RESILIENCE TO NATURE'S CHALLENGES

Kia manawaroa – Ngā Ākina o Te Ao Tūroa

EXTREME WEATHER RESEARCH PLATFORM

SYNTHESIS OF EXTREME WEATHER RESEARCH PLATFORM RESEARCH

Prepared by Climate Sigma and Resilience to Nature's Challenges (RNC) National Science Challenge

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Synthesis of Extreme Weather Research Platform research

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After the Auckland Anniversary Weekend floods and Cyclone Gabrielle in the North Island in late January and February of 2023, researchers came together to gather information that could help reduce the impact of future events.

The science system mobilised in several ways including:

- rapid provision of advice to central and local government,
- collection of perishable data, and
- $10.8 million funding for urgent science and data collection through the Extreme Weather Research Platform (EWRP).

This document is aimed at researchers, policymakers, regional science managers, or practitioners seeking a broad brush understanding of research done through the EWRP. It consolidates findings and lessons from across the platform. Research on the impact on children and families encompasses both events. Research focused on physical and environmental impacts primarily focuses on Cyclone Gabrielle.

Abbreviations

DoC—Department of Conservation

EWRP—Extreme Weather Research Platform

FOSAL—future of severely affected land

IPCC—Intergovernmental Panel on Climate Change

MfE—Ministry for the Environment

MPI—Ministry for Primary Industries

NEMA—National Emergency Management Agency

NHC—Natural Hazards Commission Toka Tū Ake (formerly EQC—Earthquake Commission)

NIWA—National Institute of Water and Atmospheric Research

Key findings and recommendations

The following are valuable insights for decision-makers planning to reduce the impacts of future extreme weather events across Aotearoa New Zealand.

Support for young people

The mental health of young people, already affected by COVID, was knocked by the extreme weather events. Specialist mental health support for young people is needed. Schools act as an important support system for young people and families. However, they are often not given adequate training and resourcing to provide this support. A protective element in decreasing future mental health issues is inclusion in forward looking response work. Many young people surveyed had clear ideas about what could be done.

Disparity in council resourcing

Regional councils have different resource levels and approaches to flood guidance, emergency management, and climate adaptation. Some councils have a chief scientist and others do not. Those councils with fewer resources will need support to bring them up to par or existing inequities are likely to worsen. We can use what we've learned from these extreme weather events to provide more useful guidance, including how and where to rebuild and how to best adapt land-use.

The difference in resourcing between regional councils is also responsible for a stark gap in pre-existing baseline data. Without baseline data it is impossible to compare the pre- and post-event landscape. This means we understand a lot more about the physical impacts of Gabrielle in Hawke's Bay than we do in Northland.

Collating data

The cost of the research project on landslides is the same as the value of the average residential house. The result of this small investment is detailed landscape mapping for the whole of the east of the North Island and Auckland. This will make it easier to provide guidance on safe building zones and land-use in those areas.

Satellite data is a game changer as it makes fast and cost-efficient data easily available. However, it can't be used during or often immediately after an extreme weather event due to cloud cover. If reconnaissance flights are being used in the hours and days immediately following flooding, adding equipment that allows scientific analysis should be a no brainer. When helicopters are already being used for post-event reconnaissance, the ability to deploy LiDAR and metric camera payloads on these flights would dramatically enhance the quality of data capture in a cost-effective manner. In extreme events, where the whole landscape is affected, LiDAR capture should also extend beyond the immediate flooded areas to encompass the entire catchment, enabling a comprehensive understanding of the flood process.

Not all agencies were able to share data during these emergencies. Where data was shared, research understanding was enhanced. There is a need for a lasting and substantive platform to serve as a repository for the knowledge and data accumulated through the EWRP.

Hazard guidance needs to incorporate what we've learned

National guidance on coastal hazard and flood risk needs to incorporate lessons from the extreme weather events in early 2023 to ensure we are building in the right places:

The national guidance on preparing for flooding has not been updated since 2010 and needs to be integrated into climate or emergency management guidance. Updated guidance needs to differentiate between 'business as usual' flooding and that caused by extra-tropical cyclones, which can be on a much larger scale.

Any flood guidance needs to include flood modelling and climate change in a consistent manner. Most flood risk modelling uses the largest flood from when records began. This means regions with 'good' information have 50 years of data, so the understanding of a 1-in-200-year flood (such as seen in Hawke's Bay during Cyclone Gabrielle) differs widely.

There is a difference between chronic coastal erosion, as seen in Cyclone Gabrielle, and sea-level rise. The national guidance on coastal hazard risk needs to be re-examined given this development in our understanding.

