

Climate Change Impacts and Implications for New Zealand to 2100

A systematic review of recent research

Implications for policy and management, and tools to support adaptation decision making in New Zealand

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Rakaia River: The cover image is used to illustrate the dynamic and changing nature of decision implications arising from climate change in New Zealand and the different pathways they can take across different domains such as freshwater resources, coastal, urban and rural settings, industries and sectors and levels of governance and institutions.

Cover photo: Nelson Boustead, NIWA

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INTRODUCTION

This review forms a component of Research Aim 4 (RA4) of the Climate Change Impacts and Implications (CCII) programme, funded by the Ministry of Business, Innovation and Employment from 2012 to 2016. CCII focused on the decision significance of climate change impacts and on enhancing capacity and increasing coordination to support decision-making about climate change impacts.

The CCII programme pursued three objectives:

- Update and improve projections of climate trends, variability and extremes across New Zealand out to 2100, based on the latest global projections;
- Generate new knowledge about the potential impacts of climate change and variability on New Zealand's environment, including our natural ecosystems and native species, and coastal guidance productive systems which depend on the environment; and
- Generate new knowledge about decision-making across the communities of practice, relevant for addressing climate risks, including how climate information is used and could be communicated.

Five inter-related research streams aimed to deliver on the overall objectives.

The RA4 research was guided by the following questions :

1. How can the emerging pressure points, and policy and management implications of climate change and variability on the NZ environment, economy and society, best be identified?
2. How can climate change science provide decision-relevant information to adaptively manage climate change impacts, where risk profiles are changing sometimes in uncertain ways generating multiple possible futures?
3. How can we best enhance the adaptive capacity of governments, business, iwi, and communities to incorporate the implications of climate change, particularly in those facing the greatest risk or with the greatest opportunity?

The process and findings of the RA4 research, as well as those of the other CCII research aims, are detailed in synthesis reports available on the CCII website <http://ccii.org.nz/outputs/>

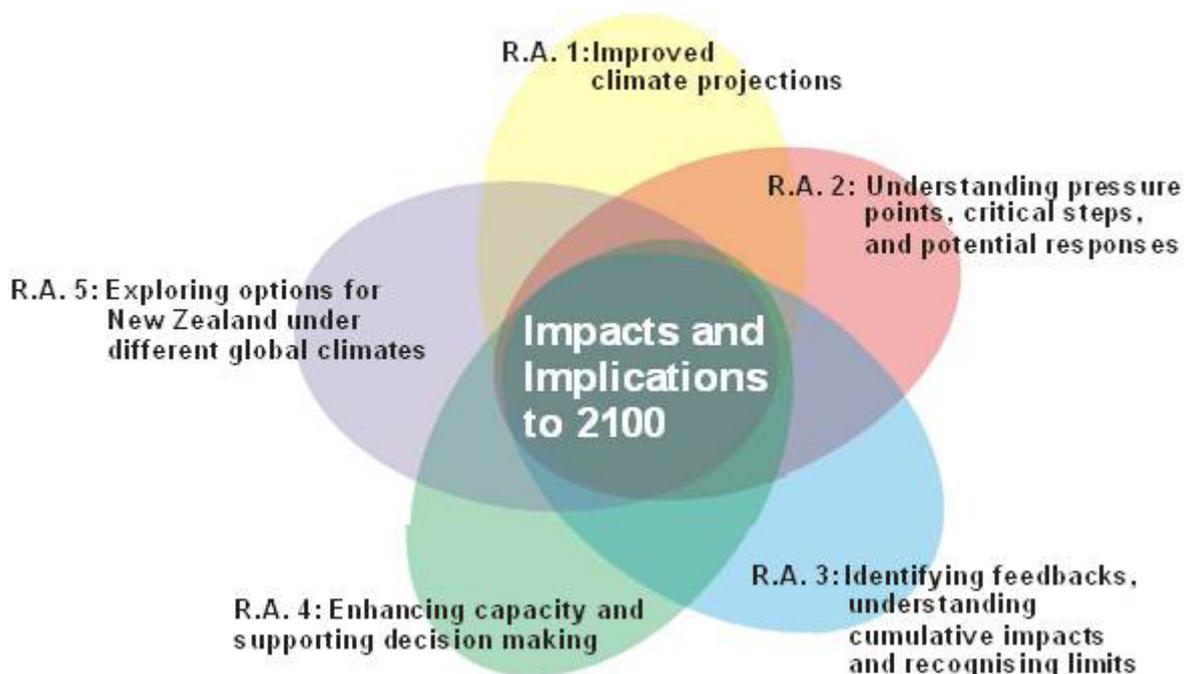


Figure 1: The CCII research aims and their interactions.

Despite uncertainties surrounding magnitude, frequency and location, the key climate change risks facing NZ are now relatively clear. The IPCC's WGII report (Reisinger et al., 2014) identified three key risks for NZ:

- Increased frequency and intensity of flood damage to settlements and infrastructure;
- Increased damage from wildfires- to ecosystems and settlements, economic losses and risks to human life;
- Increasing risks to coastal infrastructure and low-lying ecosystems from continuing sea level rise, with widespread damage if the more severe projections are realised.

Less well-understood are how these risks interface with policy and decision-making. As such, the focus of this review, and CCII's RA4 research aim more broadly, is not on climate change risks and impacts per se, but on the implications for policy and management in NZ, including the information needs and adaptive capacity of institutions and decision-makers.

Reviewing the current state of knowledge helps to ensure that research is not being duplicated and that policy links are not being overlooked. There are implications, too, for strategic planning of research and policy priorities by the academic community, governance, institutions, organisations, funding agencies and stakeholders. Research gaps can be identified, as well as research and knowledge that has been produced but is not being used to inform adaptation decision-making. This review is based on a systematic review method developed by Ford et al (2012) and Berrang-Ford et al (2015).

METHODS

A systematic review approach was used to search, select and examine recent academic and 'grey' literature¹ on climate change impacts and the implications for decision-making, policy and management. The scope and structure of the review aligns with the three key areas of inquiry that guided the RA4 research stream (outlined above). As such, the central question guiding this review is:

What has been published in or about New Zealand since August 2013 on

1. Emerging climate change pressure points and implications for policy and management
2. Tools and frameworks to support adaptive management of climate change impacts
3. Enhancing adaptive capacity so that climate change implications are incorporated into decision-making

August 2013 is significant because it was the cut-off date for inclusion of published material in *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*. This review aims to summarise **new** NZ-focused research that was not captured in the Australasia section (chapter 25) of the 2014 IPCC WG II report, **and** that relates to one or more of the three strands of the research question outlined above. An exception to the August-2013 cut-off is made for seminal papers published prior to this date that are the only one of a kind on a relevant issue.

The selected publications include studies of impacts, adaptation, resilience, vulnerabilities, and adaptive capacity in relation to decision-making, but exclude mitigation-focused studies. Studies primarily biophysical in nature were also included if a link with decision-making was made and/or implications for policy or management examined. Full inclusion and exclusion criteria are provided in Table 1 .

We identified three databases in which to search for published research: Scopus, Web of Science, and Google Scholar. The key term "climate change" and geographic search term "New Zealand" were used in conjunction with a range of qualifying phrases to identify relevant academic literature (Table 2) and grey literature (Table 3).

¹For the purposes of this review, academic literature comprises peer-reviewed papers published in academic journals. All other literature, including masters and PhD theses, and reports published by academic institutions, is classified as grey literature.

Table 1: Inclusion and exclusion criteria

Inclusion	Exclusion
Written in English	Written in other languages
Literature published between August 2013 and November 2016	Literature published prior to August 2013, with the exception of seminal reports or articles published pre-August 2013 that are the only one of a kind on a relevant issue
Peer reviewed literature indexed in Scopus, Web of Science or Google Scholar	Peer reviewed literature not indexed in these databases
Grey (non peer reviewed) literature discoverable online using a Google search	Grey (non peer reviewed) literature not freely accessible online
Reviews, articles, editorials, reports, conference proceedings, fact sheets and information sheets, public-facing regional council reports	Book reviews, book chapters, submissions, internal council reports (e.g. officer briefings to councillors, internal memos)
Explicit focus on climate change AND implications for decision-making, policy or management	No focus on climate change OR sole focus on climate change with no link to decision-making, policy or management
Studies of impacts, adaptation, resilience, vulnerabilities, and adaptive capacity in relation to decision-making	Mitigation, biophysical focus only
Published in New Zealand or about New Zealand	No New Zealand focus

The title and abstract (or executive summary) of each document was assessed according to the inclusion criteria. A snowball search of citations in included articles and of related documents and links on searched websites identified additional publications. This resulted in a total review sample of 130 publications, which were then categorised according to one of seven key sectors. After grouping the literature in this way, it was judged that two

non-sectoral categories should be added to capture the substantial literature relating to the themes of coastal issues and river flooding. Additionally, a local government sub-sector was added under the 'Governance and Institutions' category in recognition of the key responsibilities that local government has in relation to climate change adaptation in NZ, as well as the number of publications with a specific local government focus (Table 4).

Table 2: Search terms applied to each academic database

Key term	Climate change
	AND
Geographic term	New Zealand
	AND
Qualifiers	Pressure points OR Implications for policy OR Impacts and policy OR Impacts and management OR Adaptation tools OR Risks OR Adaptation and decision-making OR Adaptive Capacity OR Resilience OR Adaptation frameworks OR Decision support OR Vulnerability

Table 3: Search terms applied to Google, regional council websites, Envirolink, NGO, government department and other websites

Climate change adaptation New Zealand	Adaptive capacity New Zealand
Adaptation and decision making New Zealand	Adaptation support tools New Zealand
Climate change impacts New Zealand	Sea level rise impacts New Zealand
Coastal erosion management New Zealand	Climate change flood management New Zealand
Climate change resilience New Zealand	Climate change implications New Zealand

Table 4: Reviewed publications according to sector or theme

Category (sector or theme)	No. of publications included in review
Biodiversity, biosecurity and conservation	18
Finance (including banking and insurance)	2
Governance and institutions	19
Local Government	12
Coastal issues	18
River flooding	10
Health, well-being and culture	15
Infrastructure (including transport and utilities)	9
Primary industries (including farming, fishing, and forestry)	18
Tourism	9
TOTAL	130

Within these sectoral or thematic groupings, each article was then reviewed in-depth and sub-categorised according to its primary relevance to one of the three key research questions. As might be expected, a number of publications spanned several sectors and/or canvassed more than one of the three research questions. In these cases a judgement was made as to where the publication most comfortably fitted relative to other literature in the review. Noting that there is overlap between sectors and research questions, the structure nevertheless offers a practical way of organising and summarising a diversity of studies.

A REVIEW OF RECENT RESEARCH

This section presents recent literature on climate change impacts and implications for policy and management in NZ using an annotated bibliography style. Each annotation of approximately 200 words describes

1. How the publication relates to one of the three research themes
2. A summary of the study methods and results
3. Key learnings for adaptation in NZ- recommendations and/or gaps

Publications are listed alphabetically within each category (according to lead author), with academic literature presented first, followed by non peer reviewed literature. A short overview is provided at the start of each sectoral/thematic section. A summary of key gaps is presented at the end of the review.

BIODIVERSITY, BIOSECURITY AND CONSERVATION

Publications in this section examine potential implications of various climate change impacts for a range of biodiversity management and pest-control issues in NZ. A common conclusion across studies is that conservation and biocontrol strategies need to proactively plan for the increased threats posed by climate change, particularly in marine and freshwater ecosystems- i.e. explicitly including climate change as a threat to ensure that it is assessed alongside other threats to species and ecosystems. Barriers to successful adaptive management identified in the literature for this sector include; management practices and institutional arrangements ill-suited to the complexity and uncertainty of climate change; a lack of recognition of the types of information needed to make flexible and robust decisions; inadequate attention paid to implementation pathways, including monitoring, evaluation and adaptive learning; and insufficient linkages between management agencies and science institutions.

Climate change pressure points and implications for policy and management

Academic literature

Aguilar, G.D., Farnworth, M.J., & Winder, L. (2015). **Mapping the stray domestic cat (*Felis catus*) population in New Zealand: Species distribution modelling with a climate change scenario and implications for protected areas.** *Applied Geography*, 63, 146-154. <http://dx.doi.org/10.1016/j.apgeog.2015.06.019>

This study looks at the possible impacts of climate change on NZ's stray cat population and the associated implications for protected areas. The authors, researchers from Auckland's Unitec and from Plymouth University in the UK, used species distribution modelling to visualise the spatial characteristics of stray cats in NZ and investigate how they may impact areas that are considered to be environmentally important. Projections with a climate change scenario show a consistent increase in the area and intensity of areas suitable for stray cats. The authors overlay the protected areas of the country into the suitability maps to help identify which protected areas are more suitable for stray cats in current and a future climatic condition. The study uses data from Auckland only, which is projected to the wider NZ area, so future work can benefit from collection of actual occurrence data from the entire country. The authors also concede that further work in refining the models and the use of a bioclimatic layer representing additional emission scenarios is needed to provide a more comprehensive set of maps depicting the suitability of NZ to stray cats. This approach could contribute to the development of un-owned cat management strategies through the establishment of NZ-wide maps for current and future conditions.

Bellard, C., Leclerc, C., & Courchamp, F. (2014). **Impact of sea level rise on the 10 insular biodiversity hotspots.** *Global Ecology and Biogeography*, 23, 203-212. doi: 10.1111/geb.12093

This research paper by three Paris-based ecologists investigates the consequences of sea level rise for 10 insular biodiversity hotspots and their endemic species, including NZ. The study aimed to identify areas with the highest risk of inundation and the number of endemic species at risk of potential extinction. The authors investigated four sea level rise scenarios – 1, 2, 3 and 6 metres –and, for each, assessed the islands that would be partially or entirely submerged by overlying precise digital elevation model and island data. The number of endemic

species for each taxon (i.e. plants, birds, reptiles, mammals, amphibians and fishes) potentially affected by insular habitat submersion is estimated using the endemic-area relationship. Along with Japan and the East Melanesian islands, NZ is predicted to be least affected by sea level rise, with fewer than 60 islands combined that are threatened by having 50% of their area inundated in the future. The researchers conclude that the threat posed by sea level rise requires specific policies that prioritise insular biota on islands at risk of near future sea level rise.

Cornwall, C.E., & Eddy T.D. (2014). ***Effects of near-future ocean acidification, fishing, and marine protection on a temperate coastal ecosystem.*** *Conservation Biology*, 29(1), 207-215. doi: 10.1111/cobi.12394

The climate change impact of interest in this study is ocean acidification, and its independent and cumulative effects on a coastal ecosystem in combination with two other anthropogenic impacts -fishing and marine protection. The authors note that anthropogenic perturbations do not usually occur in isolation, and combining two or more impacts can result in different outcomes that cannot be determined by simply adding their cumulative effects together. The study used an Ecopath with Ecosim ecosystem model for the Wellington south coast, including the Taputeranga Marine reserve, for four scenarios exploring different combinations of ocean acidification, marine protection and fishing. They found that the effects of ocean acidification were only large in the absence of fishing. Ocean acidification was predicted to indirectly benefit certain species in the marine protection scenario. This was because lobster only recovered to 58% of the marine reserve biomass in the ocean acidification + marine reserve scenario, a situation that benefited the trophic groups lobsters prey on. The authors suggest that conservation and fisheries management strategies need to account for the reduced recovery potential of some exploited species under ocean acidification, and indirect responses of species to ocean acidification caused by declines in calcareous predators.

Correia, D.L.P., Chauvenet, A.L.M., Rowcliffe, J.M., & Ewen, J.G. (2015). ***Targeted management buffers negative impacts of climate change on the hihi, a threatened New Zealand passerine.*** *Biological Conservation*, 192, 145-153. <http://dx.doi.org/10.1016/j.biocon.2015.09.010>

This paper rests on the premise that in order to buffer the risks climate change poses to biodiversity,

managers need to develop new strategies to cope with an increasingly dynamic environment. The authors, based at London's Imperial College and Zoological Society, note that supplementary feeding is a commonly used form of conservation management that could help buffer the impacts of climate change but the role of supplementary feeding as an adaptation tool is not fully understood. The study quantified the relationship between weather (average temperature and total precipitation) and vital rates (survival and recruitment) of a NZ bird population, the hihi, on Kapiti Island. They then used predictive population modelling to project population dynamics under different management strategies and several IPCC climate change scenarios. The projections suggest supplementary feeding likely buffers against heavier rainfall and more stochastic precipitation patterns, but has no buffering effect under increasing temperatures. Though the conclusion is that supplementary feeding will not be able to avert the hihi population's extinction in the face of climate change on its own, it could still be considered as a valuable conservation tactic by delaying it. Two options are presented to managers when faced with decreasing effectiveness of conservation management strategies due to climate change: Find a better adaptation tool for their population, which could be a combination of current approaches or a novel solution; or reconsider the cost-benefit ratio of safeguarding a species against climate change, with the risk of deeming conservation projects unfeasible under this threat.

Floerl, O., Rickard, G., Inglis, G., & Roulston, H. (2013). ***Predicted effects of climate change on potential sources of non-indigenous marine species.*** *Diversity and Distributions*, 19, 257-267. doi: 10.1111/ddi.12048

This study compares present-day global ocean climate with future climatologies based on IPCC models and examines whether changes in global ocean climate will affect the environmental similarity of NZ's coastal environments to those of the rest of the world. The underlying rationale is that environmental changes to source and recipient regions may result in changes to the risk of non-indigenous species survival and establishment. The authors determine the environmental similarity between global coastlines and north-east NZ for 2005 and 2050 using data on coastal seawater surface temperature and salinity. Anticipated climate models from the SRES A1 scenario family are used to derive coastal climatologies for 2050. Results suggest that most global regions will experience an increase in coastal seawater surface temperatures in

coming decades. Global regions that presently have high environmental similarity to north-east NZ show no clear pattern of change, while some regions that currently have low similarity will become more similar to NZ. The models predict a widespread decrease in the seasonal variation in environmental similarity to NZ. The key messages include: Anticipated changes in the global ocean climate have potential to change the risk of survival and establishment of non-indigenous marine species arriving to NZ from other regions; and predicted changes to global human transport networks highlight the importance of incorporating climate change into conservation planning and modelling.

Gerard, P.J., Barringer, J.R.F., Charles, J.G., Fowler, S.V., Kean, J.M., Phillips, C.B., Tait, A.B., & Walker, G.P. (2012). **Potential effects of climate change on biological control systems: case studies from New Zealand.** *Biocontrol*, 58, 149-162. doi: 10.1007/s10526-012-9480-0

This research investigates the likely impacts of climate change on one weed and four invertebrate management systems in differing production sectors in NZ, and the implications for biological control systems integral to NZ's success as a country reliant on exporting quality agricultural, forestry and horticultural products. It is noted that most studies of the impacts of climate change focus on individual species, whereas biological control systems involve interactions between species at different trophic levels. The key climate change challenges identified are: Disparities in natural enemy capability to change distribution; lack of frosts leading to emergence of new pests and additional pest generations; non-target impacts from range and temperature changes; increased disruptions caused by extreme weather events; disruption of host-natural enemy synchrony; and insufficient genetic diversity to allow evolutionary adaptation. The study found that the main effect of projected climate change for the next century in NZ are species ranges moving south to follow their preferred climate conditions and shifting crop distributions. This trend may be complicated by several factors including different responses of pests and their biological control agents to north-south temperature influences and east-west rainfall influences resulting in unique new combinations for which it is not currently possible to predict the outcome. The study highlights knowledge gaps and the need for NZ decision-makers in government and industry to understand the wider issues in maintaining effective biological control systems in the face of change and recognition of the types of information needed.

Hopkins, C.R., Bailey, D.M., & Potts, T. (2016). **Perceptions of practitioners: Managing marine protected areas for climate change resilience.** *Ocean & Coastal Management*, 128, 18-28. <http://dx.doi.org/10.1016/j.ocecoaman.2016.04.014>

This paper presents a series of international case studies from four locations, including the Hauraki Gulf, to review perceptions of how climate change has been considered in the design, implementation, management and monitoring of Marine Protected Areas (MPAs). Interviews were conducted with a mix of MPA managers, academics, NGO employees and government staff in each of the case study locations. Key lessons include: Strictly protected marine reserves are considered essential for climate change resilience and will be necessary as scientific reference sites to understand climate change effects; adaptive management of MPAs is important but hard to implement; and strictly protected reserves managed as ecosystems are the best option for an uncertain future. In the NZ case study, the majority of respondents reported on the limitations of the Marine Reserves Act for establishing MPAs for any other purpose than for scientific research. Respondents considered that for an MPA network to be effective in the future, NZ should build on the foundation of marine reserves and include conservation of biodiversity as an objective for new MPAs, in line with international policy.

Jacobson, C., Hughey, K.F.D., Lynch, A.J.J., Nursey-Bray, M., O'Connell, M., Munro, P.G., Vella, K., Whiley, D., Dovers, S., & Carter, R.W. (2014) **Twenty years of pacifying responses to environmental management.** *Australasian Journal of Environmental Management*, 21(2), 143-174. <http://dx.doi.org/10.1080/14486563.2014.917594>

Using a state, pressure, response framework, this paper provides an evidence-based reflection on environmental outcomes in Australia and New Zealand across the domains of climate change, biodiversity, freshwater and marine management, emphasising the role of indigenous and business perspectives. The authors comment that responses to climate change have tended to emphasise passive risk management with unclear outcomes. They suggest a shift is needed towards deliberative policy experimentation that truly values the application of novel and diversified approaches and facilitates integrated learning across environmental domains. According to the researchers, while we are learning about governance

and management, we are not addressing governance and management outcomes in a comprehensive, cross-scale, cross-tenure, long-term and integrated manner to achieve sustainability. For example, this study suggests that often inadequate attention is paid to implementation pathways including transition arrangements, institutional arrangements, and expectations of the time needed to achieve outcomes, a lack of resourcing, poor communication, and a lack of monitoring, evaluation and adaptive learning.

Latham, A.D.M., Latham, M.C., Cieraad, E., Tompkins, D.M., & Warburton, B. (2015). ***Climate change turns up the heat on vertebrate pest control.*** *Biological Invasions*, 17, 2821-2829. doi: 10.1007/s10530-015-0931-2

Researchers at Landcare Research here explore the implications of climate change and invasive species for global food security and native biodiversity. The authors demonstrate quantitatively how a trend towards warmer winters over the past >60 years has significantly reduced the window of time for effective control of an invasive mammalian pest (European rabbit) in temperate NZ. The results suggest that where toxins are the primary method of control, these efforts may become constrained as winters become warmer. They suggest the phenomenon of a reduced timeframe for effective control of rabbits using best practice is probably generalisable to the control of other vertebrate pests, particularly in temperate systems where they are seasonably food limited. This may necessitate a shift to new baiting strategies or additional tools for pest control that are not climate sensitive. The key message is that climate change can affect the distribution and prevalence of invasive species by constraining our ability to control seasonally-food-limited vertebrate pests and that even in the short term such constraints may threaten to reduce ecosystem resilience. The key recommendation to avoid jeopardising our ability to effectively manage invasive species in the face of climate change is that researchers and pest managers develop a broad arsenal of control tools to manage pests across the seasons.

Sheppard, C.S., Burns, B.R., & Stanley, M.C. (2016). ***Future-proofing weed management for the effects of climate change: is New Zealand underestimating the risk of increased plant invasions?*** *New Zealand Journal of Ecology*, 40(3), 398-405.

This forum article synthesises research on potential synergistic effects of plant invasion and climate change and discusses the general implications for

management of weeds under climate change in NZ. An assessment of three recently naturalised subtropical species (*Archontophoenix cunninghamiana*, *Psidium guajava* and *Schefflera actinophylla*) illustrates the potential risk of invasions by such species arising with climate change. The authors note that, despite two recent DoC reports giving policy recommendations for conserving biodiversity under climate change, in which the potential of new weeds was highlighted as one of the most imminent threats, very little action has been taken. They argue that climate change needs to be accounted for in current weed management policies, but that, given a framework already exists for prioritising and ranking weeds, which includes a cost-benefit model, there is no need to 'reinvent the wheel'. Specific recommendations include: Improved prediction of potential new weeds, including consideration of up-to-date research and use of best practice modelling tools; better surveillance for new infestations through spatial prioritisation by habitat suitability and use of well-managed citizen science projects; education campaigns to raise awareness of climate change effects and new weed threats; combined efforts to future-proof NZ weed management for the effects of climate change by conservation managers, scientists and the general public.

