limited detailed knowledge about New Zealand ports. Adaptive capacity will vary considerably, and depends on factors such as port design, road and rail access, management and governance, and funding for adaptation.

B6 Risks to linear transport networks, due to changes in temperature, extreme weather events and ongoing sea-level rise

New Zealand's road and rail networks, or 'linear transport networks', are presently at risk from increases in temperature, extreme weather events, drought and sea-level rise. They are also at risk from inland and coastal flooding, coastal erosion, landslides and groundwater rise, all projected to become more frequent and severe.

Road and rail networks move people and goods across New Zealand, and provide access to critical (lifeline) utilities such as airports, ports, and power or water infrastructure. Climate change could cause temporary disruption, temporary or permanent damage, and necessitate relocation from at-risk locations.

Adapting infrastructure in a cost-effective manner is hampered by the design constraints of roads and rail. For instance, they are generally fixed, have long design lives and provide essential services that are costly to interrupt. However, new infrastructure can be located away from risk areas or designed to accommodate projected changes to the climate.

Given the location of Māori communities in coastal regions and near rivers, access roads to marae are often exposed to flooding, coastal processes and landslides. There could be more frequent damage to the transport network, cutting off marae and wider Māori communities.

B7 Risk to airports, due to changes in temperature, wind, extreme weather events and ongoing sea-level rise

Our airports are at risk due to projected changes in temperature, wind, extreme weather events and sea levels. Other hazards include inland and coastal flooding, and coastal erosion. Airports are a vital link during business-as-usual and emergencies, and are defined and listed as lifeline utilities in Schedule 1 of the Civil Defence Emergency Management Act 2002.

Climate change could damage airport infrastructure and assets, and extreme weather and flooding could compromise their operation. Increased hot days could also affect aircraft take-off and damage runways. The networked nature of airports to surrounding infrastructure such as access roads and other airports, domestically and internationally, increases the potential for cascading impacts. This heightens the consequences for New Zealand.

The adaptive capacity of airports varies – some have invested in plans to address key risks. For others, a lack of finance is a major hurdle and will limit adaptive capacity.

B8 Risks to electricity infrastructure, due to changes in temperature, rainfall, snow, extreme weather events, wind and increased fire weather

Climate change presents a range of risks for New Zealand's electricity infrastructure. These mainly relate to changes in temperature, rainfall, snow, extreme weather events, wind and fire weather. Other hazards include inland and coastal flooding. For generation infrastructure, present-day risks are low, with limited changes projected.

Our heavy reliance on renewable electricity sources (particularly hydro-electricity and wind) exposes us to climate variability. Climate change could also affect demand for electricity due to higher cooling demand in summer, and lower heating demand in winter. Transmission and distribution infrastructure is currently at risk of disruption and damage from climate hazards, including extreme weather and fire weather, and this risk will increase. If not well managed, the risks to electricity transmission and distribution infrastructure could compromise energy security.

Electricity generation in New Zealand has moderate adaptive capacity, given that the national grid has diverse sources. A number of electricity generation companies are actively assessing, modelling and planning for risks from climate change. Transmission and distribution infrastructure have lower adaptive capacity, given that many networks are already operating at capacity.

5.7 Governance domain | Rohe kāwanatanga

Table 24: Governance domain

Governance		
Most significant risks	Ratings	
	Urgency	Consequence
G1 Risk of maladaptation across all domains due to the application of practices, processes and tools that do not account for uncertainty and change over long timeframes.	83*	Extreme**
G2 Risk that climate change impacts across all domains will be exacerbated because current institutional arrangements are not fit for climate change adaptation. Institutional arrangements include legislative and decision-making frameworks, coordination within and across levels of government and funding mechanisms.	80	Extreme
Other priority risks (Stage 2)		
G3 Risks to governments and businesses from climate change-related litigation, due to inadequate or mistimed climate change adaptation.	78	Extreme
G4 Risk of a breach of Treaty obligations from a failure to engage adequately with and protect current and future generations of Māori from the impacts of climate change.	75	Major
G5 Risk of delayed adaptation and maladaptation due to knowledge gaps resulting from under-investment in climate adaptation research and capacity building.	75	Major
G6 Risks to the ability of the emergency management system to respond to an increasing frequency and scale of compounding and cascading climate change impacts in New Zealand and the Pacific region.	70	Major
G7 Risk that effective climate change adaptation policy will not be implemented and sustained due to a failure to secure sufficient parliamentary agreement.	68	Extreme
G8 Risk to the ability of democratic institutions to follow due democratic decision-making processes under pressure from an increasing frequency and scale of compounding and cascading climate change impacts.	53	Major

* Urgency rating: the adaptation and decision urgency rating for this risk.

**Consequence rating: the highest consequence rating for this risk out of all three periods (now, 2050, 2100). The [technical report](#) provides the consequence rating for each risk and period.

5.7.1 Most significant risks

G1 Risk of maladaptation across all domains, due to the application of practices, processes and tools that do not account for uncertainty and change over long timeframes

Risk summary

Climate change adds to the uncertainties that decision-makers already face (Beck, 2009; Scoones, 2019; Weitzman, 2011). Reliance on practices that embed processes and tools, which do not account for long-term uncertainty and change, will increase the likelihood of maladaptation across all domains.

Risk description

An action is maladaptive when it has a high opportunity cost, reduces incentives to adapt, disproportionality burdens the most vulnerable, forecloses other adaptation options in the future, or increases greenhouse gas emissions (Barnett and O'Neill, 2010).

Accounting for uncertainty

The future contains inherent uncertainty. Uncertainty, or a state of incomplete knowledge, arises from many sources, such as imprecise data, inexact methodology and conceptual ambiguity. Uncertainties about climate change stem from unknowable socio-demographic, technological and economic trends that will influence greenhouse gas concentrations in the future, and the sensitivity of climatic systems to these. Such uncertainties affect the rate and magnitude of the impacts of climate change that are knowable. Generally, the further we project into the future, the greater that uncertainty will be.

Failure to account for uncertainty in decision-making increases the likelihood that an action will be maladaptive.

Decision-makers need to act even when there is significant uncertainty. For example, we are confident the frequency and intensity of heavy rainfall events will increase, but we do not know how frequent or how intense they will be, or exactly when these conditions will occur.

Flexible planning and design

We are also confident of the rate and magnitude of sea-level rise out to 2050 but, beyond that, the certainty range is wider (see [section 4](#)). Planners and engineers are making decisions about the location and design of infrastructure and housing that will be in place for more than 100 years, within which climate change impacts will worsen (Lawrence et al, 2016). If decision-makers do not provide for uncertainties when locating and designing such developments, these structures will be increasingly exposed to floods and incur high damage costs. On the other hand, if they plan and design for the most extreme events, they may incur the opportunity cost of not being able to use the land, or over-designed infrastructure that is costly and becomes redundant. Either way there can be maladaptation. This implies that tools and processes are needed to inform flexible planning and design of infrastructure that can be changed and shifted before there is any damage (Mastrandrea and Luers, 2012).

Risks from using static measures

Government decision-making frameworks and well-established practices in disciplines including law, economics, engineering and planning continue to rely on static assumptions of risk and historical parameters of climatic conditions (Lawrence et al, 2013; Lawrence and Manning, 2012; Lawrence, Bell and Stroombergen, 2019; Weitzman, 2011). For example, using single flood standards (eg, a 1 in 100-year event) to plan land use and design infrastructure results in decisions that are inflexible to changing flood risk (Lawrence et al, 2013). These measures can also create a false sense of security for those just outside the zones (Lawrence et al, 2013).

Other static measures, such as minimum flood levels that are used routinely in planning, also create a false sense of security in the face of rising sea levels, increasing heavy rainfall and coastal storms. White (2019) argues dominant practices and cultures that overwhelmingly focus on data, modelling and certainty discourage new or alternative approaches to urban planning that may better support liveability or sustainability.

Inflexible interventions

It is widely recognised decision-makers must move beyond such approaches, particularly for flood risk, drought and coastal management (Kundzewicz et al, 2008; CCATWG, 2017, 2018; Lawrence and Haasnoot, 2017; Lawrence et al, 2019; Gersonius et al, 2012). Zeitoun et al (2016) similarly affirm that prevailing approaches to water security do not consider uncertainty, diversity and politics in society and therefore limit policymakers to rigid and inflexible interventions that may reproduce inequalities. In New Zealand, the use of cost-benefit analysis disproportionality burdens more vulnerable residents. The reliance on this method to prioritise flood protection has led to faster implementation in higher socio-economic areas, as higher land and asset values generate higher benefit-cost ratios (Manning, Lawrence, King and Chapman, 2015).

Decision-making tools

There are various processes and tools for adaptation decision-making under conditions of uncertainty. Examples include Robust Decision Making (Dittrich, Wreford and Moran, 2016), Real Options Analysis (Buurman and Babovic, 2016), and Dynamic Adaptive Pathways Planning (Haasnoot et al, 2013; Lawrence and Haasnoot, 2017; Lawrence et al, 2019). These are in use in a growing number of locations in New Zealand, including Hutt River (Greater Wellington Regional Council, 2015), Hawke's Bay (Daysh, 2018) and Petone (Kool, 2020) but wider uptake has generally been slow (Lawrence and Manning, 2012; Lawrence, Bell and Stroombergen, 2019). This is due to factors such as resourcing for capacity building and engagement, and caution about using new processes in settings that 'demand' certainty (Lawrence and Haasnoot, 2017; White, 2019).

The national *Coastal Hazards and Climate Change Guidance* (Ministry for the Environment, 2017b) sets out how to use some of these processes and tools, including Dynamic Adaptive Pathways Planning. Case studies such as Corbett and Bendall (2019) demonstrate practical application in New Zealand. A critique by Lawrence, Bell and Stroombergen (2019) and a practice brief (Lawrence et al, 2019) also share lessons for mainstreaming these processes and tools. However, further guidance is needed to address the constraints of planning processes and improve understanding of the dynamic nature of climate change impacts (Lawrence et al, 2018).

Consequence

Using processes and tools that characterise risks as static, and rely on historical parameters that do not account for uncertainty and changing risks, increases the risk of maladaptation. Maladaptation may limit the choices for future generations, increase the vulnerability of other systems, sectors, or groups to climate change, and increase the costs of climate change. It may also disproportionately burden New Zealand’s most vulnerable people and communities and entrench socio-economic inequity. The consequences are most likely to be borne by future generations.

Confidence: High agreement, robust evidence

There is a high degree of agreement and robust evidence that proactive, adaptation-orientated decision-making tools and processes that better account for uncertainty need to be mainstreamed, because of the ongoing, changing risks from climate change.

Adaptation

Efforts are occurring at the local government level with support from the Ministry for the Environment. These include National Science Challenges (Resilience to Nature’s Challenges and the Deep South National Science Challenge). Methods include Dynamic Adaptive Pathways Planning, coastal adaptation and associated vulnerability and economic assessment methodology and engagement, and local government pilot projects under the Government’s Community Resilience Group. The planned national adaptation plan (NAP) will take a more comprehensive cross-government approach to climate risk.

Table 25: G1 Risk of maladaptation across all domains: Urgency profile

G1 Risk of maladaptation across all domains: Urgency profile						
Urgency category	Proportion of urgency out of 100		Description of actions			
More action needed	60		Urgent action to enable the uptake of proactive adaptation tools and processes to address changing climate risks across all domains.			
Research priority	20		Catalysing action requires understanding how tools are used (and misused), and the barriers to uptake.			
Sustain current action	10		Appropriate tools are starting to be used. This needs to be sustained to build critical mass across agencies.			
Watching brief	10		Responsible agencies should monitor barriers to uptake, using nationally consistent criteria and principles.			
Adaptation urgency	83		Confidence	High agreement, robust evidence		
Consequence	Now	Major	2050	Extreme	2100	Extreme

G2 Risk that climate change impacts across all domains will be exacerbated because current institutional arrangements are not fit for climate change adaptation. Institutional arrangements include legislative and decision-making frameworks, coordination within and across levels of government and funding mechanisms

Risk summary

Adapting to the diverse impacts of climate change at different scales requires statutory and policy alignment, coordination across levels of government and with sectors, and significant ongoing funding (CCATWG, 2018). The absence of these factors has repeatedly been identified

as a barrier to effective adaptation (Boston and Lawrence, 2018; Hanna et al, 2018; Lawrence et al, 2015).

If national and local governments fail to plan and invest in risk reduction and effective adaptation initiatives, the economic, social and cultural costs of climate change will be higher (Boston and Lawrence, 2018). Adaptive capacity in all domains is likely to be challenged unless relevant statutes are strongly aligned, and actors and funding mechanisms are coordinated.

Risk description

The Climate Change Adaptation Technical Working Group (2018) recommended several actions to the Government. These include:

- establishing governance arrangements that support long-term adaptation action (Action 5)
- reviewing existing legislation and policy to integrate and align climate change adaptation considerations (Action 7)
- defining funding arrangements for climate change adaptation (Action 16).

Although Action 5 has been partially implemented through this NCCRA, local government mandates linked to the national governance arrangements and the other critical recommendations have yet to be actioned. In a review of the current arrangements for adaptation in New Zealand, Boston and Lawrence (2018) conclude existing institutional and funding arrangements are not fit for purpose, and cannot ensure sound anticipatory governance and equitable outcomes. The authors note that: “[w]ithout appropriate reforms, existing policy frameworks are destined to increase rather than reduce risk exposure, exacerbate future adaptation costs, and contribute to multiple inequities. In the interests of sound anticipatory governance, a better framework is required” (Boston and Lawrence, 2018, p44).

Statutory and policy alignment

New Zealand’s numerous laws and policies contain inconsistencies and competing objectives related to climate change adaptation (Blackett and Hume, 2011; Lawrence et al, 2018). For example, the Housing Accords and Special Housing Areas Act 2013 puts housing supply ahead of natural hazard provisions, increasing the risk of locating new housing in unsuitable areas. Lawrence and Manning (2012) also note misalignment between various acts, such as the Soil Conservation and Rivers Control Act (which has a focus on protection works that give rise to static responses), and the Resource Management Act 1991 (which has a precautionary focus), and the default to the Buildings Act in the absence of regional or district rules, can result in short-term decisions that exacerbate risk.

At the national level, many sectors operate within regulatory frameworks and policies that are not well aligned with climate change adaptation (CCATWG 2018). In addition, local council functions relating to climate change impacts are spread across different statutes. These functions include managing floods, water and stormwater, land use, emergencies and assets including infrastructure (Manning et al, 2015).

Coordination

To be effective, adaptation requires coordination across different levels of government, regions, technical and disciplinary areas, administrative boundaries, and between government and non-governmental institutions (Lawrence et al, 2018).

New Zealand's national institutional framework centres on the Resource Management Act, influences adaptation practice and, with the Local Government Act, determines the relationships between national, regional and district government. However, these two statutes do not clearly mandate climate change risk management or adaptation, nor the coordination of roles, responsibilities and actions across levels of government. The NCCRA framework empowers local government to make decisions on land use, natural hazard management, infrastructure and urban development (Lawrence et al, 2013) and allows for central government to provide consistent overarching directions and guidance through national policy statements and national environmental standards (Lawrence et al, 2012).

This coordination architecture is currently under-used due to lack of clarity (Lawrence et al, 2012; CCATWG, 2018), leaving each local council to design their responses. This increases the exposure of decisions to challenge in the courts, which may delay action (G3) (Lawrence et al, 2013). It also leads to inefficient resourcing and a poor understanding of climate change risks among decision-makers and community members (Lawrence et al, 2013).