How erosion hazard zones are decided currently differs across councils and the data from Cyclone Gabrielle could help quantify how much erosion can occur in a single storm.

Environmental and ecological impacts are ongoing

Researchers found that while native vegetation was resilient to damage from Cyclone Gabrielle overall, uncommon ecosystems and threatened species may be especially at risk from extreme weather events. Researchers recommended planting more native vegetation around waterways and wetlands to decrease the impacts of erosion and sedimentation in future flooding. They also recommended examining waterways for connectivity for freshwater species. This will allow species to recolonise these waterways after flood events. Researchers suggested that regional councils work together to design standardised monitoring protocols (fit for a range of budgets) and store data in a centralised database, which would greatly assist rapid assessments of damage and prioritisation of resources after future extreme weather events.

Involve programme coordination and communication from the beginning

Resourcing for programme coordination, communications and engagement is essential for impact in this kind of multi-organisational, transdisciplinary programme. Committing to improved project coordination, communication and engagement for impact would involve input of experts in these areas at all levels and stages of the programme from the planning and proposal phase onwards.

Background

The most recent Intergovernmental Panel on Climate Change (IPCC) report had high confidence that rainfall associated with extra-tropical cyclones will increase under climate change. While climate scientists expect fewer extra-tropical cyclones to reach Aotearoa in the future, the ones that do hit will be more extreme. Studies of extreme rainfall events in Aotearoa show that our recent extra-tropical cyclones already involve more intense rainfall than would occur in the absence of climate change.

Flooding is a national problem in Aotearoa. We know that some places are more at risk than others. In some of those places, flooding has happened more recently, so it is more top of mind. However, just because some locations have escaped until now, doesn't mean it can't happen.

In the Auckland Anniversary Day floods, an entire summer's worth of rain fell within one day, making it a 1-in-200-year event. Just over two weeks later, Cyclone Gabrielle claimed 11 lives, injured more than 2,000 people, and displaced more than 10,500. It disrupted, and in some places destroyed, power, communications and roading networks. The impact of Cyclone Gabrielle was felt across wide swathes of the North Island, from Northland to Hawke's Bay. The events were Aotearoa's third and fourth most costly natural hazard events, ever. Treasury has estimated the cost at $14.5 billion, of which $4.4 billion was insured. A large part of the damage was incurred in locations that are known to be flood prone.

Aerial photo of the Esk river valley, Hawke's Bay, looking eastward (upstream) from the junction of SH2 and SH5 on 20 February 2023. Pale brown sediment shows the extent of flooding caused by Cyclone Gabrielle. Credit: Kyle Bland | GNS Science.

Research applicability

Table 1: Extreme Weather Research Platform research projects

Research	Contact	Organisation	Nationally applicable
Growing up in NZ	Sarah-Jane Paine	University of Auckland	Yes
Flood inundation mapping	Emily Lane	NIWA	*
Stop-bank breach modelling	James Brasington	University of Canterbury	**
Landslides	Chris Massey	GNS Science	***
Slash and slips	James Shepherd	Manaaki Whenua	No
Coastal erosion	Murray Ford	University of Auckland	**
Ecological impact	Rowan Sprague	Manaaki Whenua	Yes
Marine environmental	Leigh Tait	NIWA	No
Infrastructure impact mapping	Charlotte Brown	Resilient Organisations	Yes
Flood hazard risk	Emily Lane	NIWA	Yes
Air quality assessment	Elizabeth Somervell	NIWA	**
Groundwater contamination	Stewart Cameron	GNS Science	No
Remote sensing	Sarah McDermott	NIWA	**
Emergency event data catalogue	Mark Rattenbury	GNS Science	Yes

* While the research undertaken in response to Cyclone Gabrielle is not nationally applicable, it is being incorporated into the Mā te Haumaru ō te Wai research programme, which is producing nationally applicable flood hazard and risk information.
** could be relevant with baseline data across the country
*** will be used in future national hazard models

Out of scope

Out of the scope of this synthesis are consideration of other extreme weather research and of projects from other funding streams relating to the extreme weather events in early 2023. Operational aspects, including science advisory roles, early warning systems and public alerting procedures, and geospatial common operating pictures are also not covered.

Impact on young people and their whanau

Growing Up in New Zealand asked 680 young people and 817 primary caregivers living in the areas most severely affected by the floods and/or cyclone about their experiences during and after these events. The report is available here.

Housing

Of the primary caregivers surveyed, 4% had to leave their homes. Just under half of these people were out of their house for more than a week. Most of those who had to leave their homes stayed in their local community, but just under 30% had to move away. Immediately after the event 2% of caregivers' houses were stickered and six months later there had been only one remediation. Nearly a quarter of caregivers reported that their housing costs have increased since the events.