Tompkins, D.M., Byrom, A.E., & Pech, R.P. (2013). ***Predicted responses of invasive mammal communities to climate-related changes in mast frequency in forest ecosystems.*** *Ecological Applications*, 23(5), 1075-1085.

Researchers from Landcare Research and the University of Auckland's School of Biological Sciences explored the hypothesis that in interactions between two global change drivers, invasive vertebrates and climate change will potentially make matters worse for native biodiversity. It is noted that in NZ beech forests, a highly irruptive invasive mammal community is driven by multi-annual resource pulses of beech seed (masting). Because mast frequency is predicted to increase with climate change, it is used in this study as a model system to explore the extent to which such effects may influence invasive vertebrate communities, and the implications of such interactions for native biodiversity and its management. Results suggest an increased frequency of masting (which is already occurring in NZ) will lead to stoat and rat populations being maintained at higher average abundances in beech forests. The ability of both current and in-development management approaches to suppress invasive mammals is predicted to be compromised.

Because invasive mammals are key drivers of native fauna extinction in NZ, with the additional loss of associated functions such as pollination and seed dispersal, these predictions imply potentially serious adverse impacts of climate change for conservation of biodiversity and ecosystem function. The study also highlights the importance of long-term monitoring data for assessing and managing future impacts.

Weeks, E.S., Death, R.G., Foote, K., Anderson-Lederer, R., Joy, M.K., & Boyce, P. (2016). **Conservation Science Statement. The demise of New Zealand's freshwater flora and fauna: a forgotten treasure.**

Pacific Conservation Biology, 22, 110-115. <http://dx.doi.org/10.1071/PC15038>

Climate change implications are not the primary focus of this article on NZ freshwater biodiversity, however climate change is identified as one of a number of increasing threats to the conservation of freshwater flora and fauna. The authors state that, although NZ has some of the highest levels of threatened freshwater species in the world, threatened species are often discounted in water policy and management that is predominantly focused on balancing water quality and economic development (rather than biodiversity). A range of actions are recommended to redress the balance, including changing legislation to adequately protect native and endemic fish species and invertebrates, and developing policy and best management practices for freshwater catchments in addition to lakes and rivers to also include wetlands, estuaries and groundwater ecosystems.

Grey literature

Department of Conservation. (2013). **Freshwater conservation under a changing climate.** Proceedings of a workshop hosted by the Department of Conservation, 10-11 December 2013, Wellington. Retrieved from <http://www.doc.govt.nz/Documents/conservation/climate-change-proceedings.pdf>

The authors of these proceedings describe the vulnerability of freshwater ecosystems to climate change impacts and identify the priorities for information sharing and research needed to underpin an adequate policy response and to inform future management. A decision framework is introduced to help natural resource managers to identify situations where adaptation to climate change through human intervention may be required. It is noted that agencies like DoC and regional councils are increasingly applying strategic approaches to freshwater conservation, although at the time of

publication, few programmes appeared to specifically consider climate change. More direction in regional and national policy is called for to protect freshwater ecosystems under a changing climate. Despite clear provisions for climate change in the RMA and the NPS from Freshwater Management, the authors believe the lack of a strong technical evidence base to guide policy and planning is slowing progress. Seven areas are recommended for immediate action and investment: Implement a science programme to fill key knowledge gaps; improve linkages between management agencies and science institutions; foster increased awareness; review approaches to freshwater ecosystem management; learn from international studies; establish future-focused monitoring; and apply a precautionary approach to water management.

Green, W (2014). **How climate change responses by land managers could benefit biodiversity: A think piece on the opportunities** (report prepared under contract for the Department of Conservation). Wellington, NZ: DoC.

The theme of this think piece is to identify positive opportunities and practices for land managers to implement adaptation and mitigation measures that benefit NZ's native biodiversity. An aim is to identify maladaptive options so that positive alternatives can then be identified, promoted and implemented. The paper discusses possible impacts of climate change on NZ coastal, freshwater and forest ecosystems and how the impacts of predators, weeds and fire may change. It is argued that, collectively, these impacts warrant a different level and type of response than the current approaches to conservation management on public and private lands. The author also argues that NZ's current policy framework with respect to climate change impacts on biodiversity is inadequate, with no mention of climate change in the NZ Biodiversity Strategy (2000) or the National Policy Statement on indigenous biodiversity (2011). The paper proposes that whether measures taken by land managers turn out to be adaptive or maladaptive will be strongly influenced by how concepts of resilience are understood and applied. Two key barriers to implementing successful adaptive practices outlined are psychological resistance to change; and the mismatch of institutions and governance structures designed for a more stable, predictable and less interconnected world.

NIWA. (February 2015). ***The history of benthic change in Pelorus Sound (Te Hoiere), Marlborough*** (report prepared for Marlborough District Council). Nelson, NZ: Handley, S.

Climate change impacts and implications are only a peripheral focus in this review of information relating to historic changes to the seabed of Pelorus Sound. It is noted that there is potential for increased sedimentation with predicted effects of climate change, as well as potential for increased stress in marine ecosystems with increasing intensity and periodicity of storms. It is therefore recommended that any measures that can be taken to protect and enhance the resilience of the Pelorus should be encouraged, otherwise the rate of degradation related to sedimentation especially, will likely increase.

NIWA. (March 2016). ***History of benthic change in Queen Charlotte Sound/Totaranui, Marlborough*** (report prepared for Marlborough District Council). Nelson, NZ: Handley, S.

This report has the same remit as the Pelorus Sound report above, but with a geographical focus on the neighbouring Queen Charlotte Sound/Totaranui area of Marlborough district. This report also has a more direct focus on climate change impacts than the one above. For instance, one of the key questions posed here is "What are the future risks associated with 'business as usual' approach? E.g. risks associated with climate change." The approach for this report was to undertake a wide-ranging search for historical information relating to marine and land use changes in QCS. The author notes that climate change is likely to exacerbate pervasive disturbance factors such as sediment and nutrient discharge relating to land clearance (agriculture, farming, forestry, urbanisation, industry). The report includes a section in the discussion about climate change and long term monitoring. Here the author discussed the well-documented difficulties associated with making specific predictions at scales at which appropriate management measures can be taken. Predictions are hampered by: the lack of long-term time series data to establish correlations with past environmental fluctuations; a limited understanding of the way ecosystems are structured by interactions between species and the environment; and lack of information on the tolerances of habitat-forming species to variability in the environmental factors that may be affected by climate change. In the absence of such information, a precautionary and restorative management approach is recommended.

Tools and frameworks to support adaptive management

Academic literature

Rout, T.M., McDonald-Madden, E., Martin, T.G., Mitchell, N.J., Possingham, H.P., & Armstrong, D.P. (2013). ***How to decide whether to move species threatened by climate change***, PLoS ONE, 8(10), 1-7.

This research collaboration between Australian and NZ academics develops a quantitative framework for deciding whether or not introduction of a particular species to a new area should go ahead, which species to prioritise for introduction, and where and how to introduce them. The framework can also be used to compare introduction with alternative management actions, and to prioritise questions for future research. It is designed to be simple and accessible while accommodating uncertainty, and is aimed at providing support for the existing IUCN guidelines by presenting a process for better decision-making about conservation introductions. The framework was applied to a case study of tuatara in NZ. The authors acknowledge that while introducing species to areas outside their historical range to secure their future under climate change is controversial, such introductions are already taking place. The framework makes several simplifications worth noting: It does not explicitly consider how the extinction of the source population will affect other species at that site; and using a decision tree means extinction and population establishment are treated as discrete events, when in reality these events may occur simultaneously over many years. While the framework is simple, the authors believe it is transparent and adaptable and can be informed by quantitative models, data analyses and expert judgement.

Grey literature

Christie, J.E. (2014). ***Adapting to climate change: A proposed framework for the conservation of terrestrial native biodiversity in New Zealand*** (report prepared for publication by the Department of Conservation Publishing Team). Wellington, New Zealand: DoC.

This report describes a framework to guide how DoC manages the impacts of climate change on terrestrial native biodiversity in NZ. The framework comprises five broad strategies: Improve knowledge; develop adaptation methods and decision-support tools; incorporate climate change adaptation planning into existing management, research, planning and policy; improve current management to facilitate native resilience; and raise awareness outside DoC.

Within these strategies, 14 actions covering a range of conservation practices have been identified. McGlone and Walker's 2011 review of the likely and possible impacts of projected climate change on terrestrial biodiversity in NZ provided the basis for this framework. The report suggests that predicting the direct responses of terrestrial biodiversity in NZ to climate change will be challenging in NZ than elsewhere, due to greater uncertainty surrounding climate predictions, species' responses to climate change and the ability of species to adapt, especially given the existing pressures of invasive species and human-related habitat loss on native biodiversity. The lack of systematic long-term biodiversity records for NZ, and the limited understanding of factors (including climate) driving species distribution and abundance are also identified as issues. It is recommended that DoC work programmes need to explicitly include climate change as a threat to ensure that it is assessed alongside other threats to species and ecosystems.

FINANCE (INCLUDING BANKING AND INSURANCE)

Very little recent literature with an explicit focus on the implications of climate change for the financial sector, including banking, investment and insurance, was uncovered during the course of this review. Of the two publications included, one provides an insurance industry perspective on planning for the impacts of natural hazards and climate change, and the other is a guide intended to assist councils in managing risk financing, including financing of risks associated with climate-related hazard events. A general lack of published research in this area, at least in the NZ context, is evident.

Climate change pressure points and implications for policy and management

Grey literature

Insurance Council of New Zealand. (2014). ***Protecting New Zealand from Natural Hazards- An Insurance Council of New Zealand perspective on ensuring New Zealand is better protected from natural hazards.*** Wellington, NZ: ICNZ.

This short position paper is aimed at decision-makers and "those who have an interest in ensuring NZ is better protected from natural hazards." Climate change impacts are identified in the paper as a key area of vulnerability in NZ's hazardscape, bringing an increased risk of flooding and drought, more severe

windstorms and threats to coastal areas through sea level rise. The paper explains what should be done, from an ICNZ perspective, to better protect NZ from natural disasters and climate change and calls for a step change in the country's approach to resilience. The ICNZ's recommendations span across four key areas: strategy and legislation; information to make the right decisions, funding; and insurance. Key finance-related recommendations include a commitment to long-term annual funding of initiatives to build resilience where the risk and investment trade-off justifies it, as well as a long-term bi-partisan commitment to fund measures that build pre-disaster resilience. The ICNZ report also recommends the introduction of comprehensive measures to reduce the risk of natural disasters and remove levies from insurance premiums to help keep the transfer of risk to insurance affordable and available for all.

Tools and frameworks to support adaptive management

Grey literature

Middleton, D. (2016). ***Risk financing in local government:*** (A guide prepared by Kestrel Group for LGNZ). Wellington, NZ: LGNZ.

This guide was prepared for LGNZ during the development of a business case for a Local Government Risk Agency. The guide was prepared for the assistance of local authorities and deals principally with the management of retained risks and with insurance. The insurance industry's use of the word "risk" is followed i.e. "risk" is the chance of financial loss. The guide does not discuss climate change impacts directly, but does have a strong focus on the types of hazard events for which climate change is considered a hazard amplifier. The report outlines how, having identified hazards and decided what can be avoided, retained, mitigated or contracted out, and having set up a system for the administration of retained risks, a local authority can consider the transfer of any residual risk. The author identifies traditional insurance as the obvious means, but comments that other means have been developed over the past few decades, some of which incorporate advantages for the coverage of disaster events. These are touched on only lightly in the guide, and include catastrophe bonds, risk swaps, and contingent capital. The principal focus of the guide is on helping councils to better understand risk, essential features of insurance, and dealing with the insurance market.

GOVERNANCE AND INSTITUTIONS

This section includes a wide range of different publication types covering various specific governance and institution-related issues ranging from disaster risk management to social housing, and national security, as well as a number of overview or synthesis-type publications that discuss policy-relevant implications of climate change more generally. The majority of material focuses largely on impacts and implications, with some consideration given to ways to enhance institutional adaptive capacity; fewer publications describe tools and frameworks for enabling adaptive management. Key messages include the need to develop whole-of-government policy processes; mechanisms to bring the long term into short-term political focus and enable better linkage of spatial and temporal scales of decision-making; ways to address fragmentation across different statutory frameworks; cross-disciplinary dialogues to translate diverse scientific and social-scientific knowledge into innovation regulatory, social and economic practice; integration of climate change impacts into all risk assessment methodologies; and policy and planning approaches that are receptive to, and capable of, incorporating an evolving evidence base.

Climate change pressure points and implications for policy and management

Academic literature

Basher, R. (2016). *High Stakes- Disaster Risk in New Zealand*. Policy Quarterly, 12(3).25-29.

This review discusses disaster risk as a matter of national importance and considerable policy interest. It finds that there are significant shortcomings in how disaster risk is recognised and managed in NZ. The author states that NZ can draw on extensive experience and thinking in other countries concerning disaster risk. It cites the 2005 Hyogo Framework for Action as an example of an attempt to reduce disaster risk globally, but laments that NZ has paid little attention to the framework and its guidance over the following decade. However, the author notes that there are signs that the 2015 successor agreement, the Sendai Framework for Disaster Risk Reduction, will be actively implemented here. It is argued that NZ has many well-developed institutions and capacities to address disaster risks, but there are significant shortcomings in concept, management and governance. Some of the problems identified are that the concept of risk is not well articulated in relevant laws, institutions,

documents and processes; leadership on risk-related matters lies out of sight within government structures; and information on disaster risk and its reduction is often hard to find. Steps to address the problem are proposed, including identifying disaster risk and its reduction as a core concern of government and require that it be considered as part of whole-of-government policy processes; strengthening the financing of risk reduction through a coordinated and appropriately supported national portfolio of funding mechanisms; and significantly improving the level of information provided on disaster risk and its reduction through government and other public websites and in the media.

Boston, J. (2016). *Anticipatory Governance- how well is New Zealand safeguarding the future?* Policy Quarterly, 12(3). 11-24.

This article discusses the concept of anticipatory governance and what it means in NZ. The author outlines some of the attributes of anticipatory governance, including its embracing the need for anticipatory planning and adaptive management and the development of capability and tools for rigorous risk management. The author argues that, in protecting future interests, anticipatory governance seeks robust, yet flexible, democratic institutions and processes. Climate change is identified as one of the five top global risks in terms of likelihood and impact. It is described as being among the risks which may be overlooked or poorly addressed by governments because of its characteristics as a 'looming', 'creeping' or 'emerging' policy problem. The author concludes that in order to mitigate such risks, governments must take countervailing measures, such as strong commitment devices that obligate policymakers to look beyond their immediate horizons. This includes institutional mechanisms and procedural requirements that bring the long term into short-term political focus, such as regular, dedicated and independent analyses of intergenerational issues. It is argued that governments also need to pursue strategies to enhance societal resilience and adaptive capacity. The author suggests that NZ has taken significant steps to this end in recent decades in the fields of fiscal policy, infrastructure planning, public investment and public sector management, but that in many other fields, especially social and environmental policy, the current policy institutions and frameworks are deficient.

Hopkins, D., Campbell-Hunt, C., Carter, L., Higham, J. E. S., & Rosin, C. (2015). **Climate Change and Aotearoa New Zealand. WIREs Climate Change 2015**, 6. 559-583. doi: 10.1002/wcc.355

This 'advanced review' of climate change literature identifies three key risks for NZ relating to economic connectedness, perceptions of 'clean, green' NZ, and social equity. Adaptive responses are considered in connection to key industries (agriculture, tourism) and communities (coastal, Maori), and the devolved structure of adaptation is examined. The authors argue that NZ is in an interesting position insofar as perception of action and engagement with global climate governance could be as important as the biophysical impacts in the coming decades. They suggest that explicit engagement with global climate governance has waned over time. Key knowledge gaps identified in this review relate to the full range of biophysical and socioeconomic outcomes, the impact of global perceptions, and consumer behaviours and preferences. The asymmetry of vulnerability to climate change impacts across NZ's population is highlighted as creating added complexity, but addressing social inequalities through climate change responses is presented as an opportunity to redress sociocultural, economic and health disparities. The authors comment that by increasing knowledge in these, and other areas, NZ will be in a better position to engage social actors, and increase support for more proactive government responses.

Lawrence, J. (2016) **Implications of Climate Change for New Zealand's Natural Hazards Risk Management. Policy Quarterly**, 12(3). 30-39.

This article discusses how climate change impacts such as sea level rise and high intensity rainfall will exacerbate the challenges faced by decision-makers when they are under pressure to restore normality as quickly as possible following extreme events. Using insights from a NZ-based study of the adequacy of institutional frameworks and practice for adapting to climate change, the article demonstrates how climate change impacts and current natural hazards risk responses can increase the level or residual (unavoidable) risk, and therefore challenge the capacity of NZ emergency management, flood risk reduction and planning systems to address such risks. The author suggests that changing climate risk profiles need attention in an integrated manner so that decisions can be made that are robust over a range of possible future scenarios. The author notes that

current governance and institutional rules typically result in incremental adaptation and are ill-equipped to deal with climate changes that fall outside of the range of climate experienced to date. The author argues that changes will be required to the current governance and institutional arrangements to enable implementation of robust, flexible strategies and plans as risk profiles change. Enablers of improved integration in climate change adaptation are identified, including addressing fragmentation across different statutory frameworks; better linking of spatial and temporal scales of decision-making; aligning risk frameworks, their practice and communication; mainstreaming financing strategies across development, risk reduction and adaptation; and coordination across governance frameworks and networks.

Lundquist, C.J., Fisher, K.T., Le Heron, R., Lewis, N.I., Ellis J.I., Hewitt, J.E., Greenaway, A.J., Cartner, K.J., Burgess-Jones, T.C., Schiel, D.R., & Thrush, S.F. (2016) **Science and Societal Partnerships to Address Cumulative Impacts. Frontiers in Marine Science 3**(2) doi: 10.3389/fmars.2016.00002

This paper presents a variation on science prioritisation exercises, focusing on inter-disciplinary research questions with the objective of shifting broad scale management practices to better address cumulative impacts and multiple users. Marine scientists in NZ from a broad range of scientific and social-scientific backgrounds ranked 48 statements of research priorities. At a follow-up workshop, participants discussed five overarching themes based on survey results. These themes were used to develop mechanisms to increase the relevance and efficiency of scientific research while acknowledging socio-economic and political drivers of research agendas in NZ's ocean ecosystems. Key messages with relevance to climate change impacts and implications include the need to determine the conditions under which sudden and substantive undesirable changes are likely to occur and the socio-ecological implications of such changes; assess potential solutions to management issues that balance long-term and short-term benefits and encompass societal engagement in decision-making; and establish cross-disciplinary dialogues to translate diverse scientific and social-scientific knowledge into innovation regulatory, social and economic practice. The authors conclude that transformation needs to "permeate the rooms of decision-makers" to shape and deliver change.

Reisinger, A., Kitching, R.L., Chiew, F., Hughes, L., Newton, P.C.D., Schuster, S.S., Tait, A., & Whetton, P. (2014). Australasia. In V.R. Barros, C.B Field, D.J Dokken, M.D Mastrandrea, K.J Mach, T.E Bilir, M. Chaterjee, 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.), **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. 1371-1438). Cambridge, UK and New York, USA: Cambridge University Press.

This chapter first sets out key characteristics of the Australasia region and major conclusions pertaining to this region from previous IPCC assessments. Observed and projected climate changes for Australasia are then outlined, followed by an exploration of socioeconomic trends influencing vulnerability and adaptive capacity, and approaches and constraints to the effectiveness of adaptation in the context of frameworks, governance and institutional arrangements. The chapter is then organised into sections according to key sectors and themes, comprising an examination of observed impacts; projected impacts and; adaptation in relation to each. Section headings include freshwater resources, natural ecosystems, major industries, and human society. Interactions among impacts, adaptation and mitigation responses are then discussed, with attention to interactions among local-level impacts, adaptation, and mitigation responses, as well as intra-and inter-regional flow-on effect. The chapter also discusses challenges to adaptation in managing key risks and the authors suggest that the magnitude of climate change is such that incremental and autonomous responses will not deliver the full range of adaptation options nor ensure the continued function of natural and human systems if some key risks are realised. A final section on knowledge gaps highlights a number of areas in which key uncertainties exist, for example the wide range of projected rainfall changes and their hydrological amplification are key uncertainties affecting the scale and urgency of adaptation in agriculture, forestry, water resources, some ecosystems, and wildfire and flood risks. Also, uncertainties about the rate of sea level rise, and changes in storm paths and intensity, add to challenges for infrastructure design.

Grey literature

Castalia Strategic Advisors. (2016). **The 2050 challenge: future proofing our communities**. (A discussion paper

prepared for LGNZ). Wellington, NZ: LGNZ.

This paper aims to improve understanding about the changes that NZ communities are likely to face between now and 2050 by highlighting a series of major shifts that, it is argued, will have an enduring impact on New Zealanders. The paper identifies shifts in five key areas and discusses ways that those shifts should change the way we make decisions. Responding to climate change is identified as one of the five, and the paper conveys the key message that NZ needs to be adapting and mitigating concurrently. The overarching question the paper poses in relation to adaptation is: How can we adapt to the impacts of climate change in a way that shares the burdens fairly and provides the right incentives for people to minimise the costs of climate change to NZ communities? Key facets of this problem are discussed, such as the fact that adaptation will require large amounts of resources that need to come from somewhere; communities will be differently affected by climate change; and enabling people to respond to incentives requires providing information on how climate change will affect them. In light of such issues, the paper proposes taking a 'whole of systems' approach to policy and planning, and responding to uncertain and dynamic shifts through policy and planning approaches that are receptive to, and capable of, incorporating an evolving evidence base.

Farquhar, H. (2014). **"Migration with Dignity": Towards a New Zealand Response to Climate Change Displacement in the Pacific**. (Honours Thesis, Victoria University of Wellington). Retrieved from <http://researcharchive.vuw.ac.nz/xmlui/bitstream/handle/10063/4302/thesis.pdf?sequence=2>

This thesis describes how the impacts of climate change threaten to cause the displacement of millions of people worldwide by the middle of this century and argues that international law provides insufficient protection to those who will be forced to migrate. The author states that in most cases those who are displaced will fall outside of current protection frameworks. The thesis examines why this protection deficit should be of particular concern to NZ, and argues that there are significant incentives for NZ to develop a response to the issue of climate change displacement in the Pacific. The paper concludes that in order to ensure Pacific peoples are able to migrate with dignity, pre-emptive, voluntary migration schemes should be put in place to facilitate migration flows. It is argued that these should be built upon the current

immigration framework, and include the extension of current permanent and temporary migration schemes, as well as the introduction of labour-training migration schemes. The author suggests these schemes allow migration to be used as a tool of adaptation for migrants and their communities, and allow NZ to plan and manage migration, which will not be possible if migration occurs during full-scale humanitarian crisis.

Karlik-Neale, M. (2009). ***Future of Social Housing in the Context of Climate Change and Rising Energy Prices*** (Report for URS New Zealand). Wellington, NZ: URS New Zealand.