Funding

There are currently no dedicated funds for adaptation to reduce exposure to climate change-related risks. However, there is funding for recovery from hazard events, including the Natural Disaster Fund and the Adverse Events Fund for the primary production sector (Boston and Lawrence, 2018). Re-allocating funding towards risk reduction would be more cost efficient (Deloitte Access Economics, 2013).

Significant and ongoing funding is required to implement adaptation actions. Some of the most pressing needs in New Zealand relate to the impacts of sea-level rise, which includes rising groundwater and salinisation, erosion and more damaging storm surges (B2). One metre of sea-level rise from the present day, which may be experienced by 2100 under RCP8.5 H⁺ (see [table 7](#)), will expose more than 49,000 buildings to a 100-year, extreme sea-level flood. These buildings have a replacement value of about \$12.4 billion (Paulik et al, 2020). Where managed retreat is the only option, significant investment will be required to support these communities.

Other areas where adaptation funding is either limited or absent include:

- **Compensation:** Governments are likely to face litigation (G3) seeking compensation for loss or damage due to climate change, or conversely due to the loss of existing use rights due to adaptation measures (Grace et al, 2019; Winkelmann et al, 2019).
- **Research:** There is a critical under-investment in research to support adaptation (G5) relating to biophysical and ecological changes, biosecurity, changes in the hydrological cycle influencing fluvial and pluvial flooding, and the implications of climate change on human systems such as the economy, health and health services (CCATWG, 2018).
- **Developing new and future-proofing existing infrastructure:** Investment will be required to redesign, reposition and future-proof public infrastructure (B2), especially transport networks (B6) and three waters services (B1, B4) (Boston and Lawrence et al, 2018).
- **Building capacity:** Adopting new tools and processes (G1) for decision-making in the context of uncertainty requires organisational change and capacity building at all levels of government.
- **Participation and engagement:** Extended engagement is necessary to create a shared understanding of climate change risks, and to avoid breaching the Treaty of Waitangi obligations (G4). Engagement is currently constrained by lack of resourcing (Stephenson et al, 2019).

- **Mātauranga Māori:** Indigenous knowledge is critical in developing culturally appropriate adaptation responses. Funding is required to make effective use of [mātauranga Māori](#) in adaptation.
- **Protecting taonga and the natural environment:** New Zealand’s unique ecosystems and biodiversity are poorly understood (Reisinger, Kitching et al, 2014). They are under stress from changing and intensive land use, pollution and pressures from tourism.

Funding will depend in part on bipartisan political agreement on climate change adaptation (G7) and will drive New Zealand’s fiscal capacity and economic position (E1).

Consequence

The impacts of climate change will be greater if policy and legislation remain unaligned, actors are not coordinated, and funding for adaptation remains limited. Failure to plan and invest in anticipatory risk reduction and effective adaptation initiatives will increase the risk of maladaptation, expose governments to litigation risk, decrease trust in government, and increase the likelihood of inequitable distribution of harm.

Confidence: High agreement, robust evidence

There is a high degree of agreement and robust evidence that New Zealand’s current institutional framework hinders effective adaptation efforts.

Adaptation

Adaptation efforts related to coordination within and across levels of government, alignment of statutes and adaptation finance are being partly addressed through the Climate Change (Zero Carbon) Response Act, the current review of the Resource Management Act, and the Government’s Community Resilience Group work programme. Some local councils are developing adaptation plans and working together at a regional level to coordinate adaptation efforts. The planned NAP will take a cross-government approach to address climate risk in a comprehensive manner.

Table 26: G2 Risk that climate change impacts across all domains will be exacerbated: Urgency profile

G2 Risk that climate change impacts across all domains will be exacerbated: Urgency profile			
Urgency category	Proportion of urgency out of 100	Description of actions	
More action needed	60	Lack of coordination across levels of government raises the risk of maladaptation and inaction. Align statutes and funding arrangements to reduce risk and provide the mechanisms for all levels of government to adapt.	
Research priority	10	Focused research is needed to inform adaptation action, including research into staged retreat, developing local decision triggers, and legal issues around compensation and existing use rights.	
Sustain current action	20	Current and planned measures detailed above to continue and accelerate.	
Watching brief	10	Ongoing monitoring and evaluation of all levels of government to determine if institutional arrangements are improving.	
Adaptation urgency	80	Confidence	High agreement, robust evidence

Consequence	Now	Major	2050	Extreme	2100	Extreme
-------------	-----	-------	------	---------	------	---------

5.7.2 Other priority risks for the governance domain

G3 Risks to governments and businesses from climate change-related litigation, due to inadequate or mistimed climate change adaptation

Governments and businesses face potential legal liability due to climate change. Plaintiffs may turn to the courts to seek compensation for loss due to inadequate climate change action. Governments could be liable for a range of matters including failing to adapt public infrastructure, planning decisions that increase exposure to coastal hazards, and failing to reduce greenhouse gas emissions (Iorns, 2019; Iorns, James and Stuart, 2017).

The private sector may face litigation for failing to take action and for damages from historical greenhouse gas emissions. The threat of litigation against governments who are taking actions to adapt is also, perversely, delaying adaptation (Manning et al, 2015; Lawrence et al, 2015). If litigation results in delays to adaptation, it is likely to increase the costs of climate change, thereby exposing the Government and businesses to further liability.

G4 Risk of a breach of Treaty obligations from a failure to engage adequately with and protect current and future generations of Māori from the impacts of climate change

The principles of the Treaty of Waitangi, namely partnership, participation and protection, could be breached due to failure to protect current and future generations of Māori from climate change impacts. Claims relating to climate change already sit with the Waitangi Tribunal, which has determined that climate change is a Treaty issue because of the need to prevent harm to Māori coastal property (Iorns, 2019). Treaty obligations may also be breached if specific consideration is not given to protecting Māori assets, meaningful engagement and involvement of Māori, and using *mātauranga Māori* in adaptation (Iorns, 2019).

G5 Risk of delayed adaptation and maladaptation, due to knowledge gaps resulting from under-investment in climate adaptation research and capacity building

Under-investment in research and capacity building to inform understanding of climate change risks and impacts is undermining New Zealand's ability to develop evidence-based adaptation policy. Critical research gaps relate to: atmospheric processes, hydrological cycle impacts, ecosystem responses, biodiversity and biosecurity, rural and urban communities, the economic costs of climate change, impacts on the primary sector and on heritage, effects on health and health services, use of *mātauranga Māori* to inform adaptation, cascading impacts, and how to govern adaptation at multiple scales. These gaps are a critical barrier to informed decision-making and while they remain, maladaptive actions are a key risk.

G6 Risks to the ability of the emergency management system to respond to an increasing frequency and scale of compounding and cascading climate change impacts in New Zealand and the Pacific region

Climate change will increase the frequency, severity and spatial extent of natural hazard events and create new hazards needing emergency responses. This increased demand for emergency management services may be compounded by damaged infrastructure critical to the delivery of these services. Infrastructure can be affected by extreme events such as

floods, fires or landslides as well as gradual, ongoing impacts like sea-level rise and coastal inundation, which degrade infrastructure. The cascading effects could also lead to coordination challenges including lack of clarity about responsibility for risk management.

G7 Risk that effective climate change adaptation policy will not be implemented and sustained, due to a failure to secure sufficient parliamentary agreement

To minimise future damages from climate change, the Government will need to take pre-emptive and sustained action. A strong political mandate and commitment by successive governments to adaptation is necessary. The structure of New Zealand's political system, together with an economy characterised by dominant sectors that have politicised climate change, have hindered meaningful action on both reducing emissions and adapting to climate change. The recent passing of the Climate Change Response (Zero Carbon) Act 2019 with bipartisan support is a positive development. An ongoing spirit of bipartisanship will be critical for necessary climate action.

G8 Risk to the ability of democratic institutions to follow due democratic decision-making processes under pressure from an increasing frequency and scale of compounding and cascading climate change impacts

Much of the discourse about climate change has focused on the potential impacts on natural systems, physical infrastructure, human wellbeing and economies. However, it may also pose a risk to democratic decision-making, particularly after an intense, unanticipated extreme event. The risks to due process from urgent responses to extreme events are likely to increase as hazards increase in frequency, intensity and spatial scale.

5.8 Opportunities

The NCCRA defines climate change opportunities as the potential for positive or beneficial consequences resulting from changes in climate. Some opportunities may arise in New Zealand, yet they are likely to come with risks as these are driven by the same climate variables. Furthermore, acting on perceived opportunities without fully assessing all the associated risks could result in maladaptation. For example, there could be opportunities for tourism because of drier and warmer conditions. However, realising these opportunities may place greater pressure on ecosystems already stressed by climate change. This could inadvertently increase the vulnerability of both the natural environment and the tourism sector if not carefully considered and managed.

Few opportunities were identified through the research and consultation for this NCCRA. Given this, those outlined below do not include all opportunities arising from climate change in New Zealand. Limitations to information and analysis of these opportunities in terms of risk indicate a potential research priority to inform future NCCRAs (see [section 7.2](#)). Opportunities identified for New Zealand include those for the primary sector, businesses, health and household energy.

5.8.1 EO1 Increased primary sector productivity due to warmer temperatures

Initial benefits to agriculture and forestry are predicted in the western and southern part of New Zealand and close to major rivers, due to a longer growing season, less frost and higher rainfall. Opportunities identified by NIWA (2019) include:

- **Kiwifruit:** Warmer summer temperatures are likely make more areas of the South Island suitable for cultivation. This is likely to be offset by some areas becoming less productive.
- **Apples:** likely to flower and reach maturity earlier, with increased size, especially after 2050.
- **Grapes:** Central Otago is currently the southern margin for cool-climate wine production. Wine grapes in this region will benefit greatly from warmer, drier conditions (MPI, 2010).
- **Horticulture:** New species may become viable.
- **Plantation forestry:** Growth rates (mainly *Pinus radiata*) are likely to increase due to higher CO₂ levels and wetter conditions in the south and west of New Zealand. Warmer temperatures can also stimulate decomposition of soil organic matter and mineralise more nitrogen to further boost the nutritional status of trees (Watts et al, 2008). However, fast-growing timber can reduce timber strength.
- **Pasture:** Seasonal pasture growth may increase under some scenarios and in some areas. Seasonal average growth rates show consistent, large increases in winter and spring, as expected with warmer conditions and an extended growing season.
- **Fisheries:** Increase in primary productivity in shallower surface layers is likely in southern New Zealand waters.

Productivity yields may increase for certain species due to more optimal growing environments. Higher average temperatures are associated with faster maturation, leading to an earlier harvest. Higher CO₂ concentrations will increase crop growth rates (Reisinger, Mullan, Manning, Wratt and Nottage, 2010).

However, these scenarios assume a system where nutrients and water supply are not limited, and do not consider complicating factors such as pests, extreme events and competition for dwindling resources (Wreford, Moran and Adger, 2010). Increased crop yields would result in an increased demand for water, creating a greater reliance on irrigation systems. A change in mean average temperature may also allow for the extension of existing species range and the introduction of new types of crops, although, as noted for kiwifruit, this may be offset by some areas becoming less productive. There may also be an opportunity for diversification into new areas and/or species of mahinga kai (food provisioning).

Table 27: EO1: Opportunity urgency profile

EO1: Opportunity urgency profile			
Urgency category	Proportion of urgency out of 100	Description of actions	
More action needed	60	A regulatory framework and guidance will be required to ensure that autonomous adaptations are not maladaptive.	
Research priority	20	Support research on how to underpin private sector autonomous adaptation.	
Sustain current action	0		
Watching brief	20	Watch and monitor.	
Adaptation urgency	80	Confidence	Medium agreement, medium evidence

5.8.2 EO2 Businesses providing adaptation-related goods and services

Climate change is widely recognised as a significant risk to economic activity and businesses. As discussed in Risk E1, climate change could reduce global GDP by trillions of dollars and average global incomes by a quarter (Channell et al, 2015). However, as with any disruptive

force, some businesses will benefit from new markets and opportunities. This includes opportunities to provide adaptation-related goods and services, known as autonomous adaptations, for example, insurance, adaptation finance, farming technologies, and consulting and engineering. The finance sector may also be able to develop new products and expand existing ones, such as green bonds, into the adaptation space.

Table 28: E02: Opportunity urgency profile

E02: Opportunity urgency profile			
Urgency category	Proportion of urgency out of 100	Description of actions	
More action needed	60	A regulatory framework and guidance will be required to ensure that autonomous adaptations are not maladaptive.	
Research priority	20	Support research that explores how autonomous adaptation can deliver co-benefits for emissions reduction.	
Sustain current action	0		
Watching brief	20	Watch and monitor	
Adaptation urgency	80	Confidence	Medium agreement, medium evidence

5.8.3 HO1 Lower cold weather-related mortality

In New Zealand, about 1600 more deaths occur in winter than in summer (Davie et al, 2007). New Zealand homes are, on average, colder than the World Health Organization’s recommended minimum of 18°C. Data for housing in Wellington in 2015, for example, show the mean indoor temperature was around 15°C (Rangiwhetu et al, 2018). Many factors influence mortality rates, including temperature, influenza, household crowding, moisture levels and the thermal performance of buildings (Davie et al, 2007). Rising temperatures may reduce winter mortality rates due to the effect on indoor temperatures, crowding and moisture levels. However, they could affect health in other ways that offset this benefit. There is very little research available to confirm this opportunity.

Table 29:

HO1: Opportunity urgency profile			
Urgency category	Proportion of urgency out of 100	Description of actions	
More action needed	0		
Research priority	10	Understand how cold combines with and exacerbates other factors (eg, damp) to increase winter deaths, to identify how to reduce such incidents.	
Sustain current action	60	Sustain home insulation and heating subsidy programmes and minimum insulation standards in residential rental properties.	
Watching brief	30	Watch and monitor	
Adaptation urgency	45	Confidence	Medium agreement, medium evidence

5.8.4 BO1 Lower winter heating demand

Households in New Zealand typically use about 15 per cent of their energy on space heating and 27 per cent on water heating (Electricity Authority 2018). Energy use in New Zealand

is significantly higher in winter (June to August) (Electricity Authority 2018). About a quarter of New Zealand households are estimated to be in fuel poverty (Howden-Chapman et al, 2012). Average indoor temperatures are cold by international standards and occupants regularly report that they are cold because they cannot afford to heat their houses (Howden-Chapman et al, 2012).

Fuel poverty is a factor in our higher winter rates of mortality (16 per cent) and hospitalisation (8 per cent). Warmer winters and fewer frosts could reduce demand for winter heating. This lowers costs and stress for those who cannot afford electricity (Ministry for the Environment, 2017c). However, these effects are complex to predict because non-climatic factors, such as future energy policy, energy prices and housing quality, are also important. Further, gains in energy efficiency and positive impacts on household incomes may be short-lived and could be offset by increased demand for air conditioning in summer. There is very little research available to confirm this opportunity.

Table 30: BO1: Opportunity urgency profile

BO1: Opportunity urgency profile			
Urgency category	Proportion of urgency out of 100	Description of actions	
More action needed	40	Improve housing quality for better public health and potential reductions in heating cost – eg, insulation could have dual benefits for winter heating and summer cooling.	
Research priority	20	Research is required to understand the potential benefits from warmer winters, risks from overheating in summer, and how to adapt housing stock.	
Sustain current action	0		
Watching brief	40	Watch and monitor	
Adaptation urgency	65	Confidence	Medium agreement, low evidence

6 Case studies: cascading impacts and socio-economic projections

Although the NCCRA provides a national overview of the risks and opportunities from climate change, it does not robustly consider cascading impacts, interdependencies and future socio-economic projections (see [section 2.3.2](#)). However, the two case studies in this section illustrate the importance of these matters for subsequent assessments. Each study focuses on one risk identified in the NCCRA:

- Cascading impacts and interdependencies focuses on Priority Risk B4: Risk to wastewater and stormwater systems (and levels of service), due to extreme weather events and ongoing sea-level rise ([Box 4](#)).
- Socio-economic factors focuses on Priority Risk H2: Risks of exacerbating existing inequities and creating new and additional inequities, due to differential distribution of climate change impacts ([Box 5](#)).