Fifteen young people (2%) reported that their belongings were damaged a lot and 62 (9%) reported a little damage. Young people tended to overestimate damage to their house and neighbourhood.

Access to support and services

There was considerable unmet need reported by primary caregivers:

- 34% needed but did not receive support with property, transport or belongings.
- 23% needed but didn't receive financial assistance.
- 21% needed but did not receive support with food, water or clothes.
- 17% needed but did not receive medical or mental health care.

Many participants experienced disruption to services: power (27%), internet (23%), mobile phone coverage (16%), and water (14%). Many of these services were disrupted for 3 or more days. There were big regional differences in this respect (see Table 2).

Table 2: Disruption to services across regions

Region	Internet	Power	Mobile Phone	Water
Tāmaki Makaurau/ Auckland	14% ≥3 days: 25%	16% ≥3 days: 15%	7% ≥3 days: 33%	9% ≥3 days: 43%
Tai Tokerau/ Northland	63% ≥3 days: 54%	79% ≥3 days: 48%	51% ≥3 days: 48%	37% ≥3 days: 50%
Tairāwhiti/East Coast and Hawke's Bay	91% ≥3 days: 80%	91% ≥3 days: 70%	93% ≥3 days: 76%	43% ≥3 days: 68%

Mental health and trauma

Overall, there was no difference in quality of life and resilience between young people and primary caregivers who were affected, knew someone else affected, or were not affected by the extreme weather events. However, young people who were affected or knew someone else affected by the extreme weather events reported higher depression and anxiety and worse sleep scores than those who were not affected. Depression symptom scores were slightly lower after the extreme weather events for the young people than they were after COVID. Depression scores for primary caregivers did not differ. However, primary caregivers who were affected reported greater anxiety symptoms.

Nearly 26% of caregivers reported being initially traumatised but were OK six months later. 4% said they were still traumatised six months later. 25% of caregivers reported having family members who were traumatised but now OK. 6% of caregivers reported having family members who were still traumatised. When this was extended to people caregivers knew numbers rose, with 28% knowing someone initially traumatised who was now OK and 18% knowing someone who was still traumatised.

Inclusion in future planning

Psychological research shows that inclusion in forward looking recovery and response can help decrease negative health impacts for those involved in disasters. This is also true for young people. Many of the young people surveyed expressed a wish to help in this way.

"Give us younger generation the opportunity to participate and support those in need, find ways that we can as young people to help our community. Right mindset for us to know what to do when a disaster happens."

— Young person from South Auckland.

"To create a fund for young people, to encourage them to create and design what they need during a natural disaster. Just like a flood relief fund, there should be one for the youth also."

— Young person from South Auckland.

"Make sure kids can get home if there is bad weather while at school especially if parents can't pick them up. Or if kids can't get home there is plan in place to be looked after at school and they feel safe."

— Young person from Te Tai Tokerau.

"It's not your fault. You are allowed to be sad. Talk to your friend and adults if you can. It is hard!"

— Young person from Hawke's Bay.

Caregiver preparation

Of the primary caregivers surveyed who were affected by the storm: 29% felt their household was not at all prepared, another 29% felt a little prepared, 24% felt somewhat prepared and 22% felt very prepared.

56% of caregivers reported they did not see any information or advice about how to prepare for the extreme weather events. More than half wanted more information on planning for evacuation. Around a third wanted extra information on preparing a grab bag, clearing drains, storing or stocking up on water, and purchasing other supplies.

Physical impact

Cyclone Gabrielle caused widespread flooding over much of the North Island. The flood and landslide impacts were greatest in Hawke's Bay and Tairāwhiti regions, including loss of life and significant damage to buildings, land, infrastructure, and primary production. In addition to the flooding, landslides and coastal erosion significantly altered the landscape in many areas.

Flooding

The focus of this project was to better understand the flooding that occurred due to Cyclone Gabrielle. It combined the previous peak flood flow records in priority locations in Tairāwhiti and Hawke's Bay with data from Cyclone Gabrielle to put the event into context and to enable projections for future floods. These 'flood frequency curves' project the size, impact, and likelihood of future flooding.

Researchers also built inundation models for all the affected catchments in Tairāwhiti and Hawke's Bay. These inundation models were validated against the data from on the ground and will be used to improve models that predict the impact of future extreme rainfall in these regions. Lessons learned from developing these models is also helping improve work to develop flood models for all of Aotearoa.

The lessons from this modelling will be incorporated into ongoing research into how rivers and the landscape around them change over time. The report on flooding is forthcoming.