This paper uses outputs from a scenario planning exercise undertaken by Housing New Zealand Corporation and URS to begin the process of assessing a variety of climate change response options for social landlords. Reviewed climate change response actions cover mitigation, adaptation and the internal changes that a social housing organisation would have to consider to deliver on these actions. The analysis suggests that private housing sector dynamics are likely to limit adaptation. It is argued that housing as a business sector, as a household investment, and as a key site for private consumption is highly vulnerable to external influences (e.g. global economic factors, insurance sector policy, local authority regulation) and this means the sector's ability to develop a self-determined, coherent response to the social impacts of climate change may be limited, and social housing might be expected to lead the way. The author argues that a wide range of strategies are available to improve the adaptive capacity but notes there is much less literature on adaptation responses for social housing compared to mitigation. Possible responses presented include selling high-risk properties, mitigating risk through insurance, and forging partnerships with utility companies to develop common climate change strategies. Criteria for the evaluation of response options are presented. These span three key areas: acceptability, viability, and validity. The paper concludes that social landlords have the potential to play an important role in regards to climate change, and that NZ's social tenants are among the most vulnerable to climate change impacts. The author suggests that successful responses will only be achieved in partnership with legislators, utilities and the wider housing sector. It is recommended that more work be undertaken to clearly set out the response options for NZ's social housing sector and to evaluate their viability and acceptability.

New Zealand Climate Change Centre. (2014). ***Climate Change IPCC Fifth Assessment Report New Zealand Findings***. Wellington, NZ: Hollis, M.

This four-page information sheet summarises key findings for NZ from the Australia and NZ chapter of IPCC's Fifth Assessment Working Group 2 report on Impacts, Adaptation and Vulnerability. The paper outlines how NZ's climate is changing, with long-term trends toward higher temperatures, more hot extremes, fewer cold extremes, and shifting rainfall patterns, and describes how more change is expected. Implications of climate change impacts for NZ's natural ecosystems, coastlines and floodplains, oceans and fisheries, agriculture, health and other areas are discussed. Two key adaptation challenges for NZ are identified: When and where adaptation may imply transformational rather than incremental changes; and where specific interventions could overcome adaptation constraints e.g. better coordination between central and local government. The paper identifies how flow-on effects from climate change impacts and responses outside NZ could be significant for trade-intensive sectors like agriculture and tourism, but states that little work has been done to fully understand these implications. The paper includes a short section on insurance, which outlines how insurance helps buffer the risk presented by climate change impacts and can also act as an incentive for policy holders to reduce their risk, for example through resilience ratings on buildings. However, it cautions that the effectiveness of insurance depends on the extent to which it is linked to a broader national resilience approach to disaster mitigation and response.

Office of the Prime Minister's Science Advisory Committee. (2013). ***New Zealand's changing climate and oceans: The impact of human activity and implications for the future*** (An assessment of the current state of scientific knowledge by the Office of the Chief Science Advisor). Auckland, NZ: Gluckman, P.

This report provides an update on scientific understandings of climate change and how it could affect NZ over coming decades. It focuses particularly on describing likely effects on various regions of NZ and explains why only considering predicted average changes will lead to an underestimation of the impact of predicted climate change on NZ's environment and economy. The report states that over the next 30-40 years, NZ will face significant adaptive requirements to cope with shifts in climate and there will need to

be a consequent readjustment in expectations of frequency of extreme events. The analysis suggests the impacts are likely to be greatest in domains unable to adapt quickly or in those areas already close to limits of tolerance, including natural and farming ecosystems evolved to function in current conditions and infrastructure requiring a long lead-time to plan and build, but also areas with high vulnerability such as those already prone to flooding or drought. It is also argued that because of NZ's dependence on international trade, it is important to consider NZ in a global context and not as an isolated system. The report highlights the "inevitable and unresolvable" uncertainty and complexity of climate change and argues that many decisions will be required at both national and local levels, and within both public and private sectors in spite of this. While the report does not address questions of what policy actions should be taken in response to climate change, it does pose a number of policy-relevant questions, including: What is an acceptable level of climate-related risk to society? What are the costs and benefits of adaptation or mitigation compared with other priorities? How are different stakeholders affected? The report argues that such questions require considerable reflection of societal values and science alone cannot answer them. It concludes that a risk management approach is needed and that active and adaptive management is required.

Renwick, J., Anderson, B., Greenaway, A., King, D., Mikaloff-Fletcher, S., Reisinger, A., Rouse, H., & Wratt, D. (2016). ***Climate Change Implications for New Zealand*** (Royal Society of New Zealand report) Wellington, NZ: The Royal Society of New Zealand.

The Royal Society established an expert panel to review and prepare this succinct summary of existing NZ information around the risks associated with recent and projected trends in GHG emissions, and the likely consequences for NZ in future decades and centuries. The report describes the changes in climate that are expected globally and nationally during the 21st century and six key areas of risk for NZ: coastal margins; flooding from rivers; availability of and competition for freshwater; changes to our surrounding oceans; threats to unique ecosystems; and flow-on effects from climate change impacts and responses overseas. For each of the above, the panel outlines what is already happening, what the future might hold, what the implications are, and key knowledge gaps. It was not within the panel's mandate to identify opportunities or responsibilities for

addressing the key risks, but it was intended that the information conveyed in the report could act as a basis for such a wider national discussion. Some key points emerge, including: Human systems and infrastructure may not cope with rapid change or extreme events. For example, sea levels have been relatively static for thousands of years and the development of coastal infrastructure reflects that; a changing climate creates new and amplifies existing climate-related risks for NZ. Risks can be reduced by reducing exposure and vulnerability to them; NZ is very connected internationally, thus NZ cannot chart its response to climate change based on impacts in NZ alone.

Sinclair, E. (2008). ***The Changing Climate of New Zealand's Security: Risk and Resilience in a Climate Affected Security Environment***. Institute of Policy Studies Working Paper 08(11), 1-68.

This paper describes climate change as a corrosive force capable of generating conditions of insecurity in NZ's strategic areas of interest (AOIs). It argues that if business continues as usual with a lack of global collective action, then climate change impacts will pose as risk multipliers with substantial security implications, and that unintended consequences entailing a variety of security challenges impacting upon NZ's well-being may result. The paper addresses these security implications and offers a means by which NZ decision-makers can begin confronting the uncertain security consequences of largely unabated climate change. Several overriding themes emerge from the analysis: There is an imperative to adopt different approaches to the traditional security emphasis that has sought to resist change and protect the nation against measurable and readily identifiable threats due to the complexity, non-linearity and uncertainty of climate change risks; interactions between precipitation changes, extreme weather events, water scarcity and food supply disruptions could trigger a range of security challenges within important AOIs and this in turn may weaken NZ's national security; and developing resilience nationally and assisting its development globally via the implementation of greater adaptive capacity will be a keystone for security.

Willis, G. (2014). ***Managing natural hazard risk in New Zealand- towards more resilient communities: A think piece for local and central government and others with a role in managing natural hazards***. (A discussion paper prepared for LGNZ and Regional Councils). Wellington, NZ: LGNZ.

This report reviews current arrangements for managing natural hazards risk in NZ. Though the report is not premised on a belief that the current system is in a fundamentally poor state, it identifies a range of issues. Those with relevance to climate change impacts and implications include: A lack of coordinated national leadership of risk reduction; no consistent basis to make natural hazard risk management decisions; dispersed information and guidance on natural hazards, with the public often reliant on incomplete and sometimes inaccurate information about hazards management; the context in which natural hazards management is occurring is changing – the effect of climate change, in particular, is not appropriately accounted for. The author recommends that in order to further define the issues and develop effective and targeted responses, LGNZ should advocate on behalf of the local government sector for a pan sector natural hazards and community resilience strategy to set clear strategic direction on key practice issues and the appropriate policy response. It is also recommended that a natural hazards policy platform be established as a mechanism to research and resolve natural hazards policy issues. Further, an enhanced and more integrated approach to natural hazards information is proposed, with the creation of a single information portal, which would make information more accessible and assist people to make better individual risk management decisions.

Tools and frameworks to support adaptive management

Academic literature

Tanner, T., Lewis, D., Wrathall, D., Bronen, R., Cradock-Henry, N., Huq, S., Lawless, C., Nawrotzki, R., Prasad, V., Rahman, A., Alaniz, R., King, K., McNamara, K., Nadiruzzaman, Md., Henley-Shepard, S., & Thomalla, F. (2015). ***Livelihood resilience: preparing for sustainable transformations in the face of climate change***. *Nature Climate Change*, 1, 23-26. doi: 10.1038/NCLIMATE2431

This paper asserts that the resilience concept requires greater attention to human livelihoods if it is to address the limits to adaptation strategies and the development needs of the planet's poorest and most vulnerable people. The authors suggest that although the concept of resilience is increasingly informing research and policy, its transfer from ecological theory to social systems leads to weak engagement with normative, social and political dimensions of climate change adaptation. The article describes how

a livelihood perspective helps to strengthen resilience thinking by placing greater emphasis on human needs and their agency, empowerment and human rights, and considering adaptive livelihood systems in the context of wider transformational changes. The paper does not have an explicit New Zealand focus, but one of its authors is a New Zealand-based researcher (Landcare Research) who has written extensively about climate change adaptation and resilience in a New Zealand land-use context.

Grey literature

Lawrence, J. (2015). ***The adequacy of institutional frameworks and practice for climate change adaptation decision making***. (Doctoral thesis, Victoria University of Wellington, Wellington, New Zealand). Retrieved from <http://researcharchive.vuw.ac.nz/xmlui/bitstream/handle/10063/4707/thesis.pdf?sequence=1>

This research asks if the current decision-making framework, and practices under it, are adequate to enable decision makers to make climate change adaptation decisions that sufficiently address the constraints posed by climate change uncertainty and dynamic change. The focus is on NZ's multi-scale governance and institutional framework which is highly devolved to the local level. Twelve criteria were used derived from the risk-based concepts of precaution, risk management, adaptive management and transformational change, with respect to; a) understanding and representing uncertainty and dynamic climate change; b) governance and regulations; and c) organisations and actors. The research found that the current decision-making framework enables long-term considerations and emphasises precaution and risk-based decision making. However, adaptive and transformational objectives are largely absent, coordination across multiple levels of government is constrained and timeframes are inconsistent across statutes. The analysis suggests that practitioners rely heavily upon static, time-bound treatments of risk, which reinforce unrealistic community expectations of ongoing protections, even as the climate continues to change, and makes it difficult to introduce transformational measures. Some experimentation by local government was found, but improvements to both the institutional framework and to practices that could enable flexible and robust adaptation to climate change, would require supporting policies and adaptive governance to leverage them and to sustain decision making through time. The research offers a new way of identifying

institutional barriers, enablers and entry points for change in the context of decision making under conditions of uncertainty and dynamic climate change.

Reisinger, A., & Lawrence, J. (2016). ***Predictions in an uncertain world- beyond the oxymoron***. Proceedings of the Environmental Law Intensive, Christchurch and Auckland. New Zealand Law Society Continuing Legal Education, Wellington, NZ. pp. 24.

This paper discusses the increasing wealth of evidence of the effects of climate change on natural resources and hazards relevant under NZ's Resource Management Act. It argues that, by contrast, academic engagement with practices of how to manage the effects of climate change, and in particular the application of a risk-based management paradigm to the requirements and processes set out in the RMA and other relevant statutes, is more limited but growing. The paper points to some recent developments and emerging practices, and suggests that ongoing and proactive engagement by practitioners and the courts will be required to ensure NZ's decision-making systems and actual decisions appropriately address climate change risks, consistent with the requirements in the RMA. A number of insights are offered to inform development of climate-risk management under the RMA in ways that are flexible and robust over long timeframes, including: A focus on 'predicting' climate change can result in prematurely collapsing a wide range of possible futures, which is counter-productive to a risk-based assessment and management approach; scenarios need to consider changes in climate-related hazards as well as exposure and sensitivity of the environment to those hazards; and a dynamic approach to risk management is essential when dealing with continuously evolving climate change and the capacity for surprises based on incomplete knowledge.

Tonkin & Taylor. (2016). ***Risk Based Approach to Natural Hazards under the RMA*** (Report prepared for Ministry for the Environment). Wellington, NZ: Tonkin & Taylor.

Tonkin & Taylor was engaged by the Ministry for the Environment (MfE) to provide a framework for a risk-based approach to managing and planning for natural hazards under the RMA. MfE intends that this framework will become the foundation for a possible new National Policy Statement and other national level guidance or interventions on natural hazards, providing consistency across the country. The report presents the results of analysis undertaken in order to determine good practice for risk management

in natural hazards planning; issues and challenges to achieving good practice; and ways to overcome barriers to good practice. The report recommends that the impacts of climate change should be an integral part of all risk assessment methodologies, and identifies a number of areas in which climate change impacts may be particularly relevant, including subdivisions and developments: in floodplain areas, close to rivers, or within other river channels; close to or within the coast; on or close to steep hillsides; and those that rely on rain water supply. It is also recommended that information, modelling and mapping of natural hazards should incorporate the impacts of climate change, and that uncertainties around climate change must be identified and acknowledged. Further, the report recommends addressing the issue of how to deal with climate change in a nationally consistent manner, in detail, in guidance documents and tools.

Enhancing adaptive capacity

Academic literature

Manning, M., Lawrence, J., Ngaru King, D., & Chapman, R. (2014). ***Dealing with changing risks: A New Zealand perspective on climate change adaptation***. *Regional Environmental Change*, 14(4). doi: 10.1007/s10113-014-0673-1

This paper considers NZ's adaptive capacity through an empirical research approach, working with government practitioners at three levels and with Maori communities. Very different perceptions of risk, and structural inertia on planning processes emerged as key issues for implementing adaptation responses. The authors comment that the use of static frameworks biases responses towards retrospective, rather than anticipatory analysis, and that ongoing socioeconomic changes in NZ also raise the risk of structural effects caused by climate change impacts becoming unevenly distributed across society. Their analysis indicates that a national and regional strategic approach, centred on a dynamic view of climate risk, is necessary for effective decisions at the local government and community level. They also suggest that effective adaptation requires better identification of barriers and opportunities for addressing changing risk, together with more effective and continuous social engagement. The paper concludes that NZ has made some significant changes to its economy, planning processes and social structures in response to major issues such as financial crises, social inequity and natural hazards other than climate change and that the social contract

between citizens and governments now needs to be extended to cover the potential for major disruptions from ongoing climate changes.

Grey literature

Cronin, K., Doody, B., & Greenaway, A. (2011). **Degrees of Possibility: Igniting Social Knowledge around Climate Change** (Workshop Report). Wellington, NZ: New Zealand Climate Change Centre.

This report provides a background to a 2010 workshop that sought to examine the question “How can social knowledge contribute to our understandings of and responses to the phenomenon of human-induced climate change?” The report summarises keynote papers from the workshop and provides a record of the ideas developed in the discussion groups and observations of the day. Conclusions are drawn about the opportunities and challenges identified through this process, and recommendations for future work are made. The authors suggest the document provides a rich source of information about research issues, questions and methods as a platform for future cross-organisational planning of climate change-related social science. The report lists ways in which social science can contribute to understanding climate change: improving social understanding of the relationship between climate and societies; providing new perspectives and potential breakthroughs in the debates around climate change and supporting cohesive social discussion and constructive policy development; applying knowledge and tools to create pathways for institutional transformation; and providing evidence to support decision-makers in institutions and organisations. Recommendations for advancing social knowledge around climate change include identifying innovative research methods, including mechanisms to effectively transfer social science knowledge to end-users in government, industry and the community; and identifying where social science can be integrated with biophysical science in existing and planned climate change research agendas in NZ.

Manning, M., Chapman, R., Hales, S., Howden-Chapman, P., King, D., Kjellstrom, T., Lawrence, J., & Lindsay, G. (2011). **Synthesis: Community vulnerability, resilience and adaptation to climate change in New Zealand** (Report produced as part of the Community Vulnerability, Resilience and Adaptation research programme). Wellington, NZ: New Zealand Climate Change Research Institute.

This report was produced as part of a broader research programme focused on developing a consistent

framework for considering the different areas of potential vulnerability to climate change in NZ, and on how social or structural resilience can be developed so as to deal with potentially adverse effects. The report summarises the key issues that emerged from the research programme, and the extent to which these have set up a basis for developing more comprehensive approaches in future. The main focus areas were on Maori community responses to climate change; local government management of the risks related to climate; and climate effects on human health. The authors observe that there are no simple indicators of vulnerability or of adaptive capacity, so they cannot be measured directly, and they suggest that more needs to be done to develop a synthesis in a NZ context so as to have a comprehensive framework for allocating resources to adaptation that into account continuing climate changes. The report makes several concluding recommendations, including: Development of adequate responses is becoming urgent and needs to be linked to social perceptions of values in natural and managed resources; and two-way interactions regarding climate change adaptation between climate scientists and NZ decision-makers are becoming increasingly important.

LOCAL GOVERNMENT

This local government section includes reports and studies produced or commissioned by local government organisations, as well as papers in which local government is the subject of research, or the intended users/beneficiaries of the research. Local government-specific findings include: Central government statutory direction is important, but is insufficient without the integration of practice under a supporting institutional architecture to drive action at the local level; standardised information collection across councils and risk assessment methods that address uncertainties are important; engagement with communities is needed to foster understanding of the dynamic and changing nature of climate risks and the range of response options available to address them.

Climate change pressure points and implications for policy and management

Academic literature

Lawrence, J., Sullivan, F., Lash, A., Ide, G., Cameron, C., & McGlinchey, L. (2013) **Adapting to changing climate risk by local government in New Zealand: institutional practice barriers and enablers**. Local Environment: The International Journal of Justice and Sustainability, doi: 10. 1080/13549839.2013. 839643

With a similar focus to the previous report, this paper examines the role of institutional arrangements, the players operating under them, and the barriers and enablers for adaptation decision-making in NZ. The paper explores how the roles and responsibilities between national, regional and local governments influence the ability of local government to deliver long-term flexible responses to changing climate risk. They find that the disciplinary practices of law, engineering and planning, within legal frameworks, result in the use of static mechanisms which create inflexible responses to changing risk. Several enablers are identified that could create better integration between the different scales of government, including better use of national policy instruments, shared professional experience, standardised information collection and risk assessment methods that address uncertainties. The paper suggests that engagement with communities will be needed to foster understanding of the dynamic and changing nature of climate risks and the range of response options available to address them. It is also argued that some land-uses will require long lead-times, others may be phased out and new flexible and adaptive methods for estimating costs and deciding who pays will need to be developed. The authors conclude that having statutory duties by themselves is insufficient without the integration of practice under a supporting institutional architecture that can drive coherent action at the local level while reflecting community aspirations.

Grey literature

Greater Wellington Regional Council. (2015). **Climate Change Strategy** (A strategy to guide the Wellington Regional Council's climate change response). Wellington, NZ: GWRC.

This strategy is designed to provide an overarching document to align and coordinate climate change actions across Greater Wellington Regional Council's (GWRC's) responsibilities and operations. It builds on work programmes already underway, and aims to raise awareness of climate change drivers and impacts, and help coordinate regional effort through collaboration and partnerships. The strategy also aims to help strengthen information-sharing and integration across GWRC's departments, between councils, with central government, and with the community. The strategy is intended to act as a guide for climate resilience activities across GWRC, and to provide clear strategic direction on GWRC's intentions and priorities in this respect. The strategy's 3 overarching objectives relate to mitigation; adaptation; and awareness and

engagement. The adaptation objective is: Risks from climate change-related impacts are managed and resilience is increased through consistent adaptation planning and actions based on best scientific information. The strategy outlines GWRC's mandate to undertake climate change adaptation planning, as expressed through various legislation. It discusses projected impacts and implications of climate change for the Wellington region, and outlines the range of GWRC roles and functions that relate to these impacts. The strategy affirms GWRC's commitment to acting in the face of uncertainty, and taking a risk management approach. Accompanying the strategy is a short implementation plan that outlines actions under each of the strategy's 11 policies, and performance measures that will be used to evaluate progress on the objectives of the strategy.

Lawrence, J., & Quade, D. (2011). **Perceptions on flood-risk management and climate change- implications for local government decision making** (Report produced as part of the Community Vulnerability, Resilience and Adaptation research programme). Wellington, NZ: New Zealand Climate Change Research Institute, Victoria University of Wellington.

This report explores the barriers and constraints to adaptation in a context where there is pre-existing settlement and infrastructure, geographical constraints, and existing investment in a major flood-control scheme in the Hutt Valley. The report then addresses possible ways the barriers and constraints could be overcome. The research draws on a household survey, a workshop with local government practitioners, and in-depth interviews. The analysis identified a potential for maladaptation if flood-risk management and planning were to disregard differing vulnerabilities across the population, the incentives and motivations for households to prepare for future floods, and the potential for present decisions to limit future choices. The implementation of available adaptation options may be constrained by limits on available funding, or the fraction of damages avoided by adaptation could be suboptimal if there is an imbalance in the extent to which damage potential and upfront costs are considered. Key conclusions include the following: Overcoming barriers to adaptation requires open debate, leadership, and adaptive management; central government statutory direction is important; and using a wide range of measures to manage flood risk provides flexibility to deal with uncertainty and changing risks.

NIWA. (June 2015). ***Relationship between Climate Modes and Hawke's Bay Seasonal Rainfall and Temperature*** (Report prepared for Hawke's Bay Regional Council). Auckland, NZ: Fedaeff, N., & Fauchereau, N.

This report, prepared for Hawke's Bay Regional Council, describes the main climate modes affecting NZ and explores their relationship with temperature and rainfall in the Hawke's Bay region. Although climate change is not directly assessed in this report, the authors comment that the climate cycles described will be superimposed on top of the impacts of climate change. They suggest that, because of this, adaptation to changes in climate will need to incorporate both the shorter scale natural climatic variations as well as longer term trends. The report notes that present guidance for NZ from the Ministry for the Environment (2008, currently being updated) suggests that a currently-experienced extreme rainfall (e.g. 24-hour extreme with a 100-year return period) could occur approximately twice as often (i.e. 50-year return period) under a local warming of about 2 degrees Celsius. These more intense extreme rainfall events are projected to elevate future flood risk. It is noted that the increased flood peak resulting from increased precipitation extremes will also interact with rising sea levels, making coastal settlements and stormwater drainage in low-lying areas particularly vulnerable.

NIWA. (August 2015). ***Climate Change and Variability-Tasman District*** (Report prepared for Tasman District Council). Auckland, NZ: Chappell, P., Mullan, B., Paul., V., Bell, R., & Law, C.

This report describes changes that may occur over the coming century in the climate of the region administered by the Tasman District Council, and outlines some possible impacts of these changes. After summarising expected NZ national and regional impacts of climate change from the IPCC Fifth Assessment Report chapter on Australia and NZ, Tasman District's present climate is described, followed by projections for the District's future climate. The latter includes a substantial decrease in cold nights, an increase in the number of hot days, and an increase in the frequency of both heavy rainfall and drought. The report does not include a detailed evaluation of the likely impacts of climate change on the Tasman District, of the vulnerability of the District to these impacts, or of investigating options for adapting to them. However, it does suggest some particular impact, vulnerability, and adaptation issues

to which Tasman District Council may wish to give consideration. These include implications of sea level rise and coastal change for planning and development in coastal areas; implications of potential changes in rainfall and of drought frequency for water demand, availability and allocation, including planning for irrigation schemes and storage; opportunities that climate change may bring for new horticulture crops- and infrastructure and land use issues that may arise; and implications of climate change, including potential changes in flood frequency and in coastal hazards, for land use planning.

Pak, I. (2015). ***Climate Effects Consolidated Report for River Scheme Sustainability Project*** (Report prepared for Bay of Plenty Regional Council). Whakatane, NZ: Bay of Plenty Regional Council.

This report summarises what is known about climate change and climate cycles in the Bay of Plenty. It consolidates findings from a range of reports on an international, national and regional level, and provides guidance on how Bay of Plenty Regional Council could or should use this information in its policy, guidelines and projects. The report states that the Bay of Plenty can generally expect warmer and drier conditions in the future, though more frequent and intense rainfall events will carry an associated risk of increased flooding and erosion. The report states that the Council aims to future-proof the region against climate change by providing advice and developing policy to help the region adapt and become more resilient to the effects of climate change and then provides some examples of what the Council is doing to address climate change. These include setting policy and rules through the Regional Policy Statement and Regional Coastal Environment Plan; funding rivers and drainage schemes that provide flood protection in the region; providing technical advice through a coastal calculator and floodplain mapping; and providing advice to territorial authorities on district plan changes associated with flooding, climate change impacts, and areas to be released for development. The report also discusses the Council's River Scheme Sustainability Project, which incorporates climate change for future decision-making in a 100-year framework for each flood scheme catchment. The report makes a number of recommendations to the Council, several of which relate to incorporating updated climate change information and projections once new guidance material is published by the Ministry for the Environment.

