National SCIENCE Challenges

THE DEEP SOUTH

Te Kōmata o Te Tonga

Te Hiku O Te Ika

Climate Change project

Project Summary Report 2018

Contents

Acknowledgements

The Te Hiku Climate Change project has been a team effort; a large group across a range of sectors each playing an important part.

We thank the Deep South National Science Challenge for the opportunity to be involved in this programme of work, and for their support throughout.

Our Te Hiku communities were at the centre of the project. The commitment of the Community Researchers who collected local data during the two-years was amazing and made the approach to the project possible. Their role in daily recording of rainfall and temperature, undertaking a community household survey, household water sampling, interviewing kaumatua and attending project meetings all contributed to the success of the project.

Kia ora ki a koutou to the iwi of Te Aupouri and Te Rarawa, and Te Hiku Iwi Development Trust for your support and interest in the project, as well as the Whāriki Research group (Massey University), the Institute of Environmental Science and Research (ESR), National Institute of Water and Atmospheric Research (NIWA) for your skills and expertise that contributed to the project.

Ngā mihi mahana ki a koutou katoa!

Executive Summary

The research aimed to explore the implications of climate change for drinking water supply sustainability in three Te Hiku communities - Te Kao, Pawarenga and Motukaraka, in the far north of Aotearoa. The project provided an opportunity to gather local data, raise the profile of climate change and start strategizing about the likely impacts on these small rural communities.

The iwi of Te Hiku O Te Ika have long shared the concerns of te iwi Māori about widespread environmental degradation, and latterly the impact of climate change on people, places and ecosystems. Isolation means that roof-fed tank systems are our predominant source of drinking water; understanding the impact of climate change on water supplies was a vital first step to enabling our communities to prioritise, prepare for, minimise and mitigate detrimental effects.

The research project built transferrable community capabilities that will be useful in addressing other local climate change issues of concern and thus has far reaching implications for rangatiratanga and kaitiakitanga around indigenous flora/fauna, mātauranga, sustainability practices and policy.

The project contributed to the Vision Matauranga themes on several levels. Working with our communities to prepare for the effects of climate change on our people, ecosystems, lands and economy by creating specific, located, Māori knowledge about water sustainability as a key dimension of community viability in Te Hiku, through undertaking community risk assessments, processes to develop actions, building community capability, and the sharing of climate change knowledge within and beyond iwi networks.

Introduction

Te Hiku Climate Change was funded as one of the Ministry for Business, Innovation and Employment (MBIE), Deep South National Science Challenge projects. The two-year contract between NIWA (contracted by MBIE to meet the terms of the Challenge), and Te Hiku Iwi Development Trust focussed on the impact of climate change on three small rural communities - Te Kao located in the rohe of Te Aupouri, Pawarenga on the Whangape harbour beside the west coast, and Motukaraka on the Hokianga harbour, both in the rohe of Te Rarawa.

A large research team provided a wide range of skills and expertise. Data collection was undertaken by mana whenua community researchers at each location - Te Kao: Kevin Wilton, Robyn Pako, Errol Murray, Rangimarie Rameka; Pawarenga: Hank Dunn, Sam Tecklenburg; Motukaraka: Len Neho, Jackie Thompson, Lisa Waipouri. Kaio Hooper (NgaiTakoto), Troy Brockbank (Stormwater 360; Te Rarawa, Ngati Hine, Ngapuhi), Helen Moewaka Barnes (Whāriki; Ngati Hine, Ngati Wai), Tim McCreanor (Whāriki Research Group, Massey University), Elaine Moriarty (ESR water quality specialist), Christian Zammit (NIWA hydrologist), and Wendy Henwood (Te Rarawa) worked together to achieve the objectives of the project.

Project aim

The aim of the project was to learn more about household and community drinking water supplies, challenges and threats. We were interested in whanau and hapū understandings of climate change and the possible effects on drinking water. We were keen to access existing matauranga and kaitiakitanga practices regarding weather patterns, and climate variations across Te Hiku rohe. This information would form the basis of finding local solutions and ways to reduce and/or manage the impact of climate change on water quality, supply and sustainability in the three Te Hiku communities.

Context

The area known as Te Hiku comprises the five northern most iwi (Ngati Kuri, Te Aupouri, Ngati Kahu, NgaiTakoto, Te Rarawa). The Te Hiku Iwi Development Trust emerged from the Te Hiku Treaty Settlement as a vehicle to work collectively on projects and issues where there were shared interests. Water is of major importance and concern to the collective; water has a mauri and connects the people and the land, a common whakapapa to Rangi and Papa. Quality drinking water is the basis for community survival; upholding manaakitanga responsibilities depends on water, existing mātauranga Māori and kaitiakitanga practices about weather and management of drinking water guide solutions.