Landslides

Even prior to the extreme weather events of early 2023, landslides cost Aotearoa New Zealand on average $250 million each year (in 2014 NZ$). However, in major events, such as the Kaikōura Earthquake and Cyclone Gabrielle, landslides can cause up to $2 billion in damages. Landslides have also caused more fatalities than earthquakes, volcanoes and tsunami combined over the past few hundred years. Landslides resulting from Cyclone Gabrielle caused the death of five people as well as damaging houses, power lines, bridges, roads and creating dams across channels.

The main focus of the landslide project was to map where landslides occurred as a result of the extreme weather events of early 2023. The team mapped more than 150,000 landslides in what is believed to be the largest ever recorded human mapping of landslides resulting from a single event.

Mapping of the landslides was prioritised based on four levels with the highest priority allocated to where there was risk to life, to the lowest that was relevant only for scientific interest – these were guided and defined by the end users of the data. Information includes where the landslide material came from, the estimated size of the landslide source, how far it went, of what it was made, its movement type, how much debris it moved, and how much damage it did. This information has been provided to lifelines organisations, Hawke's Bay, Tairāwhiti and Auckland councils, and central government agencies. However, the Northland, Coromandel

and Tararua regions had limited or no post-Cyclone Gabrielle imagery available to enable mapping and as a result were unable to be included in much of the research.

Landslide forecast models for all of Aotearoa New Zealand can now be trained and developed further, using the vast number of landslides mapped in this project. This will enable us to build predictions on where failures might occur in the future. This will allow us to plan better and reduce insurance costs. The report on landslides is forthcoming, but more information on the project is here.

Slash and slips

A rapid assessment of land damage across Tairāwhiti, Hawke's Bay using satellite photos found more than 300,00 landslides. Hill country land under native forest was less affected than land under exotic forest (see Table 3). Areas in pasture and harvested pine were the most affected. Pine is often planted on hill country areas that have been in pasture, which is likely to have a history of soil disturbance. In Tairāwhiti/ Gisborne, pine was planted in areas with extensive erosion damage in an attempt to stabilise the land. Regenerating native vegetation takes longer than pine to stabilise highly erodible areas.

The report on slash and slips is here.

Table 3: Land slide potential compared to pastoral hill country

Location	Native vegetation	Exotic forest
Southern Hawke's Bay	90% less likely	80% less likely
Northern Hawke's Bay	90% less likely	60% less likely
Tairāwhiti	50% less likely	same extent of sliding

Coastal Erosion

Cyclone Gabrielle was the first storm where satellite imagery allowed accurate quantification of what was lost to chronic storm-related coastal erosion. While coastal erosion was widespread from Northland to Hawke's Bay, with losses of up to 20m in some areas, it was only a decadal scale event. The weather, while extreme, was mitigated somewhat as the cyclone did not occur at the same time as a spring tide and the ocean swell didn't exacerbate its effects.

However, losing large chunks of dunes across such a large expanse of coastline creates a snowball effect that will reduce resilience against future storms. In addition, some locations may have eroded more after the cyclone than during it, possibly due to the lowering of the beach level. Researchers are now examining recovery in selected sites to see whether the volume of sand stripped from the beach is returning and how long it takes to get back to a pre-storm state.

Currently erosion hazard zones and how these are defined differs between regional councils. The data collected by this project will go into a model that combines both long-term (sea-level rise) and chronic (storm) coastal erosion. Researchers hope this will be used to improve hazard zoning and set back distances, quantifying how many houses are within chronic coastal erosion zones. This information should be included in the next update of the Ministry for the Environment (MfE) coastal hazard guidance alongside sea-level rise.

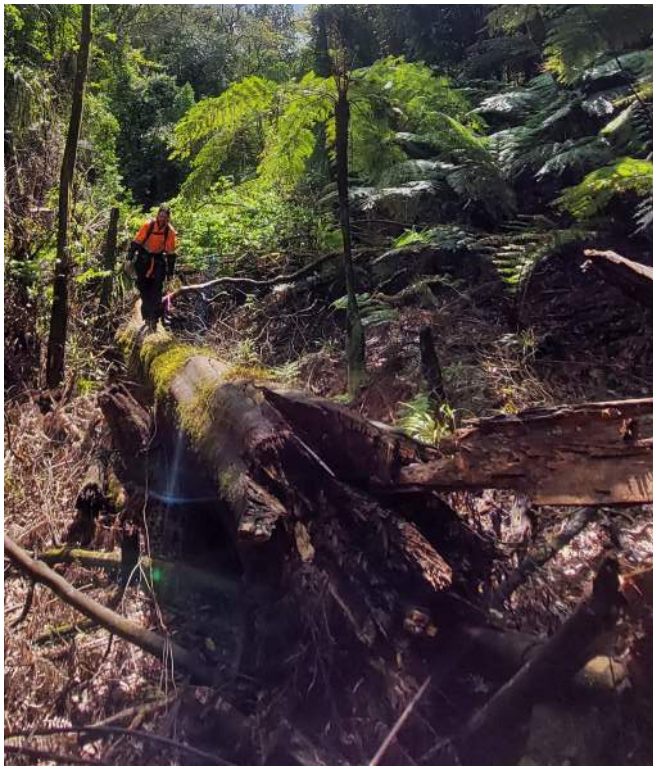
Researchers on this project have met with all regional councils, MfE, NIWA, DoC, and consultants working in this space and believe awareness of this issue is now high. The report on coastal erosion is forthcoming.