Box 4: Case study: Cascading impacts and interdependencies

What is a cascading impact?

The NCCRA framework describes cascading impacts as a chain of events “where a primary threat is followed by a dynamic sequence of secondary hazards”. For example, floods can badly damage roads, and compromise electricity grids and potable water supply. Damage could disrupt tourism and supply chains, with flow-on to other value domains. Similarly, a rise in groundwater levels can cause household dampness and mould, unstable road foundations and increased liquefaction potential, with a cumulative effect on many domains and sectors (Ministry for the Environment, 2017c).

Why are cascading impacts relevant to the NCCRA?

Applying the concept of cascading impacts to climate change is still in its infancy. So too is the understanding of how impacts will cascade through domains and subsystems (Adger et al, 2009; Eakin et al, 2009; Lawrence et al, 2016).

Cascading impacts challenge traditional risk assessment, which tends to consider each risk in isolation. However, the NCCRA value domains are interlinked – impacts on one could flow on to others.

Cascades may create feedback loops that compound the impacts over time. This raises the prospect of catastrophic risks (Clarke et al, 2018), with implications for adaptation planning and preparedness. Framing risks as cascading can help clarify and address these feedback loops. Literature on teleconnections, where impacts in one location affect another at some distance, shows that impacts will be wider than expected (Adger et al, 2009; Eakin et al, 2009; Liu et al, 2013; Moser and Hart, 2015).

Cascading impacts from risks to wastewater and stormwater systems (Risk B4)

Figure 10: Cascading systems loop – Risks to wastewater and stormwater systems (rainfall only) (Risk B4)

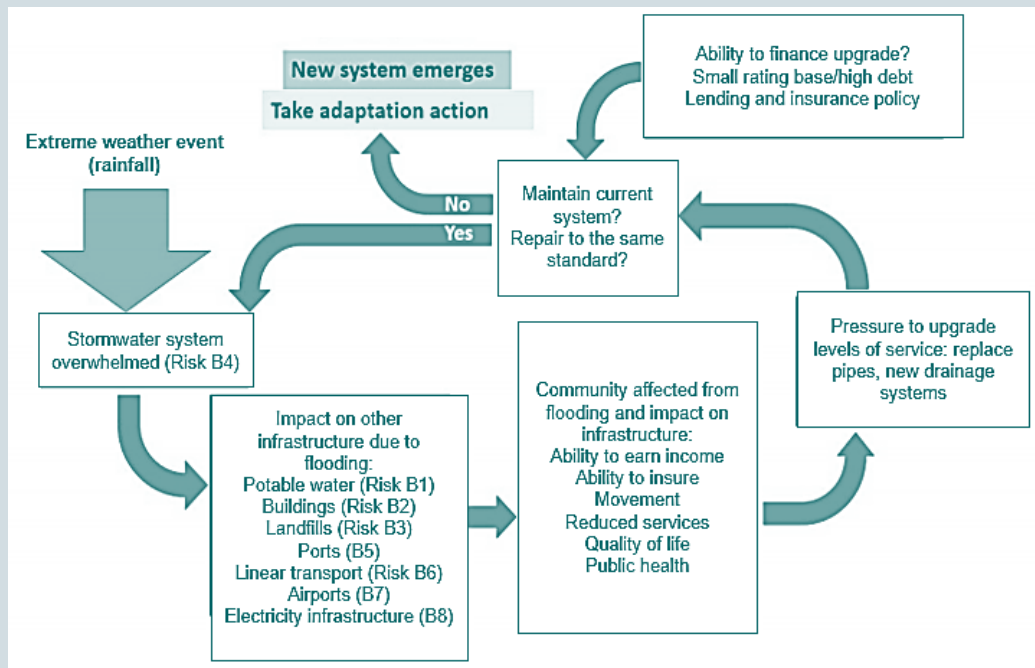


Figure 10 shows the flow-on effects when extreme rainfall overwhelms stormwater systems. It is based on cascading system diagrams developed by Lawrence et al (2018).

Cascading effects could include frustration in the community from repeat flooding, the disruption and cost of evacuations, and increased pressure to take adaptation action. Appropriate and timely action depends on adequate local government funding, which might include cost sharing with communities, the Government and the private sector.

The cascade is not likely to end with a single circuit, because of the increasing frequency of extreme rainfall events. Rather, each event will trigger the same set of impacts until either an adaptive action occurs, and a new system emerges, or the community has to live with a stormwater system that is overwhelmed more often. Over time, the more frequent the failure, the greater the impacts on the community. The impacts and implications cascade across different domains and intensify over time.

Implications for future NCCRAS

Using cascades as scenarios can support a more holistic understanding of the consequences of climate risks, for example through:

- identifying the links between domains, and between climate change variables and hazards
- a richer assessment of the risks than via traditional methods
- ‘stress-testing’ of risk assumptions.

This will foster the design of adaptation responses that are flexible yet robust under different future conditions. The challenge of assessing cascading risks has been acknowledged by other NCCRAS, including the *United States Fourth National Climate Change Risk Assessment*, which concludes that “characterizing the nature of such interactions and building the capacity to model them are important research challenges” (Clarke et al 2018). Future NCCRAS could consider new approaches that facilitate this.

Box 5: Case study: Socio-economic trends and projections

Why are socio-economic factors relevant to the NCCRA?

Socio-economic factors, such as economic growth, population and demographics, could influence future vulnerability. Even in the absence of climate change, they could alter levels of risk to many of the hazards in this NCCRA. For example, changing land use has increased flood risk (Warren et al, 2016).

Since the exact future socio-economic pathway cannot be known, it is necessary to use scenarios of plausible futures. The socio-economic variables typically considered in other NCCRAs are population, GDP and land-use change. There is currently limited experience applying socio-economic scenarios to understand climate change impacts in New Zealand (Warren et al, 2016).

Socio-economic factors in Risk H2 (page 60): Exacerbating inequities and creating new ones

The effects of climate change are not spread evenly across the population. Access to resources to meet individual, family and community wants and needs is already unequal. Some groups are marginalised, with poorer social outcomes (eg, in health, employment, and access to education or welfare and support services). Climate change is likely to exacerbate these inequities, and generate new ones.

Islam and Winkel (2017) identify three channels for the higher impact of climate change on the disadvantaged: greater exposure to the adverse effects; higher sensitivity to damage; and less ability to cope and recover. Each channel is influenced by socio-economic factors.

Exposure of disadvantaged groups to adverse effects

Most of New Zealand's main centres are on the coast or on the floodplains of major rivers. The population is expected to further concentrate in cities. By 2050, 40 per cent of people will live in Auckland (30 per cent currently). Other cities, including Wellington, are also expected to grow. Forecast population growth for Wellington in the next 25 years is 1.9 per cent per annum (Wellington City Council, 2016). By 2050, the working age population will need to support almost double the number of people aged over 65 (LGNZ, 2016). The aging population in main centres is likely to increase significantly over the next few decades, increasing their exposure to impacts such as sea-level rise and coastal flooding (Royal Society of New Zealand, 2014).

Increase in disadvantaged groups' sensitivity to damage

Given the same level of exposure, disadvantaged groups are generally more sensitive to damage from climate hazards (Islam and Winkel, 2017). Unsurprisingly, both the young and elderly are more sensitive. New Zealand's population is ageing and the ethnic composition is also changing, with an increase in the proportion of Māori, Pacific and Asian ethnic groups (Smeith and Dunstan, 2004). Māori are among the most vulnerable to climate change, given their particular reliance on the environment as a cultural, social and economic resource (Ministry for the Environment, 2018).

Decrease in disadvantaged groups' ability to cope and recover

Inequality implies fewer resources for disadvantaged groups to undertake coping and recovery measures. New Zealand is moving away from '9 to 5' permanent employment. One-third of workers are not in salaried, full-time jobs. This includes part-time, contracting and multiple jobs. One benefit is that jobs are more flexible (for example, for those raising children). However, research suggests around half of those in temporary work are not doing so out of choice (LGNZ, 2016). The impact of the Covid-19 pandemic on casual workers reflects the heightened exposure and risk.

Automation is also changing the nature of work and could lead to structural changes in employment. It has been suggested that 46 per cent of New Zealand jobs are at high risk of automation before 2050 (LGNZ, 2016). The jobs of the future do not appear to be like many of the jobs of the past. Such trends could reduce resources for households and communities, in turn reducing their ability to cope and recover from damage. This broadens the inequalities New Zealand could face, compounded by climate impacts.

Implications of socio-economic factors

Interactions between climate, socio-economic drivers and other environmental pressures are likely to shift the vulnerability landscape. For some groups, vulnerability may continue and they are likely to form a larger part of the population, such as the elderly. Much of our knowledge originates from research on events (eg, storms or floods) where risk factors have already shaped property values, exposing those with fewer economic means to greater hazards. However, ongoing change and cascading impacts are very likely to create new groups of vulnerable people.

Implications for future NCCRAs

Future NCCRAs should consider how socio-economic factors might influence climate change risk. This could include identifying trends that could affect risks, and comparing the contribution of socio-economic projections with other factors. As socio-economic change is uncertain, the literature and other NCCRAs commonly use scenarios to explore how these trends influence risks.

Shared Socio-economic Pathways (SSPs) have been developed globally (eg, Arnell and Lloyd-Hughes 2014; Hasegawa et al, 2015; O'Neill et al, 2015), and for New Zealand (Frame and Reisinger, 2016). SSPs have been applied in New Zealand (Frame et al, 2018; Lawrence et al, 2018; Craddock-Henry et al, 2018) and used to develop and test adaptive tools (Lawrence et al, 2018). SSPs were found to be a practical tool for impact and vulnerability assessments because they include assumptions about how socio-economic change may help or hinder the ability to mitigate or adapt to climate change.

7 Uncertainty and gaps

7.1 Risk and uncertainty

The future climate is inherently uncertain, with the level of uncertainty increasing further into the future. Uncertainty, or a state of incomplete knowledge, arises from many sources including data, methodology, conceptual ambiguity, and the unknowable physical processes; and socio-demographic, technological and economic trends that influence future greenhouse gas concentrations, and the sensitivity of climatic systems to these concentrations.

Uncertainty in the results of this risk assessment does not mean that impacts are less likely to occur, but rather that understanding of their timing, extent or consequences is imprecise. There are likely to be additional risks we are not yet aware of due to limitations in our knowledge and understanding (see [section 7.2](#)).

More is known about some risks than others. For example, based on scientific and geospatial information, reasonably robust predictions can be made about the impacts of rising sea levels on coastal assets. Much less is known about the response of species or ecosystems to pronounced changes in climatic conditions. Similarly, the complexity of social-ecological systems, including the thresholds at which they fundamentally change or cease to function, makes it difficult to predict how climate change risks will flow and change across domains, geographies and time periods.

The NCCRA process was designed to gather a wide range of information on climate risks and opportunities for New Zealand. Although constrained by time, the NCCRA is based on an extensive review of the literature and expert judgements by many subject matter specialists, engaging broadly with stakeholders and Māori/iwi. However, as with all assessments, there is potential for findings to be weighted towards the knowledge and expertise of those involved.

It is also not possible to assess accurately how uncertainty has propagated through the NCCRA analysis. The uncertainties could compound in unexpected ways. For example, there is uncertainty about the climate science, future socio-economic scenarios, global and national policy settings – such as those that govern emissions reduction – and the exposure, sensitivity and adaptive capacity of elements at risk. Each of these will propagate through the analysis in complex ways that cannot be identified in this first NCCRA.

A confidence rating is provided for all risks assessed. The rating follows the *Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties* (Mastrandrea et al, 2010). Based on this guidance, the NCCRA uses two metrics for communicating the degree of certainty in key findings: confidence in the validity of a finding based on available literature, and on expert agreement. For more on this rating, see the [method report](#).

7.2 Gaps in knowledge

The NCCRA has identified a number of knowledge, information and data gaps that should be examined to better understand and address the priority risks and opportunities. The sections below outline these critical gaps, which will need to be addressed to inform the next NCCRA in 2024.

7.2.1 Opportunity-based gaps

As noted in [section 5.8](#), very few opportunities were identified through the research and consultation for this NCCRA, and they are not well researched or understood. Acting on these perceived opportunities without fully assessing the implications could result in maladaptation. Further research into the opportunities is a clear priority.

7.2.2 Domain-based gaps

Gaps were identified as part of the literature reviews for Stages 1 and 2 of the assessment, and through engagement to support these stages. Specific gaps were identified in each domain as part of the detailed risk and opportunity assessment – see table 31 below, grouped by domain but not prioritised. Figure 8 also indicates specific risks with the highest research needs to support adaptation. Further information on such gaps is in the [technical report](#).

Table 31: Domain-based knowledge gaps

Domain	Gaps
Natural environment	<ul style="list-style-type: none"> • Current understanding of how New Zealand’s indigenous ecosystems and species will respond to climate change is very limited, reflecting a long-standing shortfall in research funding for understanding or predicting climate change impacts. The potential for interactions between the effects of climate change and other human-induced pressures has been explored in recent workshops and review articles (Macinnis-Ng et al, nd). • Monitoring and detecting change in the distributions of indigenous species in response to climate change is frequently constrained by New Zealand’s lack of a single, easily accessible repository for distribution data (eg, as in the Atlas of Living Australia). Storage of critical data is uncoordinated, with access often constrained by the competitive model under which New Zealand’s research organisations are funded and run. • Research is required into the distributions and resilience of carbonate-dependent species, including those important for aquaculture or ecosystems. • Research is required to develop understanding of the effects of climate change on ocean dynamics and productivity, and flow-on effects on ecosystem composition and species distributions.
Human	<ul style="list-style-type: none"> • Associated processes such as the spread of diseases, and how quality and access to resources will affect people’s physical health, is poorly understood across New Zealand. • Social vulnerabilities and their relationship with climate change impacts require further exploration. There are two aspects. First, how climate hazards will affect already vulnerable groups, such as Māori. Specific risks to Māori social, cultural, spiritual and economic wellbeing from the loss and degradation of lands and waters, and loss and degradation of species and biodiversity, are relatively unknown. Second, what new vulnerabilities and inequities could emerge. • There has been limited exploration of how climate change could affect social cohesion and community connectedness, place attachment and self-identify. • There is very limited research on the sensitivity of cultural heritage sites, including Māori cultural heritage, to climate change. Further research is required to understand where sites are and how they could be affected.
Economy	<ul style="list-style-type: none"> • It is unclear how climate change may flow into and through New Zealand’s financial system. In particular, the economic costs of inaction at the national and regional scales, and across sectors are unquantified (Climate Change Adaptation Technical Working Group, 2018). • There is limited research into supply chain disruption due to climate change in a New Zealand context.

