Building natural hazard resilience; what knowledge “push” do we need?

Professor Shane J. Cronin
Director of the Resilience Challenge
National Science Challenges
University of Auckland and GNS Science, New Zealand
What do I mean by Resilience?

The features of a system to:
- anticipate threats,
- accept there will be impacts,
- quickly pick up the pieces,
- learn and adapt from the experience
to better absorb and rebound from future shocks.
Resilience Challenge Mission

Bring about a “step-change” in New Zealand’s resilience to natural hazard by transforming our governance, business, public and science knowledge and responsibilities

Image: stuff.co.nz
Our Partners

- Other programme leaders from: ResOrgs and Market Economics
- Key researchers also from: Landcare, U Waikato, Auckland Council, Awanuiārangi
- Partnerships with lifelines/utility organisations and unitary authorities in districts and regions throughout New Zealand
Resilience Value Proposition

- New Zealand is the third most vulnerable economy in the world to the impact of natural disasters as a percentage of GDP (Centre for Economics and Business Research, 2012, Lloyds Global Underinsurance Report 2012).

- Since 1900, natural disasters cost this country an average 1% of its GDP in any year (Insurance Council for New Zealand: 2014 Protecting New Zealand from Natural Hazards).

- If the Resilience Challenge succeeds in reducing the severity of impacts by just 5%, this would have a total net present value of $9.7 billion.
Resilience Challenge in the NZ Hazards Landscape

Underpinning Hazard Research
Case studies

NATIONAL
Governance
Hazard
Economics
Matauranga
Rural
Trajectories

AUCKLAND
Urban (Lead)
Economics
Culture
Infrastructure
Trajectories

TARANAKI
Matauranga
Economics

CANTERBURY
Rural (Lead)
Infrastructure
Hazard, Governance
Economics, Culture

WELLINGTON
Culture
Urban
Matauranga

CHRISTCHURCH
Infrastructure
Urban

HAWKES BAY
Edge (Lead)
Governance
Economics
Hazard
Culture
Matauranga
“Laboratories”

**Rural** – *Tom Wilson* – Rural resilience support, supply-chain resilience, community resilience to wildfire

**Urban** – *Suzanne Wilkinson* – Urban resilience network, Resilient Auckland communities, planning, infrastructure and businesses

**Edge** – *Paul Kench* – Shared answers for coastal futures.

**Matauranga Māori** – *Jon Procter* - Wāhanga Tuatahi (Tikanga Māori), Wāhanga Tuarua (Māori Assets), Wāhanga Tuatoru (cultural landscapes and kaitiakitanga)
Science/policy tensions

Policy Domain
Requires RELEVANCE

Hybrid boundary zone
Requires LEGITIMACY

Science Domain
Requires CREDIBILITY

DEMANDS
- Simple information
- Applied science
- Demand-driven (consultancy)
- Inter-disciplinarity
- Real time
- Timely process

DEMANDS
Balance
Compromise
Inclusion
Transparency

DEMANDS
- Uncertain, complex information
- Basic science
- Supply-driven (autonomy)
- Disciplinarity
- Long term
- Quality assessment

Resilient Cities Network Development Project: Resilience of New Zealand Cities – An Expert Overview
FOR EACH CITY:

- Resilience Strategy
- Resilience Measurement
- Shocks, Stresses and Strains
- Hazards Knowledge and Awareness
- Community Resilience
- Infrastructure Resilience
- Governance for Resilience
- Economics of Resilience
- Future

National Resilience Framework (Horrocks, 2014)
FINDINGS

Resilience Strategies on Rockefeller 100 Res Cities framework, Wellington and Christchurch

Auckland is doing its own thing

Smaller cities are generally under-resourced, follow Civil Defence – Emergency Management guides.
Rural Laboratory – Kaikoura Case Study

Destination tourism and agriculture
Agribusiness
Climate change impacts
Wildfire as a community hazard
• Agribusiness + Tourism

• Socially important for regional economies and identities.