Before (red lines) and after (green lines) Cyclone Gabrielle comparison of the shoreline at three North Island beaches: Whangamatā, Bay of Plenty (left), Mahanga, northern Hawke's Bay (middle), and Matarangi, Coromandel Peninsula (right). Analysis of several beaches has shown a pattern of 5—15m erosion in pockets along the North Island east coast. Credit: Murray Ford.

Environmental impact

Cyclone Gabrielle is the first tropical cyclone where there has been a substantial and dedicated effort to quantify impacts on indigenous ecosystems of Aotearoa. To safeguard hard-fought environmental gains against future extreme weather events, we need to identify the species, ecosystems, and conservation infrastructure most at risk.

As with much of the other EWRP research, our ability to assess the impacts of Cyclone Gabrielle depended on the availability of pre-cyclone baseline data. For some regions and ecosystems, such as braided rivers and wetlands in the Hawke's Bay, we were able to compare pre- and post-cyclone data to quantify changes in ecosystem condition and species presence and abundance.



Windfall in the Aongatete Forest, caused by Cyclone Gabrielle. Credit: Warwick Allen | Manaaki Whenua Landcare Research.

Eco-systems

While native ecosystems were largely resilient to damage from Cyclone Gabrielle in the short term, the long-term impacts are still uncertain. This is because although our native ecosystems may be adapted to cope with the occasional extreme weather event, novel pressures such as invasive species may influence long-term recovery.

Project leaders recommended:

- Establishing significant areas of native vegetation around waterways and wetlands to decrease the impact of erosion and sedimentation in future flooding.
- Examining waterways for connectivity for freshwater species to allow recolonisation after flood events, otherwise species lost from upstream will be lost for good.
- Prioritising climate change adaptation plans for conservation infrastructure and assembling 'disaster response kits' to prepare for future extreme weather events.

Braided rivers

Leveraging three years of pre-cyclone data (2019-2021), researchers examined changes in habitat and abundance of birds along 292 km of braided rivers in the Hawke's Bay. They recorded population declines for all four focal

native wader species: pohowera (banded dotterel), black-fronted dotterel, poaka (pied stilt), and tōrea (South Island pied oystercatcher). This was linked to increased silt in the Ngaruroro and Tūtaekurī Rivers. It was also found that aquatic macroinvertebrate species that favour healthy braided riverbeds such as mayflies, stoneflies and caddisflies were replaced in high impact areas by species that can tolerate sediment.

Wetlands

Researchers resurveyed 22 wetlands across Hawke's Bay for which pre-cyclone data were available. They found that wetlands were largely resilient to the large volumes of water that they captured: wetland condition declined by an average of 5%, with isolated impacts occurring due to sedimentation and damage to vegetation.

Wetland monitoring in the Kaweka Range.
Credit: Warwick Allen | Manaaki Whenua Landcare Research.

Endangered species

While Researchers examined several endangered species. The nationally critical **tara iti** (fairy tern), possibly Aotearoa's rarest bird, is presumed to have lost 15% (seven birds) of its population in Cyclone Gabrielle. At Cape Sanctuary, nine individuals of the nationally threatened **tūturuatu** (shore plover) were lost (3% of its global population). This illustrates the impact of extreme weather on species that have a small range or population size and emphasises that threatened species are especially at risk from extreme weather events.

The **whio** (blue duck) that typically breed in the Ruahine Forest Park have not been found to be breeding again in the main affected rivers. Researchers are unsure if this indicates population decline or movement. However, it is likely that because their food in these rivers has been wiped out, there will be negative impacts on their breeding condition that could lead to long-term population decline.

The spawning habitat for **īnanga** has not recovered after the cyclone. Īnanga are coming upstream but there is nowhere for them to lay eggs as the riparian vegetation has gone. Research is continuing to investigate whether īnanga are affected by changes in the connectivity between waterways if their refuge habitats have been disturbed.