Domain	Gaps
	<ul style="list-style-type: none"> • There is limited evidence of how climate change will impact on the banking and insurance sectors. There is a research gap around the quality of housing stock and its exposure to insurance sector retreat. There is no consistent data collection system across New Zealand on this retreat. • The fisheries sector suffers from a lack of research, particularly into vulnerability of whole ecosystems and taxa-specific species.
Built environment	<ul style="list-style-type: none"> • A lack of consistent hazard information at a national scale, such as flooding from rivers and surface water, results in a knowledge gap for hazard exposure. This is particularly prevalent when looking to understand scenarios and timeframes. • Further understanding of interdependencies and interactions between infrastructure sectors and shared risk appreciation across sectors would strengthen risk management and adaptation. • Research is required to understand the locations of landfills and the associated risk across New Zealand. • Little is known about climate change risks, including interdependencies and cascading impacts, to our ports.
Governance	<ul style="list-style-type: none"> • Understanding how decision-support tools are used (and misused) and barriers to best practice uptake requires more research to ensure high-quality, coordinated decision-making across New Zealand. • A coordinated, comprehensive research platform to inform effective adaptation is missing and needs to be prioritised to ensure research is accessible. • An understanding of the dependencies and feedback loops across all domains, locations and timescales would benefit climate risk management adaptation (Lawrence, Blackett et al, 2018; Lawrence, Blackett and Cradock-Henry, 2020). • Investigating socio-cultural, technological and disciplinary barriers to transformational adaptation across multiple scales would facilitate faster, system-wide change (Reisinger, Kitching et al, 2014). • As outlined in the case study in section 6, it is unclear how cascading consequences will affect governance, social and ecological systems (Lawrence, Blackett et al, 2018; Lawrence, Blackett and Cradock-Henry, 2020). • Further clarification is needed on how land and water users will be affected by compounding risks, for more effective policy (Climate Change Adaptation Technical Working Group, 2018). If the exposure of these users is misunderstood, this will reduce the effectiveness of any policy.

7.2.3 Mātauranga Māori-based gaps

Mātauranga Māori plays an important role in informing risk assessments, adaptation and adaptive capacity, not just for climate-sensitive Māori communities but for all of New Zealand. New Zealand has many diverse groups and communities, each with their own values, beliefs and priorities. When assessing risk, this presents a challenge to integrate the complexities and uncertainties of all groups.

As a knowledge system, mātauranga Māori provides a framework for an integrated, holistic approach to understanding the impacts of climate change. Importantly, it identifies ways to adapt and prepare for change, and to change practices to reduce negative impacts.

Mātauranga Māori has a regenerative philosophy, one that presents a greater opportunity for long-term responses to engage meaningfully with iwi and hapū. A suite of literature supports this philosophy. These explore ways in which incorporating an indigenous cultural perspective into scientific methodologies can inform risk assessment. The NAP could capture this.

Mātauranga Māori encompasses all aspects of knowledge, including philosophy, beliefs, language, methods, technology and practice (Harmsworth and Awatere, 2014). While mātauranga can be widely held, mātauranga Māori is often held at a local level and can be considered sacred or specific to an iwi, hapū or whānau. Such knowledge can be gifted or shared and must be treated with the same level of respect by those who receive it. Mātauranga Māori has also evolved from being wisdom not only of the past, but also of contemporary forms (new approaches using traditional knowledge), representing the dynamic and evolving nature of Māori worldviews and culture.

Matters for consideration and concern raised at the hui during the NCCRA's engagement included:

- The current NCCRA framework, which was developed by the Ministry for the Environment, is not part of a Māori framework and therefore the relationship between the domains, their risks, and mātauranga Māori is unclear. Mātauranga Māori provides a holistic framework for viewing the world. The linear and reductive framework required by risk assessment methodology makes it difficult to bring these two frameworks together. In some instances, this restricted the ability for participants to frame Māori risks for integration into the wider framework.
- Mātauranga Māori (or more specifically the knowledge held by a particular Māori group) includes information held sacred to a particular iwi/hapū, as well as information that could be made available by an iwi/hapū to others. However, the appropriate timing for sharing this information, who should share it (eg, the [kaumātua](#), [pākeke](#), [rangatahi](#) or those with mandate), and how to share it (ie, the appropriate forum) is not always clear. There were differing views at the hui in this regard.
- Some participants noted that mātauranga Māori should form the basis of understanding te ao Māori (the Māori worldview), specifically at a local iwi/hapū level. This raised the tension between achieving a pan-Māori perspective on national risks for New Zealand, versus regional and local perspectives on more local climate risks and opportunities.
- There was general consensus that investment in more discussion about Māori concepts could unlock a way forward for Māori on climate change, and that mātauranga Māori is a key component that would drive such an approach. This discussion should be led by Māori at the iwi/hapū level, with the Crown as a partner.

It was widely acknowledged a longer timeframe would be required to bring mātauranga Māori into future NCCRAs and to inform the NAP.

8 Next steps

The Climate Change Response (Zero Carbon) Amendment Act 2019 (the Act) required preparation of this NCCRA no later than one year after the start of the Act (November 2019). The NCCRA has a critical role to play in providing the best available evidence and assessment to decision-makers, to support a planned approach to climate change risks and opportunities.

The Act requires the preparation of a risk assessment at least every six years. Future NCCRAs will be carried out by the Climate Change Commission. This assessment lays the groundwork for the next by documenting the assessment and engagement method in detail, and providing the Government with the tools (spreadsheets and engagement materials) as well as raw data and records of engagement. The Government and the Commission have the option of building on this information and consultation. The research priorities and other information/data gaps highlighted here will need to be addressed as soon as possible if they are to inform the next NCCRA in 2024.

The Act requires the Minister for Climate Change to prepare a national adaptation plan (NAP) in response to this NCCRA. The plan will be prepared by the Minister with input from Māori/iwi, local government, key stakeholders and the general public. It will:

- define the Government's objectives for adapting to climate change, and how it will meet these
- respond to the priority risks, opportunities and gaps set out in this risk assessment.

Work is already under way to prepare for the NAP, which will be published before mid-2022. The Climate Change Commission will monitor its implementation, and report to the Minister every two years on its effectiveness.

References

- Adger W N, Brooks N, Bentham G and Agnew M. (2004). *New indicators of vulnerability and adaptive capacity. Final Project Report*. Tindall Centre for Climate Change, Research University of East Anglia, Norwich, January.
- Adger N W, Dessai S, Goulden M, Hulme M, Lorenzoni I, Nelson D R ... Wreford A. (2009). Are there social limits to adaptation to climate change? *Climatic Change*, 93, 335–354.
- Aglietta M and Espange E. (2016). *Climate and finance systemic risks, more than an analogy? The Climate fragility hypothesis*. CEPII Working Paper.
- Aikman H, Davis A, Miskelly C, O'Connor S and Taylor G. (2001). *Chatham Islands threatened birds: recovery and management plans*. Department of Conservation.
- Arnell N W, Lloyd-Hughes B. (2014) The global-scale impacts of climate change on water resources and flooding under new climate and socio-economic scenarios. *Climatic Change* 122, 127–140.
- Auckland Council. (2019). *Auckland Regional Pest Management Plan 2019–2020*. Auckland Council. Retrieved from <https://www.aucklandcouncil.govt.nz/have-your-say/topics-you-can-have-your-say-on/regional-pest-management-plan/Documents/auckland-regional-pest-management-plan-2019-2029.pdf>
- Ausseil A G E, Van der Weerden T J, Beare M H, Texeira E, Baisden T, Loeffering M, Guo J, Keller E, Law R and Noble A. (2019). *Climate impacts on land use suitability*. Report produced for Deep South National Science Challenge Contract Report LC3573. Manaaki Whenua – Landcare Research.
- Barnett J and O'Neill S (2010). Maladaptation. *Global environmental change—Human and policy dimensions*, 20, 211–213.
- Basher L, Elliot S, Hughes A, Tait A, Page M, Rosser B, Jones H. (2012). *Impacts of climate change on erosion and erosion control methods – A critical review*. Ministry of Primary Industries. Retrieved from <https://www.mpi.govt.nz/dmsdocument/4074-impacts-of-climate-change-on-erosion-and-erosion-control-methods-a-critical-review-final-report>
- Basnet C, Childerhouse P, Foulds L R and Martin V. (2006). Sustaining supply chain management in New Zealand. *International Journal of Logistics Systems and Management* 2(3): 217–229.
- Batten S, Sowerbutts R, Tanaka M (2016). *Let's talk about the weather: The impact of climate change on central banks*. Bank of England Staff Working Paper 603.
- BECA. (2019). *Additional analysis for drinking water costs for compliance*.
- Beck U. (2009). *World Risk Society and Manufactured Uncertainties*. Firenze University Press.
- Bellingham P J, Towns D R, Cameron E K, Davis J J, Wardle D A, Wilmshurst J M and Mulder C P. (2010). New Zealand island restoration: seabirds, predators and the importance of history. *New Zealand Journal of Ecology*, 34(1), 115–136.
- Bendall S. (2018). *Report of the Northern and Southern Cell Assessment Panels*. Hawke's Bay Regional Council. Retrieved from <https://www.hbcoast.co.nz/assets/Document-Library/Assessment-Panel-Report-FINAL-28.2.18-reduced-size.pdf>
- Berry H L, Bowen K and Kjellstrom T. (2010). Climate change and mental health: A causal pathways framework. *International Journal of Public Health*, 55(2), 123–132.
- Berry H L and Welsh J A. (2010). Social capital and health in Australia: An overview from the household, income and labour dynamics in Australia survey. *Social Science and Medicine*, 70(4), 588–596.
- Blackett P and Hume T M. (2011). *Governance issues with respect to coastal erosion management in New Zealand* (Issue November).
- Boege V. (2018). *Climate change and conflict in oceania: Challenges, responses and suggestions for a policy-relevant research agenda*. Toda Peace Institute.

- Boston J. (2016). Anticipatory Governance: how well is New Zealand safeguarding the future? *Policy Quarterly*, 12(3), 11–24.
- Boston J and Lawrence J. (2018). Funding Climate Change Adaptation: the case for a new policy framework. *Policy Quarterly*, 14(2), 40–49.
- Boyd P W and Law C S. (2011). *An ocean climate change atlas for New Zealand water*. NIWA.
- Brander K. (2010). Impacts of climate change on fisheries. *Journal of Marine Systems*.
- BRANZ. (2008). *Soil expansivity in the Auckland Region*. Addendum study report No 120A.
- Buckett N R, Jones M S and Marston N. (2010). *House condition survey report – Condition comparison by tenure*. BRANZ Study Report 264.
- Business Continuity Institute. (2019). *BCI supply chain resilience report 2018*. Retrieved from: <https://www.thebci.org/uploads/assets/uploaded/c50072bf-df5c-4c98-a5e1876aafb15bd0.pdf>
- Buurman J and Babovic V. (2016). Adaptation Pathways and Real Options Analysis: An approach to deep uncertainty in climate change adaptation policies. *Policy and Society*, 35(2), 137–150.
- Campbell J R. (2019). *Climate Change, migration and land in Oceania*. Toda Peace Institute.
- Campiglio E, Dafermos Y, Monnin P, Ryan-Collins J, Schotten G and Tanaka M. (2018). *Climate change challenges for central banks and financial regulators*. *Nature Climate Change*, 8, 462–468.
- Cann K F, Thomas D R, Salmon R L, Wyn-Jones A P and Kay D. (2013). Extreme water-related weather events and waterborne disease. *Epidemiology and Infection*, 141(4), 671–686.
- Carlman I. (2005). The rule of sustainability and planning adaptivity. *Ambio*, 34.
- Cenek P, Turner R, Flay R, Pirooz A S, Jamieson N and Carpenter P. (2019). *Tools and knowledge to improve New Zealand’s long-term resilience to wind storms: final research report*. WSP OPUS.
- Champion P D. (2018). Knowledge to action on aquatic invasive species: Island biosecurity – the New Zealand and South Pacific story. *Management of Biological Invasions*, 9(4), 383–394.
- Chan K K, Grunbaum D, Arnberg M and Dupont S. (2016). Impacts of ocean acidification on survival, growth and swimming behaviours differ between larval urchins and brittlestars. *ICES Journal of Marine Science*, 73(3), 951–961.
- Chang-Richards A, I-Kai Wang K and Fakhruddin B. (2018). *Climate, housing and health profiling: Promoting housing quality to improve health and wellbeing*. University of Auckland. Retrieved from <https://cdn.auckland.ac.nz/assets/auckland/arts/our-research/research-institutes-centres-groups/ppi/policy-briefings/climate-housing-and-health-profiling.pdf>
- Channell J, Curmi E, Nguyen P, Prior E, Syme A R, Jansen H R, Rahbari E, Morse E L, Kleinman S M and Kruger T. (2015). *Energy Darwinism II: Why a low carbon future doesn't have to cost the Earth*. Citi GPS: Global Perspectives and Solutions August 2015.
- Chapman R. (2015). *Time of useful consciousness: Acting urgently on climate change*. In *Time of useful consciousness: Acting urgently on climate change*. Bridget Williams Books.
- Clarke L L, Nichols R, Vallario M, Hejazi J, Horing A C, Janetos K, Mach M, Mastrandrea M, Orr B L, Preston P, Reed R D, Sands and White D D. (2018) Sector Interactions, Multiple Stressors and Complex Systems. In *Impacts, risks and adaptation in the United States: Fourth National Climate Assessment, Volume II* [D R Reidmiller, C W Avery, D R Easterling, K E Kunkel, K L M Lewis, T K Maycock and B C Stewart (eds)]. US Global Change Research Program, Washington, DC, USA.
- Climate Change Adaptation Technical Working Group [CCATWG]. (2017, December). *Adapting to Climate Change in New Zealand: Stocktake Report from the Climate Change Adaptation Technical Working Group*. Ministry for the Environment. <https://www.mfe.govt.nz/publications/climate-change/adapting-climate-change-new-zealand-stocktake-report-climate-change>
- Climate Change Adaptation Technical Working Group [CCATWG]. (2018). *Adapting to Climate Change in New Zealand: Recommendations from the Climate Change Adaptation Technical Working Group*.

- Cohen L and Frazzini A. (2008). Economic links and predictable returns, *Journal of Finance*, 63(4), 1977–2011.
- Committee on Climate Change (2016). *UK Climate Change Risk Assessment 2017 Synthesis Report*. www.theccc.org.uk/uk-climate-change-risk-assessment-2017/synthesis-report/
- Corbett E and Bendall S. (2019). Clifton to Tangoio Coastal Hazards Strategy 2120, Hawke’s Bay, New Zealand. In: *Responding to rising seas: OECD country approaches to tackling coastal risks*, Chapter 6, p137–154, OECD Publishing, Paris.
- Cornwall C E and Hurd C L. (2016). Experimental design in ocean acidification research: problems and solutions. *ICES Journal of Marine Science*, 73(3), 572–581.
- Corti T, Wüest M, Bresch D and Seneviratne S. (2011). Drought-induced building damages from simulations at regional scale. *Natural Hazards and Earth System Sciences*, 11, 3335–3342.
- Cradock-Henry N A. (2017). New Zealand kiwifruit growers’ vulnerability to climate and other stressors. *Reg Environ Change*, 17, 245–259.
- Cram F. (2017). Kaupapa Māori health research. In P Liamputtong (Ed.), *Handbook of research methods in health and social sciences*. Singapore: Springer.
- Crawford-Flett K, Blake D, Pascoal E and Wallace T. (2018). *New Zealand Stopbank Networks: Understanding Resiliency Challenges*. Retrieved from <https://ir.canterbury.ac.nz/handle/10092/15991>
- Cross E L, Peck L S, Lamare M D and Harper E M. (2016). No ocean acidification effects on shell growth and repair in the New Zealand brachiopod *Calloria inconspicua*. *ICES Journal of Marine Science*, 73(3), 920–926. <https://doi.org/10.1093/icesjms/fsv031>
- Cunsolo A and Ellis N. (2018). Ecological grief as a mental health response to climate change-related loss. *Nature Climate Change*, 8.
- Cutter S L and Finch C. (2008) Temporal and spatial changes in social vulnerability to natural hazards. *PNAS* 7(105): 2301–2306. <https://doi:10.1073/pnas.0710375105>
- Dafermos Y, Nikolaidi M and Galanis G. (2018). Climate Change, Financial Stability and Monetary Policy, *Ecological Economics*, 152, 219–234.
- Daysh M. (2018). *Report of the northern and southern cell assessment panels. Final Report, Clifton to Tangoio Coastal Hazards Strategy 2120*.
- Davie G S, Baker M G, Hales S and Carlin J B. (2007). Trends and determinants of excess winter mortality in New Zealand: 1980 to 2000. *BMC Public Health*, 7(263).
- Deep South Challenge. (2017, October). *New Zealand’s water systems particularly vulnerable to climate change*. Retrieved from Deep South National Science Challenge: <https://www.deepsouthchallenge.co.nz/news-updates/new-zealands-water-systems-particularly-vulnerable-climate-change>
- Deloitte Access Economics. (2013). *Building our nation’s resilience to natural disasters*.
- Department of Building and Housing. (2006). *External moisture – An introduction to weathertightness design principles*. Wellington: Department of Building and Housing.
- Department of Conservation. (2019). *Protecting taonga species*. Retrieved from Department of Conservation.
- Department of Conservation. (2020). *New Zealand biodiversity – a hotspot*. Retrieved from Department of Conservation: <https://www.doc.govt.nz/nature/biodiversity/nz-biodiversity-strategy-and-action-plan/new-zealand-biodiversity-action-plan/new-zealand--a-biodiversity-hotspot/>
- Department of Conservation. (nd). *Pests and threats*. Retrieved March 25, 2020, from Department of Conservation | Te Papa Atawhai: <https://www.doc.govt.nz/nature/pests-and-threats/>
- Department of Internal Affairs [DIA.] (2017). *Report of the Havelock North Drinking Water Enquiry: Phase 2*. Department of Internal Affairs.