• Rural regions are experiencing:
  • Structural change
  • Social change
  • Globalisation and teleconnections

• Integrated Hazard with water management and climate change adaptation
Programme Overview

1. Resilience Solutions for Rural New Zealand co-produce and broker innovative solutions for enhancing the resilience of rural New Zealand

2. Multi-level Resilience develop and apply an integrated, analytical framework for promoting resilience at multiple scales across rural value chains

3. Resilience to Wildfire Challenges will co-develop resilience initiatives for wildfire with communities and integrate resilience initiatives within a multi-hazard environment
Resilience to Wildfire Challenges:
Improving community resilience

• Hazard modelling –
  - Prometheus models for likelihood and consequence
  - Interface with infrastructure and other hazard

• Community resilience and community-based planning
  – Kaikōura district case study: stakeholder and community engagement with focus on iwi

• Māori engagement for wildfire resilience
  – Karikari Peninsula research
  – Hokianga case study

• Volunteering: formal & informal
  – International literature review and learnings for New Zealand
Rural focus project AF8: planning for a future Alpine Fault earthquake

- **GOAL:** to build a collective South Island earthquake response plan for a future Alpine Fault earthquake
  - South Island Alpine Fault Earthquake Response (SAFER) Plan
- Involves all 6 South Island CDEM Groups
- Joint practitioner and research funding

### Risk team
- 30+ researchers
- 6 Universities
- 2 CRIs
- 2 Consulting firms

### Response team
- 6 CDEM groups
- Project AF8 Programme Manager
- MCDEM
Project AF8 – collaboration dynamic

INFORMS
POLICY/PRACTICE

Rural

DEFENCE FORCE
WELFARE
EMERGENCY SERVICES
CDEM
HEALTH
LOCAL COUNCILS
REGIONAL COUNCILS

INFORMS
RESEARCH

EQC
RNC
QuakeCoRE
NIWA
UNIVERSITIES
GNS SCIENCE
DI, HAZARDS TOOLBOXES

INDUSTRY GROUPS
COMMUNITY GROUPS
IWI/RUNANGA
RURAL SECTOR
LIFELINES INFRASTRUCTURE
NGOs
INFORMS PRACTICE

Resilience to Nature’s Challenges
Kia manawaroa – Ngā Ākina o Te Ao Tūroa

National Science Challenges

Ministry of Civil Defence & Emergency Management
Te Rākau Whālamarumaru
Exposure maps show the likelihood of a section of road being affected by a landslide

1 = almost certainly
0 = almost impossible

5 sections are particularly exposed:

1. Arthur’s Pass
2. Lewis Pass
3. Fox Hills (Franz-Fox)
4. Haast Pass
5. Milford Road (Homer Tunnel)
What is the End-User Experience?

Loss of Service (electricity distribution)  
Restoration Priorities

- Scale of outage...
- Duration of outage...
  - Time slices through the scenario

Collaboration with CDEM (including lifeline) agencies to establish level of service estimates, restoration priorities.
  - Aftershocks
  - Accessibility
  - Available resources
  - Interdependencies

Build a picture of recovery through time
Lessons...

• Impact is most useful information (not hazard)
  – Casulties, damage, disruption of infrastructure
  – Economic and social impact information

• Communication is essential and has been a challenge
  – Visualizations work well
  – Scenarios highly effective…but need to show range of possibilities (uncertainties)

• Gaps
  – Habitability post-earthquake
  – Economic and social information....pre-event recovery planning
  – Benefits of risk reduction strategies/Costs of increasing risk
  – *Aftershock sequence*

• End-users don’t always know what they want...has to be a collaboration
LIVING AT THE EDGE - Lab

To develop tangible, viable and acceptable resilient solutions to support communities living in vulnerable coastal settings

- **Team:** 11 researchers from 6 science agencies in NZ
- **Approach:** Active consultation with stakeholder groups in Hawke’s Bay in April-June 2016, focal site initially coastal communities between Clifton and Tangoio (including Haumoana, Te Awanaga & Clifton)
- **End-users:** HBRC, NDC, HDC and other stakeholders. NB: HBRC are a viable co-funder of the work
The Science Problem

- Accelerate coastal erosion
- Increased frequency & extent of coastal flooding
- Elevate groundwater & salinization
- Impacts on coastal communities

How do we improve the resilience of coastal communities to the impending coastal crisis?