Conservation infrastructure

Researchers interviewed workers at 64 ecosanctuaries across the North Island to represent impacts of Cyclone Gabrielle on conservation infrastructure. Eco-sanctuaries are defined as locations under pest management for multiple species that span more than 25 hectares.

Damage from wind (75% of ecosanctuaries) and erosion (70%) was widespread, followed by flooding (39%) and sediment deposition (27%). Most ecosanctuaries reported multiple impacts on conservation activities. Damage to infrastructure was widely reported, often paired with disruption to conservation activities such as pest control and native species monitoring. Some infrastructure damage is likely to lead to longer-term problems, such as incursions through damaged predator-proof fences. Because eco-sanctuaries are primarily staffed by local volunteers, most expected the capacity of their workforce to decrease because those people were also coping with personal impacts of the extreme weather.

It was encouraging that the broader network of ecosanctuaries was resilient to cyclone impacts, with no reported local extinctions and a resolve to rebuild what was lost and keep pushing forward with conservation projects. However, with extreme weather events expected to increase in severity, this resilience will continue to be tested. More information on findings from eco-sanctuaries is here.

The integrated report on ecological impacts is forthcoming.

Marine environment

Tairāwhiti

Aerial surveys of the marine environment in Tairāwhiti between Te Araroa and Anaura Bay have shown that what was kelp forest supporting kōura (crayfish), paua, and butterfish has disappeared. It is likely that slash in the marine environment in the volume caused by Cyclone Gabrielle caused a big physical disturbance in certain areas. Of more concern is the sediment carried out to the sea during the flooding. This has covered the usual rocky sea floor, and although kina are thriving, kelp and kōura spawn have nothing to attach to and are dying. Even more worrying is the appearance of a phytoplankton that causes shellfish poisoning. This can lead to paralysis in those who eat affected kai moana. The local crayfish fishery is suffering and the cultural aspects of mahinga kai are badly affected.

In Tokomaru Bay, sea grass beds are appearing where they have never been seen before. These seagrasses prefer sediment and indicate a possible eco-system shift.

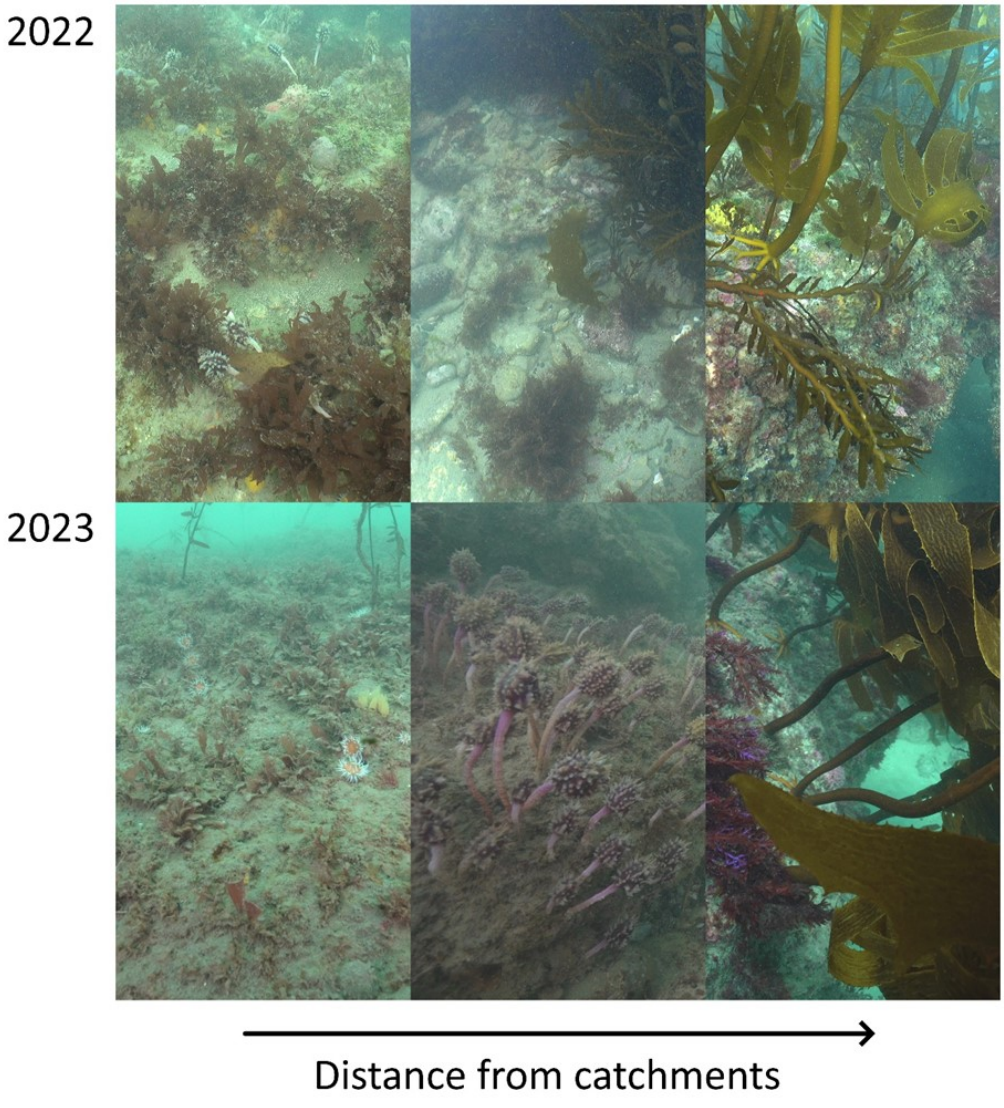
Researchers have held hui from Gisborne to Ruatoria to discuss these results and understand the requirements on the ground. The marine research, which has captured terabytes of imagery over 300 hectares of reef, is ongoing. This will include modelling the possible impacts from the volume of sediment.