- Department of Internal Affairs [DIA.] (2018). *Three Waters Review*.
- Derraik J G B and Slaney D. (2007). Anthropogenic environmental change, mosquito-borne diseases and human health in New Zealand. *EcoHealth*, 4(1), 72–81.
- Dittrich R, Wreford A and Moran D. (2016). A survey of decision-making approaches for climate change adaptation: Are robust methods the way forward? *Ecological Economics*, 122, 79–89.
- Domanski D and Zabai A. (2016). Wealth inequality and monetary policy. *BIS Quarterly Review*, March, 45–64.
- Eakin H, Winkels A and Sendzimir J. (2009). Nested vulnerability: exploring cross-scale linkages and vulnerability teleconnections in Mexican and Vietnamese coffee systems. *Environmental Science and Policy*, 12, 398–412.
- Electricity Authority. (2018). *High-level implications of climate change on electricity security of supply*.
- Ellis L. (2018). *How should the risks of sea-level rise be shared?* Discussion document for Deep South National Science Challenge, NIWA, Wellington.
- Enarson E. (2007). Chapter 13: Identifying and addressing social vulnerabilities. In W L Waugh and K Tierney (eds), *Emergency Management: Principles and practices for local government* (2nd Ed). Washington DC: ICMA Press, pp 257–278.
- Espiner S and Becken S. (2014). Tourist towns on the edge: conceptualising vulnerability and resilience in a protected area tourism system. *Journal of Sustainable Tourism*, 22(4), 646–665.
- Fankhauser S and Tol R S J (2005). On climate change and economic growth, *Resource and Energy Economics* 27:1–17.
- Fisher, B. (2011). Climate change and human security in Tuvalu. *Global Change, Peace and Security*, 23(3), 293–313.
- Forestry New Zealand. (2020). *Indigenous (native) forestry*. Retrieved from Ministry for Primary Industries: <https://www.mpi.govt.nz/growing-and-harvesting/forestry/indigenous-forestry/>
- Fothergill A, Maestras E and Darlington J. (1999). Race, ethnicity and disasters in the United States: A review of the literature. *Disasters* 23(2): 156–173.
- Fothergill A and Peek L. (2004). Poverty and disasters in the United States: A review of recent sociological findings. *Natural Hazards* 32(1): 89–110.
- Frame D J, Rosier S M, Noy I, Harrington L J, Carey-Smith T, Sparrow S N, Stone D A, Dean S M (in press). Climate change attribution and the economic costs of extreme weather events.
- Frame D, Rosier S, Carey-smith T, Harrington L and Dean S. (2018). *Estimating financial costs of climate change in New Zealand*. New Zealand Climate Change Research Institute and NIWA.
- Frame B and Reisinger A. (2016). Climate change impacts and implications: exploring options for New Zealand under different global climates. Synthesis report RA5. In: *Climate change impacts and implications for New Zealand to 2100*.
- Francis M, Morrison M, Leathwick J and Walsh C. (2011). Predicting patterns of richness, occurrence and abundance of small fish in New Zealand estuaries. *Marine and freshwater research*. 62. 1327–1341. 10.1071/MF11067.
- Frankham R. (1997). Do island populations have less genetic variation than mainland populations? *Heredity*, 78, 311–327.
- French A, Vital M and Minot D. (2015). Bank of England Quarterly Bulletin 2013, Q1. *Bank of England Quarterly Bulletin*, Q3, 242–258.
- Freudenburg W, Gramling R, Laska S and Erikson K T. (2008). Organising hazards, engineering disasters? Improving the recognition of political-economic factors in the creation of disasters. *Social forces*, 87(2), 1015–1038.

- Fyers A. (2016, Dec 7). Blowing bubbles: Who loses the most when a housing bubble bursts. *Stuff*. <https://www.stuff.co.nz/business/property/86784216/blowing-bubbles-who-loses-the-most-when-a-housing-bubble-bursts>
- Gallic E and Vermandel G. (2020). Weather shocks. *European Economic Review*, 124.
- Gassenher M, Keck A and The R. (2010). Shaken, not stirred: the impact of disasters on international trade, *Review of International Economics*, 18 (2): 351–368.
- Gazeau F, Parker L M, Comeau S, Gattuso J P, O’Connor W A, Martin S, Ross P M. (2013). Impacts of ocean acidification on marine shelled molluscs. *Marine Biology*, 160, 2207–2245.
- Gerard P J, Barringer J R, Charles J G, Fowler S V, Kean J M, Phillips C B ... Walker G P. (2013). Potential effects of climate change on biological control systems: Case studies from New Zealand. *BioControl*, 58(149), 149–162.
- Gersonius B, Morselt T, van Nieuwenhuijzen L, Ashley R and Zevenbergen C. (2012). How the failure to account for flexibility in the economic analysis of flood risk and coastal management strategies can result in maladaptive decisions. *Journal of waterway, port, coastal and ocean engineering*, 138(5).
- GHD, Boffa Miskell and The Wastewater Specialists. (2019). *Addendum cost estimates for upgrading wastewater treatment plants*.
- Giejsztowt J, Classen A T and Deslippe J R. (2019). Climate change and invasion may synergistically affect native plant reproduction. *Ecology*.
- Glavovic B C, Saunders W S and Becker J S. (2010). Land-use planning for natural hazards in New Zealand: the setting, barriers, ‘burning issues’ and priority actions. *Nat Hazards*, 54, 679–706.
- Grace E S, France-Hudson B T and Klivington M J. (2019). *Reducing risk through the management of existing uses: tensions under the RMA*. Lower Hutt (NZ): GNS Science. p131. (GNS Science report; 2019/55).
- Greater Wellington Regional Council. (2015). *Flood protection: Option flexibility and its value Hutt River City Centre Upgrade River Corridor Options Report*. Prepared for GWRC by Infometrics and PS Consulting Ltd. Greater Wellington Regional Council, Wellington.
- Guerin K. (2007). *Adaptive governance and evolving solutions to natural resource conflicts*. New Zealand Government. Wellington: The Treasury.
- Guillard-Goncalves C, Pereira S, Garcia R and Zezere J. (2016). Assessment of physical vulnerability of buildings and analysis of landslide risk at the municipal scale: Application to the Loures municipality, Portugal. *Natural Hazards and Earth Systems*, 16.
- Halloy S R and Mark A F. (2003). Climate-change effects on alpine plant biodiversity: A New Zealand perspective on quantifying the threat. *Arctic, Antarctic and Alpine Research*, 35(2), 248–254.
- Hamilton D P, McBride C, Ozkundakci D, Schallenberg M, Verburg P, de Winton M ... Ye W. (2013). Effects of climate change on New Zealand lakes. In C R Goldman, M Kumagai and R D Robarts, *Climatic change and global warming of inland waters: Impacts and mitigation for ecosystems and societies* (pp 337–366). John Wiley and Sons, Ltd.
- Hanna C, White I and Glavovic B. (2018). *Managed retreat governance: Insights from Matatā, New Zealand* (Issue August).
- Harmsworth G R and Awatere S. (2013). Indigenous Māori knowledge and perspectives of ecosystems. *Ecosystem services in New Zealand – Conditions and trends*.
- Harrington L J, Gibson P B, Dean S M, Mitchell D, Rosier S M and Frame D J. (2016). Investigating event-specific drought attribution using self-organizing maps. *Geophysical Research: Atmospheres*, 121(21).
- Hawke’s Bay Regional Council. (2016). *Clifton to Tangoio Coastal Hazards Strategy 2120*. Retrieved from <https://ref.coastalrestorationtrust.org.nz/site/assets/files/8306/clifton-to-tangoio-coastal-hazard-strategy-2120-draft-aug-2016.pdf>

- Hayward B. (2008a). Let's talk about the weather: Decentering democratic debate about climate change. *Hypatia*, 23(3), 79–98. <https://doi.org/10.1111/j.1527-2001.2008.tb01206.x>
- Hayward B. (2008b). Nowhere far from the sea: Political challenges of coastal adaptation to climate change in New Zealand. *Political Science*, 60(1), 47–59.
- Hendy J, Halliday A, Ausseil A, Burton R, Bell K, Deans N ... Zammit C. (2018). *Drought and climate change adaptation: impacts and projections*. Motu, Deep South Science Challenge.
- Hennessy K, Fitzharris B, Bates B, Harvey N, Howden M, Hughes L, Warrick R. (2007). Australian and New Zealand. In *Climate Change 2007: Impacts, adaptation and vulnerability* (pp 507-540). Cambridge: Cambridge University Press.
- Hinkel J, Lincke D, Vafeidis A, Perrette M, Nicholls R J, Tol R S J, Marzeion B, Fettweis X, Ionescu C and Levermann A. (2014). Future coastal flood damage and adaptation costs. *Proceedings of the National Academy of Sciences*, 111(9).
- Holdaway R J, Wiser S K and Williams P A. (2012). Status assessment of New Zealand's naturally uncommon ecosystems. *Conservation Biology*, 26(4), 619–629.
- Hong H, Li F W and Xu J. (2019). Climate risks and market efficiency. *Journal of Econometrics*, 208(1), 265–281.
- Hopkins D. (2013). The social phenomenon of climate change: contextual vulnerability, risk perception and adaptation in the ski industry of Queenstown, New Zealand. 1–396.
- Howden-Chapman P, Chapman R, Hales S, Britton E and Wilson N. (2010). Climate change and human health: Impact and adaptation issues for New Zealand. In: Nottage R A C, Wratt D S, Bornman J F and Jones K. (Eds), *Climate change adaptation in New Zealand: Future scenarios and some sectoral perspectives* (pp 112–121). New Zealand Climate Change Centre, Wellington.
- Howden-Chapman P, Viggers H, Chapman R, O'Sullivan K, Telfar Barnard L, Lloyd B. (2012). Tackling cold housing and fuel poverty in New Zealand: a review of policies, research and health impacts. *Energy Policy*. 49:134–42.
- Innes J I, Kelly D, Overton J M C, and Gillies C. (2010). Predation and other factors currently limiting New Zealand forest birds. *New Zealand Journal of Ecology*. 34. 86–114.
- Insurance Council of New Zealand. (2017). *Cost of natural disasters*. Retrieved 2020, from <https://www.icnz.org.nz/natural-disasters/cost-of-natural-disasters/>
- Insurance Council of New Zealand. (2020). Media Release: 2019 weather-related losses reach \$118.8 m. Retrieved from <https://www.icnz.org.nz/media-resources/media-releases/single/item/2019-weather-related-loses-reach-1188-m/>
- Iorns C. (2019). *Treaty of Waitangi duties relevant to adaptation to coastal hazards from sea-level rise*. June, 190 pp.
- Iorns C, James V and Stuart T. (2017). Courts as decision-makers on sea-level rise adaptation measures: Lessons from New Zealand, in W Leal Filho (ed) *Climate change impacts and adaptation strategies for coastal communities*. Springer International Publishing.
- Interim Climate Change Committee. (2019). *Accelerated electrification*.
- IPCC. (2007). *Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M L Parry, O F Canziani, J P Palutikof, P J van der Linden and C E Hanson (Eds). Cambridge University Press, Cambridge, UK.
- IPCC. (2013). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [T F Stocker, D Qin, G K Plattner, M Tignor, S K Allen, J Boschung, A Nauels, Y Xia, V Bex and P M Midgley (Eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp10.

- IPCC. (2018) Annex I: Glossary [Matthews, J B R. (Ed)]. In: *Global Warming of 1.5°C. An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development and efforts to eradicate poverty*. [V Masson-Delmotte, P Zhai, H O Pörtner, D Roberts, J Skea, P R Shukla, A Pirani, W Moufouma-Okia, C Péan, R Pidcock, S Connors, J B R Matthews, Y Chen, X Zhou, M I Gomis, E Lonnoy, T Maycock, M Tignor and T Waterfield (Eds)]. In press.
- IPCC. (2014) *Summary for policymakers. In: Climate change 2014: Impacts, adaptation and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [C B Field, V R Barros, D J Dokken, K J Mach, M D Mastrandrea, T E Bilir, M Chatterjee, K L Ebi, Y O Estrada, R C Genova, B Girma, E S Kissel, A N Levy, S MacCracken, P R Mastrandrea and L L White (Eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp 1–32.
- IPCC. (2019) *Summary for policymakers. In: IPCC special report on the ocean and cryosphere in a changing climate*. [H O Pörtner, D C Roberts, V Masson-Delmotte, P Zhai, M Tignor, E Poloczanska, K Mintenbeck, A Alegría, M Nicolai, A Okem, J Petzold, B Rama, N M Weyer (Eds)]. In press.
- Islam N and Winkel J. (2017). *Climate change and social inequality*. Department of Economic and Social Affairs. Working Paper No 152. https://www.un.org/esa/desa/papers/2017/wp152_2017.pdf
- Jakes P J and Langer L E. (2012). The adaptive capacity of New Zealand communities to wildfire. *International Journal of Wildland Fire*, 21, 764–772.
- James V, Gerard P and Iorns C. (2019). *Sea-level rise and local government: Policy gaps and opportunities (Deep South National Science Challenge)* (Issue July).
- Jaques R, Jones M, Marston N, Saville-Smith K and Shaw P. (2015). Storm resilience of New Zealand housing and the implication for older people – Preliminary study. *International Journal of Sustainable Built Environment*, 4(2), 341–347.
- Jentsch A and Beierkuhnlein. (2008). Research frontiers in climate change: Effects of extreme meteorological events on ecosystems. *C R Geoscience*, 340, 621–628.
- Johnson P and Rogers G. (2003). Ephemeral wetlands and their turfs in New Zealand. *Science for Conservation*, 230, 109.
- Jones R, Bennett H, Keating G and Blaiklock A. (2014). Climate change and the right to health for Māori in Aotearoa/New Zealand. *Health and Human Rights*, 16(1), 54–68.
- Jones R, Keating G and Hales S. (2014). Health and equity impacts of climate change in Aotearoa-New Zealand and health gains from climate action. *The New Zealand Medical Journal*, 127(1406), 16–31. <http://www.nzma.org.nz/journal/subscribe>
- King D, Penny G and Severne C. (2010). The climate change matrix facing Māori society. In W D Nottage R A C. (Ed), *Climate change adaptation in New Zealand: future scenarios and some sectoral perspectives* (pp 100–111). Wellington: New Zealand Climate Change Centre.
- Kool R. (2020) Preparing for sea-level rise: An adaptive managed retreat case study. In part fulfilment of a Masters of Engineering, Danish Technical Institute and Victoria University of Wellington.
- Kovats S and Osborn D. (2016). Chapter 5: People and the built environment. In *UK Climate Change Risk Assessment*.
- Krishnamurthy P K. (2012). Disaster-induced migration: Assessing the impact of extreme weather events on livelihoods. *Environmental Hazards*, 11(2), 96–111.
- Kundzewicz Z, Mata L, Arnell N, Doll P, Jimenez B, Miller K, Oki T, Sen Z and Shiklomanov I. (2008). The implications of projected climate change for freshwater resources and their management. *Hydrological Sciences Journal/Journal des Sciences Hydrologiques*, 53(1), 3–10.