How can we improve science, and the delivery of science, to underpin decision-making in an environment of deep uncertainty?
Aims of the Edge

To develop **pathways that enable communities** to meaningfully engage, understand and contribute to the **resolution of intense conflicts in high-risk locations**, especially those exacerbated by changing climate, environment, socio-economic and land development scenarios.

...will co-produce understanding of **local-scale experience of hazards** and **support the implementation of shared adaptation pathways**, to be integrated with enabling planning and governance processes.
The EDGE is both:

• Implementing research activity within the process, and....... 

• Researching entire process...and evaluating lessons on collaborative decision-making
Physical Science

Science questions identified

- Post earthquake coastal response near Haumoana (XBeach-G)

MSc project: Sophia Brown, UoA
Climate change impacts on weather-related hazards
Community Understanding of Coastal Hazards

- Evaluated community values
- Knowledge of different hazards
- Attitudes to different management strategies
- Willingness to pay
Supporting change in adaptation planning

First robust trial of *Dynamic Adaptive Pathways Planning (DAPP)* in a Coastal Context in NZ

A clear decision support process
First robust trial of *Dynamic Adaptive Pathways Planning (DAPP)* in a Coastal Context in NZ

**Outcomes**

Short-term investment decisions can be made that don’t close off future options

Explores different pathways and identifies robust and flexible ones

Defines use-by date of options when objectives are no-longer met when the path can be changed

Monitors signals and triggers to identify risks and opportunities for timely actions
“the idea of being **forced to shift home** and relocate to some as yet undefined location so the ocean can move further inland, **seems ludicrous to most Cape Coast residents**” and “to make kneejerk reactions that impact coastal villages such as Haumoana, based on 105-year climate change and sea rise projections seems incomprehensible”.

“**Managed retreat is not a solution, it is merely the consequence of doing nothing**...”

*Community member – Haumoana,*
Changing Attitudes
Managed Retreat

“…we will need to look at managed retreat within 30 years….”

Same community member – Haumoana, May 2017

**NORTHERN CELL**

<table>
<thead>
<tr>
<th>Pathway One</th>
<th>Coastal Unit D: Westshore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short term</td>
<td>Medium term</td>
</tr>
</tbody>
</table>

- **RENOURISHMENT**
  - Regular gravel and sand renourishment to offset erosion losses in combination with beach maintenance and planting
- **MANAGED RETREAT**
  - Property and Assets relocated outside coastal hazard zone, natural character of coastline reinstated
  - Property and Assets relocated outside coastal hazard zone, natural character of coastline reinstated

**NOTES:**
- Combination of gravel renourishment and offshore sand nourishment in the short term. *(Gravel – Land based replenishment at key areas. Sand – Material placed offshore, using marine plant, and allowed to naturally migrate northwards and towards the beach raising foreshore levels)*
- Gravel – Land based replenishment at key areas
- Sand – Material placed offshore and allowed to naturally migrate northwards and towards the beach raising foreshore levels
- Staged managed retreat of assets over the medium to long term when risk becomes unacceptable due to erosion losses and sea level rise.
Māori Resilience Lab

Mātauranga Māori and Mātauranga a Iwi identification of resilient strategies
Research Highlights 2017

**Legislative review.**
Environmental management plans reviewed to explore synergies for resilience/emergency management strategies.