The global rise in average temperatures driven by increased carbon dioxide in the upper atmosphere produced by human activity, are known to be changing weather patterns worldwide. The more extreme weather predicted, including higher temperatures and sea level rise is likely to impact on the lives of people in Te Hiku. Drought, storm events, flooding, and erosion could result in risks to people, land, waterways, and species. Habitats and ecosystems determine the plants and animals that can survive and flourish, the lifestyles, land use and places that can be occupied, and the infrastructure needed which in turn determines survival and community viability.

Methods

Project development

Research locations

Three small rural communities were selected to participate in the project based on a north-south spread throughout Te Hiku, different environments, and local interest in participating. Te Kao is about 70km north of Kaitaia, the majority have roof and tank drinking water systems, some households are connected to a local lake supply. Motukaraka is an area on the north shore of the Hokianga harbour where the households are exclusively reliant on roof and tank supplies for drinking and other water. The coastal settlement of Pawarenga about 45km north west of

Rawene, are dependent on roof and tank systems with an additional supply for marae from a small lake situated in the Warawara forest.

Community action research design

The community action approach kept the focus for the research on each community; working in ways that suited each community, recruiting community researchers to the research team to gather local data, participating in local hui, acknowledging local knowledge

Following discussion and agreement with key people at each location, community researchers were appointed for data collection, and information and training was provided as required. Temperature and rainfall gauges were installed at each site (GPS coordinates recorded) and several documents were prepared for the community researchers including a one-page summary about the project as a hand-out, recording sheets for temperature and rainfall data and information for households about a drinking water survey. Once established a collective project hui was convened in Kaitaia. Bringing the local Researchers together was a valuable opportunity to connect the three communities, build relationships and to better understand climate change in general and the specific drinking water issues for each – some were shared and some unique.

The Community Researchers played a pivotal part in the project; they worked closely with the research team and led activities in their respective communities. All three communities split the role to make more manageable; one taking the daily weather recordings, and another undertaking the household surveys and water quality sampling.

In addition to gathering information at project hui and informally at other relevant meetings, several kaumatua were interviewed to hear their experiences and perspectives of climate change. This involved one focus group, and four individual interviews with kaumatua who had observed local weather patterns over their lifetime in these communities.

Building community capacity and capability and developing opportunities to increase networks and collaborations is an important part of community action. The project was show-cased and well received on several occasions including presentations at the Te Hiku Environmental Symposium (Korou Kore Marae, Kaitaia, October 2016), the Deep South Symposium (Wellington, September 2017), and the 3rd National Māori Conservation Hui (Korou Kore Marae, March 2018).

Climate modelling (NIWA)

The role of NIWA scientist Dr Christian Zammit in the project was to run the climate change investigation by computer modelling of most likely climate futures for participating Te Hiku communities and their potential impact on roof water availability and security (using *E. coli* as an indicator). This objective was completed through five interrelated components:

i) Collection of local climate information to create local scale climate change projections.
ii) Development of a model linking *E. coli* to climate variables to predict likely impact of climate change on *E. coli* generation.

iii) Development of climate change projection for each community.
iv) Development of projections for roof water supply and *E. coli* generation under climate change scenarios.
v) Development of a decision support tool that enable to test simple management scenarios with the community.

Local climate information collation

The data collected during this process (daily total precipitation and temperature at 9am), by a community researcher in each community, was used to develop an understanding on how local climate conditions vary day to day with regional scale information. The regional scale information is provided by NIWA's Virtual Climate Station Network (VCSN) which generates daily gridded (5km spatial resolution) climate information (precipitation and temperature) based on existing climate observations. The closest VCSN grid point to each community (identified through mapping of each community) was selected as representative of the regional information.

The climate information was collected over the period September 2016 to March 2018. The 9am collection time was to align with the generation VCSN information. The local information was plotted against the regional information for visual assessment of data collection errors (e.g. time of the data collection) or sub-regional weather effects not identified at regional scale (e.g. convective storm affecting small area). The local information was concatenated to monthly time scale to develop a simple bias correction of the precipitation and temperature that was then be applied to future climate change projections.

Note that such bias corrections are usually determined based on a 30 year time period (WMO, 2017 http://www.wmo.int/pages/prog/wcp/ccl/faq/faq_doc_en.html). As a result, it is likely that a large bias (representing the weather over the period 2016-2018) is present in the established bias correction.