- Kutzner D. (2019). Environmental change, resilience and adaptation in nature-based tourism: conceptualising the social-ecological resilience of birdwatching tour operations. *Journal of Sustainable Tourism*, 27(8), 1142–1166.
- Lake R, Bolton A, Brightwell G, Cookson A, Benschop J, Burgess S and Tait A. (nd). *Adapting to climate change: Information for the New Zealand food system*.
- Laurence J and Bentley L. (2016). Does ethnic diversity have a negative effect on attitudes towards the community? A longitudinal analysis of the causal claims within the ethnic diversity and social cohesion debate. *European Sociological Review*, 32(1), 54–67.
- Law C S, Bell J J, Bostock H C, Cornwall C E, Cummings V J, Currie K, Tracey D M. (2017). Ocean acidification in New Zealand waters: trends and impacts. *New Zealand Journal of Marine and Freshwater Research*.
- Law C S, Rickard G J, Mikaloff-Fletcher S E, Pinkerton, M H, Behrens E, Chiswell, S M and Currie K. (2018). Climate change projections for the surface ocean around New Zealand. *New Zealand Journal of Marine and Freshwater Research*, 52(3), 309–335.
- Law C S, Rickard G J, Mikaloff-Fletcher S E, Pinkerton M H, Gorman R, Behrens E, Chiswell S M, Bostock H C Anderson O and Currie K. (2016) *The New Zealand EEZ and South West Pacific. Synthesis Report RA2, Marine Case Study*. Climate Changes, Impacts and Implications (CCII) for New Zealand to 2100. MBIE contract C01X1225. 41pp.
- Lawrence J, Bell R, Blackett P, Stephens S and Allan S. (2018). National guidance for adapting to coastal hazards and sea-level rise: Anticipating change, when and how to change pathway. *Environmental Science and Policy*, 82(June 2017), 100–107.
- Lawrence J, Bell R and Stroombergen A. (2019). A hybrid process to address uncertainty and changing climate risk in coastal areas using dynamic adaptive pathways planning, multi-criteria decision analysis and real options analysis: A New Zealand application. *Sustainability*, 11(2), 1–18.
- Lawrence J, Blackett P, Cradock-Henry N A, Flood S, Greenaway A and Dunningham A. (2016). *Climate change impacts and implications for New Zealand to 2100 synthesis report: RA4 Enhancing capacity and increasing coordination to support decision making*. December 2016, 77.
- Lawrence J, Blackett P, Cradock-Henry N A and Nistor B J. (2018). *Climate change: The cascade effect. Cascading impacts and implications for Aotearoa New Zealand*. Wellington: Deep South Challenge.
- Lawrence J, Blackett P and Cradock-Henry. (2020). *Cascading climate change impacts and implications. Climate Risk Management*.
- Lawrence J and Haasnoot M. (2017). What it took to catalyse uptake of dynamic adaptive pathways planning to address climate change uncertainty. *Environmental Science and Policy*, 68, 47–57
- Lawrence J, Haasnoot M, McKim L, Atapattu D, Campbell G, Stroombergen A. (2019). From theory to practice: a timeline of interventions by a change agent with the developers and users of Dynamic Adaptive Policy Pathways (DAPP). In Marchau V, Walker W, Bloeman P. *Decision-making under deep uncertainty: From theory to practice*. Springer International Publishing.
- Lawrence J and Manning M. (2012). *Developing adaptive risk management for our changing climate. A report of workshop outcomes under an Envirolink Grant*.
- Lawrence J, Sullivan F, Lash A, Ide G, Cameron C and McGlinchey L. (2015). Adapting to changing climate risk by local government in New Zealand: institutional practice barriers and enablers. *Local Environment*, 20(3), 298–320. <https://doi.org/10.1080/13549839.2013.839643>
- Lawrence J, Wolf A and Reisinger A. (2012). *Institutional transformation in a devolved governance system: possibilities and limits*.
- Leathwick J R. (1995). Climatic relationships of some New Zealand, forest tree species. *Journal of vegetation science*, 6, 237–246.

- Levin K, Cashore B, Bernstein S and Auld G. (2012). Overcoming the tragedy of super wicked problems: Constraining our future selves to ameliorate global climate change. *Policy Sciences*, 45, 123–152.
- LGNZ (2016). *The 2050 challenge: future proofing our communities: A discussion paper*. <https://www.lgnz.co.nz/assets/e1a77509ff/42597-LGNZ-2050-Challenge-Final-WEB-small.pdf>
- LGNZ. (2019). *Vulnerable: the quantum of local government infrastructure exposed to sea-level rise*.
- LGNZ. Liu J, Hull V, Batistella M, DeFries R, Dietz T, Fu F, Hertel T, Izaurralde R C, Lambin E, Li S, Martinelli L, McConnell W, Moran E, Naylor R, Ouyang Z, Polenske K, Reenberg A, de Miranda Rocha G, Simmons C, Verburg P, Vitousek P, Zhang F and Zhu C. (2013). Framing sustainability in a telecoupled world. *Ecology and Society*, 18, 2: 26.
- Lim-Camacho L, Plagányi É E, Crimp S, Hodgkinson J H, Hobday A J, Howden S M and Loechel B. (2017). Complex resource supply chains display higher resilience to simulated climate shocks. *Global Environmental Change*, 46, 126–138.
- Lin Q, Wang Y, Liu T, Zhu Y and Sui Q. (2017). The vulnerability of people to landslides: A Case study on the relationship between the casualties and volume of landslides in China. *International Journal of Environmental Research and Public Health*, 14(2).
- Lloyd's. (2014). *Catastrophe modelling and climate change*. Accessed 3 March 2020, from <https://www.lloyds.com/~media/lloyds/reports/emerging-risk-reports/cc-and-modelling-template-v6.pdf>
- Macinnis-Ng C, McIntosh A, Monks J, White R, Waipara N, Boudjelas S ... Peltzer D. (nd). Climate change impacts exacerbate conservation threats in island systems: a New Zealand case study. *Frontiers in Ecology and the Environment*.
- Manning M, Lawrence J, King D N and Chapman R. (2015). Dealing with changing risks: a New Zealand perspective on climate change adaptation. *Regional Environmental Change* 15(4), 581–594.
- Mastrandrea M and Luers A. (2012). Climate change in California: scenarios and approaches for adaptation. *Climate Change*, 111.
- Ministry of Business, Innovation and Employment (MBIE). (2017). *Planning and engineering guidance for potentially liquefaction-prone land*. Wellington: MBIE.
- McBride G, Reeve G, Pritchard M, Lundquist C, Daigneault A, Bell R ... Zammit C. (2016). *The Firth of Thames and Lower Waihou River. Synthesis Report RA2, Coastal Case Study*. Climate Changes, Impacts and Implications (CCII) for New Zealand to 2100.
- McBride G, Tait A and Slaney D. (2014). Projected changes in reported campylobacteriosis and cryptosporidiosis rates as a function of climate change: A New Zealand study. *Stochastic environmental research and risk assessment*, 28(8), 2133–2147.
- McDowall R M. (2003) Impacts of introduced salmonids on native galaxiids in New Zealand upland streams: A new look at an old problem, *Transactions of the American Fisheries Society*, 132:2, 229–238.
- McGlone M S, Salinger M J and Moar N T. (1993). Palaeovegetation studies of New Zealand's climate since the last glacial maximum. In H E Wright, J E Kutzbach, T Webb III, W F Ruddiman, F A Street-Perrott and P J Bartlein (Eds). *Global climates since the last glacial maximum*, pp 294–317. Minneapolis: University of Minnesota Press.
- McGlone M and Walker S. (2011). Potential effects of climate change on New Zealand's terrestrial biodiversity and policy recommendations for mitigation, adaptation and research. *Science for Conservation*, 1–77.
- McGuire L, Ford E and Okoro C. (2007). Natural disasters and older US adults with disabilities: implications for evacuation. *Disasters* 31(1): 49–56.
- McIntosh A, McHugh P, Dunn N, Goodman J, Howard S, Jellyman P, O'Brien L, Nyström P and Woodford D. (2010). The impact of trout on galaxiid fishes in New Zealand. *New Zealand Journal of Ecology*. 34. 195–206.

- McKim L. (2016). *A systematic review of recent research: Implications for policy and management and tools to support adaptation decision-making in New Zealand*. New Zealand Climate Change Research Institute.
- Met Office (2015) <http://www.metoffice.gov.uk/news/release/archive/2015/one-degree>
- Ministry for the Environment. (2001). *A guide for the management of closing and closed landfills in New Zealand*. Retrieved from https://www.mfe.govt.nz/sites/default/files/closed-landfills-guide-may01_0.pdf
- Ministry for the Environment. (2017a) Adapting to sea-level rise. <https://www.mfe.govt.nz/climate-change/climate-change-and-government/adapting-climate-change/adapting-sea-level-rise>
- Ministry for the Environment. (2017b, December) *Coastal hazards and climate change guidance for local government*, Ministry for the Environment. <https://www.mfe.govt.nz/sites/default/files/media/Climate%20Change/coastal-hazards-guide-final.pdf>
- Ministry for the Environment. (2017c, December). *Adapting to climate change: Stocktake report from the Climate Change Adaptation Technical Working Group*. Ministry for the Environment. <https://www.mfe.govt.nz/publications/climate-change/adapting-climate-change-new-zealand-stocktake-report-climate-change>
- Ministry for the Environment. (2018, September). *Climate change projections for New Zealand: Atmosphere projections based on simulations from the IPCC Fifth Assessments, 2nd Edition*. Ministry for the Environment. <https://www.mfe.govt.nz/publications/climate-change/climate-change-projections-new-zealand>
- Ministry for the Environment. (2019). *Arotakenga Huringa Ahuarangi: A framework for the National Climate Change Risk Assessment for Aotearoa New Zealand*, Wellington, Ministry for the Environment.
- Ministry for the Environment and Stats NZ. (2020). *New Zealand's Environmental Reporting Series: Our freshwater 2020*. Available from www.mfe.govt.nz and www.stats.govt.nz.
- Ministry of Civil Defence and Emergency Management (MCDEM). (2019) *National Disaster Resilience Strategy*. <https://www.civildefence.govt.nz/assets/Uploads/publications/National-Disaster-Resilience-Strategy/National-Disaster-Resilience-Strategy-10-April-2019.pdf>
- Mooney H A and Hobbs R J. (2000). *Invasive species in a changing world*. Washington DC: Island Press.
- Mortimer R, Sharp B and Craig J. (1996). Assessing the conservation value of New Zealand's offshore islands. *Conservation Biology*, 10(1), 25–29.
- Moser S C, Hart J A F. (2015). The long arm of climate change: societal teleconnections and the future of climate change impacts studies. *Climatic Change* 129, 13–26.
- Ministry for Primary Industries [MPI]. (2010, November). *Introduction to climate change 13: Effects and impacts: Otago and Southland*. Ministry for Primary Industries. <https://www.mpi.govt.nz/dmsdocument/26992-effects-and-impacts-otago-and-southland>
- Ngāi Tahu. (2008). Te tāhū o te whāriki | Anchoring the foundation.
- National Institute of Water and Atmospheric Research [NIWA]. (2016, November 7). *Implications of climate change for New Zealand's freshwaters*. National Institute of Water and Atmospheric Research. Retrieved December 15, 2019, from <https://niwa.co.nz/freshwater-and-estuaries/freshwater-and-estuaries-update/freshwater-update-71-november-2016/implications-of-climate-change-for>
- National Institute of Water and Atmospheric Research [NIWA]. (2019) *Seven station series temperature data*. <https://niwa.co.nz/our-science/climate/information-and-resources/nz-temp-record/seven-station-series-temperature-data>
- National Institute of Water and Atmospheric Research [NIWA]. (2019) *Sea levels and sea-level rise* <https://niwa.co.nz/natural-hazards/hazards/sea-levels-and-sea-level-rise#c1>

- New Zealand Foreign Affairs and Trade. (nd). *Supporting SMEs*.
<https://www.mfat.govt.nz/en/trade/free-trade-agreements/free-trade-agreements-in-force/cptpp/supporting-smes/>
- Northland Regional Council. (2011). *Drought 2010/2011*. Retrieved from
<https://www.nrc.govt.nz/resource-library-archive/environmental-monitoring-archive2/annual-environmental-monitoring-archive/2011/2010-2011-annual-environmental-monitoring-report/hydrology-case-study/drought-20102011>
- O’Connell E, Greenaway T, Moeke T, McKeeking S. (2018). *He Ara Waioira: A pathway towards wellbeing – Exploring te ao Māori perspectives on the Living Standards Framework for the Tax Working Group*. New Zealand Treasury Discussion Paper 18/11. Wellington: Treasury. Retrieved from
<https://treasury.govt.nz/sites/default/files/2018-09/dp18-11.pdf> (19 July 2019)
- Ogden J, Stewart G and Allen R. (1996). Ecology of New Zealand Nothofagus forests. In T Veblen, R Hill and J Read, *The ecology and biogeography of Nothofagus forests* (pp 25-82).
- Oh C and Reuveny R. (2010) Climatic natural disasters, political risk and international trade, *Global Environmental Change*, 20 (2): 243–254.
- O’Meara T A, Hillman J R and Thrush S F. (2017). Riding tides, cumulative impacts and cascading changes to estuarine ecosystem functions. *Scientific Report*, 7.
- Opie K, March A, Leonard J and Newnham G. (2014). *Indicators of fire vulnerability: Risk factors in Victorian settlements*. CSIRO.
- Oppenheimer M, Campos M, Warren R, Birkmann J, Luber G, O’Neil B ... van Vurren D. (2014). Emergent risks and key vulnerabilities. In: Field CB, Barros VR, Dokken DJ et al (Eds). *Climate change 2014: impacts, adaptation and vulnerability. Part A: global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge UK and New York.
- Otago Regional Council. (2016). *The Natural Hazards of South Dunedin*. Dunedin.
- Parkinson D and Zara C. (2013). The hidden disaster: domestic violence in the aftermath of natural disaster, *Australian Journal of Emergency Management* 28(2).
- Parliamentary Commissioner for the Environment. (1996). *Historic and cultural heritage management in New Zealand*. Accessed 12 February 2020, from <https://www.pce.parliament.nz/media/1526/historic-and-cultural-heritage-management-in-new-zealand-june-1996-small.pdf>
- Parsons D M, Sim-Smith C J, Cryer M, Francis M P, Hartill B, Jones E G ... Zeldis J. (2014). Snapper (*Chrysophrys auratus*): a review of life history and key vulnerabilities in New Zealand. *New Zealand Journal of Marine and Freshwater Research*, 48(2), 256–283.
- Pattle Delamore Partners Ltd. (2011). *New Zealand guidelines for the monitoring and management of sea water intrusion risks on groundwater*.
- Paulik, R, Craig, H and Collins, D. (2019a). *New Zealand Fluvial and Pluvial Flood Exposure*. Wellington: NIWA.
- Paulik R, Stephens S, Wadhwa S, Bell R, Popovich B and Robinson B. (2019b). *Coastal flooding exposure under future sea-level rise for New Zealand*. New Zealand: The Deep South Challenge. Retrieved from
[https://www.deepsouthchallenge.co.nz/sites/default/files/2019-08/2019119WN_DEPSI18301_Coast_Flood_Exp_under_Fut_Sealevel_rise_FINALper cent20\(1\)_0.pdf](https://www.deepsouthchallenge.co.nz/sites/default/files/2019-08/2019119WN_DEPSI18301_Coast_Flood_Exp_under_Fut_Sealevel_rise_FINALper cent20(1)_0.pdf)
- Pearce P, Bell R, Bostock H, Carey-Smith T, Collins D, Fedaff N, Woolley J. (2018). *Auckland region climate change projections and impacts*. Auckland: National Institute of Water and Atmospheric Research.
- Pryde P R. (1997). Creating offshore island sanctuaries for endangered species: The New Zealand perspective. *Natural Areas Journal*, 17(3), 7.