**Community Hazard Monitoring.**
Iwi developing and implementing their own volcano monitoring methods.

**Hapu/Marae Resilience.**
Hui held plans and guidelines developed for emergency management.

**Indigenous Knowledge Publications.**
New GIS methods to document past response and recovery.

**Kaikoura Earthquake Response.**
Engineering analysis for health and well being of Maori.
Toolboxes

**Governance** – *Vivienne Ivory* – Successful resilience decisions, governance contexts

**Infrastructure** – *Liam Wotherspoon* – Resilient networks and community infrastructure

**Economics** – *Garry McDonald* – Benefit-cost incentives, valuing resilience initiatives

**Culture** – *Julia Becker* – Resilience norms, Citizen science, Social media and resilience

**Hazards** – *Mark Bebbington* – size/frequency hazard-spectrum, scenario approaches

**Trajectories** – *John Vargo* – Resilience Indicators, Resilience digital information system
Resilient Governance
Rural Mobility

How do decisions affecting resilience of a multi-modal, multi-agency, multi-regional transport network (system) get made?

- Who is involved?
- Where are the key interactions between parties?

**Case:** Canterbury / West Coast transport network

- North Canterbury 2016 earthquake
- Applying system view to governance of infrastructure networks

Figure 2. Rasmussen’s risk management framework. *Source: Adapted from Rasmussen (1997).*
Rural Mobility: Pilot Actor Map

Central
- National Crisis Mgmt Centre
- Ministry of Foreign Affairs and Trade (international assistance)
- National Security Committee of Cabinet (NSC)
- CDEM Group Emergency Mgmt Office/EEC
- Emergency services personnel

Local
- NZ Search and Rescue
- USAR staff

RESPONSE + PREPARATION
- New Zealand Transport Agency
- Ministry of Civil Defence & Emergency Mgmt
- Ministry of Transport

RESPONSE + RECOVERY + PREPARATION
- Lifelines groups (power, water, roads, ports)
- Port companies (Centreport, Marl., Nelson)
- Network contractors NOC
- Seismologists, assessors, engineers, planners designers, & other scientists

RECOVERY + PREPARATION
- Embassies (e.g. Chinese, Brit, US)
- Consultants
- Road Network Mgmt Alliance
- Local business community
- Land care

RECOVERY
- Rail freight companies
- Producers/ manufacturers
- Fonterra
- Hospitality and tourist operators
- Retailers
- Contractors
- Social and business recovery managers
- Tankers
- Farmers/growers

Identified by all experts
Identified by 3+
Identified by 2+
Identified by 1
• Impact assessment and network modelling
  – West Coast & Canterbury and Auckland
• Component modelling and site characterisation

• NZ research: mapping and collaboration
  – Universities
  – QuakeCoRE
  – Stakeholders & Lifelines groups
  – Riskscape
  – VISG & DEVORA

Image: Scott Kelly, ISS
Kaikoura EQ Infrastructure Impacts

**Transportation**  Day 0

Rapid mobilization of infrastructure data with stakeholders

**Telecommunications**

**Result:** Detailed post-event evidence base of infrastructure impacts and decision making

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*Davies et al.*

*Giovinazzi et al.*
Kaikoura EQ Infrastructure Impacts

Result: Detailed post-event evidence base of infrastructure impacts and decision making

Hughes et al.
Liu et al.
3 Waters

Rapid mobilization of infrastructure data with stakeholders

Electric Power
Electric Power Systems Resilience

Liu et al.

Electric power network process modelling for natural hazard events to assess degradation of system function

Components

- Hazard Model
- Network Process Model
- Network Outage Simulator
- Fragility Function

Power flow, state estimation, and transient stability analysis

From GM sim + coseismic hazards

Broad scale co-seismic hazard modelling linked to GM sim

Result: Framework to move from electricity network reliability towards resilience quantification
Modelling of Network Dependencies

Zorn et al.

Hierarchical network of network models

Direct vs dependencies based network disruptions

Scenario and simulation based disruption propagation

Result: Quantification and simulation of national infrastructure network dependencies
Hazards Toolbox – cascading and inter-dependent hazards

**Graph theory** or network theory used to analyse and quantify complex systems in geography, ecology and atmospheric sciences (Phillips et al., 2015). Extended to natural hazard related impact and risk assessment.