Wang, M., Li, Y., & Yin, C. (2015). **An assessment of the impacts of climate change in the Waikato region: Applying CMIP5 data** (Report prepared for Waikato Regional Council). Hamilton, NZ: Waikato Regional Council.

This report provides a broad technical assessment of the physical effects of climate change in the Waikato region. Ensembles (or parallel scenarios) of up to 40 CMIP5 Global Climate Models were used to generate the future scenarios. Based on the findings of this assessment, the report provides recommendations for more in-depth impact assessments to inform adaptation strategies and processes for the Waikato region. The authors suggest that following from this, it should be possible to identify a range of indicators and adaptation options needed to respond to the projected future effects of climate change in the region. They state that detailed analyses of bio-physical impacts, risks and specific adaptation strategies for human, managed or natural systems in the region are not part of this report. It is noted that these would include impacts that affect the Regional Council's core functions and responsibilities of natural hazard management, biodiversity and biosecurity management, and coastal area management, water and land management and regional planning among others. They also note that climate change has implications for regional agricultural productivity, and infrastructure that require more detailed assessments. Recommendations include: Localised and more detailed assessment of flood risk with future climate change using hydrological modelling and incorporating socio-economic and land-use variables; an in-depth assessment of drought risk, particularly given the dependence of the regional economy on agriculture; an assessment of thresholds for water scarcity for natural and managed systems; and identification of thresholds for the likely implications of changing habitat conditions and ecosystem dynamics.

Tools and frameworks to support adaptive management

Grey literature

Bay of Plenty Regional Council. (2016). **Natural Hazard Risk Assessment User Guide**. Regional Policy Statement for the Bay of Plenty. 1-34.

As a result of feedback received through submissions and hearings, the Bay of Plenty Regional Council decided that implementation guidance on the methodology for risk assessment included in the Bay of Plenty Regional Policy Statement. This full

User Guide replaces interim guidance issued with the Regional Council's decisions on submissions. The User Guide is not part of the RPS, but is provided to assist users of the RPS. The Guide is relevant to the regional community who participate in RMA processes, or may require resource consent, as well as to the Regional Council, and city and district councils of the region as they review their regional, city or district plans or prepare changes to existing plans in relation to natural hazards issues. The Guide notes the general approach to hazard risk assessment promoted in the Ministry for the Environment climate change guidance manuals for local government (2008) and states that the concepts and approaches proposed in those guidelines provide useful context for applying the RPS's natural hazard policies.

Kilvington, M., & Saunders W.S.A. (2015). **"I can live with this." The Bay of Plenty Regional Council public engagement on acceptable risk**. (Report no. 86 prepared as part of the GNS Science Miscellaneous Series). Lower Hutt, NZ: GNS Science.

This report details the Bay of Plenty Regional Council's 2014 public engagement process on natural hazard risk, undertaken as a contribution to developing the natural hazards component of the proposed Regional Policy Statement. The process was considered an innovative and successful approach to public engagement on a difficult topic. Analysis in the report suggests there are several key points that contributed to this: The process was specifically designed to meet some of the unique challenges of communication on risk, such as the need to build capacity for judgement by providing a means for people to understand complex risk concepts; consider the implications for themselves and their community; and enable them to realistically reflect on both the consequences and the likelihood of natural hazard events before making decisions about risk acceptability, and link judgements on risk acceptability to implications for local government policy or action. The process used a risk based planning framework, and took an adaptive approach, allowing the project team to reflect on the process, and amend where necessary. One of the leanings from the process was the importance of regional councils linking with city and district councils to enable integration and shared expertise. A section near the end of the report explores the application of the Bay of Plenty process for the Wellington region. Development of climate change adaptation policies is presented as a possible opportunity to apply an engagement process on levels of risk for natural hazards and risk management in the Wellington region.

New Zealand Planning Institute. (2013). **Plan Topics: Climate Change** (An RMA Quality Planning Resource). http://www.qualityplanning.org.nz/images/documents/plan_topics/Climate_Change/Climate_Change_GN.pdf

This guidance note provides an overview of how particular regard may be given to the effects of climate change by local government in NZ, as per the provisions in section 7 of the Resource Management Act. It provides information on expected climate change effects in NZ and advice on methods for considering and addressing climate change effects under the RMA. The aim of the guidance note is to promote understanding about the effects of climate change; provide best practice information on how to assess the significance of, and respond where necessary to, the effects of climate change. A particular focus is how this can be done within local authorities' existing risk assessment, policy-making and decision-making processes. The guidance note outlines that in the context of the RMA, there are two ways in which particular regard may be given to the effects of climate change: As an integral part of making decisions on resource consent applications and notices of requirement under the RMA for which the effects of climate change may be significant; and in proactively assessing RMA policy statements and plans. The second point directly relates to council's broader strategic planning initiatives.

Saunders, W.S.A., Beban, J.G., & Kilvington, M. (2013). **Risk-based land use planning for natural hazard risk reduction**. (Report no. 67 prepared as part of the GNS Science Miscellaneous Series). Lower Hutt, NZ: GNS Science.

This report outlines the content of an online toolkit on risk-based planning developed by GNS Science. The toolkit is designed for decision-makers, planners, and others with an interest in risk-based planning. It aims to support risk-based land use policy and plan development in local government, and presents techniques, practice steps and options for enabling local government to review multiple natural hazard risks within councils, with external stakeholders, and with the wider community. Similar to the toolbox itself, the report has three key sections: Setting the scene for why this approach is important; the five-step risk-based approach for natural hazards; and examples of implementation. One of the examples given of implementing this approach is of a natural hazard risk communication and public engagement process on climate change impacts in Otago coastal communities.

This section details a community-based strategic risk management approach employed as part of a pilot project aimed at providing a way for local government to work with communities on risk assessment and planning for challenges associated with climate change and sea level rise. The authors conclude this approach has wide application for either a specific issue (e.g. coastal erosion) or a broad range of issues (e.g. urban design).

Enhancing adaptive capacity

Academic literature

Russell, S.L., Greenaway, A., Carswell, F., & Weaver, S. (2014). **Moving beyond "mitigation and adaptation": examining climate change responses in New Zealand. Local Environment, The International Journal of Justice and Sustainability**, 19(7), 767-785. doi 10.1080/13549839.2013.792047

Expressions of agency in relation to climate change in NZ provide the focus of enquiry for this article. This research finds that relationships or social networks linked through local government are building capabilities to respond to climate change. It is suggested that local government-facilitated networks can play a critical role in strengthening relationships across community groups in order to build capabilities within NZ to respond to climate change. Therein, opportunities may arise to engage in the creation and sharing of knowledge for climate action by actors within science and research, with policy and business communities, and beyond. However, the authors argue that the framework of "mitigation-adaptation" will need to be supplemented by a more diverse suite of mental modes for making sense of climate change. Use of appropriate languages, cultural reference points, and metaphors embedded in diverse histories of climates and change are recommended, to assist actors in their climate actions. They conclude that their study reveals the importance of paying attention to everyday responses to climate change, and new images of citizenship and climatic relationships opening up through actions.

COASTAL ISSUES

Reports commissioned by regional councils and the Parliamentary Commissioner for the Environment (PCE), and prepared by NIWA dominate the recent NZ impacts and implications literature on coastal issues. Unsurprisingly, reports commissioned by regional councils explore region-specific coastal issues such

as regional policy and management implications of coastal erosion, storm surge and sea level rise, while publications commissioned or produced by PCE examine these issues across regions and at a national scale. A range of short to mid-term coastal protection measures are recommended to mitigate impacts. However, several publications suggest the lowest-risk long-term solution will be to retreat away from the coastline. A range of factors to enable successful coastal adaptation planning and to increase adaptive capacity of communities and decision-makers in a coastal setting are identified. These include: access to high quality data (LiDAR surveys, local knowledge); a multidisciplinary team; appropriate financial and human resources; commitment to the process from the appropriate decision-making organisation (e.g. council) and an understanding that successful adaptation is not just a process of picking a single number or selecting a single option and thus 'solving' the issue; collaborative strategic planning approaches e.g. coastal communities mapping out adaptive pathways, including managed retreat options. A number of tools (coastal calculators, inundation tools, sensitivity indices) and best practice guides have been developed to assist coastal communities and planners in assessing risks and vulnerabilities.

Climate change pressure points and implications for policy and management

Grey literature

Komar, P.D., & Harris, E. (2014). **Hawke's Bay, New Zealand: Global Climate Change and Barrier-Beach Responses** (Report prepared for Hawke's Bay Regional Council). Oregon, USA: Hawke's Bay Regional Council Asset Management Group.

The objective of this study is to investigate Hawke's Bay's ocean processes that are important to erosion and flooding hazards. This involved analyses of waves, tides and changing sea levels and, based on their projected magnitudes, an assessment of the future hazards to shore-front properties spanning the 21st century. The report is primarily concerned with the stretch of coast from Tangoio to Cape Kidnappers, as this is the most heavily developed coastal area in Hawke's bay and the most susceptible to erosion and flooding. The projections, based on several studies by climatologists, place the net rise in sea level at 0.9 to 1.3m by 2100, in which case the potential erosional retreat of its gravel ridges would on average amount to 10-15m. The authors note that still greater impacts would occur if the changing climate also produces

more intense storms, which in turn generate more extreme waves and surge elevations. The report ends with a general consideration of the management responses that may be required and reasonably undertaken to improve the protection of properties and infrastructure. This includes the phasing out of commercial mining to halt loss of gravel and sand and improve the beach sediment budget. It is also recommended that special consideration be given towards the fates of coastal properties, which are already experiencing problems with erosion and, with rising seas and increased storm intensities, will be at significantly greater risk in the future. The report stops short of suggesting managed retreat as an adaptation option.

NIWA. (2012, revised 2015). **Review of West Coast Region Coastal Hazard Areas** (Report prepared for West Coast Regional Council). Christchurch, NZ: Measures, R., & Rouse, H.

This report details the outcomes of a review of Coastal Hazard Areas (CHAs), undertaken as part of the West Coast Regional Council's review of its Regional Coastal Plan. The authors consider evidence from literature, observations made in actual and virtual field trips, and other reports or studies of relevance. 26 CHAs are recommended, some existing, some new, and some where boundaries have been altered. Each CHA is documented in a table including a map and details of location, assets at risk, hazard processes, priority assessment, existing management, and relevant references. The review focuses on the lateral extent of hazard areas along the coast, and does not consider 'zones' or 'setbacks'. It is noted that work may be required to properly map the landward extents of some high priority hazard 'zones' to allow for adaptation to sea level rise. The authors recommend further investigations could include looking at potential changes to flooding extent due to storm-waves and storm surge, changes in coastal erosion, river mouth blocking, and the exacerbation of these by rising sea-level. They suggest a best practice approach would include funding of coastal LiDAR surveys for key areas.

NIWA. (October 2015). **National and regional risk exposure in low-lying coastal areas. Areal extent, population, buildings and infrastructure** (Report prepared for the Parliamentary Commissioner for the Environment). Hamilton, NZ: Bell, R.G., Paulik, R., & Wadwha, S.

NIWA was commissioned by the PCE to provide a nationally-consistent coastal risk exposure as a first

pass assessment at the national level, aggregated up from a comparison of results at the regional level. The analysis in this report is the first consistent attempt at quantifying the risk exposure in low-lying coastal areas across NZ and enabling a comparison between different regions and urban areas to assist in prioritising national and regional effort in adaptation to more frequent coastal hazard impacts. Risk exposure is expressed as counts of normally-resident population, land-cover, land parcels and built assets present within various elevation bands up to 3 metres above present-day mean high water spring tide mark, along with replacement costs for buildings in NZ dollars. A summary of key results in terms of coastal risk exposure in NZ, is depicted in infographic form in the report. Of the regions with LiDAR datasets available, two-thirds of the people resident in the most exposed 0-1.5m coastal elevation zone lived in either Canterbury, Hawke's Bay, Bay of Plenty, or Auckland. Nationally there are over 68,000 buildings in the 0-1.5m elevation zone, with Canterbury and Hawke's Bay having the most buildings at this low-lying elevation. Total national replacement costs for enumerated buildings of all classes was calculated at NZD\$19.3B for the lower-lying 0-1.5m zone rising to around NZD\$52B across the wider 0-3m elevation zone. Highest proportion of risk exposure for a region in the lowest-lying elevation band (0-0.25m) occurs in Waikato and Otago regions. A key conclusion was that the only robust approach to coastal risk assessments is to use high-resolution and accurate LiDAR Digital Elevation Models.

NIWA. (July 2015). ***The effect of sea-level rise on the frequency of extreme sea levels in New Zealand*** (Report prepared for Parliamentary Commissioner for the Environment). Hamilton, NZ: Stephens, S.

Like the above, this NIWA report was commissioned by the PCE to provide technical information to inform the PCE's series of reports on sea level rise impacts and implications in NZ. The purpose of this publication is to document methods used for the sea-level exceedance calculations, present results, and make general conclusions about the effect of sea level rise on extreme sea-level frequency. The report extends early work by calculating the likelihood of occurrence of large historical sea-level events with reported hazard impacts at Auckland, Wellington, Christchurch and Dunedin. The effects of historical sea level rise were investigated, along with four median future sea level rise projection trajectories from the IPCC's Fifth Assessment Report. NIWA provided the PCE with

tables of the percent of high waters exceeding high sea-level thresholds, in digital format. The report describes a non-linear relationship between the rate of sea level rise and the increase in frequency of extreme sea-levels being reached- the frequency will rise increasingly fast as sea level rises. Sites with small tidal range, such as Wellington are more sensitive to sea level rise and will experience a greater increase in extremes than sites with large tidal range such as Auckland.

NIWA. (2016). ***Managing and adapting to coastal erosion at Granity, Ngakawau and Hector*** (Report prepared for West Coast Regional Council). Hamilton, NZ: Allis, M.

This report was prepared for West Coast Regional Council to aid in decision-making processes associated with ongoing erosion problems at the villages of Granity, Ngakawau and Hector. The advice relates to erosion issues along the frontage and options for coastal defence structures aimed at protecting residential land and property. The report outlines a number of potential measures, as a basis for future discussion between the regional council and residents, and recommends the community should be involved in developing a long-term adaptation strategy, monitoring the beaches, and undertaking active vegetation management. Specific near-term management and adaptation recommendations presented include: Filling beachfront gaps to provide a continuous line of defence and eliminate out-flanking erosion within already defended sections; tie-in or wrap-around walls to reduce outflanking erosion and wash-around sediment deposition which is causing vegetation die-back and reducing protection levels; and aggressive replanting to reduce impacts of storm wash over events. In a section on future approaches to managing coastal change, the report discusses the concept of adaptation pathways, as a process of managing changing levels of risk and enabling communities to adjust to changing conditions. The author stresses that ultimately the lowest-risk long-term solution will be to retreat away from the coastline.

PCE. (2014). ***Changing climate and rising seas: Understanding the science*** (Parliamentary Commissioner for the Environment report). Wellington, NZ: Parliamentary Commissioner for the Environment.

PCE. (2015). ***Preparing New Zealand for rising seas: Certainty and Uncertainty*** (Parliamentary Commissioner for the Environment report). Wellington, NZ: Parliamentary Commissioner for the Environment.

Two recent reports published by the Parliamentary Commissioner for the Environment explore the impacts and implications of sea level rise for NZ. The first (2014) report promotes a better understanding of the science of climate change and the processes driving sea level rise. It also discusses the varying impacts that sea level rise will have around the country, including associated issues like storm surge and flooding. The report aimed to generate conversation about the implications of sea level rise impacts for communities and decision-makers across NZ, and was written with the intent of making the science of climate change, and specifically sea level rise, accessible and relevant for New Zealanders. It highlights the increasing awareness and concern about the issue within the insurance and local government sectors, and calls for stronger national direction and leadership to address the growing threat of sea level rise. The second (2015) report published a year later, aims to further increase understanding of how sea level rise will affect NZ, as well as show how low-lying coastal areas around NZ can be accurately mapped in a standardised way. It also describes how some councils have begun to plan for sea level rise, and identifies problems with, and gaps in, the direction and guidance provided by central government. Specific recommendations made in the report to the Minister for the Environment and the Minister for Conservation include: Take direction on planning for sea level rise out of the NZ Coastal Policy Statement and put it into another NPS, such as that envisaged for dealing with natural hazards; specify that councils develop whole coast plans for dealing with sea level rise, and expand coastal monitoring systems to enable adaptive management; set standards for the use of IPCC projections of sea level rise to ensure they are used consistently across NZ; specify planning horizons that are appropriate for different types of development; and establish a working group to assess and prepare for the economic and fiscal implications of sea level rise.

Tools and frameworks to support adaptive management

Academic literature

Joshi, SR., Vielle, M., Babonneau, F., Edwards, NR, & Holden, PB. (2015). ***Physical and Economic Consequences of Sea Level Rise: A Coupled GIS and CGE Analysis Under Uncertainties***. *Environmental Resource Economics* doi 10.1007/s10640-015-9927-8

This paper develops a modelling framework that links GEMINI-E3, a regional, multi-sectoral and

computable equilibrium model, with a cost-benefit analysis approach at local level using geographical information system tools, to assess the physical and economic consequences of sea level rise in the 21st century. A set of future scenarios is developed spanning the uncertainties related to global warming, the parameters of semi-empirical sea level rise estimates, and coastal developments (cropland, urban areas and population). The importance of incorporating uncertainties regarding coastal development is highlighted. The simulation results suggest that the potential development of future coastal areas is a greater source of uncertainty than the parameters of sea level rise itself in terms of the economic consequences of sea level rise. They find that the economic impact of sea level rise could be significant when loss of productive land along with loss of capital and forced displacement of populations are considered. Further, highly urbanised and densely populated coastal areas of NZ are likely to suffer significantly if no protective measures are taken. The authors therefore suggest that coastal areas need to be protected to ameliorate the overall welfare costs to various regions, including NZ and Australia.

Grey literature

NIWA (September 2012). ***Coastal Adaptation to Climate Change: Mapping a New Zealand Coastal Sensitivity Index*** (Report prepared for MBIE contract C01X0802). Hamilton, NZ: Goodhue, N., Rouse, H., Ramsay, D., Bell, R., Hume, T., & Hicks, M.

This report details work undertaken to build a national picture of physical coastal sensitivity for NZ. This is intended as a first step in understanding where the impacts of climate change on coastal margins may be most significant and where potential adaptation activities may most usefully be targeted. The authors first reviewed international studies of coastal sensitivity and identified the key parameters used to develop coastal sensitivity indices. In conjunction with available geomorphic and oceanographic information, they then developed Coastal Sensitivity Indices for inundation and coastal erosion for NZ's soft shore coastline. These indices were created by combining four geomorphic and three oceanographic variables. An expert panel then assigned relative scores and weightings to the geomorphic and oceanographic variables based on how they are likely to be affected by climate change. Two interactive online maps were produced, which can be used to identify coastal areas that are more sensitive than others to the potential

impacts of climate change-induced coastal inundation and erosion. This information is expected to assist councils and government bodies to 'home in on' areas of increased sensitivity for adaptation planning and response. The Coastal Sensitivity Index is also designed to contribute to raising levels of political and community awareness of coastal hazards and how such hazards might alter with climate change. The authors caution that the indices are not an absolute measure of potential risk of future inundation or erosion under climate change and should not be used as a replacement for local (beach scale) risk assessments.

NIWA. (2014). ***Extreme sea-level elevations from storm-tides and waves along the Gisborne District coastline*** (Report prepared for Gisborne District Council). Hamilton, NZ: Stephens, S., Robinson, B., & Gorman, R.

NIWA was commissioned to provide estimates of coastal storm inundation elevations along the open coast of the Gisborne region. The study estimates the frequency and magnitude of storm-tide, large waves and the total combined sea-level from the two, at 33 locations along the Gisborne District coastline. Results of the study were built into a Microsoft Excel spreadsheet tool supplied to the Council. This "Coastal Calculator" makes the study outcomes and substantial data instantly and easily accessible for coastal-inundation hazard risk assessments including the effects of sea-level rise, as required by the NZ Coastal Policy Statement. The authors suggest the Calculator is "future-proofed" in that it easily incorporates future updates of mean sea level datum shifts and/or sea level rise estimates, and the values are transparent to the user. The authors note the Calculator only provides vertical inundation levels at the coastline and does not produce the extent, depth or volume of inland inundation. The report provides information on methods to map coastal hazard zones using the information contained in the Calculator. Another report by some of the same authors (NIWA, 2013) was commissioned a year earlier by Auckland Council to calculate extreme sea level elevations and their likelihood around the entire coastline of the Auckland region, and to map selected inundation areas. That study used hydrodynamic models calibrated against tide-gauge and wave buoy measurements to calculate storm-tide and wave setup along the coastline, and applied joint-probability modelling techniques to calculate the occurrence likelihood of the extreme sea-level elevations.

Pattle Delamore Partners Ltd. (2011). ***New Zealand Guidelines for the Monitoring and Management of Sea Water Intrusion Risks on Groundwater*** (Prepared for Envirolink Project 420-NRLC50). Christchurch, NZ: Callander, P., Lough, H., & Steffens, C.

This report presents a technical guideline to help in the analysis of risks to groundwater arising from sea water intrusion in the NZ setting. The preparation of this guideline document, and the Excel spreadsheet that accompanies it, is in response to an Envirolink proposal submitted by a sub-committee of the Regional Council Groundwater Forum, who selected the title Saline Intrusion Monitoring Tool. A section of the guideline is devoted to consideration of the effects of sea level rise on sea water intrusion risks. The authors suggest that for the purposes for the guideline document, and taking into consideration regional plan (10 year) and consent (up to 35 year) duration periods, it would seem reasonable to consider potential climate change-induced sea level rise out to 2040. A value at the top end of the estimated range (+0.2m) is used recognising the shorter-term variations that also affect sea levels. The guideline states that whilst there is still much uncertainty about the magnitude of climate change effects, it is appropriate to consider predictions of changes that might occur over the next 50-100 years.

Ramsay, DL., Gibberd, B., Dahm, J., & Bell, RG. (2012). ***Defining coastal hazard zones and setback lines. A guide to good practice***. Hamilton, NZ: NIWA.

This best-practice guide was developed to assist local authorities to make sustainably-based decisions for the avoidance or mitigation of coastal hazard risks within their land-use planning and development decision-making. The guide focuses on approaches to defining present and future coastal hazard exposure as an input to development setbacks to manage risk from coastal-related hazards and the effects of climate change. It is intended to aid technical staff from regional or unitary councils, coastal territorial authorities, and coastal hazard practitioners and is designed to complement the Ministry for the Environment guidance manual Coastal hazards and climate change: A guidance manual for local government (Ministry for the Environment, 2008) in encouraging a risk-management approach and ensuring coastal hazards and the impacts of climate change are appropriately taken into account in policy, planning and resource consent decision-making. The guide promotes a framework to enable

increased robustness and accounting of uncertainties within coastal hazard assessments and associated development setbacks. It is not prescriptive in terms of the methods used to define areas of coastal margins at risk from hazards, but aims to build on established approaches commonly used in NZ to determine future coastal change, but to better characterise uncertainty by applying it in a pragmatic way.