- Quilter P, van Ballegooy S and Reinen-Hamill R. (2015). The effect of sea-level rise on liquefaction vulnerability: A case study for consideration of development on coastal plains and reclamations. In: *Proceedings of the Australasian Coasts and Ports Conference 2015*. Auckland.
- Rahel F J and Olden J D. (2008). Assessing the effects of climate change on aquatic invasive species. *Conservation Biology*, 22(3), 521–533.
- Rangitāiki River Scheme Review Panel. (2017). *Rangitāiki River Scheme Review – April 2017 Flood Event*. Bay of Plenty Regional Council.
- Rangiwhetu L, Pierse N, Viggers H and Howden-Chapman P. (2018). Cold New Zealand council housing: Getting an upgrade. *Policy Quarterly*, 14(2), 65–73.
- Reese S and Ramsay D. (2010). *RiskScope: Flood fragility methodology*. Wellington: NIWA.
- Reisinger A, Mullan A B, Manning M, Wratt D W and Nottage R A. (2010). Global and local climate change scenarios to support adaptation in New Zealand. In R A Nottage, D S.
- Reisinger A, Kitching R L, Chiew F, Hughes L, Newton P C D, Schuster S S, Tait A and Whetton P. (2014). Australasia. In V Barros, C B Field, D J Dokken, M D Mastrandrea, K J Mach, T E Bilir, C M K L Ebi, Y O Estrada, R C Genova, B Girma, E S Kissel, A N Levy, S MacCracken, M P R and L L White (Eds.), *Climate Change 2014: Impacts, adaptation and vulnerability. Part B: Regional aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp 18–26). Cambridge University Press. <https://doi.org/10.1016/B978-0-444-53643-3.00185-0>
- Reisinger A, Lawrence J, Hart G and Chapman R. (2014). From coping to resilience: The role of managed retreat in highly developed coastal regions of New Zealand. *Climate change and the coast: Building resilient communities*, 285–310. <https://doi.org/10.1201/b18053>
- Reserve Bank of New Zealand. (2019). *Financial Stability Report May 2019*.
- Reserve Bank of New Zealand. (2020). *Reserve Bank Climate Change Strategy*. Accessed 3 March 2020, from <https://www.rbnz.govt.nz/financial-stability/climate-change/strategy>
- RNZ. (2020). *Auckland water shortages causing logistics nightmare*. RNZ.
- Roberts L, Brower A, Kerr G, Lambert S, McWilliam W, Moore K, Quinn J, Simmons D, Thrush S, Townsend M, Blaschke P, Costanza R, Cullen R, Hughey K, Wratten S. (2015). *The nature of wellbeing: how nature's ecosystem services contribute to the wellbeing of New Zealand and New Zealanders*. Wellington: Department of Conservation.
- Robertson H A, Ausseil A G, Rance B, Betts H and Pomeroy E. (2019). Loss of wetlands since 1990 in Southland, New Zealand. *New Zealand Journal of Ecology*, 43(1), 1–9.
- Robertson H, Bowie S, Death R and Collins D. (2016). *Freshwater conservation under a changing climate. Proceeding of a workshop hosted by the Department of Conservation*. (p 87). Wellington: Department of Conservation.
- Rosser B, Dellow S, Haubrock S and Glassey P. (2017). New Zealand's national landslide database. *Landslides*, 1–11.
- Rouse H, Bell R, Lundquist C J, Blackett P, Hicks D M and King D N. (2017). Coastal adaptation to climate change in Aotearoa-New Zealand. *New Zealand Journal of Marine and Freshwater Research*, 51(2), 183–222.
- Royal Society | Te Apārangi. (2017). *Human health impacts of climate human health change for new impacts of climate change for New Zealand*. April, 1–18.
- Salinger M J. (1987). Impact of climatic warming on the New Zealand growing season. *Journal of the Royal Society of New Zealand*, 17(4), 363–371.
- Salinger J M, Renwick J, Behrens E, Mullan B A, Diamond H J, Sirguey P, Cullen N J. (2019). The unprecedented coupled ocean-atmosphere summer heatwave in the New Zealand region 2017/18: drivers, mechanisms and impacts. *Environmental Research Letters*, 14(4).

- Schallenberg M, Hall C J and Burns C W. (2003). Consequences of climate-induced salinity increases on zooplankton abundance and diversity in coastal lakes. *Marine Ecology Progress Series*, 251, 181–189.
- Scoones I. (2019). *What is uncertainty and why does it matter?*, STEPS Working Paper 105, Brighton: STEPS Centre.
- Scott H, McEvoy D, Chhetri P, Basic F and Mullett J. (2013). *Climate change adaptation guidelines for ports – Enhancing the resilience of seaports to a changing climate report series*. Gold Coast: National Climate Change Adaptation Research Facility.
- Smeth and Dunstan. (2004) *Ethnic population projections: issues and trends*
http://archive.stats.govt.nz/browse_for_stats/population/estimates_and_projections/ethnic-pop-projections-issues-and-trends.aspx
- Smith L T. (2005). On tricky ground – Researching the native in the age of uncertainty. In N K Denzin and Y S Lincoln (Eds), *The Sage handbook of qualitative research* (pp 1–12). Thousand Oaks, California.
- Smith K R, Woodward A, Campbell-Lendrum D, Chadee D, Honda Y, Liu Q ... Sauerborn R. (2014). Human health: impacts, adaptation and co-benefits. In *Climate change 2014: Impacts, adaptation and vulnerability. Part A: Global and sectoral aspects, Contribution of Working Group II to the Fifth Assessment Report of the IPCC* (pp 709–754). United Kingdom and New York: Cambridge University Press.
- Stephenson J, Barber J, Barth J, Bond S, Diprose G, Heyd C, Kirk N, Laurie-Fendall R, Orchiston C, Saunders W, Simon K, Thomas A and Vincent N. (2019). *Community development for adaptation (CD4A): Council-community engagement for a climate-impacted future*.
- Stephenson J, Barth J, Bond S, Diprose G, Orchiston C, Simon K and Thomas A. (2019). Engaging with communities for climate change adaptation: introducing community development for adaptation. *Proceedings of the Rodney Davies Research Symposium, NZPI Conference 2019*.
- Stephenson J, Orchiston C, Saunders W, Kerr S, MacMillan A, McKenzie L, Willis S. (2018). *Communities and Climate change: Vulnerability to rising sea and more frequent flooding*. Motu: Economic and Public Policy Research.
- Stern N. (2006). *The economics of climate change: The Stern review*. Cambridge: Cambridge University Press.
- Sweet M J, Bulling M J and Williamson J E. (2016). New disease outbreak affects two dominant sea urchin species associated with Australian temperate reefs. *Marine Ecology Progress Series*, 551, 171–183.
- Task Force on Climate-related Financial Disclosures [TCFD] (2017). *Recommendations of the Task Force on Climate-related Financial Disclosures – Final Report*. Available at <https://www.fsb-tcfd.org/wp-content/uploads/2017/06/FINAL-2017-TCFD-Report-11052018.pdf>
- Tauranga City Council. (2019, May 1). *Flooding from rising groundwater*. Retrieved from Tauranga City Council: <https://www.tauranga.govt.nz/living/natural-hazards/understanding-our-hazards-studies-maps-and-data/flooding/flooding-from-rising-groundwater>
- The Makara Beach Project. (nd). *The Makara Beach Project*. Retrieved March 26, 2020, from wcc.maps.arcgis.com/apps/MapSeries/index.html?appid=57e797777a96430c8074182984622a6a
- The Royal Society of New Zealand. (2016). *Climate change implications for New Zealand*.
- The Treasury. (2018). *Our Living Standards Framework*. Retrieved from <https://treasury.govt.nz/information-and-services/nz-economy/living-standards/our-living-standards-framework> (19 July 2019)
- The Treasury (2019a). *The Wellbeing Budget 2019*. <https://treasury.govt.nz/sites/default/files/2019-05/b19-wellbeing-budget.pdf>
- The Treasury (2019b). *An Indigenous Approach to the Living Standards Framework*. <https://treasury.govt.nz/sites/default/files/2019-01/dp19-01.pdf>

- Thomsen M S, Mondardini L, Alestra T, Gerrity S, Tait L, South P M, Schiel D R. (2019). Local extinction of bull kelp (*Durvillaea* spp) due to a marine heatwave. *Frontiers in Marine Science*, 6 (MAR), 1–10.
- Thorburn P J, Wilkinson S N and Silburn D M. (2013). Water quality in agricultural lands draining to the Great Barrier Reef: Causes, management and priorities. *Agriculture Ecosystems and Environment*, 180, 4–20.
- Thrush S F, Hewitt J E, Cummings V J, Ellis J I, Hatton C, Lohrer A and Norkko A. (2004). Muddy waters: elevating sediment input to coastal and estuarine habitats. *Frontiers in Ecology and the Environment*, 2, 299–306.
- Thuiller W, Richardson D M and Midgley G F. (2007). Will climate change promote alien plant invasions? *Ecological Studies*, 193, 197–211.
- Timmins S M, Williams P A. 1991. Weed numbers in New Zealand’s forest and scrub reserves. *New Zealand Journal of Ecology* 15: 153–162.
- Tomiolo S, Harsch M A, Duncan R P and Hulme P E. (2016). Influence of climate and regeneration microsites on *Pinus contorta* invasion into an alpine ecosystem in New Zealand. *AIMS Environmental Science*, 3(3), 525–540.
- Tompkins E and Adger N. (2004). Does adaptive management of natural resources enhance resilience to climate change? *Resilience Alliance Inc*, 9(2).
- Tompkins D M, Byrom A E and Pech R P. (2013). Predicted responses of invasive mammal communities to climate-related changes in mast frequency in forest ecosystems. *Ecological Society of America*, 23(5), 1075–1085.
- Ton K T, Gaillard J C, Adamason C E, Akgungor C and Ho H T. (2019). Expanding the capabilities of people with disabilities in disaster risk reduction. *International Journal of Disaster Risk Reduction*, 34, 11–17.
- Tortajada C and Joshi Y. (2013). Water demand management in Singapore: Involving the public. *Water Resources Management: An International Journal, Published for the European Water Resources Association (EWRA)*, 27(8). 2729–2746.
- Trujillo-Pagan N. (2007). “Katrina’s Latinos: vulnerability and disasters in relief and recovery”. In K A Bates and R S Swan (Eds). *Through the eye of Katrina: Social justice in the United States*. Durham, NC: Carolina Academic Press, pp 147–168.
- UK Government Office for Science. (2011). *Foresight: Migration and global environmental change*. <https://go.nature.com/31A0Xmr>
- Uma S R, Bothara J, Jury R and King A. (2008). *Performance assessment of existing buildings in New Zealand*. 2008 NZSEE Conference.
- UNEP Emissions Gap report. (2019). <https://www.unenvironment.org/resources/emissions-gap-report-2019>
- Urich P, Li Y and Burton D. (2017). *When extreme rainfall disrupts a water supply – The case of Auckland City, New Zealand – March 2017*. Retrieved from <https://www.climsystems.com/blog/post/when-extreme-rainfall-disrupts-a-water-supply-the-case-of-auckland-city-new-zealand>
- Van Vliet M T and Zwolsman J J. (2008). Impact of summer droughts on the water quality of the Meuse river. *Journal of Hydrology*, 353, 1–17.
- Wakelin A, Gomez-Gallego M, Jones E, Smail S, Lear G and Lambie S. (2018). Climate change induced drought impacts on plant diseases in New Zealand. *Australasian Plant Pathology*, 47(101), 101–114.
- Wardle A, Barker G, Yeates G, Bonner K and Ghani A. (2001). *Ecological Monographs*, 71, 587–614.
- Warren R, Watkiss P, Wilby R L, Humphrey K, Ranger N, Betts R, Lowe J and Watts G. (2016). *UK Climate change risk assessment evidence report: Chapter 2, approach and context*. Report prepared for the Adaptation Sub-Committee of the Committee on Climate Change, London.
- Warren M. (2018). Trust and democracy. In E Uslaner (Ed). *The Oxford handbook of social and political trust*. Oxford University Press.

- WasteMINZ. (2018). *Technical guidelines for disposal to land*. Retrieved from <https://www.wasteminz.org.nz/wp-content/uploads/2016/04/Technical-Guidelines-for-Disposal-to-Land-9Aug18-FINAL.pdf>
- Watercare. (nd) *Where your water comes from*. Retrieved from <https://www.watercare.co.nz/Water-and-wastewater/Where-your-water-comes-from>
- WaterNZ. (2015). *National Performance Review 2014–2015*.
- WaterNZ. (2016). *National Performance Review 2015–2016*.
- WaterNZ. (2017). *National Performance Review 2016–2017*.
- WaterNZ. (2018). *National Performance Review 2017–2018*.
- Watt M S et al. (2019). Assessment of multiple climate change effects on plantation forests in New Zealand. *Forestry: An International Journal of Forest Research* 92(1): 1–15.
- Watts M S, Kirschbaum M U F, Paul T S H, Tait A, Pearce H G, Brockerhoff E G, Moore JR, Bulman L S and Kriticos D J. (2008). *The effect of climate change on New Zealand's planted forests: Impacts, Risks and Opportunities, Prepared for the Ministry of Agriculture and Forestry*. Climacloud. [http://climatecloud.co.nz/CloudLibrary/2008-07-effect-of-climate-change-on-nz-planted-forests\[1\].pdf](http://climatecloud.co.nz/CloudLibrary/2008-07-effect-of-climate-change-on-nz-planted-forests[1].pdf)
- Weeks E S, Death R G, Foote K, Anderson-Lederer R, Joy M K and Boyce P. (2016). Conservation Science Statement 1. The demise of New Zealand's freshwater flora and fauna: a forgotten treasure. *Pacific Conservation Biology*, 22(2), 110–115.
- Weir T and Virani Z. (2011). Three linked risks for development in the Pacific Islands: Climate change, disasters and conflict. *Climate and Development*, 3(3), 193–208.
- Weitzman M L. (2009). On modelling and interpreting the economics of catastrophic climate change. *The Review of Economics and Statistics*, 91(1), 1–19.
- Weitzman M. (2011). Fat-tailed uncertainty in the economics of catastrophic climate change. *Review of Environmental Economics and Policy*, 5(2).
- Wellington City Council. (2016). *Wellington City Profile: Facts about the City* <https://wellington.govt.nz/~media/about-wellington/profile/files/wellington-city-profile.pdf>
- White V, Jones M, Cowan V and Chun S. (2017a). *BRANZ 2015: House condition survey: Comparison of house condition by tenure*. BRANZ.
- Wilcock R J, Nash D, Schmidt J, Larned S T, Rivers M R and Feehan P. (2011). Inputs of nutrients and fecal bacteria to freshwaters from irrigated agriculture: Case studies in Australia and New Zealand. *Environmental Management* 48, 198–211. <https://doi.org/10.1007/s00267-011-9644-1>
- Williams S E, Shoo L P, Isaac J L, Hoffmann A A and Langham G. (2008). Towards an integrated framework for assessing the vulnerability of species to climate change. *PLoS Biology*, 6(12), 2621–2626.
- Wilson K J. (2009). *The state of New Zealand's birds 2009: Conservation of migratory birds*.
- Wistow J, Dominelli L, Oven K, Dunn C and Curtis S. (2015). The role of formal and informal networks in supporting older people's care during extreme weather events. *Policy and Politics*, 43(1), 119–135.
- Winkelmann H, Glazebrook S and France E. (2019). *Climate change and the law*.
- Woodward A, Hales S and de Wet N. (2001). *Climate change: Potential effects on human health in New Zealand*. 27. [https://www.mfe.govt.nz/sites/default/files/Climate change potential effects on human health in New Zealand.pdf](https://www.mfe.govt.nz/sites/default/files/Climate%20change%20potential%20effects%20on%20human%20health%20in%20New%20Zealand.pdf)
- Wreford A, Moran D, Adger N. (2010). *Climate change and agriculture: Impacts, adaptation and mitigation*. Paris, OECD.
- Zeitoun M, Lankford B, Krueger T, Forsyth T, Carter R, Hoekstra A Y ... Matthews N. (2016). Reductionist and integrative research approaches to complex water security policy challenges. *Global Environmental Change*, 39.