Hawke's Bay

The study of the marine coastal environment in Hawke's Bay was helped immensely because the mouth of the Esk River and the surrounding marine environment was surveyed just before Cyclone Gabrielle. The comparison showed dramatic changes in the marine environment with a loss of seaweed and kelp. Impacts stretched for 3-5km away from the Esk river outfall.

The researchers had an existing relationship with hapū in Tangoio. Examination of the marine environment there also showed some major impacts, even though the Tangoio River is much smaller than the Esk. Local hapū are interested in the impact of the freshwater as well as the sediment and will use eDNA testing and drones to monitor their moana.

The report on marine impact is forthcoming.



Comparison of three rocky reef locations at increasing distance from major freshwater catchments before (2022) and after (2023) Cyclone Gabrielle. Credit: Leigh Tate | NIWA.

Assessing damage

Researchers across the EWRP were confident that the data collected and analysed through the platform would enable more rapid response and assessment in the future. Their hope is that the research undertaken in response to the extreme weather events in early 2023 will bring about a common understanding between different regions about what might occur in the future.

Infrastructure

Researchers collected data on where and how critical infrastructure was damaged during the early 2023 extreme weather events and for how long it was restricted or out of service. Infrastructure and Civil Defence organisations fed data into the project. The aim was to capture how Aotearoa New Zealand's critical infrastructure systems work as an integrated whole and how they can be improved to better withstand future events. This information has been mapped but is not yet publicly available.

Two reports on key infrastructure lessons were also produced. The links below are to the associated policy briefs:

- Critical infrastructure recovery: Key lessons
- Building resilience through recovery: investment decision making

Land damage

The Elevation Aotearoa LiDAR programme, part funded by Provincial Growth Fund, aims to create high resolution maps of 80% of the country by the end of 2025. Regional councils are required to match the funding for this to occur in their region and there are significant parts of the country where this will not occur due to funding constraints.

Because Hawke's Bay was already mapped under this programme, researchers could understand how Cyclone Gabrielle affected the landscape. This enabled them to understand the extent, depth, and volume of the silt, sediment and debris deposited. It also showed where rivers had scoured the landscape. Having a baseline allowed comparisons including changes in riverbed levels and an understanding of how much was eroded and where it ended up.

Information was given to local iwi trusts, NHC, MPI and MfE for their stakeholders. The LiDAR mapping also provided vital information on stop-bank slumping that allowed the Hawke's Bay Regional Council to prevent potential failure. The slumping would not have been caught by a purely visual assessment.

Hazard risk

Some preliminary research was undertaken into stop-bank breaches or 'overtopping'. If all the stop-banks along a particular river are designed for the same 1-in-100-year event, it is difficult to know where breaches will occur in a bigger flood. Prolonged overtopping can lead to breaching through erosion of the outer side of the stop-bank, as occurred in the Heretaunga Plains. This leads to the next question: should we be designing for failure in the 'best' place? For example, overtopping upstream in the Heretaunga Plains is likely to involve less risk to life than overtopping in Napier.

Ngāti Kahungungu have been using the modelling developed through this work to examine what would happen if the river was taken out of its current stop-bank 'straight jacket'. Questions include whether a more meandering river would help 'recharge' groundwater and provide more conveyance for water from extreme rainfall.