Visits were organized with each of the community climate observers to support them in the setting of the rainfall and temperature gauges. The site visits were useful to explain observed difference with the VCSN and to engage in discussion of issues specific to each community.

E. coli model

Based on the need of this project and following *E. coli* data collection in each community (see section hereafter) a simple statistical model was established to link observed *E. coli* concentration in water tanks to climate variables. This simple model does not take into account the following causes: i) effect of possum-rats-birds population and their impact on *E.coli*; ii) colour and orientation of the roof in regards to existing vegetation exposure. The following variables were used to generate such model:

- *E. coli* concentration was calculated as an average for each community. However, the model can be tailored to one specific household if need to be.
- Explanatory variables:

- Cumulative precipitation over the past 7 days. This was found to best represent the large inflow of *E. coli* being mobilised at the start of a rainfall event.
- Average daily temperature in the days preceding the rainfall event. This was established through sensitivity analysis at each site and was found to vary by between 2 and 5 days
- A temperature threshold that characterised roof tank water. This parameter represents the exposure of the roof and tank to direct sunlight, the colour of the tank, the material of the tank and other system characteristics.

The statistical model built for each community takes the following form:

$$[E - coli] = \alpha \sum_{i=-7}^{i=0} P_i + \beta(Avg\ T + \Delta T)^{\gamma}$$

Where [*E-coli*] represents the concentration of *E-coli*, P the cumulative precipitation over the previous 7 days, Avg T is the average temperature preceding the rainfall event, and ΔT the temperature threshold representative of each water tank. Each model was calibrated on the average *E. coli* concentration of the day using Microsoft excel solver minimising the Mean Average Error (MAE) and the Root Mean Square Error (RMSE representing the variance of the *E. coli* simulations)

Climate change simulations

Climate data are generated from a suite of Regional Climate Model (RCM) simulations with sea surface forcing taken from Global Climate Models (GCMs). These coupled climate models are driven by natural climate forcing such as solar irradiance and historical and modelled anthropogenic forcing driven by emissions of greenhouse gases and aerosols, based on 4 Representative Concentration Pathways (RCPs), but are otherwise free-running in that they are not constrained by historical climate observations applying data assimilation. As part of the fifth IPCC assessment report (AR5) (IPCC 2014), NIWA assessed up to 41 GCMs from the AR5 model archive for their suitability for the New Zealand region. Validation of those GCMs was carried out through comparison with large scale climatic and circulation characteristics across 62 metrics (Ministry for the Environment 2016). This analysis provided a performance-based ranking based on New Zealand's historical climate. The GCMs were then used by NIWA to drive statistically based regional climate simulations for performing change impact assessments across New Zealand. The six best performing independent models, where projections across all four RCPs were available (van Vuuren et al. 2011), were selected for dynamical downscaling; that is, sea surface temperatures and sea ice concentrations from the six models are used to drive an atmosphere-only global circulation model, which in turn drives a higher resolution RCM for New Zealand. The output data fields are bias-corrected relative to a 1980-1999 climatology and subsequently further downscaled to an approximate 5 km grid (Sood 2014). The resulting 24 RCM output (bias-corrected and downscaled to 5 km) are then provided as input to subsequent analysis over the period 1971-2100.

The climate change fields (precipitation and temperature projections) for total daily precipitation and average daily temperature were extracted from national scale simulations

(MfE, 2016) at the location of the closest VCSN point. Local climate change projections were then bias corrected using the local vs regional corrections factor established previously.

Roof water supply and *E. coli* modelling

A literature review of the estimation of roof water supply was carried out and the roof water supply model was then developed to take into account climate change scenarios. The model was developed on the following assumptions:

- Water usage established per person (200L/day- LEARNZ http://www.learnz.org.nz/water172/bg-standard-f/water-use). This requirement and use is assumed not to change under climate change.
- An average monthly occupancy rate is provided under 3 climate time slices: i) current (1986-2005); ii) mid-century (2046-2065, called 2050s) and end of century (2080-2099, called 2090s)
- An average roof area used for the collection of the rainwater. This area could be conceptualised as the area of a roof for a single household or an average roof area for a community, or roof of the Marae.
- A first flush rain system is implemented as diversion. This first flush is expressed in term of mm of water per event and can be converted from the roof capture surface area (usually estimated to be 1 or 5mm per event).
- Roof evaporation is calculated based on tank evaporation formulation (https://www.finishing.com/174/85.shtml). This formulation is dependant only on temperature.
- Roof water runoff is defined as the daily precipitation less the daily roof evaporation and the first flush diversion.
- Water year- are calculated from 1 April to 31 March in order to take into account potential summer drought.
- Roof water availability is defined as the difference between cumulative need and cumulative roof runoff received at monthly time step.
- *E. coli* concentration in water tanks is calculated at each community based on the statistical model (established previously) and depending only on climate variables.