Waikato Regional Council & e-Spatial. (2016). Waikato Regional Council Coastal Inundation Tool. <http://coastalinundation.waikatoregion.govt.nz/>

Waikato Regional Council partnered with e-Spatial to develop an online tool to help people assess the potential impacts of projected sea level rise scenarios on Waikato's coastal properties. The Coastal Inundation Tool allows people to self-select how different levels of sea level rise may generally affect their coastal areas and individual properties. The tool also allows people to assess storm effects, and information on tsunami inundation for selected areas is also available. It does not make predictions about when such sea level rises may occur. The purpose of the tool is to see what areas may be subject to inundation, and to identify areas in which a better understanding of the extent of the effects of inundation is required. The tool only shows 'static' water levels. It does not include the effects of currents, friction, waves or other hydraulic processes that affect water movement or inundation. The tool shows 'connected inundation', which represent areas where water could directly flow to the sea for a chosen water level, and 'disconnected inundation', which represent areas that are at or below a chosen water level, but may have no direct flow path to the sea. The tool is not intended to provide specific information that could be used to define actual coastal inundation hazards or minimum floor levels for specific properties.

Ministry for the Environment (2017). **Coastal hazards and climate change: Guidance for local government.** 3rd edition. Revised by Bell R, Lawrence J, Allan S, Blackett P, and Stephens S.

This guidance revises the Ministry for the Environment guidance manual Coastal hazards and climate change: A guidance manual for local government (Ministry for the Environment, 2008). It provides updated information and good practice guidance on coastal erosion from storms and sea level rise and changes in long-term sediment processes and budgets; coastal inundation from storms and changed climate conditions or gradual persistent inundation from high tides due to sea level rise; and rising ground water

and salinization in coastal lowlands caused by sea level rise. The guidance is given within a risk-based, adaptive management framework, to strengthen the integration of coastal hazards and climate change considerations into land-use planning, resource management, building consenting, asset and flood risk management and emergency management. The approach of this guidance differs from previous versions and from current coastal management practice with regard to its treatment of uncertainty and the central role played by community engagement in the decision-making process. The guidance shifts from a linear approach to hazard risk management, to a focus on 'testing' response options against a range of scenarios before making decisions on pathways to reduce or avoid risk. The Dynamic Adaptive Pathways Planning approach is recommended for analysis, to accommodate change in the future without locking in investments that make adjustments difficult or costly, when agreed objectives fail to be met at trigger or decision points. Monitoring and review of decisions occurs in an iterative cycle as new information comes to hand.

Enhancing Adaptive Capacity

Academic literature

Harman, B.P., Heyenga, S., Taylor, B.M., & Fletcher, C.S. (2015). **Global Lessons for Adapting Coastal Communities to Protect against Storm Surge Inundation.** *Journal of Coastal Research* 31(4). 790-801.

This article reviews the international literature on coastal adaptation options (including options to defend, accommodate, or retreat) to manage inundation risk, focusing on developed liberal economies, including Australia, the UK, and NZ. The authors identify the favoured strategies adopted by these nations, probe the influence of physical and institutional context on the selection of these options, and identify what lessons might be exchanged or future directions inferred. The review emphasises distinctions between how government responsibility is exercised in different countries, including the degree of centralisation; the "fit" of options to local coastal environments and social values (i.e. their suitability and acceptability); and the transferability of different adaptation options in international contexts. The NZ Coastal Management Statement is discussed with regard to its recommendation to consider planned retreat in areas of high coastal hazard risk. The authors observe that in the countries reviewed, adaptation in urban coastal

settlements is presently dominated by regulatory planning controls and engineering structures. They conclude that adaptation preferences are strongly shaped by the spatial distribution of risk and physical character of settlements and populations on coasts, and by the existing institutional arrangements and culture relating to the management of natural hazards such as coastal inundation.

Milfont, T.L., Evans, L., Sibley, C.G., Ries, J., & Cunningham, A. (2014). **Proximity to Coast Is Linked to Climate Change Belief**. PLoS ONE 9(7). doi: 10.1371/journal.pone.0103180

This study examines the relationship between physical proximity to the coastline and climate change belief. It is based on the premise that proximity to coast may be related to experiencing or anticipating the effects of climate change such as sea level rise. Using a national probability sample of 5,815 New Zealanders, the results show that people living in closer proximity to the shoreline possess greater awareness that climate change is happening and express greater support for government regulations to address it. The results indicate that physical place plays a role in the psychological acceptance of climate change, perhaps because the effects of climate change become more concrete and local. This could be because coastal-dwellers may be more likely to: Experience large climate change-related impacts such as flooding and storms; consider potential sea level rise, which may require local adaptation; or pay more attention to local weather, due to more time spent outdoors at the beach. However, as the study's findings indicate association only, it is also possible that people with stronger acceptance of climate change tend to seek out coastal areas i.e. the causal arrow may go the other way. An implication of the study results for policymakers is that it may be useful to create targeted campaigns, for example, discussing with individual metropolitan areas the effects they might experience, and how to prepare for them. Another tactic might include encouraging people to consider more deeply their experiences of local weather and environmental habitats, which may have already changed within their lifetimes. Additionally, if the goal is to increase awareness of the risks in general, expending more energy on inland communities may be helpful, as coastal communities appear slightly more risk-aware.

Rouse, H.L., Bell, R.G., Lundquist, C.J., Blackett, P.E., Hicks, D.M., & King, D.N. (2016). **Coastal adaptation to climate change in Aotearoa-New Zealand**. *New*

Zealand Journal of Marine and Freshwater Research. doi: 10.1080/00288330.2016.1185736

In the context of varying geographical, social, cultural and policy contexts, this paper reviews research contributions and activities concerning coastal adaptation to climate change in NZ. It reflects on the insights derived from the emerging school of scholarship and considers what lessons have been learned to help NZ address the future challenges of adaptation to climate change on coasts and estuaries. The paper identifies a number of 'success factors' to enable collaborative adaptation planning, including access to high quality data (such as topographical data or local knowledge), a multidisciplinary team, appropriate financial and human resources, and commitment to the process from the appropriate decision-making organisation (e.g. council). A key challenge identified is to assist engineers, planners and communities to understand that successful adaptation is not just a process of picking a single number, selecting a single option for action, and thus 'solving' the issue (it is observed that this has been the approach adopted by many councils in traditional hazard line or zone setting). The concept of adaptation pathways to facilitate adaptation planning is discussed. A number of research gaps are highlighted, including sustainable approaches to adaptation of the built environment to avoid maladaptation and negative environmental side effects on biophysical systems that transition between marine and freshwater systems (e.g. estuaries, wetlands). Also, the paper notes that other than single-building examples of retreat from the coast, there are no examples of a coastal community mapping out pathways towards a more sustainable future. Consequently, considerably more research is required in the policy/planning space with community engagement to better prepare and support communities and decision-makers in commencing and undertaking strategic adaptation planning.

Grey literature

Bloomfield, S.E.M. (2011). **Inhabiting the shifting edge: increasing the adaptive capacity of coastal sand spit communities in a changing climate** (Masters thesis, Victoria University of Wellington, NZ). Retrieved from: <http://researcharchive.vuw.ac.nz/handle/10063/2116>

This master's thesis uses urban design and landscape architecture to investigate the role of open spaces in increasing the adaptive capacity of NZ's sand spit communities in the face of climate related change.

The author argues that urban design and landscape architecture have the potential to encourage interaction at the interface of social and ecological systems within coastal communities, and that the design of open spaces can encourage more sensitive development patterns and increase communities' awareness of coastal processes. It is suggested that these spaces can become the focus of social capital building while ensuring the environment has the capacity to absorb potential climate changes. The research focuses on three sand spit resort communities on the east coast of the North Island. Through a series of design studies, a range of strategies are proposed and tested in response to potential climate change impacts and sea level rise. An aim is to augment the "exclusive and expensive coastal beach trend" to provide for all potential beach users. It is argued that diversification in both the users and the types of use in these coastal areas will increase the social capital investment and awareness, enhancing the adaptive capacity of the spit system.

Hart, G. (2011). ***Vulnerability and adaptation to sea-level rise in Auckland, New Zealand*** (Report produced as part of the Community Vulnerability, Resilience and Adaptation research programme). Wellington, NZ: New Zealand Climate Change Research Institute, Victoria University of Wellington.

This report sets out the findings of an Auckland-based case study investigating vulnerability and adaptation to sea level rise at two coastal settlements, Mission Bay/ Kohimarama and Kawakawa Bay. A case study methodology was applied to conduct an in-depth investigation of the issues related to planning for long-term sea level rise and coastal hazards management at the study sites, and more generally for existing development in the Auckland region. The study found that coastal management at the participating councils was in the early stages of considering sea level rise effects, and that in most instances the use of adjusted flood-mitigation measures was considered adequate for protecting private property against hazard risk. However, guidance information generated by the councils did not take into account the potential for higher rates of sea level rise by 2100. The study's findings suggest that existing settlements may be 'locked in' to a coastal adaptation approach focused on maintaining the current coastline through coastal stabilisation. The author notes that this approach decreases community resilience and increases vulnerability in the long term, even if found to be a successful short-term response. The report concludes

that retreat offers an alternative approach for increasing resilience, however strong opposition from communities is expected. Developing trusted climate science information, education around coastal hazard risk, and participatory community-led decision making were identified as central enablers for a retreat approach to be included as a viable coastal adaptation option for communities in the Auckland region. A more recent publication (Reisinger et al, 2014) that explores the role of managed retreat using the same two case studies, concludes that it will require far-sighted local authorities to reach early community agreement on: Which assets should be protected or retreated; what restrictions to place on investment in assets that cannot be protected or where further investment would jeopardise the resilience of the community over time; the stages of retreat; and the allocation of financial support.

RIVER FLOODING

Most of the recent NZ climate change impacts literature exploring flood issues in riverine environments refers to a Hutt Valley case study undertaken as part of the 2011 Community Vulnerability, Resilience and Adaptation research programme. Publications based on this case study research include reports and journal articles examining vulnerability to increased flood risk with climate change, and tools and frameworks to address climate change uncertainties and support adaptive management of changing flood risk. As well as the Hutt Valley case study-based research, a small number of other reports examine flood risk management issues in a NZ context, and outline barriers and recommendations. Key recommendations from the literature include: government policy and direction that addresses changing climate risk and provides more robust support to local government responsibilities (e.g. national direction under the RMA or national guidance in the absence of such direction); methods to address the variability in capability and capacity at regional/local levels (e.g. a capacity-building programme to enable local government to translate national directives into practical reality); integrated catchment management (i.e. integrating 'all-hazards' thinking with flood risk management); improved information transfer between researchers and councils, and regional and local councils; adoption of a flexible investment approach (e.g. through an adaptive pathways framework); and proactively exploring opportunities to reduce risk and adapt to

climate change in day-to-day local planning and decision-making.

Climate change pressure points and implications for policy and management

Grey literature

Ballinger, J., Jackson, B., Reisinger, A., & Stokes, K. (2011). ***The potential effects of climate change on flood frequency in the Hutt River*** (Report produced as part of the Community Vulnerability, Resilience and Adaptation research programme). Wellington, NZ: New Zealand Climate Change Research Institute, Victoria University of Wellington.

This study was undertaken as a small component within the overall research project to illustrate a risk-based approach to decision-making under climate change. The study models climate change impacts on river flow and flooding using NIWA's hydrological model TopNet. Results indicate the potential for a significant increase in flood frequencies over the 21st century under climate change scenarios, but also a significant spread of results depending on the emissions scenario and climate model. Under a high emissions scenario, flood return periods could reduce to a fifth of current-day values on average. Under a scenario where global temperature increase is limited to 2 degrees Celsius, return periods would still about half by the end of the 21st century. However, the spread across different models is large and the authors suggest that rather than using a single number for future changes in flood risk, a risk-management approach that considers uncertainties and evaluates impacts and response options across a range of alternative futures is warranted. Also, potential changes in land use or river channels were not taken into account. The authors note that substantial changes could significantly affect the characteristics of the catchment and hence the magnitude and timing of flood events.

Rouse, H. (2012). ***Flood risk management research in New Zealand: Where are we, and where are we going?*** (GNS Science Report 2012/04). Christchurch, NZ: NIWA.

This report provides a preliminary analysis of the state of river flood risk management in NZ and identifies research gaps to help inform the guidance of NZ's long-term flood research agenda. These issues were explored by way of a literature review and a survey of key informants, including researchers and river managers. The paper first explores existing flood risk management practices in NZ, including the national

context for flood risk management such as legislative drivers and key organisations, and looks at regional flood risk management practices. It then provides a brief overview of research in areas that contribute to a better understanding of flood processes such as climate, flood flows and inundation research, flood vulnerability studies and research around community awareness of and preparedness for flood hazards. The report then identifies gaps in flood research and provides ideas for an improved NZ flood hazard research agenda. The author identifies the need for more research or better tools in a number of areas including: Regional flood frequency estimations; vulnerability assessment; post-event impacts assessments; engagement tools; and LiDAR data. The author suggests that flood risk management is subject to similar barriers as coastal erosion management, including: Lack of clear national directive; poor representation of national or regional interests in local decision-making; absence of long-term planning; power issues in matters of development vs. community; and resourcing and information gaps in councils. Recommendations to improve flood risk management in NZ include: National direction under the RMA or national guidance in the absence of such direction; integrated catchment management i.e. integrating 'all-hazards' thinking with flood risk management and other aspects of water management; improved information transfer between researchers and councils, and regional and local councils; and methods to address the variability in capability and capacity at regional levels.

NIWA. (2014). ***Assessment of the Effects of Large-scale Climate Oscillations on the Flood Risk in the Bay of Plenty*** (Report prepared for the Bay of Plenty Regional Council). Auckland, NZ: Fedaeff, N., &McKerchar, A.

This report, prepared for the Bay of Plenty Regional Council, describes the main climate oscillations affecting NZ and the Bay of Plenty region and the impacts they have on rainfall, river flow and resulting flood risk. The authors note that a warmer climate due to climate change poses an additional risk of more extreme rainfall events and therefore elevated flood risk in the future. The report states that the combination of climate change, interacting natural climate oscillations, as well as other variables such as land use change, make longer-term impacts to flood risk difficult to determine. The authors suggest that until firmer guidance becomes available, the best course of action for designers estimating design

parameters for permanent works such as bridges and stopbanks, and for planners seeking to delineate flood hazard areas and to schedule priorities, is to use all the available records, particularly those extending over two or more phases of the Interdecadal Pacific Oscillation, as a guide for frequency analyses. It is advised that there is currently insufficient evidence for delaying infrastructure expenditure based on the timing and effects of the climate cycles analysed in the report. However, they comment that it is possible that with more data, the weak relationships identified in the report may be strengthened and therefore used in future infrastructure investment planning. They also conclude that such continued monitoring will be vital in any future assessment of the potential impacts of climate change.

Tools and frameworks to support adaptive management

Academic literature

Lawrence, J., & Haasnoot, M. (2016). **What it took to catalyse uptake of dynamic adaptive pathways planning to address climate change uncertainty**. *Environmental Science & Policy*, 68, 47-57. <http://dx.doi.org/10.1016/j.envsci.2016.12.003>

This paper discusses the application of the Dynamic Adaptive Policy Pathways (DAPP) approach for implementing climate-resilient pathways in conditions of uncertainty and change. To better understand what it takes to catalyse uptake of DAPP to better address uncertainty and change than typical static planning approaches, the authors examined the role of a simulation game facilitated by a knowledge broker, in a real-life local decision setting on flood risk management in the Hutt Valley. Four intervention phases over four years are described and their influence analysed: Creating interest through framing the science; increasing awareness using the Game; experimenting with DAPP; and uptake of DAPP. They found that a knowledge broker introducing new framing of changing risk profiles, facilitating use of the Game and the DAPP approach in a real-life decision making setting, with contextual support from events and (inter)national reports, catalysed the uptake of adaptive pathways planning. They also identified enabling requirements necessary for embedding adaptive planning into decision-making practice for addressing uncertainty and change. This was the first such application of DAPP in New Zealand which is now being picked up by other councils for flood and coastal management.

Lawrence, J., Reisinger, A., Mullan, B., & Jackson, B. (2013). **Exploring climate change uncertainties to support adaptive management of changing flood-risk**. *Environmental Science and Policy* 33. 133-142.

This paper presents a methodology to explore the implications of alternative climate change scenarios for flood frequency, and apply it for illustrative purposes to the Hutt River. The authors state that while climate change creates a dynamic risk, flood risk management decision-making based on single 'best estimate' scenarios is entrenched in decision-making frameworks and professional operating practices. They suggest that this conceals uncertainties and focuses attention on enhancements to existing protection structures, giving a false sense of security to those living within presumed safe zones. They argue a more nuanced, risk-based approach is needed to reflect climate change uncertainties, but this is constrained by the high cost and complexity of modelling. The methodology presented here is argued to be quick and relatively low-cost. The researchers then evaluate the salience of this approach for planning responses with flood managers and planners. They found that when flood risk managers were presented with a range of possible futures and their respective consequences using the methodology presented, the pitfalls of 'picking' a number or 'best estimate' could be reduced. The approach also allows consideration of different land use activities and assets according to their function and lifetime. However, the authors note that the method outlined and the shift in thinking it can generate, is only part of the challenge – the institutions and organisational cultures surrounding decision-making were highlighted as being influential and deeply entrenched, creating leadership challenges yet to be fully explored.

Grey literature

Ballinger, J., Jackson, B., Pechlivanidis, I., & Ries, W. (2011). **Potential flooding and inundation on the Hutt River** (Report produced as part of the Community Vulnerability, Resilience and Adaptation research programme). Wellington, NZ: New Zealand Climate Change Research Institute, Victoria University of Wellington.

As part of the NZ Climate Change Research Institute-led Community Vulnerability, Resilience and Adaptation research programme, this study models inundation depth and extent within populated areas of the Hutt Valley under different magnitude flood events.

High resolution LiDAR was used and its coverage determined the area modelled, which covers the Hutt Valley floodplain from the river mouth upstream to Birchville. Data limitations, including the lack of information on stage-discharge characteristics at flood flows and potential transfers of water between surface and subsurface sources, were considered by the authors to be the most limiting issues in the study, as they necessitated making significant assumptions. The authors comment that the inundation model would need significant refinement before it could be used as a robust guide for planning purposes. Flood hazard maps are presented to illustrate the modelling results. The authors stress that these are indicative only due to the research limitations.

Greater Wellington Regional Council. (2015). **Flood Protection: Option Flexibility and its Value. Hutt City Centre River Corridor Options Report** (prepared for Greater Wellington Regional Council by Infometrics & PS Consulting). Wellington, NZ: Greater Wellington Regional Council.

This report looks at the value of pursuing flood protection options that are flexible, rather than adopting a single solution that cannot be adapted to deal with changing and unpredictable external conditions- namely climate change and its effect on peak river flows and consequent flooding. The authors suggest that a flexible investment strategy that enables a change in course in the future is more likely to deliver a lower cost outcome than pursuing a single option, unless the probability of climate change-induced change in flood frequency and its associated economic loss is almost certain. The concept of Dynamic Adaptive Policy Pathways approach (DAPP) as a framework for assessing the value of a flexible investment strategy is briefly discussed, and Real Options Analysis (ROA) is applied to the flood protection investment options for the Hutt City Centre Upgrade Project to demonstrate the value of adopting a flexible investment approach. The effects of changing the benefit metric from avoiding expected loss, to Value for Money based on a Multi-Criteria Analysis, are also presented. This is the first time ROA has been applied to the DAPP in New Zealand.

NIWA (2010). **RiskScape: Flood fragility methodology** (Report prepared for New Zealand Climate Change Research Institute, Victoria University of Wellington). Wellington, NZ: Reese, S., & Ramsay, D.

This report summarises development of the methodologies and approaches incorporated in the

RiskScape model to define the damage to property, infrastructure and people due to flood inundation events. RiskScape has been developed by NIWA and GNS Science to provide an easy-to-use decision-support tool that converts hazard exposure information into likely consequences for a region, such as damages and replacement costs, casualties, disruption and number of people affected. It is intended that consequences and risks for each region presented on a common platform can then be used to inform planning and prioritised risk-mitigation measures that link directly to the severity of the risks. The authors advise that the methodologies outlined in this report are based on the RiskScape flood module developed by NIWA and current at the time of writing (2010) but are liable to future change as ongoing research and further survey data refine and extend the approaches.

Enhancing adaptive capacity

Academic literature

Lawrence, J., Quade, D., & Becker, J. (2014).

Integrating the effects of flood experience on risk perception with responses to changing climate risk.

Natural Hazards 72. doi 10. 1007/s11069-014-1288-z

This paper uses the Hutt Valley household survey data collected for the case study described in the report above to examine links between flood experience, risk perception and propensity for adaptation actions when changing climate risk is likely. Results suggest previous flood experience contributes to heightened perception of risk, increased household preparedness, greater willingness to make changes, greater communication with councils, and more advocacy for spatial planning to complement existing structural protection. Those who lacked experience were more likely to be normalised to their prior benign experiences and thus optimistic about flood consequences. The authors suggest the results indicate that harnessing positive aspects of experience and communication of changing risk through engagement strategies could help shift the focus from citizens' expectation that governments will always provide protection, to a citizen-local government-central government dialogue about the changing character of flood risk. Governmental policy and direction is recommended that addresses changing climate risk and gives more robust support to local government responsibilities. The researchers advise that this could include integrating disaster risk reduction and climate change adaptation with resilient adaptive pathways framing, thus better

reflecting anticipatory adaptation in institutional frameworks. Suggested ways of doing this include elevating natural hazards and the effects of climate change into the Principles of the RMA as Matters of National Importance; and promulgating a National Policy Statement for natural hazards that links climate change effects to responses to natural hazards that are likely to be exacerbated by climate change, and to disaster risk reduction. A recent book chapter identifying barriers and opportunities for reducing flood risk and building adaptive capacity in the face of climate change (Glavovic, 2014) promotes similar approaches, and advocates for framing flood risk and adapting to climate change as an integrated and adaptive process that requires deliberative governance.

Grey literature

Lawrence, J., Tegg, S., Reisinger, A., & Quade, D. (2011). ***Vulnerability and adaptation to increased flood risk with climate change- Hutt Valley summary*** (Report produced as part of the Community Vulnerability, Resilience and Adaptation research programme). Wellington, NZ: New Zealand Climate Change Research Institute, Victoria University of Wellington.

This report sets out the findings of a Hutt Valley case study on flooding, one of three case studies explored as part of Community Vulnerability, Resilience and Adaptation programme. This study examined the effects of climate change on the frequency and severity of flooding of the Hutt River over the next century; the impacts of a range of flood events on the Hutt Valley community; socio-economic factors influencing the community's ability to adapt, cope with and recover from flooding; social and institutional barriers constraining adaptation; and the opportunities for improving adaptive capacity. Key findings with regard to barriers to adaptation and opportunities for improving adaptive capacity include: Uncertainty of climate change projections collides with councils' need for 'robust' or definitive planning guidance; using the 'best-estimate' scenario underestimates the real risk of more extreme events; leadership on risk issues often emerges only after significantly damaging events; a number of practices can improve adaptive capacity. Pooling resources, improving access to LiDAR, using aerial photos of past floods, and the LTP process are examples of opportunities for improved assessment and communication of climate change and flood risk.

Quade, D., & Lawrence, J. (2011). ***Vulnerability and adaptation to increased flood risk with climate change - Hutt Valley household survey*** (Report produced as

part of the Community Vulnerability, Resilience and Adaptation research programme). Wellington, NZ: New Zealand Climate Change Research Institute, Victoria University of Wellington.

This report was prepared as part of the same Victoria University-led programme as the above, and is based on a survey of households in the Hutt Valley conducted in mid-2010. Key issues explored were whether residents' past flood experiences and socio-economic characteristics affect their preferences for and perceptions of measures for managing flood risk and present and future responsibility, liability, and protection for flooding affected by climate change; and whether different ways of communicating flood risk affect residents' understanding of flood risk and preferences for measures to manage flood risk. Key findings include: Overall, respondents were very concerned about flood risk and management and no significant differences were found between flood-affected and unaffected respondents regarding acceptable level of flood risk and preferred planning horizons in flood-risk management; respondents preferred proactive measures to mitigate flood risk, with improvements to the stormwater network the top priority; respondents preferred flood risk to be dealt with collectively than individually, with city and district councils assigned the highest responsibility. However, respondents also indicated that it was a personal responsibility to avoid flood hazard in the first place by not building in high-risk areas; results of the case study provided only partial support for the proposition that flood experience contributes to people's preferences for, and perceptions of, measures for managing flood risk and the current and future roles and responsibilities for managing flooding affected by climate change.