Riskscape

This project increased the ability of RiskScape to provide multi-hazard scenarios on an information sharing platform. This allowed RiskScape to assist in planning for recovery after Cyclone Gabrielle.

The RiskScape impact assessment tool provides a range of scenarios to rapidly assess natural hazard impacts for areas in Hawke's Bay and Tairāwhiti affected by Cyclone Gabrielle including fluvial flooding, landslides, coastal flooding, earthquake shaking and liquefaction, and tsunami. The tool enables planners to visualise how to mitigate the impacts of different hazard and how to minimise losses to the community. It does this by allowing planners to see what would occur if building floor levels were lifted, or river stop banks were raised. The tool can calculate expected future building damage and reinstatement costs, and displacement days for different events. This allows planners to compare the difference in losses across various risk management actions.

The changes to RiskScape made in this project allow planners and researchers to better evaluate adaptation measures for hazard risk reduction and will help inform decision making. These tools were provided to NHC and NEMA and demonstrated to Treasury and have potential future value for risk-aware land-use planning, as well as for post-disaster recovery planning.

Platform coordination

The Resilience National Science Challenge was asked to provide connection, coordination and communication of the collective work of the Platform. The key benefits of this coordination included:

- **Building Connections**; The platform helped researchers stay informed about each other's projects, building a sense of community. Providing a central platform allowed everyone to easily access information, ask questions, and stay updated, further streamlining progress.
- **Meaningful Engagement**; By providing a central hub for communication and updates, the platform facilitated more meaningful interactions and involvement from stakeholders, researchers, and users alike. The Regional Science Managers Hui enabled researchers to directly interact with regional science managers, fostering valuable partnerships and facilitating direct feedback loops.

The role of the coordinators was not, however, communicated by the funder to the project teams when funding was approved. Commitment of time, effort, and resource during the planning and proposal phase is essential for building a foundation for coordination and engagement. To ensure stakeholders receive the most efficient and streamlined engagement, plans need to be shared between researchers and coordinators. Greater role clarity from the start of the project would have helped avoid overlapping efforts while identifying potential synergies and interdependencies between projects. This is likely to have enhanced the overall impact and value for money of the EWRP.

There is a need for a lasting and substantive platform to serve as a repository for accumulated knowledge. This would provide continuity and greater cohesion while facilitating meaningful information sharing, cross-project synergy, and sustained engagement with stakeholders.

Further research needs

Collection and coordination of information

The coordination and accessibility of data and information across researchers and science-users was mentioned often. There are considerable advantages to bringing information together into a robust system for data collection and sharing. Such a platform (that acts as a clearinghouse for emerging data) would also help ease disparity between regional councils if it was open access.

Lack of information on communities

While we understand some of how the extreme weather events of early 2023 affected young people and families, there are still gaps in our understanding of the breadth of impact on people and communities. This includes information about how people accessed support and their expectations about how long lifeline services would take to be restored. We also know little about the longer-term impact on communities, particularly how physical and infrastructure disruption affects the social and economic outcomes of communities and businesses.

Recovery processes

Deeper investigation of recovery processes including decision making and organisational and operational challenges is required. This should include elements such as community input, silt management and land remediation, infrastructure recovery, insurance and residential rebuild, and the future of severely affected land (FOSAL) policies.

Assessing physical impacts

We do not know enough about the effects that sediment in rivers have on flooding. We need to understand how sediment deposited by floods impacts different land-uses, including residential and commercial buildings and land used for agriculture or horticulture. We also need to take the impact of sediment into account when modelling flood inundation and calculating flood frequency and damage. What are the long-term impacts of sediment, and how we deal with it, on future flood risk? We also need to better plan for the residual risk created by stop-banks. Can we design failure into stop-banks, so they flood 'better' places if an overdesign event occurs?

Environmental impact and recovery

All environmental project leaders agreed about the value of monitoring now and into the future. They suggested that regional councils work together to design standardised monitoring protocols (fit for a range of budgets) and store data in a centralised database, which would greatly assist rapid assessments of damage and prioritisation of resources after future extreme weather events.

Further targeted data collection and spatial analysis of connectivity is needed in freshwater ecosystems to determine how connectivity influences how long it takes a species to recover. This should also encompass the difference between recovery times for local versus whole catchment disturbance.

Further research is also needed to understand:

- Long-term impacts of extreme weather on native vegetation (e.g. slow tree death of flooded forest) and how recovery is influenced by other pressures such as invasive ungulates and weeds.
- Which species and uncommon ecosystems are managed, and where, so we can act swiftly if a regional event is forecast.
- The effect of freshwater 'bloom' on marine life.

Synthesis of Extreme Weather Research Platform research

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