Decision Support tool

The information outlined above was then collated and summarised within an aid-to-decision tool that facilitated choice among options, was built on Microsoft excel. This tool contains three suites of tabs:

- Climate change tabs, which summarise the regional climate change information from across all RCMs and all RCPs over the period 1971-2005 (hindcast) and 2006-2099 (future).
- Scaling tabs, which enable users to i) identify which precipitation and temperature monthly bias correction to apply; ii) identify the first flush threshold to test; and iii) the parameters of the *E. coli* model.

- Scenario tabs, which enable users to specify the daily water use per person, the monthly occupancy rate, collection roof area and associated graphical outputs expressed as average roof water availability (per roof area) and average *E. coli* concentration in water tanks (compared to World Health Organisation standard). This average is calculated across the 6 RCMs for each RCPs and time slice considered.

The resulting aid-to-decision tool is available to the end-user and community with minimal training requirements.

Existing climate and water databases, records and relevant reports of relevance to the Te Hiku communities were reviewed by Christian. He identified the locations of the existing information available within NIWA Climate database. Summary maps showing the community locations and GPS coordinate for each weather recording station were provided. Climate change time series are currently extracted for each location, model (Global Circulation Model) and radiative forcing (named Representative Concentration Pathway- RCP).

Visits were organized with each of the community climate observers to check on the setting of the rainfall and temperature gauges. The site visits were useful to explain observed differences with the VCSN and to engage in discussion of issues specific to each community.

Water supply research design

Household survey

A household survey was developed to obtain information about household occupancy, water system infrastructure, and issues of concern about drinking water in each of the project locations. The questionnaires were administered by community researchers to 94 households (inhabited by 284 people) across the three communities.

Household water sampling for *E. coli*

A literature review was carried out on the microbial quality of roof water in New Zealand and overseas. From this it was apparent that microbial contamination of roof water supplies was common. Sources of contamination include leaves, animals, twigs etc. The impact of climate change on roof water was also reviewed worldwide. Consequences of which included less regular, but heavier rainfall events and increase in air temperature leading to an increase in the water temperature of roof water. While testing of the water samples for a range of microbial indicators and pathogens was desirable, given the geographic isolation this was not possible. It was decided to focus exclusively on *E. coli*, the most common problem as a sentinel species that is waterborne, widespread, mostly of faecal origin, pathogenic in humans, easy to test for and a useful indicator of the presence of other less common harmful microbes.

An alternative method involving the use of a citizen science technique was employed. A number of *E. coli* testing kits known as Compartment Bag Tests (CBT) and portable incubators were sourced for the project. The CB test involved adding the sampled water to the supplied 'compartment bag' then placing it for 24 hours at 37°C in the incubator provided. Any change in the sample colour to blue/green in the bag indicates *E. coli* presence and the level of contamination is given by colour match with the chart supplied. The use of the kits was demonstrated to the community and information on the importance of sanitary conditions while sampling. At different stages in the project duplicate samples were tested by both the community and an IANZ accredited laboratory. This showed good correlation between the two methods. More information about the CBT can be found at: https://www.aquagenx.com/ This is a potentially invaluable breakthrough that will be of great interest to many rural community settings where water testing presents significant logistical challenges. The process highlighted the usefulness of community being able to undertake their own preliminary test. This validated the value in continuous low-cost monitoring by the community to detect changes in the water quality of their supplies and will aid in identifying possible causes of this.

Initially water samples were taken from six households at each site and repeated three time (one week apart, 54 tests). Where high levels of *E. coli* were recorded, sampling was repeated. In addition, nine CBT samples from a further five homes were taken at Motukaraka.

Findings

Rainfall and temperature

Analysis of the daily data recorded at each site showed that there were some interesting divergences between manual and regional information from the VCSN. These differences, representing the effect of local topography, orientation, micro-climatology, were factored into the datasets used for the climate modelling that Christian had designed. What follows are brief descriptions of what we learned for each location and the NIWA projections for climate change in temperature and rainfall by the end of the century.

The community-based research was invaluable for highlighting interesting temperature and rainfall variations with Te Hiku as well as the divergence from the VCSN data. For example, the rainfall data show a difference of 600mm per annum between Te Kao and Pawarenga, while the temperature range shows the latter has a microclimate in that respect as well. The comparison of local data with VCSN data helped with the calculation of appropriate adjustments to the climate modelling data.