HEALTH, WELL-BEING AND CULTURE

Literature in this section spans a wide range of health and livelihood implications of climate change, though a majority of the in-depth studies focus specifically on the potential spread of pathogens and infectious disease as a function of future climate change in NZ. Recent NZ-specific studies examining other health-related implications of climate change, such as possible implications for mental and cultural health and well-being, appear less prevalent. Several publications discuss equity issues in relation to the health impacts of climate change, and the increased vulnerability of particular sub-sections of the NZ population, including children, the elderly, Maori,

and those already living in poverty. A broad suite of tools and frameworks are presented, with the aim of assisting, in various ways, in the planning and implementation of adaptive strategies for increasing resilience to climate change impacts on health. A number of these were developed as part of the Health Analysis and Information for Action (HAIFA) resource system, the first international project of its kind. HAIFA aims to provide central, regional and local authorities with information to help formulate and plan the implementation of responses and adaptive strategies for increasing human health resilience to the infectious disease consequences of climate change. Health-related policy recommendations in the literature include undertaking health impact and equity analyses of public policy decisions; and development of region-specific adaptive responses to reflect localised climate change health impacts. The role of health professionals in advocacy and awareness-raising is promoted.

Climate change pressure points and implications for policy and management

Academic literature

Bennett, H., Jones, R., Keating, G., Woodward, A., Hales, S., & Metcalfe, S. (2014). **Health and equity impacts of climate change in Aotearoa- New Zealand, and health gains from climate action.** *New Zealand Medical Journal*, 127(1406), 16-31.

This paper discusses the threat to health and health equity posed by climate change in New Zealand. It outlines how, under all climate projections reported in Intergovernmental Panel on Climate Change Fifth Assessment Report, New Zealand will experience direct impacts, biologically mediated impacts, and socially mediated impacts on health. The authors state that these impacts will disproportionately affect populations that already experience disadvantage and poorer health. The paper updates both Metcalfe et al's Special Article on climate change and health in the NZMJ in 2009, and Phipps et al's paper on the climate change challenge for General Practice in New Zealand in the NZMJ in 2011. The authors outline a wide range of possible health impacts of climate change in New Zealand, including food security and nutrition, mental health and suicide, injury and illness from extreme weather events, food and water borne disease, cardio-respiratory disease and allergic diseases. The paper suggests that public policy decisions should include a health impact analysis as well as an equity analysis to avoid adverse health impacts and ensure

that interventions contribute to reducing social and health inequities. The authors conclude that health professionals have a responsibility to raise awareness of the health implications of climate change and to press for urgent action.

McBride, G., Tait, A., & 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, 2133-2147. doi: 10.1007/s00477-014-0920-5

This research uses an existing calibrated linear SIR (Susceptible Ill Recovered) model to make predictions about the proportional change in the reported rate of two pathogens under climate change and variability: the bacterium *Campylobacter* and the protozoan oocyst *Cryptosporidium*. The authors argue both are of particular importance to NZ, given its extensive and intensive agricultural farming systems, and that previous studies have indicated that rates of illnesses associated with these pathogens (campylobacteriosis and cryptosporidiosis) may increase as temperature rises and as rainfall becomes more intense. This study is the first to combine SIR modelling with climate change projections. The SIR model outputs provide projected changes in reported disease incidence as a function of temperature and rainfall for the years 2015, 2040 and 2090. These are calculated for three climate change scenarios: low (B1), medium (A1B) and high (A2) emissions of greenhouse gases for four seasons. Projections show the potential for substantial changes in reported rates by the year 2090 across NZ, with children most at-risk. Average annual rates of increase of reported campylobacteriosis are predicted to rise by as much as 20% and by 36% for cryptosporidiosis (children, A2 scenario, 2090). The authors suggest it is important to consider the wider national health and economic impacts and the adaptive capacity for communities and organisations to respond to these potential impacts. They reflect that, in many regions of NZ where population density is low, primary health services are often not numerable or accessible. Thus, adaptive planning on how the projected disease increases may place a burden on communities and the health system should be considered.

Lal, A., Hales, S., Kirk, M., Baker, M.G., & French, N.P. (2016). **Spatial and temporal variation in the association between temperature and salmonellosis in NZ.** *Australian and New Zealand Journal of Public Health*, 40(2), 165-169. doi: 10.1111/1753-6405.12413

This study models the relationship between weather, climate and infectious disease in order to help identify high-risk periods and the determinants of longer term trends. The study provides a detailed examination of the non-linear and delayed association between temperature and salmonellosis in three NZ cities (Auckland, Wellington and Christchurch). City-specific associations between weekly maximum temperature and the onset date for reported salmonella infections (1997-2007) were modelled using non-linear distributed lag models, while controlling for season and long-term trends. Relatively high temperatures were positively associated with infection risk in Auckland and Christchurch, although the former showed evidence of a more immediate relationship with exposure to high temperatures. There was no significant association between temperature and salmonella risk in Wellington. The authors conclude that projected increases in temperature with climate change may have localised health impacts, suggesting that preventative measures will need to be region-specific. This is the first study to explore the non-linear and time-dependent association of temperature and salmonellosis risk across cities.

Grey literature

Hambling, T., & Bandaranayake, D. (2012). Editorial: Climate change and waterborne diseases in New Zealand and the role of primary care in the early detection of common source waterborne disease outbreaks. ***New Zealand Public Health Surveillance Report 10***(4) ISSN 1178-8313.

This article outlines evidence that climate change-related alterations in temperature, rainfall, surface water availability and water quality could affect the burden of water-related diseases. Previous studies are cited that report associations between certain gastrointestinal, water temperature and precipitation events, as well as evidence to suggest that outbreaks of waterborne infectious disease follow extreme water-related climatic events. The paper points to recent waterborne disease outbreaks in NZ as examples of the greater challenges water suppliers will face in ensuring provision of safe water as climate change impacts become more pronounced. It then discusses the development of a vulnerability assessment tool as part of the Health Analysis and Information for Action (HAIFA) programme, which aims to provide support for communities in understanding why their water supply may be vulnerable to heavy rain events and severe drought, and how they can reduce vulnerability.

The paper also discusses how waterborne disease surveillance data are useful for detection of outbreaks and for evaluating current approaches for providing safe drinking and recreation water. The authors suggest, however, that many waterborne outbreaks are unrecognised or underreported and that, ideally, an early warning system based on syndromic surveillance to identify clusters of gastrointestinal illness would be useful for detecting outbreaks at an earlier stage. The report concludes that primary care physicians can assist in early detection of outbreaks through notification to the medical officer of health on suspicion of a cluster of gastrointestinal illness rather than waiting for laboratory confirmation.

Massey University Centre for Public Health. (2014). ***Environmental Health Indicators New Zealand. Vulnerability to Climate Change*** (factsheet prepared by the Centre for Public Health Research). Wellington, NZ: CPHR.

This factsheet explains why some groups of people will be more at risk than others to the effects of climate change in NZ. Potentially vulnerable groups highlighted here include babies and young children, the elderly, indigenous populations, and those living in poverty. The authors emphasise the need to identify the location, size and type of vulnerable groups in a community to help plan what additional support might be required for these groups to adapt to climate change. In a NZ context, the data on vulnerable populations could be used by local authorities to help decide how to target information on preparing for climate changes, including extreme weather events. To demonstrate the impact of age vulnerability, the authors suggest an area with a large percentage of elderly or young people may need more support to cope with unexpected events, for example they might need transport to collect essential supplies before a severe storm. The analysis suggest Maori are more likely to be vulnerable to climate change due to a greater proportion of Maori living in the north and east of NZ where heat pressure is expected to increase, and because the Maori economy is heavily reliant on climate-sensitive primary industries.

NZ College of Public Health Medicine. (2013). ***Policy Statement on Climate Change***. Wellington, NZ: NZ College of Public Health Medicine. Retrieved from http://www.nzcphm.org.nz/media/74098/1._nzcphm_climate_change_policy__final_comms_version2_.pdf

This substantive statement replaces the NZCPHM's brief policy statement adopted in June 2012. The

purported purpose of the policy statement is to outline the importance of health within climate change impacts so that public health professionals and others can take action. The statement describes the cause and extent of global climate change, the urgency, and the risks to human health and wellbeing. According to the policy statement, climate change should be an essential component of health policy, and equity outcomes should be key priorities within climate change policy. The statement identifies a number of increased public health activities necessary to help prepare for and cope with the health impacts of climate change in NZ. Among these are health service planning that accommodates likely increased burden from climate-sensitive diseases, strengthening the resilience of health infrastructure and services to extreme events, and public health monitoring and management of drinking water and recreational water.

Tools and frameworks to support adaptive management

Academic literature

Canyon, D.V., Burkle Jr, F.M., & Speare, R. (2015). ***Managing community resilience to climate extremes, rapid unsustainable urbanisation, emergencies of scarcity, and biodiversity crises by use of a disaster risk reduction bank***. *Disaster Medicine and Public Health Preparedness*, 9(6), 619-624. doi: 10.1017/dmp.2015.124

This brief report presents and recommends a community-focused model to generate rapid information to assist decision-makers in the event of a sudden-onset climate-related disaster. The model, currently being applied in NZ, the UK, and Australia, is designed to overcome barriers to success in the traditional “top-down” approach to managing crises and recognises the capacity of citizens and community organisers to facilitate responses and recovery if provided the opportunity and resources. The authors’ premise is that all communities are “unique and discrete” from one another and, therefore, time and resources must be allocated to determine and analyse what the risks are within each community and what would be required to anticipate, prepare for, respond to and recover from threatening events. The proposed framework is as follows: Survey all communities, partners, and collaborators to determine the capacity and capability of a community in preparing for and responding to climate extremes and climate change; store all data in a national disaster risk reduction bank; identify gaps and work with communities before

crises occur to mitigate identified risks; enable rapid on-demand, online access to the data; and immediately forward response requirements to crisis-affected communities without any additional assessment.

Grey literature

Adlam, B. (2012). ***Risk Assessment Tool (DAISY) for Emerging Human Infectious Diseases*** (prepared as part of the Health Analysis and Information for Action (HAIFA) project). Porirua, NZ: Environmental Science and Research Limited.

This technical report describes how the DAISY (Disease Attribute Intelligence System) risk assessment tool was constructed for six indicator diseases (campylobacteriosis, cryptosporidiosis, Neisseria meningococcal infectious disease, influenza, Ross River and dengue fevers) for the HAIFA climate change project. The author observes that while many risk assessment tools are based on static elements that are inherent to the infectious disease, in an emerging infectious disease situation, climatic events and regional or local vulnerabilities are changeable and the level of risk is often difficult to determine. The DAISY risk assessment tool addresses this issue by incorporating changing elements of risk during disease emergence. Using DAISY, the research team monitored down to Territorial Local Authority level changing risk for the six indicator diseases on a monthly basis from January 2008 to November 2009 using surveillance and outbreak data from ESR’s EpiSurv system. The report lays out the basic DAISY tool structure, provides details of previous DAISY applications, and describes the application of DAISY for the six climate change indicator diseases listed above.

Baker, V., Kelly, S., Lange, M., & Nokes, C. (2012). ***Literature review on dynamics/contextual factors affecting ‘information for action’ for the climate change and human health nexus*** (prepared as part of the Health Analysis and Information for Action (HAIFA) project). Porirua, NZ: Environmental Science and Research Limited.

The purpose of this review is to develop a robust understanding of the key concepts and factors for supporting ‘information for action’ with respect to climate change and human health. It investigates the dynamics, relationships, activities and components that form the climate change and human health nexus, and focuses on the links between knowledge, awareness and action in this context. The review looks firstly at the context and definitions, and introduces several dynamic models that relate to the nexus of

climate change and human health. Uncertainty is highlighted as a key feature and potential barrier to adaptation planning. Different terminologies and approaches are discussed with a focus on social capital and information and communication as key components of adaptive capacity for communities and organisations. The implications of different institutional characteristics for adaptation planning are discussed, with an emphasis on empirical studies of the local government or environment, and the public health sectors. A section on adaptive capacity explores how concepts can be translated into working models of how things happen and get done. The process of mainstreaming is also addressed.

Hambling, T. (2012). ***Environmental Health Indicators: development of a tool to assess and monitor the impacts of climate change on human health*** (prepared as part of the Health Analysis and Information for Action (HAIFA) project). Porirua, NZ: Environmental Science and Research Limited.

This report describes the methods used to select and develop a core set of Environmental Health Indicators (EHIs) to explore the relationships between and impacts of climate variation and change on food- and water-borne diseases in NZ. In particular, the report focuses on salmonellosis and cryptosporidiosis and presents working examples of EHIs for salmonellosis. The report also illustrates how EHIs can be used as a tool to aid environmental health decision-making, by forming a basis for describing and better understanding the environmental health causal chain/networks for climate variation and change, and food- and water-borne diseases. It also provides a resource for discussion about how to reduce the burden of disease from environmentally driven health issues by identifying and developing measures to assess, quantify and monitor human health vulnerability, informing the design and targeting the interventions, and measuring the effectiveness of adaptation and mitigation activities. The report also seeks to encourage a multidisciplinary approach to link existing environmental and epidemiological data and networks. The author suggests that analysis of such data will contribute to an enhanced understanding of the relationships between climate change and human health.

Tompkins, D., Brock, A., Jones, G., McBride, G., Tait, A., Benschop, J., Marshall, J., French, N., Harper, S., Parshotam., A., Ye, W., Anderson, D., MacLeod., & Slaney, D. (2012). ***Modelling the impacts of climate***

change on infectious diseases in New Zealand (prepared as part of the Health Analysis and Information for Action (HAIFA) project). Porirua, NZ: Environmental Science and Research Limited.

This report describes the methodological approaches used in the development of the disease specific predictive models (mathematical, statistical and mechanistic) for climate change projections via the analysis of health, demographic, climate, and environmental data at the 5x5 km spatial scale across NZ. Disease projections were made for the three greenhouse gas emission scenarios B1 (low), A1B (medium), and A2 (high) and the three time periods 2015, 2040, and 2090. The disease projection results can be viewed via the purpose built geographic information system portal on the HAIFA resource system website. The report describes how, using HAIFA, end-users are able to: Make predictions of which infectious diseases and contributing risk factors, will be of key concern to human health; predict changes in the occurrence levels of these infectious diseases due to climate change; identify the communities and population groups most likely at risk from these infectious diseases; and recognise the infectious diseases predicted to most threaten specified communities and population groups. The authors believe this information will help end-users plan responses to the potential impacts of climate change.

Nokes, C. (2012). ***Water supply climate change vulnerability assessment tool handbook*** (prepared as part of the Health Analysis and Information for Action (HAIFA) project). Porirua, NZ: Environmental Science and Research Limited.

This handbook explains how to use a Vulnerability Assessment Tool developed for assessing the vulnerability of water supplies to climate change. The author describes how drinking water treatment processes remove the microorganisms that cause disease from water, but that this removal process is made more difficult by droughts and floods, which are expected to become more frequent and intense in NZ with climate change. This tool is intended to help small communities and their water suppliers adapt to these challenges. Specifically, the tool is designed to help users assess the vulnerability of their community to being without water that is safe to drink because of heavy rain or droughts, understand the characteristics of their water supply and community that are contributing to the vulnerability, and decide

what actions to take to reduce the vulnerability of their community's water supply. The handbook is intended for those who are responsible for ensuring communities have access to wholesome water during weather or climatic episodes.

Enhancing adaptive capacity

Academic literature

Loosemore, M., Chow, V., & McGeorge, D. (2014).

Managing the health risks of extreme weather events by managing hospital infrastructure. *Engineering, Construction and Architectural Management*, 21(1), 4-32. <http://dx.doi.org/10.1108/ECAM-10-2012-0060>

This paper outlines how a predicted increase in climate change related extreme weather events will present hospitals with new health related and physical risks which were not originally anticipated in building and infrastructure designs. Markus et al's building systems model is used to analyse a range of adaptive strategies to cope with such events. The research involved focus group interviews with a wide range of hospital stakeholders across three case study hospitals in Australia and New Zealand which have experienced extreme weather events. It is concluded that effective adaptive strategies must balance responses across different organisational sub-systems. Contrary to previous research, the findings indicate that hospital managers do see hospital infrastructure as an important component of disaster response. However, it is the least adaptable of all response subsystems, making other options more attractive in the heat of a crisis. Recommendations are made to improve the adaptive capacity of healthcare facilities to cope with the future health challenges of climate change risk. For example, the authors conclude that their findings show it is important for hospital facility managers to work cooperatively with other external authorities such as public infrastructure, aged care and government organisations in developing effective responses. The qualitative case study approach adopted may limit the generalisability of the findings, given the variety and complexity of facilities and stakeholders involved.

Parsons, M. & Nalau, J. (2016). ***Historical analogies as tools in understanding transformation.*** *Global Environmental Change*, 38, 82-96. <http://dx.doi.org/10.1016/j.gloenvcha.2016.01.010>

This article starts by describing how historical analogies of environmental change and stress have previously been used to examine vulnerability to the impacts of climate change. The authors then suggest

that historical analogies of social transformations can likewise help identify what factors are conducive to transformation. The authors draw on the historical example of the environmental transformation of New Zealand from predominantly woodlands into farmlands; a transformation they suggest was inextricably linked with the social transformation of indigenous Maori society following European colonisation. Through this NZ case study, the paper seeks to illustrate how such historical transformations involved widespread changes to indigenous governance regimes, agricultural systems, production and consumption patterns, lifestyles, values and worldviews, and both beneficial and negative outcomes for local peoples. The authors argue that using this type of historical framework to think about transformational change provides an opportunity to assess the processes that shape both vulnerability and resilience, and the circumstances under which transformational change occurs, as well as the potential dangers of irreversible changes.

INFRASTRUCTURE (INCLUDING TRANSPORT AND UTILITIES)

Recent infrastructure-focused studies for NZ number relatively few. The 2012 NIWA-led programme that developed the Urban Impacts Toolbox to assist councils in adapting to the impacts of climate change on urban infrastructure and the built environment is still the most current and comprehensive set of publications on the topic in NZ. Literature in which infrastructure impacts are discussed but are not the central focus are included in other sections of the review. Key messages conveyed in the literature regarding climate change implications for NZ infrastructure include: the need to exercise caution in committing to infrastructure investments where information is being updated due to changing risk profiles; relatedly, infrastructure responses should not be static but, instead, must continuously evolve to address new evidence and shifting trends, both global and domestic; social learning through community engagement can enhance adaptive capacity and public support for climate-resilience infrastructure decisions; and systems-thinking, resilience approaches, and real options theory can help in analysing policy issues and making sound infrastructure decisions amidst uncertainty.

Climate change pressure points and implications for policy and management

Grey literature

Grimes, A. (2012). **Optimal Infrastructure Adaptation to Climate Change** (Motu Note #11). Wellington, NZ: Motu Economic and Public Policy Research.

This paper examines some of the key issues that could be taken into account when designing and implementing climate change adaptation policies with regard to infrastructure investments. A seawall as an infrastructure investment to adapt to coastal flooding is used as an example in the analysis. Two key lessons stemming from the analysis are to spread the nature of adaptation responses to climate change across margins that reduce the probability of an adverse event (e.g. a flood), the exposure given such an event, and the loss given the exposure; and to be cautious in committing to irreversible infrastructure investments that may no longer be optimal as our understandings of the severity and frequency of climate change outcomes are revised. The paper discusses two ways of thinking about issues of adaptation to climate change. In cases where risks can reasonably be quantified (where there are well-defined likelihoods of particular events happening) a “certainty equivalent” analysis based on financial market credit loss methods can provide useful policy insights. Where uncertainties are prevalent, “real options” theory can provide useful insights for analysing policy issues. The author outlines the relevance of both these economic approaches. The analysis is based on economic insights and does not incorporate legal responsibilities (e.g. those that apply to regional councils in NZ).

National Infrastructure Unit. (2014). **Infrastructure evidence base –scenario/trends analysis** (National Infrastructure Unit discussion document). Wellington, NZ: NZ National Infrastructure Unit.

This publication summarises the outcomes of an investigation into future pressures placing demand on NZ’s infrastructure for a range of plausible scenarios. Climate change impacts are identified as a key driver of change with potential to exert significant influence over NZ’s infrastructure requirements. Climate change impacts are also identified as some of the key uncertainties surrounding infrastructure requirements. The report states that the rate at which sea levels rise will have varying impacts on NZ’s low-lying, coastal infrastructure, and an increasing prevalence of droughts will threaten the productivity of NZ’s agricultural sector. The report considers three

potential future scenarios that include a range of climate change impacts with varying frequency and severity. Key messages from this scenario modelling investigation are that responses should seek to: Leverage the positive drivers of change (e.g. embrace cost-effective new technologies) and mitigate the negative drivers of change (e.g. develop and implement climate change adaptation plans); and exploit the opportunities presented by interdependence (e.g. intelligent networks that improve asset utilisation), whilst simultaneously managing the risks of interdependence (e.g. resilience planning to protect against failure propagation). Finally, the report suggests the infrastructure response is not expected to be a static plan but that instead the response must continuously evolve to address new evidence and shifting trends, both global and domestic.

Renwick, J.A. (2013). **Climate change and its implications for the Ruataniwha water storage scheme** (report prepared for Hawke’s Bay Regional Investment Company Limited). Napier, NZ: Hawke’s Bay Regional Investment Company Limited.

This report outlines factors that influence the NZ climate, climate change scenarios for NZ and the implications for the Hawke’s Bay region and the Ruataniwha water storage scheme. Climate projections are based on the IPCC’s 2007 Fourth Assessment Report. Key findings for the Hawke’s Bay and Ruataniwha water storage scheme are as follows: Hawke’s Bay is likely to see climate changes consistent with the projections for NZ as a whole. Warming of between 2 and 3 degrees Celsius is likely by 2100. Rainfalls are likely to decrease in winter and spring, and increase slightly in summer and autumn. Flows from the headwater of the Makaroro River are likely to rainfalls coming from western regions into the Ruahine ranges, hence flows from the headwaters of the Makaroro River are likely to exhibit small average increases in winter and spring, and small decreases in summer and autumn. The risk of heat waves and drought are likely to increase significantly by the end of the century. The risk of heavy rainfall events is also likely to increase but likely not until the late 21st century.

Weir, J. and Davidson, P. (2016). **Groundwater Report: Wairau Aquifer Groundwater Model- Prediction of Climate Change Impacts** (report prepared for Marlborough District Council). Christchurch, NZ: Aqualinc Research Limited.

This report was produced in order to help Marlborough

District Council better understand how the groundwater resources of the Wairau Plains will be affected by climate variability and future climate change. An existing Wairau Plain aquifer model, developed by Marlborough District Council and Aqualinc in 2008, was refined and used to simulate the impacts on the groundwater resources from climate change. Several scenarios were developed: Sea level rise; removal of flow augmentation in Gibson Creek from the Waihopai and Wairau rivers; reduction of Wairau River flows (and associated recharge to groundwater); and reduction in land surface recharge. Some of the key results with regard to sea level rise were that sea level rise is likely to have the greatest effect close to the coast and in rivers seaward of SH1; and an increase in shallow groundwater levels due to a rise in sea level may adversely affect land use in the coastal area. Several pieces of future work were recommended: Instigate regular monitoring of the saltwater interface in coastal rivers and groundwater; review and analyse gaugings and other hydrological information for Gibson Creek and other main tributaries; update the model with new time series of land surface recharge and pumping and other relevant hydrological data, and calibrate to measured data up to present date; and consider using this updated model for predicting the effects on the saltwater-freshwater interface.

Tools and frameworks to support adaptive management

Academic literature

Sullivan, F. (2016). ***Strategies for Managing Infrastructure Risk- an update***. *Policy Quarterly* 12(4).