Example: Heckmann & Schwanghart (2013) used network theory to explore the sediment cascade in an Alpine catchment of Austria.
Preliminary application to simulate earthquake, coseismic landslides and dambreak floods impacting assets at Franz Josef
Graph Theory - analysis of the interactions between natural and man-made systems

- Natural and societal systems represented as networks using nodes and edges
- Allows different networks to be interrelated (e.g. geological hazards and power grid)
- Cascading impact of initial hazards through connected networks

- Exposure networks developed in a co-creative effort with the communities and, more holistically, with all the people potentially involved.

- An accurate network of exposed elements needs to be based on the combined “insider knowledge” of communities, experts, officials and emergency services.
Economics toolbox – motivating resilience

Key
- Green: Enabling Pathways to Resilience
- Yellow: Valuing Resilience Initiatives
- Red: Motivating Resilience

Culture

Urban

Rural

Edge

Multi-Hazard

Governance

Risk-scape

Targets

MBIE NHRP Quake-CORE Others

CS1

CS2

CS3
What’s Included in MERIT?

Wider Economic Impacts using the Dynamic Economic Model

Results for Region, NZ – GRP, Income etc by industry

Riskscape – Hazard, Building Damage, Infrastructure Outage Maps

Direct Impacts of People & Business Relocation

Direct Impacts on Transport – Fuel, Road, Rail, Water, Air, Ports

What’s the MERIT modelling process?

Modelling the Economics of Resilient Infrastructure Tool
## Kaikōura Earthquake 2016

<table>
<thead>
<tr>
<th>Regional Results</th>
<th>Baseline GDP ($\text{2016}_m$)</th>
<th>OPTIONS 1&amp;2</th>
<th>OPTION 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimated change in GDP ($\text{2016}_m$)</td>
<td>% change from YE March 2016</td>
<td>Estimated change in GDP ($\text{2016}_m$)</td>
</tr>
<tr>
<td></td>
<td>0-12 months</td>
<td>12-24 months</td>
<td>Total (0-24 months)</td>
</tr>
<tr>
<td>Total New Zealand</td>
<td>241,200</td>
<td>-402</td>
<td>-62</td>
</tr>
<tr>
<td>Canterbury</td>
<td>32,900</td>
<td>-107</td>
<td>-10</td>
</tr>
<tr>
<td>Rest of New Zealand</td>
<td>208,300</td>
<td>-295</td>
<td>-53</td>
</tr>
</tbody>
</table>

## Industry Results

<table>
<thead>
<tr>
<th>Industry Results</th>
<th>Estimated change in Value Added ($\text{2016}_m$)</th>
<th>% contribution to GDP loss</th>
<th>Estimated change in Value Added ($\text{2016}_m$)</th>
<th>% contribution to GDP loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-12 months</td>
<td>12-24 months</td>
<td>Total (0-24 months)</td>
<td>% contribution to GDP loss</td>
</tr>
<tr>
<td>All industries</td>
<td>-382</td>
<td>-57</td>
<td>-439</td>
<td>94%</td>
</tr>
<tr>
<td>Agriculture</td>
<td>-21</td>
<td>-9</td>
<td>-31</td>
<td>7%</td>
</tr>
<tr>
<td>Other primary</td>
<td>-36</td>
<td>-7</td>
<td>-43</td>
<td>9%</td>
</tr>
<tr>
<td>Food manufacturing</td>
<td>-115</td>
<td>-4</td>
<td>-119</td>
<td>26%</td>
</tr>
<tr>
<td>Wood and paper manufacturing</td>
<td>-37</td>
<td>-2</td>
<td>-39</td>
<td>8%</td>
</tr>
<tr>
<td>Other manufacturing</td>
<td>-86</td>
<td>2</td>
<td>-84</td>
<td>18%</td>
</tr>
<tr>
<td>Utilities, construction &amp; transport</td>
<td>174</td>
<td>-75</td>
<td>98</td>
<td>-21%</td>
</tr>
<tr>
<td>Trade and hospitality</td>
<td>-36</td>
<td>4</td>
<td>-32</td>
<td>7%</td>
</tr>
<tr>
<td>Government, education &amp; health services</td>
<td>-87</td>
<td>22</td>
<td>-65</td>
<td>14%</td>
</tr>
<tr>
<td>Other services</td>
<td>-140</td>
<td>13</td>
<td>-126</td>
<td>27%</td>
</tr>
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</table>
Spatial MERIT
Uptake: NZTA Resilience Group