Appendix A: Glossary

Key term	Definition
Adaptation	Adjustment to actual or expected climate change and its effects. In human systems, adaptation seeks to moderate or avoid harm, or to take opportunities. Intervention may facilitate adjustment (IPCC, 2014).
Adaptive capacity	The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (IPCC, 2014).
Assets	Things of value, which may be exposed or vulnerable to a hazard or risk. Physical, environmental, cultural or financial/economic element that has tangible, intrinsic or spiritual value (see taonga) (Ministry for the Environment, 2019).
Baseline	The baseline (or reference) is any datum against which change is measured.
Biodiversity	The variability among living organisms from terrestrial, marine and other ecosystems. Biodiversity includes variability at the genetic, species and ecosystem levels (IPCC, 2014).
Cascading effects (of climate change)	Effects that flow on from a primary hazard to compound and affect other systems in a dynamic sequence.
Climate	The narrow definition is the average weather. More rigorously, the statistical description of the mean and variability of quantities over months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system (IPCC, 2014).
Climate change	A change in the state of the climate identified (eg, through statistical tests) by changes or trends in the mean and/or the variability of its properties, and that persists for an extended period, typically decades to centuries. Includes natural internal climate processes or external climate forcings such as variations in solar cycles, volcanic eruptions and persistent anthropogenic changes in the atmosphere or in land use (IPCC, 2014).
Climate projection	The simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases (GHGs) and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative forcing scenario, which is in turn based on assumptions about, for example, socio-economic and technological developments that may or may not be realised (IPCC, 2014).
Co-benefits	The positive effects a policy or measure for one objective might have on other objectives, irrespective of the net effect on overall social welfare. Often subject to uncertainty and depend on circumstances and implementation, among other factors. Also known as ancillary benefits (Ministry for the Environment, 2019).

Key term	Definition
Community	A geographic location (community of place), a community of similar interest (community of practice), or a community of affiliation or identity (such as industry) (Ministry for the Environment, 2019).
Compound hazards and stressors	Cumulative hazards which will become more significant as adaptation thresholds are reached, eg, for a coastal area, a persistent wet season (high groundwater, lower field capacity) is followed by a coastal storm on the back of sea-level rise coincident with intense rainfall, leading to compound flooding (Ministry for the Environment, 2019).
Confidence	A qualitative measure of the validity of a finding, based on the type, amount, quality and consistency of evidence (eg, data, mechanistic understanding, theory, models, expert judgement) and the degree of agreement (Ministry for the Environment, 2019).
Consequence	The outcome of an event that may result from a hazard. It can be expressed quantitatively (eg, units of damage or loss, disruption period, monetary value of impacts or environmental effect), semi-quantitatively by category (eg, high, medium, low level of impact) or qualitatively (a description of the impacts) (adapted from Ministry of Civil Defence and Emergency Management [MCDEM], 2019). It is also defined as the outcome of an event affecting objectives (ISO/IEC 27000:2014 and ISO 31000: 2009) (Ministry for the Environment, 2019).
Disaster	Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery (IPCC, 2014).
Driver	An aspect that changes a given system. Drivers can be short term but are mainly long term in their effects. Changes in both the climate system and socioeconomic processes including adaptation and mitigation are drivers of hazards, exposure, and vulnerability. Drivers can, thus, be climatic or non-climatic (Ministry for the Environment, 2019).
Emissions	The production and discharge of substances that are potentially radiatively active (ie, absorb and emit radiant energy) in the atmosphere (eg, greenhouse gases, aerosols) (Ministry for the Environment, 2019).
Exposure	Lack of protection, where people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings could be adversely affected by a change in external stresses that a system is exposed to. In the context of climate change, these are normally specific climate and other biophysical variables (IPCC, 2007). Lack of protection against loss or harm in a hazard zone, affecting the number, density or value of people, property, services, or other things we value (taonga) (MCDEM, 2019).
Extreme weather event	An event that is rare at a particular place and time of year. Rare is normally defined as 'as rare as or rarer than the 10th or 90th percentile of a probability density function estimated from observations'. The characteristics of extreme weather will vary from place to place. When a pattern persists, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is itself extreme (eg, a season of drought or heavy rainfall) (IPCC, 2014).

Key term	Definition
Financial risk	Risks involving financial loss to firms. Generally relate to markets, credit, liquidity and operations.
Frequency	The number or rate of occurrences of hazards, usually over a particular period (Ministry for the Environment, 2019).
Greenhouse gas (GHG)	Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H ₂ O), carbon dioxide (CO ₂), nitrous oxide (N ₂ O), methane (CH ₄) and ozone (O ₃) are the primary greenhouse gases in the Earth's atmosphere.
Hazard	<p>The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources (IPCC, 2014).</p> <p>In this report, it usually refers not only to climate-related events (such as floods or heatwaves) but also evolving trends or their gradual physical impacts (IPCC, 2014).</p>
Heatwave	A period of abnormally and uncomfortably hot weather (IPCC, 2014).
Impacts (consequences, outcomes)	The effects on natural and human systems of extreme weather and climate events, and of climate change. Generally refers to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure due to the interaction of climate changes or hazardous climate events within a specific period, and the vulnerability of an exposed society or system (IPCC, 2014).
Intergovernmental Panel on Climate Change (IPCC)	Intergovernmental Panel on Climate Change – a scientific and intergovernmental body under the auspices of the United Nations.
Land use	Human activities in a certain land cover type. Purposes for managing land (eg, grazing, forestry, conservation). Urban land use has implications for city management, structure and form, and for energy demand, GHG emissions and mobility (IPCC, 2014).
Land-use change	A change in the human use or management of land, which may change land cover. This may affect the surface albedo, evapotranspiration, sources and sinks of GHGs, or other properties of the climate system and may thus give rise to radiative forcing and/or other impacts on climate, locally or globally (IPCC, 2014).
Likelihood	The chance of an outcome occurring, where this might be estimated probabilistically (IPCC, 2014).
Lock-in	The situation where decisions, events or outcomes at one point in time constrain adaptation, mitigation or other actions or options at a later time (IPCC, 2014).
Māori values and principles	Māori values and principles derive from Māori views of the world. Instruments through which Māori make sense of, experience, and interpret the world. They form the basis for Māori ethics and principles (Ministry for the Environment, 2019).

Key term	Definition
Mātauranga Māori	Mātauranga Māori or Māori knowledge has many definitions that cover belief systems, epistemologies, values, and knowledge both in a traditional and contemporary sense. Mātauranga Māori incorporates knowledge, comprehension and understanding of everything visible and invisible existing in the universe (Ministry for the Environment, 2019).
Mitigation	A human intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2014).
Percentiles	A value on a scale of 100 that indicates the percentage of the data set values that is equal to, or below it. The percentile is often used to estimate the extremes of a distribution. For example, the 90th (or 10th) percentile may be used to refer to the threshold for the upper (or lower) extremes.
Representative concentration pathway (RCP)	A suite of future scenarios of additional radiative heat forcing at the Earth's surface by 2100 (in Watts per square metre), which is the net change in the balance between incoming solar radiation and outgoing energy, radiated back up in the atmosphere. Each RCP can be expressed as a greenhouse gas concentration (not emissions) trajectory adopted by the IPCC for its Fifth Assessment Report (AR5) in 2014 (IPCC, 2014).
Residual risk	The risk that remains (and may continue to rise) in unmanaged form, after risk management and adaptation policies have been used to adapt to climate change and more frequent hazards, and for which emergency response and other actions must be maintained, or limits to adaptation addressed. Policy interventions and adaptation plans will need to reconcile changing residual risks with changing (evolving) societal perceptions of tolerable risk.
Resilience	The capacity of social, economic and environmental systems to cope with a hazardous event, trend or disturbance by responding or reorganising in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation (IPCC, 2014).
Risk	The potential for consequences where something of value is at stake and where the outcome is uncertain, recognising the diversity of values. Risk is often represented as probability or likelihood of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. It also refers to the potential, when the outcome is uncertain, for adverse consequences on lives, livelihoods, health, ecosystems and species, economic, social and cultural assets, services (including environmental) and infrastructure. Risk results from the interaction of vulnerability, exposure and hazard. To address the evolving impacts of climate change, it can also be defined as the interplay between hazards, exposure and vulnerability (IPCC, 2014).
Risk assessment	The qualitative and/or quantitative process of identifying, analysing and evaluating risk, with entry points for communication and engagement, and monitoring and reviews (AS/NZS ISO 31000:2009, Risk Management Standard).
Shock	A sudden, disruptive event with an important and often negative impact for New Zealand.
Stress	A long-term issue with an important and often negative impact for New Zealand.

Key term	Definition
Stressor (climate)	Persistent climatic event (eg, change in seasonal rainfall) or rate of change or trend in variables such as the mean, extremes or the range (eg, ongoing rise in mean ocean temperature or acidification), which occurs over a period of time (eg, years, decades or centuries), with important effects on the system exposed. This in turn increases vulnerability to climate change (Ministry for the Environment, 2019).
System	A set of elements working together as parts of an interconnected network or a complex whole.
Taonga Māori	<p>Taonga Māori refers to tangible and intangible items that are highly valued in Māori culture. Taonga Māori include:</p> <ul style="list-style-type: none"> • natural environment (whenua/land, ngahere/forests, awa/rivers, maunga/mountains and moana/ocean) • human and non-human capital (whānau/families, hapū/sub-tribes, iwi/tribes) and spiritual (mauri/the intrinsic life force within living entities) • social capital (mātauranga Māori/Māori knowledge, intergenerational transfer of knowledge) • economic capital (financial value of assets including land holdings) • material capital (buildings including marae, commercial investments and private homes) (MfE, 2019).
Three waters	Drinking water, wastewater and stormwater.
Uncertainty	A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many sources, from imprecise data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour (IPCC, 2014).
Value domain	The NCCRA framework outlines five ‘value domains’ for assessing risks and opportunities. These represent values, assets and systems that may be at risk from climate-related hazards, or could benefit (opportunities). They are a hybrid of Treasury’s Living Standards Framework and those used in the National Disaster Resilience Strategy (The Treasury, 2018; Ministry of Civil Defence and Emergency Management, 2019). They are interconnected and apply at the individual, community and national level. They include tangible and intangible values.
Vulnerability	<p>The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm, and lack of capacity to cope and adapt (IPCC, 2014).</p> <p>Assessing vulnerability is broader than conventional risk assessments; it includes indirect and intangible consequences on the four wellbeings, and adaptive capacity (eg, communities, whānau, hapū and iwi may be resourceful but may lack the resources, insurance access and mandate or capacity to adapt) (Ministry for the Environment, 2019).</p>
Wellbeing	Wellbeing is achieved when people are able to lead fulfilling lives with purpose, balance and meaning (The Treasury 2019a). The Treasury Living Standards Framework notes that intergenerational wellbeing relies on growth, distribution and sustainability of four interdependent capitals: natural, social, human and financial/physical. The Crown–Māori relationship is integral to all four capitals (The Treasury, 2018). Within te ao Māori – the Māori world – the drivers of wellbeing are considered

Key term	Definition
	<p>against the values that imbue te ao Māori with a holistic perspective. These values are interconnected and span multiple aspects of wellbeing. Wellbeing results from the application of these values through knowledge, beliefs and practices (The Treasury, 2019b).</p>

Appendix B: Te reo glossary

Key term	Definition
Māori	English
Ahurea	Culture
Awhina	Support
Hapū	A section of a tribe, secondary tribe
Hui	Meeting, gathering
Huringa āhuarangi	Climate change
Iwi	Tribe, tribal group
Kaitiakitanga	Stewardship of natural resources; intergenerational sustainability
Kaumātua	Elder, person of status
Kaupapa	Topic, subject
Kaupapa Māori	This concept has many definitions and is used in various contexts. To ensure that nothing is left out, we offer those broader definitions here: Māori approach, topic, customary practice, institution, agenda, principles, ideology – a philosophical doctrine, incorporating the knowledge, skills, attitudes and values of Māori society (Ministry for the Environment, 2019).
Kawa	Ceremony, protocol
Korero	Talk, discourse, information
Kura taiao	Living treasures, and the ecosystems which they form in terrestrial, freshwater and marine environments
Mahi ngātahi	Engagement, participation
Mahinga kai	Food gathering
Mana	Authority, dignity, governance, power
Mana whenua	Power from/authority over land or territory
Manaakitanga	Care, reciprocity
Mātāpono	Principle
Mātauranga Māori	Māori knowledge systems. These are context specific to indigenous Māori people, and the term has its origins in Aotearoa New Zealand. It has many definitions that cover belief systems, epistemologies, values and knowledge, in a traditional and contemporary sense. The knowledge, comprehension or understanding of everything visible and invisible in the universe (Ministry for the Environment, 2019).
Mauri	The life force
Ōhanga	economic, economy
Pākeke	Adult
Rangatahi	Young person
Rangatiratanga	Leadership, autonomy
Rohe	Land, territory, domain, boundary

Key term	Definition
Taiao	Environment
Tangata	People
Taonga Māori	<p>Taonga are tangible and intangible items that are highly valued in Māori culture. They include:</p> <ul style="list-style-type: none"> • natural environment (whenua/land, ngahere/forests, awa/rivers, maunga/mountains and moana/ocean) • human and non-human capital (whānau, hapū, iwi) and spiritual (mauri) • social capital (mātauranga Māori) • economic capital (financial value of assets including land holdings) • material capital (buildings including marae, commercial investments and private homes) (Ministry for the Environment, 2019).
Te ao Māori	The Māori world and worldview
Te Tiriti o Waitangi	The Treaty of Waitangi
Tikanga	Procedures, lore, practices
Tūrangawaewae	Place where one has the right to stand
Urupā	Burial ground, cemetery
Wāhi taonga	Place where taonga are held or kept
Wāhi tapu	Sacred place
Whakapapa	Genealogy that links to one's ancestors
Whakatipu rawa	Business, enterprise
Whanaungatanga	Connectedness and relationships
Whenua	Land, territory, nation