This short article published in a local government-focused edition of *Policy Quarterly* asserts that local government has recognised the need to stand back and take stock of whether risk in NZ is being managed in the most rational and sustainable way. The National Infrastructure Unit infrastructure plan, the Ministry of Civil Defence and Emergency Management resilience strategy, and the Parliamentary Commissioner for the Environment's reports on sea level rise are cited as examples of central government agencies responding to NZ's vulnerability to hazards, including climate change impacts. The author suggests that consideration is needed about the choices that exist for addressing future risk and who will bear the costs. The author argues that a risk management approach will enable local authorities to address priority issues with their communities, and comments

that infrastructure that provides core services to communities could be the first to be affected by rising sea levels and storm surges, rainfall events of greater intensity and frequency and other hazard events. The author concludes that, while risk management has the potential to be viewed as part of the "merry-go-round of favoured policy themes that come and go depending on political leanings at the time", risk management at its simplest supports prudent financial management and decision-making in a constrained fiscal environment.

Grey literature

NIWA, MWH, GNS and BRANZ. (2012). ***Impacts of Climate Change on Urban Infrastructure and the Built Environment: Urban Impacts Toolbox and Handbook***. Retrieved from <https://www.niwa.co.nz/climate/urban-impacts-toolbox>

This comprehensive suite of decision-support tools was developed under the MSI (now MBIE) funded research programme "Impacts of Climate Change on Urban Infrastructure and the Built Environment". The programme was led by NIWA in collaboration with MWH New Zealand Ltd, BRANZ and GNS. The main goal in creating the toolbox was to respond to the needs of regional, district and city councils by providing guidance and decision tools that can be used by urban council staff and policy makers to reduce the potential adverse effects of climate change. It is the first example of a toolbox approach being used for climate change assessment in NZ. The key outputs from the project are the 5 "toolbox trays" that together comprise 50+ thematically grouped PDF guidance documents covering flooding, sea level rise and storm surge, heavy rainfall induced landslides, heavy rainfall and urban drainage, supply and demand of potable water, and other hazards. A handbook document serves as a companion to the toolbox and provides an overview of the toolbox structure and guidance on its use. The toolbox is primarily designed for urban council engineers, asset managers, hazard analysts and planners with responsibilities for infrastructure management, asset management, consents, transport, urban development, strategic planning and emergency management.

Hughes, JF & Healy K. (2014). ***Measuring the resilience of transport infrastructure*** (NZ Transport Agency research report 546). Wellington, NZ: AECOM New Zealand Ltd.

NZTA engaged AECOM to develop a framework and assessment tool to measure the resilience

of the NZ land transport system (road and rail) that allows consideration of various scales (asset/network/region). Two “resilience principles” formed the basis of the framework development: Technical principles (robustness, redundancy, safe-to-fail); and organisational principles (change readiness, leadership and culture, networks). The framework involves an initial determination of the context of the resilience assessment, followed by a detailed assessment of resilience measures, which combine to generate a resilience score ranging from 4 (very high resilience) to 1 (low resilience). Climate change impacts are discussed a number of times throughout the report, and are included for evaluation in the framework as examples of “longer-term stress events”. The report discusses the relationship between sustainability and resilience and suggests the concepts overlap over a time scale, with resilience being achieved in the short term via adaptation, and leading into sustainability over the medium term through mitigation and ultimately reaching sustainability through transformation. Sea level rise is given as an example, with resilience achievable, in theory, through a variety of structural, planning and response activities/adaptations. Due to project constraints, detailed real-scenario testing of the framework was not undertaken.

Mason, D., & Brabhakaran, P. (2016). **Resilience of State Highways. Recommended Regional Assessment Methodology for Low Frequency Hazard Exposure** (NZ Transport Agency Report, Issue 1). Wellington, NZ: Opus International Consultants.

This report presents the methodology developed for a regional level assessment of the resilience of the state highway network to low frequency, high impact natural hazards. The framework is consistent with the broader national resilience framework, but uses more detailed regional information, including detailed corridor assessments at the regional level. Two resilience metrics are used in the methodology to assess the resilience of the State Highway Network: Availability State= level of access after the event, representing the level of service; and Outage State= duration of reduced access at the above availability state. Resilience is defined in the report as the ability to readily recover and return to original form from adversity. This definition of resilience suggests an emphasis on enabling ‘business as usual’ by focusing on maintaining core functions in the face of hazards events and impacts. It doesn’t appear to conceptualise resilience in a more transformational way; that is, in

a way that sees resilience as being not simply about maintaining the status quo, but about innovation and transformation into more desirable forms and functions. Climate change does not feature heavily in the assessment methodology. The main reference to climate change is in the context of storms, floods and coastal hazards; flood models that incorporate an assessment of climate change impacts are identified as key data sets required for regional resilience assessments.

Enhancing adaptive capacity

Grey literature

Taptiklis, N. (2011). **Climate resilient water management in Wellington, New Zealand** (NZCCRI 2011 report 09 produced as part of the Vulnerability, Resilience, and Adaptation to Climate Change programme). Wellington, NZ: NZ Climate Change Research Institute, Victoria University of Wellington.

This report sets out the findings of a case study on Wellington urban water supply management, one of three case studies undertaken as part of the Community Vulnerability, Resilience and Adaptation to Climate Change research project led by Victoria University and funded by the Foundation for Research, Science and Technology. This case study research aimed to gain a detailed understanding of the factors influencing water use and management in the four cities of the Wellington region, and how specific response options could affect future community and institutional adaptive capacity, and increase or decrease resilience to water shortages. This case study into climate change adaptation and urban water management used systems-thinking, resilience, and complex systems science approaches. The study found that Wellington’s present water supply capacity is sufficient to meet increased demand due to population growth and climate change in all but the driest years to 2090. It is cautioned that an approach focused primarily on supply management could increase vulnerability to water shortages. In terms of enhancing adaptive capacity to increase resilience to water shortages, the analysis in this case study indicates that this requires social learning, which could be facilitated through participative and collaborative involvement in water management.

PRIMARY INDUSTRIES (INCLUDING FARMING, FISHING, AND FORESTRY)

The impacts and implications literature in this section examines vulnerabilities and adaptive responses

across a range of operations in the primary production sector including sheep, beef and dairy farms, vineyards, plantation forestry, and kiwifruit orchards. A lack of recent NZ-focused literature was found on the decision-making implications of climate change for other horticultural activities (e.g. other food crop industries), and for fisheries². Information needs and knowledge gaps identified include: information regarding the relative impact of different agricultural adaptation options on regional profitability under a range of projected climatic changes; strategies to address factors such as urban expansion, an aging population, and other processes of rural change that are cited as potential constraints on future adaptation; and development of spatial models and decision support systems that integrate the complexities of future climate impacts to provide a means of mitigating the detrimental influences of climate change in the primary industries. A number of tools and strategies for enabling adaptive management of climate change impacts and enhancing adaptive capacity in the primary sector are presented. These include: Fostering social networks; representing and valuing farmer knowledge in the formation of adaptation strategies; supporting collective learning to address resilience challenges; and taking an interdisciplinary approach to climate change adaptation decision-making by forging connections between regional planners, researchers and policy-makers and farmers and rural communities to assess opportunities and adaptation options for different regions and farm systems.

Climate change pressure points and implications for policy and management

Academic literature

Cradock-Henry, N. (2016). ***New Zealand kiwifruit growers' vulnerability to climate and other stressors.*** *Regional Environmental Change*. doi: 10.1007/s10113-016-1000-9

This study develops and applies a bottom-up contextual assessment of vulnerability to climate and other stressors among NZ kiwifruit growers. The research draws on in-depth, semi-structured interviews with kiwifruit growers and orchard managers, workshops and analysis of secondary data. The findings suggest that climate and markets are the main sources of exposure for growers, with sensitivity moderated by location. The study revealed that growers employ mostly short-term, reactive

adaptive strategies to manage climate exposure. Warmer and drier conditions are likely to have adverse effects for kiwifruit production and compound existing vulnerabilities. An aging population, urban expansion, and other processes of rural change are cited as potential constraints on future adaptation. Current adaptations to climatic conditions such as intensification and increased fertiliser or chemical use have long-term sustainability implications. Future adaptive capacity is likely to be influenced by the combined effects of technological developments; shifting human capital; and land-use change, which are driven by exogenous forces such as overseas markets and regulatory requirements, over which growers have little control. The author suggests that in order to realise opportunities and minimise losses, longer-term strategic responses are required.

Lee, J.M., Clark, A.J., Roche, J.R. (2013). ***Climate-change effects and adaptation options for temperate pasture-based dairy farming systems:*** a review. *Grass and Forage Science. The Journal of the British Grassland Society*, 68, 485-503. doi: 10.1111/gfs.12039

This review describes predicted changes in climate in NZ and southeast Australia, likely effects on the feedbase used in the pasture-based dairy industry and the flow-on effect on milk-solids production and profitability. Potential adaptation options to allow farmers to take advantage of new opportunities and minimise negative impacts of climate change are also identified. For example, the review identifies that, in many regions, annual pasture production is predicted to increase due to carbon dioxide fertilisation and warmer temperatures during winter/spring. Production may decline however in regions with either reduced rainfall or severe flooding. The study suggests that, should this occur, farmers could strategically use supplementary feed, reduce stocking rates, irrigate or sow alternative plant species with greater drought tolerance. The authors suggest that pasture-based dairy systems have high levels of adaptive capacity, and there are opportunities to continue to improve production efficiencies particularly where rainfall change is small. A key recommendation is that more information be obtained regarding the relative impact of different adaptation options on regional profitability under a range of projected climatic changes. Also, it is recommended that additional efforts be made to ensure farmers have the necessary information and skills to implement changes successfully.

²It should however be noted that a marine case study report (Law et al, 2016) produced as part of the CCII RA2 workstream was being prepared for publication at the time that this review was being undertaken.

Lieffering, M., Newton, P.C.D., Vibart, R., & Li, F.Y. (2016). **Exploring climate change impacts and adaptations of extensive pastoral agricultural systems by combining biophysical simulation and farm system models.** *Agricultural Systems*, 144, 77-86. <http://dx.doi.org/10.1016/j.agsy.2016.01.005>

This study models the impacts and tests the effects of potential adaptations to climate change for two NZ sheep and beef grazing enterprises located in regions that have contrasting climate change projections: Southland and Hawke's Bay. For both enterprises, the researchers examined six management systems varying in farming intensity and the tactics used to respond to changes in feed supply and demand. The effects of the impacts and adaptations were determined by examining the economic viability of the systems. Pasture growth over two 20-year periods was modelled using downscaled climate projections and a pasture simulation model. The resultant pasture growth curves were used in a farm system model to both determine impacts and test the benefits of adaptation. For both regions, there were only slight increases in total annual pasture growth but marked changes in seasonality that required changes in the management system. For Southland, there were clear benefits of climate change that were accentuated by adaptation, while in Hawke's Bay climate change had no positive impacts and adaptation was not effective. The study considered short and medium term tactical adaptations (e.g. buying in supplementary feed), and strategic adaptations (e.g. changing to another known production system), but, importantly, did not consider transformational adaptations. Other issues not considered include the influence of climate change on weeds and the impacts on pasture production, and the effects of climate change on animal diseases, feed intake and heat stress, all of which could potentially impact farm performance.

Moore, J.R., & Watt, M.S. (2015). **Modelling the influence of predicted future climate change on the risk of wind damage within New Zealand's planted forests.** *Global Change Biology*, 21, 3021-3035. doi: 10.1111/gcb.12900

This study identifies wind as the major abiotic disturbance in NZ's planted forests. The researchers link a mechanistic wind damage model to an empirical growth model for radiata pine and a process-based growth model to predict the risk of wind damage under different future emissions scenarios and assumptions about the future wind climate. Results showed that increased tree growth rates under the

different emissions scenarios had the greatest impact on the risk of wind damage. The increase in risk was greatest for stands growing at high stand density under the A2 emissions scenario with increased CO₂ concentration. The increased productivity under this scenario resulted in increased tree height, without a corresponding increase in diameter, leading to more slender trees at greater risk from wind damage. This risk was further increased by increases in the extreme wind climate that are predicted to occur. The authors conclude that determining how climate change affects plantation productivity is complex as impacts are expressed both directly and through changes in abiotic and biotic factors. It is recommended that spatial models and decision support systems that integrate the complexities of future climate impacts be developed to provide a useful means of mitigating the detrimental influences of climate change.

Niles, M.T., Lubell, M., & Brown, M. (2015). **How limiting factors drive agricultural adaptation to climate change.** *Agriculture, Ecosystems and Environment*, 200, 178-185. <http://dx.doi.org/10.1016/j.agee.2014.11.010>

This paper develops a theoretical approach to connect agro-ecosystem diversity with farmer decision-making in the context of agricultural adaptation to climate change. The researchers argue that limiting factors within a farm system (future climate concerns) influence the adoption of adaptation practices differently across regions and farm systems, and that such factors vary based on historical climate changes, agro-ecological contexts, infrastructure and adaptive capacity. The study uses farmer survey data from Hawke's Bay and Marlborough to demonstrate how limiting factors mediate the effect of past climate experiences on the adoption of adaptation strategies differently in the two regions, with water acting as a limiting factor in Hawke's Bay and water and temperature in Marlborough. The authors conclude that limiting factors are likely the most immediate issue for a system and could result in short-term responses, which may ultimately hinder longer-term transformative adaptive strategies. Future work could more clearly distinguish climate change experiences by different temporal time frames to determine whether nearer term experiences have greater influences on behaviours than longer-term trends. It is recommended that researchers, regional planners, and policy makers can build on this work by utilising a more interdisciplinary approach for climate change adaptation decision-making and working with farmers and rural communities to assess the most limiting

factors and related adaptation practices for a given region and farm system.

Prokopy, L.S., Arbuckle, J.G., Barnes, A.P., Haden, V.R., Hogan, A., Niles, M.T., & Tyndall, J. (2015). **Farmers and Climate Change: A Cross-National Comparison of Beliefs and Risk Perceptions in High-Income Countries.** *Environmental Management*, 56, 492-504. doi: 10.1007/s00267-015-0504-2

Looking across six study sites- Scotland, Midwestern United States, California, Australia, and two NZ locations, Marlborough and Hawke's Bay- this paper examines farmers' beliefs and concerns about climate change. The study discovers a wide variety of beliefs regarding climate change and that only in Australia do a majority of farmers believe that climate change is anthropogenic. In all locations, a majority of farmers believe climate change is not a threat to local agriculture. NZ farmers' risk perceptions varied substantially between sites: 41% of Hawke's Bay respondents agreed that climate change poses more risks than benefits to agriculture compared to 32% of Marlborough farmers. Interestingly, however, Marlborough farmers were more likely to support adaptation measures with 49% indicating they would participate in a government incentive program, compared with only 42% in Hawke's Bay. The difference may be explained by the large number of Marlborough farmers working in the wine industry, which tends to have a higher rate of adoption of climate-related practices and participation in sustainability programs. The authors conclude that high-income country farmers may be under-prepared to mitigate risk and/or actual yield loss or be positioned to efficiently take advantage of any benefits associated with climate change. They recommend climate information be better disseminated to the agricultural community to induce and guide adaptive measures.

Rhodes, D., & Stephens, M. (2014). **Planted forest development in Australia and New Zealand: comparative trends and future opportunities.** *New Zealand Journal of Forestry Science*, 44(1): S10, 1-14.

This paper reviews the status of planted forests in Australia and New Zealand and discusses opportunities for further development taking into account factors such as emerging markets for ecosystem services, climate change impacts and social attitudes towards planted forests. A key consideration identified here is the impact of climate change on forest growth. Plantation growth may increase from rising atmospheric carbon dioxide

but may decrease from rising temperature and increased water loss. Increased temperature may increase productivity in some regions and for some species, such as an extended growing season in higher altitude regions and reduced frost. The other major consideration highlighted here is the impact of secondary effects of climate change. In NZ, these include stronger winds and more high intensity rainfall as well as less risk of fungal disease in drier areas but increased risk from fire and insect attack. Key adaptive management responses include spacing and thinning, watering and nutrient regimes, fire management, pest, disease and weed management, use of genotypes and site selection, climate monitoring and establishment practices. The authors suggest that close attention with need to be applied to managing future climate change risks and opportunities arising through predicted increases and decreases in forest growth across regions and other risks posed by drought, wind and fire.

Sturman, A., & Quenol, H. (2013). **Changes in atmospheric circulation and temperature trends in major vineyard regions of New Zealand.** *International Journal of Climatology*, 33, 2609-2621. doi: 10.1002/joc.3608

This paper uses major vineyard regions of NZ as a case study to illustrate regional disparities in climate change impacts resulting from downscale effects of larger scale atmospheric circulation. Trends in air temperature in Marlborough show an increase in temperature range. It is noted that more hot days and frosts are of concern to viticulturalists, and this trend not only differs from other major vineyard areas, but also occurs at other sites in eastern parts of the country. Changes in weather patterns are shown to be closely linked to larger scale changes in atmospheric circulation via the Southern Annular Mode and Southern Oscillation. The results show that significant regional variations in the impact of global warming can occur over areas of complex terrain such as NZ. Climate trends in NZ's most productive wine-growing area (Marlborough) and inconsistent with those observed in other vineyard regions such as central Otago, Nelson and Hawke's Bay. Given that possible impacts on wine production are likely to differ between regions, the authors recommend that development of adaptation strategies in response to predicted future climates needs to be based on detailed investigation of the thermal regime in each wine-producing area, rather than application of blanket predictions of temperature range over whole countries.

Grey literature

Infometrics. (2011). ***The Economic Implications of Climate-Induced Changes in Agricultural Production*** (Report prepared for NIWA). Wellington, NZ: Stroombergen, A.

This paper analyses the effects of climate-induced changes in agricultural production, including forestry. Two previous papers (Tait et al, 2005; Stroombergen, 2008) looked at the effects of climate on agricultural production by econometrically estimating the effect of climate variability (in particular, drought) on the production of milk solids and meat with a panel dataset, and then incorporating the production effects into a general equilibrium model in order to assess the economy-wide implications of changes in agriculture production. The results showed negative economic effects. This report uses a different methodology to estimate the effects of future climate change on agricultural and forestry output. Instead of looking at adverse climatic events, notably droughts, this study focuses on the longer-term impacts of projected climate change based on a number of models and scenarios. There is also explicit modelling of the relationship between temperature, water availability and plant growth. As before, the results are then fed into a general equilibrium model of the NZ economy. Under some scenarios, the wider economic effects are negative, but most results show a positive effect. The author comments that the differences between these and earlier results are largely because plants, animals and farm management are adversely affected by short-term departures from 'normal' climatic conditions, whereas progressive climate change over many decades allows more (albeit not unlimited) time for adaptation.

Manderson, A., & Dymond, J. (2015). ***Climate change impacts on water quality outcomes from the Sustainable Land Use Initiative*** (report prepared for Horizons Regional Council). Palmerston North, NZ: Landcare Research Manaaki Whenua.

Horizons Regional Council contracted Landcare Research to investigate climate change implications for future sediment yield as it related to the Sustainable Land Use Initiative (SLUI). The study estimated sediment yields for the Horizons region under four climate change scenarios drawn from the IPCC 4th Assessment. Downscaled IPCC 5th Assessment results were not available at the time of analysis. Impact on future sediment yields were modelled by relating regional temperature

change to storm magnitude, then storm magnitude to landslide density (landslides being the most significant source of sediment across the North Island). Under all scenarios, climate change was projected to increase sediment loading in the region's rivers. Recommendations include: prioritising water management zones that have the highest sediment yield rates and the highest rates of increase under climate change; consider increasing investment in strategies that promote long-term protection from erosion, such as land retirement and natural regeneration; and consider re-evaluating all SLUI management scenarios under the latest IPCC 5th Assessment scenarios as these differ considerably from the 4th Assessment scenarios used in this report in terms of design and quality of modelling data.

Renwick, J., Mullan, B., Wilcocks, L., Zammit, C., Sturman, J., Baisden, T., Keller, L., Kirschbaum, M., Meason, D., Harrison, D., Verkerk, G., Cooke, A., Marshall, P., & Clark, A. (2013). ***Four Degrees of Global Warming: Effects on the New Zealand Primary Sector*** (Ministry for Primary Industries Technical Information Paper No: 2013/49). Wellington, NZ: NIWA.

This report presents a 'what-if' scenario for aspects of the NZ primary sector should a global average temperature rise of 4 degrees Celsius eventuate. The results from two global climate models, the Canadian Climate Centre model and the German Planck Institute model, exhibiting four degrees of global mean surface warming (over approximately the coming century) were downscaled for NZ and applied to a range of models relevant to the primary sector. The main findings include: large increases in growing degree days and frost-free periods; significant changes in seasonality of pasture growth, with irrigation demand projected to increase in spring and summer; significant increases in forestry productivity (*Pinus radiata* and *Eucalyptus fastigata*) mainly driven by reduced frost frequency and higher temperatures; significant increases in animal heat stress in many dairying areas of NZ with the potential for associated detrimental impacts on production, reproduction and welfare. Suggested adaptive measures include introduction of more heat-tolerant breeds, milking only during the cooler months and providing more shade and cooling.

Weaver, S. (2008) ***Climate change and food security*** (Institute of Policy Studies Working Paper 08/12). Wellington, NZ: School of Government, Victoria University of Wellington.

This paper explores global trends associated with food

security and climate change and the linkages between them. The paper suggests the most significant direct impacts of climate change on food security in NZ are likely to be associated with losses in crop productivity in eastern regions that become warmer and dryer, regions that are likely to suffer from increased incidence of flood damage, and coastal regions that are vulnerable to sea level rise combined with storm surges during cyclone events. The author notes that adaptive capacity for agricultural productivity is considerably greater in NZ than in many other parts of the world including Australia. Regarding fisheries, the paper suggests one potentially significant impact stems from ocean acidification and the subsequent threat to the marine food chain. NZ's economic and political connectivity to the rest of the world is cited as significant in terms of the likelihood of experiencing flow-on effects of climate change and its impacts on food security in other nations. An example given is grain prices rising as a result of drought in Australia, which then increase the price of staple foods in grain-importing nations like NZ. The paper outlines implications of the global situation for NZ, including the potential gains to be made from rising food commodity prices as an exporter, but that this may be coupled with rising production costs resulting in insignificant net benefits to NZ, particularly as NZ is also a food importer. The author suggests efforts to increase domestic food self-sufficiency, thereby lowering food import costs, could be explored. Diversifying the economy to lower risks associated with a high primary production export base is presented as another option, as well as exporting agricultural production innovations to developing nations to increase their food security.

Tools and frameworks to support adaptive management

Academic literature

Ausseil, A.G.E., Bodmin, K., Daigneault, A., Teixeira, E., Keller, E.D., Kirschbaum, M.U.F., Timar, L., Dunningham, A., Zammit, C., Stephens, S., Cameron, M., Blackett, P., Harmsworth, G., Frame, B., Reisinger, A., Tait, A., & Rutledge, D. [2016]. ***Climate change impacts and implications: an integrated assessment in a lowland environment of New Zealand***. Paper presented at the 8th International Congress on Environmental Modelling and Software, Toulouse, France. Retrieved from <http://scholarsarchive.byu.edu/cgi/viewcontent.cgi?article=1416&context=iemssconference>

This paper presents a framework to evaluate socio-

economic and environmental impacts of future climate and land-use change, and gives results for one scenario in a typical lowland environment in NZ. The future scenario was designed as a combination of global climate and socio-economic assumptions, along with NZ-specific policy assumptions. The authors evaluated the impacts and implications of this scenario through an integrated assessment using both a quantitative and narrative approach. The quantitative results were obtained using biophysical models operating at a sector (primary production) and landscape level (e.g. water supply, pest risk, wetland vulnerability). The selected scenario contained almost no attempt to curtail climate change on a global scale and only very limited, reactive local efforts. In this scenario, costs of production would generally increase due to a need for increased environmental management for pest control and water shortages, with a higher risk for a decline in commodity prices due to increased global competition. The goal of this framework is not to describe every possible policy landscape but to select a finite number of representative policy assumptions to produce a set of plausible climate policy scenarios. The authors suggest this would provide key messages to decision makers, giving trade-offs and synergies between positive and negative outcomes from climate and socio-economic pathways.