YouTube clip on Transport-MERIT:
https://youtu.be/IRVD3PvZHHY

The economic impacts of road outages in New Zealand
1. **Developing Social Norms**
   Investigate how to develop social norms for resilience. Includes qualitative (e.g. focus group) and quantitative (e.g. survey) work, and research into cultural Kaupapa.

2. **Emerging Technologies**
   Investigate how information and communication technologies (via Facebook and Twitter) can contribute to a resilient culture.

3. **Connecting Citizens to Science**
   Investigate citizen science as a tool for involving New Zealanders in science activities (including developing a strategic framework).
The influence of Social norms

- Rules and standards understood by members of a group (Cialdini, 2003)
- Guide our behaviour
- Encouraging pro-environmental behaviours (e.g., Abrahamse & Steg, 2013)
  - Reducing littering
  - Recycling
  - Water conservation
- Important in encouraging resilient behaviour
  - People more likely to prepare when others prepare (e.g. Mileti & Darlington, 1997)
  - Descriptive norm message increase preparedness behaviour (Japan; Ozaki & Nakayachi, 2015)
Challenges of Measuring Resilience at a Community Level

RESILIENCE IS DEPENDENT ON:

- Individual, community and societal factors
- Context
- Interactions
- Timeframes.

LOCAL VS NATIONAL AND REGIONAL VIEWS

- Variable perspectives.
- Consequent actions required to resilience will differ from place to place.
- How to integrate local community resilience ‘indicators’ with national and regional indicators?

“Resilience measurements need to account for place-based conditions and dynamics.”

Kwok et al., (2017)
New Zealand Place-Based Resilience Index

To compare ‘resilience’ characteristics across NZ’s geography and over time.

This index will allow us to benchmark resilience, monitor progress, and evaluate the efficacy of resilience interventions.
The factors that contribute to national disaster resilience (Horrocks, 2017)
Draft National Spatial Resilience Index

Northland

Wellington

Canterbury
Wellington Region
CAU-level Information

CANNONS CREEK NORTH
Mean score: 0.48
WEAKNESSES
- Low life satisfaction
- High loneliness
- High number of renters
STRENGTHS
- High proportion pre-retirement age
- Relatively high basic disaster preparedness
Canterbury Region
CAU-level Information

KAIKOURA TOWNSHIP

Mean score: 0.63

WEAKNESSES
- Relatively low household income
- Few large businesses
- Small numbers of government/professional sector employees

STRENGTHS
- Mostly English speaking, long-term residents
- Low loneliness
- High life satisfaction
- High self-rated health
Growth... new contestable projects 2017-2019

Resilience to flow-on impacts to NZ Regional economies
Disaster preparation in Auckland’s SE Asian communities
Electricity Distribution resilience framework
Resilience in transient worker communities

Legal framework for managed retreat
Technology in resilience citizen science
Kaupapa Maori tsunami planning
Rural value chain resilience
Lessons so far...

- Resilience to Natural Hazards is complex, different approaches needed depending on scale and circumstance
- Knowledge of hazard is not enough
- Partnerships between science-government-private sector needed
- Entrenched boundary issues between local and regional government (or between local authorities and communities must be overcome) (e.g. acceptable risk, managed retreat)
- Resilience must become “normal” for it to really function – *Resilience as a state-of-mind*