Fowler, A.M., Aiken, S., & Maree, K. [2013].

Vulnerability of pastoral farming in Hawke's Bay to future climate change: Development of a pre-screening (bottom-up) methodology. *New Zealand Geographer*, 69, 120-135. doi: 10.1111/nzg.12015

This article presents a pre-screening methodology and associated tools for testing the climate-sensitivity of non-irrigated pasture in Hawke's Bay. This is done by using a simple daily water balance model to simulate near-surface hydrological processes and empirical relationships between transpiration and pasture dry matter production. Core to the methodology is the idea that sensitivity to future climate change is best assessed within the context of natural climate variability. Key results can be summarised as: Best guess is for minor impacts; direction of change is uncertain; plausible impacts are significant (plausible climate futures indicate that mean pasture production may be impacted by up to about + or - 10%). The authors suggest the methodology presented here could be used immediately to undertake a pre-screening assessment similar to the Hawke's Bay example described, provided that expertise and

resources were at hand to meaningfully interpret the results and deal with any data and software issues that may arise. They caution, however, that a pre-screening assessment, designed to be easily and cheaply applied, required significant science compromises and the methodology presented here cannot take the place of a full impact assessment that accounts for local specifics, such as soil characteristics and seasonal differences in projected precipitation changes.

Ivkovic, M., Hamann, A., Gapare, W.J., Jovanovic, T., & Yanchuk, A. (2015). **A framework for testing radiata pine under projected climate change in Australia and New Zealand**. *New Forests*, 47, 209-222. doi: 10.1007/s11056-015-9510-8

This study investigates how genetic field tests could be utilised under anticipated climate change to address the threat climate change poses to genetic improvement in plantations due to suboptimal matching of improved planting stock to new climate conditions. The researchers use principal component analysis and Mahalanobis distance measures to find the closest match between climate of plantation regions in the future and current climate of field test sites. For NZ, the most notable climate shifts are those of the Nelson/Marlborough plantation region becoming equivalent to the climate space currently occupied by the Southern North Island and East Coast plantations. The analysis reveals that making appropriate genetic selections under future climates will be less problematic in some regions than in others. For example, climate shifts towards non-analogue conditions are most likely for the Northland region. The authors suggest there are limited options to address this issue. One option would be to include in the analysis other *Pinus radiata* growing regions of the world such as Chile. This paper does not address the role of other factors influencing growth and survival such as soil type, or silvicultural treatments and their interaction with climate. The authors recommend that a comprehensive climate change adaptation strategy for radiata pine plantations could pursue additional management interventions such as planting on more mesic sites where summer dry periods become problematic.

Grey literature

Boyd, P.W., & Law, C.S. (2011). **An ocean climate change atlas for New Zealand waters** (report 79 prepared as part of the NIWA information series). Wellington, NZ: NIWA.

In a world-first, NIWA designed a regional climate

change ocean 'atlas' for NZ's Exclusive Economic Zone (EEZ). This short publication provides underpinning information on the principles on which the climate change atlas for New Zealand waters is based. It is intended that the information will transition to a web-based atlas, which will be a living archive supplemented with additional information, for example on the distribution of species that have not previously been surveyed or mapped, or new experimental findings. It is envisioned that such a web-based atlas can be used to explore the many perturbations possible for a wide range of marine life across the EEZ, and that it will also reveal critical knowledge gaps that will require research efforts in coming years. It is thought that the existence of such a resource will also minimise overlap in research being carried out across the EEZ. Given the close ties between climate and biodiversity/ecology, NIWA also plans to make explicit links to national and international web-based repositories of such information, which NIWA currently manages or contributes to, such as the Global Biodiversity Information Facility, and NZ Freshwater Information System.

Enhancing adaptive capacity

Academic literature

Nettle, R., Ayre, M., Beilin, R., Waller, S., Turner, L., Hall, A., Irvine, L., & Taylor, G. (2015). **Empowering farmers for increased resilience in uncertain times**. *Animal Production Science*, 55, 843-855. <http://dx.doi.org/10.1071/AN14882>

This article poses the question: Do current ways of doing and organising research, development and extension (RD&E) in the dairy sector in NZ and Australia contribute to supporting farm adaptability? The paper reports on results from an examination of case studies of challenges to resilience in the dairy sector in Australia and NZ (i.e. dairy farm conversion, climate change adaptation, consent to farm) and the contribution of dairy RD&E in enhancing resilience of farmers, their farms and the broader industry. Focusing on the concepts of adaptive capacity and resilience, the analysis of these case studies indicates that RD&E supports adaptability in general, but varies in the strength of its presence and level of activity in the areas known to enhance adaptability. This analysis is used to generate principles for dairy scientists and others in the RD&E system to consider in research designs, engaging different farmers in research, and presenting research results differently. Through using an empowerment framework, 5 strategies for

enhancing adaptive capacity were identified across the case studies: Foster social networks; acknowledge diverse roles and knowledge integration mechanisms; represent and value farmer knowledge in the formation of adaptation strategies; support collective learning to address resilience challenges; and practice a degree of flexibility in governance arrangements. The authors conclude that one area of emerging importance is the need for more emphasis on impacts, opportunities and/or vulnerabilities from cross-scale interactions (farms, regions, the environment, society), without which, adaptability will be constrained and resilience threatened.

Niles, M.T., Brown, M., & Dynes, R. (2015). ***Farmer's intended and actual adoption of climate change mitigation and adaptation strategies***. *Climatic Change*, 135, 277-295. doi: 10.1007/s10584-015-1558-0

In this research collaboration between US and NZ researchers, the authors apply the Theory of Planned Behaviour with the aim of assessing whether different factors affect intended versus actual adoption of climate behaviours among farmers in NZ. Data was collected through a mix of interviews and a telephone survey of around 500 farmers in Hawke's Bay and Marlborough in 2010-2012. Through multiple regression models the study tested hypotheses related to the Theory of Planned Behaviour around the role of attitudes, subjective norms, and perceived capacity in affecting intended and actual adoption. Results suggest there are different drivers of intended and actual adoption of climate change practices. The study found no evidence that climate change policy support significantly influences either intention or actual adoption. Only perceived capacity and self-efficacy were important predictors of both intended and actual adoption. The results suggest a disconnect between intended and actual behaviour change and that using data about intention as a guiding factor for programme and policy design may not be wise. The authors conclude that fostering perceived capacity and self-efficacy for individuals may be crucial for encouraging actual adoption of climate change adaptation measures.

TOURISM

Despite tourism's significant direct and indirect contributions to the NZ economy, and the exposure of the industry to climate change impacts, the literature on climate change implications for the tourism sector is relatively modest, at least in comparison

to the more voluminous literature concerning NZ's other key export industry, agriculture. A cluster of ski industry-specific studies, examine the industry's vulnerabilities and ability to adapt, with a general underestimation of climate risks and a propensity for 'optimistic bias' reported. Similar findings are reported in the several recent papers included here on glacier tourism. Key points of commonality in the conclusions and recommendations across studies include: diversification of activities as an adaptation measure; inclusion of non-quantifiable and non-climatic risks when considering the impact of climate change on a local or regional scale (e.g. differing risk perceptions among stakeholders); documenting case-specific adaptive strategies, so knowledge and experience can be shared by those responsible for managing climate-vulnerable tourism assets; location-specific strategies that identify short term adjustments, medium term adaptations and potentially longer term alternatives; and more proactive interactions between private tourism operators and public spheres of governance to overcome barriers to adaptation (e.g. planning laws inhibiting adaptation efforts).

Climate change pressure points and implications for policy and management

Academic literature

Hendrikx, J., Zammit, C., Hreinsson, E.O., & Becken, S. (2013). A ***comparative assessment of the potential impact of climate change on the ski industry in New Zealand and Australia***. *Climatic Change* 119, 965-978. doi: 10.1007/s10584-013-0741-4

This paper is the second recent study to examine the impacts of climate change on the Australasian ski industry. While the previous paper (Hopkins et al, 2012) engaged Australian tourists and NZ ski industry representatives to assess perceived relative vulnerability to climate change of the neighbouring countries' ski industries, this paper, for the first time, makes a direct comparison between the two countries, providing both an estimate of absolute impacts at a given site, as well as the relative impacts between the countries. The direct comparison was enabled through using the same snow model, same 3 global climate models and same techniques to calibrate the model for all locations. Based on the hypothesis that the relative change in maximum Snow Water Equivalent and reduction in snow-days will be a key driver in the Australia-NZ tourism industry, results show that the NZ snow industry is likely to see a positive response to the impacts of climate change, at least initially. This

may be an oversimplification however, as the domestic NZ market may reduce with decreased snow, and the relative snow differences alone may not be the most important variable for driving Australia-NZ tourism flows. Snowmaking and economic components of ski industry vulnerability were not considered; only the modelled changes in the natural snow component. Diversification of both snow-based and non-snow-based activities is recommended as a key adaptation measure for winter sports destinations.

Hopkins, D. (2013a). ***The perceived risks of local climate change in Queenstown, New Zealand***. *Current Issues in Tourism*, 1-19. doi: 10.1080/13683500.2013.776022

This article is one of several published papers by the author exploring perceptions of climate change and associated information needs within the Australasian ski industry (e.g. Hopkins et al, 2012; Hopkins, 2013b, Hopkins, 2014). This study used qualitative, semi-structured interviews with four stakeholder groups connected to the ski industry in Queenstown. The research aimed to identify current scientific knowledge on climate change risks to Queenstown's ski industry and to critically address how the risk of climate change is perceived. The paper reports three main findings: Scientific reporting and expert interviews expect climate change to manifest inter-annual variability up to the 2050s; current climatic variability is perceived to be the greatest risk to the ski industry at present; and climate change is perceived to be distant and a greater threat to other people and other places giving rise to 'optimistic bias'. The author suggests these findings identify the importance of including non-quantifiable as well as non-climatic risks when considering the impact of climate change on a local or regional scale. She concludes that risk perceptions can be broad-ranging and diverse and, given these perceptions will determine adaptive responses and mitigative behaviours, they are critically important to maintaining rural communities and regional economies that are reliant on weather.

Hopkins, D. (2014). ***The sustainability of climate change adaptation strategies in New Zealand's ski industry: a range of stakeholder perceptions***. *Journal of Sustainable Tourism*, 22(1), 107-126. doi: 10.1080/09669582.2013.804830

This paper provides a qualitative, perceptual study of ski industry stakeholder in Queenstown, addressing the perceptions of climate change adaptation by the core industry, wider industry actors, local community and tourists. It answers two research questions: What are perceived as the main climate change adaptation

strategies for Queenstown's ski industry? How do ski industry stakeholders perceive current adaptation strategies in terms of sustainability? The study identifies two main approaches to addressing climate change in Queenstown's ski industry: exploiting the increased vulnerability of Australia's ski industry; and snowmaking technology. It finds snowmaking central to addressing both current weather variability and medium/long-term future climate change. Ski-field operators use snow-making to ensure the industry's economic sustainability, but with little consideration for environmental or social sustainability, and some local people questioning snowmaking on ethical and environmental grounds. The study found perceptions of negative externalities around snow-making, including maladaptation in the longer term due to developing an unsustainable business model which is more vulnerable to increasing temperatures and extreme events. The paper calls for closer attention to the long-term sustainability of climate change adaptation in the wider tourism industry and, like the previous paper outlined above, emphasises the importance of stakeholder social perceptions in the context of climate change impacts, and their criticality for affecting adaptation responses.

Stewart, E.J., Wilson, J., Espiner, S., Purdie, H., Lemieux, C., & Dawson, J. (2016). ***Implications of climate change for glacier tourism***. *Tourism Geographies*, 18, (4), 377-398. doi: 10.1080/14616688.2016.1198416

This study employs a mixed-methods approach to investigate visitor experiences and stakeholder perspectives through an assessment of climate-related changes and impacts on tourism at the glaciers in Westland Tai Poutini National Park. Bio-physical conditions at Franz Josef and Fox Glaciers were reviewed in order to assess the magnitude and rate of retreat. Perceptions of climate change risk and awareness of impacts in the National park were assessed through stakeholder interviews, and a visitor survey was used to better understand how impacts at these sites have affected and may continue to affect visitor experience. Results revealed the importance of viewing the glaciers as a significant travel motive of visitors, suggesting a 'last chance' dimension to their experience. The results also demonstrate a high adaptive capacity of local tourism operators under rapidly changing conditions, evidenced by the ability to understand the bio-physical trends and react quickly to future glacier change. This is contrary to work elsewhere that suggests operators (and destinations

in general) have a relatively low adaptive capacity given their dependence on the resource. The authors recommend that, given the magnitude and rate of change, it is critical to document case-specific adaptive strategies, so knowledge and experience can be shared by those responsible for managing climate-vulnerable natural assets in protected areas. They conclude that diversification and potential feature/location substitution will require careful deliberation to ensure that adaptations balance visitor expectations/experiences and the maintenance of ecological integrity.

Grey literature

Becken, S., Wilson, J., & Reisinger, A. (2010). Weather, Climate and Tourism. ***A New Zealand Perspective (Land Environment and People Research Report No. 20)*** prepared as part of the Foundation of Research, Science & Technology funded project "Preparing the Tourism Sector for Climate Change". Christchurch, NZ: Lincoln University, Canterbury.

This report is part of a larger project "Preparing the tourism sector for climate change", which sought to identify which parts of the tourism sector are most vulnerable to climate variability and change, and what adaptation measures could be put in place to reduce vulnerability. The focus of this report is the impact of weather on tourists, and to a lesser extent tourism businesses, in NZ. Three individual research projects are described, from which an integrated discussion and key themes are presented, and conclusions drawn. The following implications for the tourism sector are discussed: Although weather is not a key driver for tourism in NZ, it is an important facilitator. Future changes of climate towards more erratic and disruptive conditions may constrain tourism activities and impact on businesses' bottom line; tourists are willing users of weather information and successful adaptation to adverse conditions could benefit from tailored information provided to tourists before and during their travels. There is an opportunity to address current gaps and improve the flow of information between providers and tourism end-users; Tourism operators could consider the extent to which they depend on weather and the risks associated with adverse weather conditions. A vulnerability assessment could explore projected changes in climate and assess how they might affect business impacts, as well as considering the different degrees of adaptability of different types of tourists. The report recommends the NZ government could

build on communication efforts on climate change in other sectors (e.g. agriculture) to address potential knowledge gaps within the tourism sector, with key vulnerabilities and adaptive responses communicated to increase tourism sector resilience.

Tools and frameworks to support adaptive management

Academic literature

Becken, S., Zammit, C., & Hendriks, J. (2015). ***Developing Climate Change Maps for Tourism: Essential Information or Awareness Raising?*** *Journal of Travel Research*, 54 (4), 430-441. doi: 10.1177/0047287514528286

This paper uses a case study from NZ's Southern Lakes region to link tourism operators' information requirements with climate change projections. Interviews with 42 stakeholders were conducted to gain insight into the climate parameters that would be useful for their planning (mean precipitation, extreme wind conditions, mean temperature, and frost days). These findings were then used to generate sector-relevant maps. Climate change maps were produced based on global and regional models to generate detailed climate projection information for the A2 emission scenario in the form of regional scale, colour-coded maps. A final stakeholder workshop was held to determine the usefulness of the maps. Feedback from stakeholders indicated that the maps highlighted interesting seasonal and spatial patterns of change that could be useful for tourism planning and investment. A perceived limitation was that, while the maps were intended to "simplify" climate impacts through visualisation, the actual parameters might still be too complex and difficult to understand for lay people. At the same time, however, they may not be complex enough to capture the reality of what impacts matter to users. The combination of different climate parameters may be of relevance e.g. for aviation the combination of wind and visibility might be important, while for ski fields the combined effect of precipitation and temperature may be paramount. The identification of thresholds could be another aspect to incorporate. Also, the presentation of means rather than extreme values is insufficient to inform specific planning such as for flood risk management.

Hopkins, D. (2014). ***Applying a Comprehensive Contextual Climate Change Vulnerability Framework to New Zealand's Tourism Industry.*** *AMBIO A Journal of the Human Environment*, May 2014. doi: 10.1007/s13280-014-0525-8

This paper introduces a comprehensive contextual vulnerability framework and applies it to NZ's tourism industry to explore its value in interpreting a complex, human-natural environmental system with multiple competing vulnerabilities. The framework is designed to inform government policy and industry decision-making, integrating understandings of climate change within the broader context of internal and external social, physical, economic, and institutional stressors. The author suggests that dominant frames of climate change vulnerability focus on vulnerability as the outcome of impacts after enacting adaptive capacity, and that a tendency to focus on technical adaptation strategies to reduce associated risks can further perpetuate inequalities due to a reliance on economic capacity. The paper suggests there are many knowledge gaps in understanding the vulnerability of NZ's tourism industry to climate change and that, to better inform policy, greater focus is required on the range of possible vulnerabilities (climatic and non-climatic) and their interplay. Another key recommendation is that research should explore the direct impacts on local-scale tourism operations stemming from national and international responses to climate change, in order to better prepare NZ for changes ahead.

Hughey, K., & Becken, S. (2014). ***Understanding climate coping as a basis for strategic climate change adaptation- The case of Queenstown-Lake Wanaka, New Zealand***. *Global Environmental Change*, 27, 168-179. [http:// dx.doi.org/10.1016/j.gloenvcha.2014.03.004](http://dx.doi.org/10.1016/j.gloenvcha.2014.03.004)

Like the two studies by Hopkins discussed above this paper focuses on climate change impacts and the implications for tourism in the Queenstown area. This paper proposes and tests a decision support tool, the coping framework, to be used by businesses to think about climate change implications and adaptation strategies. The paper described how 'coping', which can be observed outside the 'ideal' range of a particular environmental gradient, requires business adjustments so as to cope with increasingly marginal conditions up to a Critical Stop Point. It is recommended that to ensure on-going viability, tourist destinations need to be proactive and develop a strategic approach to adaptation, which should include: clarity around the destination's longer term tourism vision; identification of keystone attractions and businesses at risk of climate change; and a strategy that identifies further short term adjustments, medium term adaptations and potentially longer term alternatives. The study observed little positive/

proactive interaction between private providers of adaptations and the public sphere of governance, for example one sky diving operator's adaptation was constrained by planning law. Study participants called for closer relationships between regional tourism organisations and local businesses over climate change matters to start bridging institutional divides. The authors pose two concluding questions: Who will take a lead in regional level strategic adaptation considerations? Will the sum of individual responses be sufficient in the face of a lack of central government adaptation leadership?

Enhancing adaptive capacity

Academic literature

Espinero, S., & 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. doi: 10.1080/09669582.2013.855222

This study evaluates the susceptibility of Franz Josef and Fox Glaciers to change at multiple scales, including threats of flooding, rising fuel prices and climate change scenarios (which imply serious glacier melting). Using 24 stakeholder interviews, the study looks at concepts of vulnerability and resilience to examine dimensions of change and response that have shaped the community, conservation and tourism in the geographically-isolated region. The study finds high levels of vulnerability do not necessarily determine low levels of resilience and vice versa. Risk of natural disasters featured most prominently among interviewees' concerns, more so than energy and climate risks, possibly because of the perennial exposure of the region to floods, rock fall, slips and road washouts. There is evidence in the data presented here that high levels of historical resilience might contribute to a false sense of security among some sectors of the tourism industry, and encourage mal-adaptive strategies inconsistent with the magnitude of macro-level risk factors.

The authors conclude that flexible, inclusive and accountable governance structures are likely to be essential in responding to the vulnerability and resilience issues raised here.

CONCLUSIONS: KEY RESEARCH GAPS

Climate change pressure points and implications for policy and management

Key knowledge gaps and areas that merit further investigation include the following:

- Potential climate change impacts and implications for NZ infrastructure assets including utilities;
- Potential climate change impacts and implications for the NZ finance sector, including banking and insurance;
- Possible impacts and implications for urban systems - 'urban issues' was not explored as a theme in its own right in this review but it is clear that a number of aspects relating to urban systems could warrant further research, due to the added pressures stemming from the concentration of populations, economic activities, and fixed assets in urban areas, and the density of the built environment;
- The potential for cascading impacts affecting biodiversity management, pest management and the conservation sector such as interactions between pests and diseases, and possible whole-of-ecosystem responses to multiple stressors (e.g. ocean acidification, nutrient supply, and temperature);
- Indirect effects of climate change on human health resulting from, for example, forced migration and economic and political uncertainty. These could potentially have a greater impact on health over time than direct impacts (e.g. from extreme weather events) by acting on the broader determinants of health.
- The vulnerability of NZ's tourism industry to climate change and its interaction with infrastructure. This links in with the issue of cascading impacts noted above, and also with knowledge gaps highlighted in the 1st and 3rd bullet points above concerning implications for infrastructure and urban systems (e.g. water supply and quality). The literature suggests that to better inform policy, greater focus is required on the range of possible vulnerabilities (climatic and non-climatic) and their interplay, as well as national responses to climate change and the impacts these will have on local-scale tourism operations;

- Flow-on effects from climate change impacts and responses outside NZ could be significant for trade-intensive sectors like agriculture and tourism, but little work has been done to fully understand these implications.

Tools and frameworks to support adaptive management of climate change impacts

While specific information needs vary across sectors, the literature reviewed here suggests there are a number of resources and tools that could be developed and usefully applied to support adaptive management of climate change risks across different decision-making contexts. These include:

- Frameworks that incorporate changing risk as an element of institutional design;
- Improved probabilistic methods of estimating joint hazard risks (for example, storm surge and sea level rise, or combined fluvial and coastal flooding);
- Tools to help promote better understanding of how to address uncertainty when translating risk assessments into planning and policy measures, and ways to enable decisions to be made under uncertain and changing conditions (e.g. where there are no definitive numbers or timeframes);
- Tools to help prevent ad hoc and unconnected responses from working against each other, and leading to maladaptation; and
- Greater use of and access to LiDAR surveying.

Sector and location-specific tools and information resources that are required include:

- Improved integration of information from scientists, policy analysts, and decision-makers on assessing, planning and responding to sea level rise issues;
- Improved elevation information about river beds, floodplains and urban areas to inform flood inundation modelling, and improved operational flood forecasting to help manage flood events;
- Integrated understanding for the agriculture sector of interactions between climate and water availability, and integrated land use models to assist climate-sensitive landscape planning, and inform choices between different agricultural production systems, forestry, horticulture, and other forms of land use; and

- Visualisation tools that combine different climate parameters of relevance to different sectors or industries (e.g. the combination of wind and visibility for aviation, or the combined effect of precipitation and temperature for ski fields) plus identification of thresholds and extreme values (not just means) to inform specific planning such as flood protection.

Enhancing adaptive capacity so that climate change implications are incorporated into decision-making

A range of general and sector/industry-specific recommendations are made in the literature reviewed here on ways to enhance adaptive capacity in NZ to help ensure climate change implications are incorporated into decision-making. These are discussed in the introductory commentary at the start of each of the sections above. Research gaps that merit further attention include:

Analysis of design features of institutions that are able to respond to changing climate risk profiles, and governance and management arrangements that are conducive to long term adaptive planning and enable deliberative and anticipatory approaches;

Methods to overcome the mismatch between the time horizons for adaptation decisions and political and commercial systems and processes;

Efforts to deepen understanding of how Mātauranga Māori informs different aspects of climate change adaptation planning such as flood management, coastal planning, and assessments of the changing state of freshwater environments;

Examples of ways to engage with NZ's most vulnerable populations (e.g. within small or remote coastal communities) and ways to build capacity to use scientific knowledge for adaptation; and

Development of sustainable approaches to adaptation of the built environment to avoid maladaptation and negative side effects on social and biophysical systems.

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IPCC AR5 Chapter 25 Australasia, with the exceptions noted in the Methods section of the review. Peer review was undertaken by Judy Lawrence CCRI at Victoria University of Wellington.

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