Analysis of the local climate change projection for precipitation and temperature (ie regional climate change projections bias corrected by local information) can be summarised as follow:

- At Te Kao, temperatures are expected to increase by 1 degree by mid-century and 3 degrees by end of the century for the most extreme RCP scenario. It is important to note that change expected under RCP2.6 (i.e. scenario meeting the Paris agreement on CO_2 emissions), change in temperature will be felt in the second part of the year. Annual precipitation volumes are expected to remain constant by mid-century and end of century, except for RCP4.5 (business as usual) for which an increase precipitation deficit is expected from June to November.

- Pawarenga is expected to exhibit the same behaviour as Te Kao for temperature and annual precipitation volume. It is important to note that precipitation volumes are expected to increase from January to July under RCP2.6
- Motukaraka is expected to follow the same patterns as per Pawarenga.

Consequently, climate change impact on roof water supply (under an assumption of a 1mm first flush diversion and assuming roof area is 100m^2) is expected to be as follow for each community in comparison with current situation:

- Te Kao: Roof water supply is expected for all RCPs by mid-century to remain stable from April to August, with a slightly increased deficit from September to February, and increased availability in March. A similar behaviour is expected across RCMs by the end of the century with larger deficit (up to 13%) from September to February. In order to meet current consumption demand and to limit the period with water supply deficit (across future climate conditions), roof capture area will need to increase by 80%
- Parawenga: By mid-century roof water supply is expected to remain stable to current level across all RCPs. By the end of century, roof water supply collected is expected to be less than current condition from October to February across all RCPs. This deficit is expected to increase with the radiative emission. From a water supply point of view, roof capture area does not need to increase to meet current consumption demand and to limit period with water supply deficit.
- Motukaraka: By mid-century roof water supply is expected to remain stable to current level across all RCPs (in annual term) and characterised by a slight deficit (from current conditions) from August to February. The same trend is expected for the end of century with a larger deficit experienced over the same time period. In order to meet current consumption demand and to limit period with water supply deficit, roof capture area will need to increase by 100%.

It is important to note that despite the prediction that annual average precipitation volume might remain similar, patterns are expected to be different (mid-summer increase is likely across RCPs).

The climate projections based on scenario modelling within this project, suggest that temperature could increase by up to 5-6 degrees across the rohe over the next hundred years. This work also predicts that while rainfall volumes may be similar, patterns may be different; precipitation overall will tend to decrease, except that in mid-summer it is likely to increase. By the end of century, the most extreme scenario suggests an increase in the annual volume of roof-available water of up to 20%.

Water quality and microbes

The relationship between the concentration of *E. coli* and potential pathogens present was explored. *E. coli* is the bacteria of choice when determining the safety for consumption of drinking water. *E. coli* is used as it is present in high concentrations in multiple environmental sources such as human and animal faeces. The presence of *E. coli* indicates the potential for pathogens such as *Campylobacter* to be present. It is the pathogens which cause illness in the population, not the indicator bacteria *E. coli.* But, due to the high cost to test a water sample for pathogens such as *Campylobacter* ($350), water is routinely tested for the indicator bacteria *E. coli* ($25).

At Motukaraka levels above recommended guidelines of > 10 *E. coli*/100ml were revealed; 16 of 53 samples with more than 10 *E. coli*/100ml and 4 out of 53 samples with greater than 100 *E. coli*/100 ml. At Te Kao and Pawarenga the measurements show *E. coli* levels between 1 and 6 organisms/100ml.

Together the survey and *E. coli* monitoring studies converge with the climate change findings to signal increased risk of contamination going forward. Weather pattern changes (higher average air temperatures combined with decreasing general rainfall) may mean more microbes in tank water creating a potential health risk depending on their source. The source of the microbes determines the human health risk posed by the bacteria. The potential risks to water supply from *E. coli* presence were raised with the community, including gastroenteritis, vomiting, diarrhoea and in rare occasion's hospitalisation and death.

Climate change impact in *E. coli*

Using the aid-to-decision tool it is possible to run several scenarios coupling the effect of climate change on water supply and the expected impact on *E. coli*. For the sake of simplicity in our report to the community, the following scenario was run as an illustration of the information generated and the resulting community discussion. In that scenario the following assumptions were made:

- The average number of people occupying each household per month is set to an average of 3.
- The number of people per household remain the same under climate change.
- First-flush diversion of 1mm per rainfall event is in place. This threshold is independent of the roof surface area, but can easily be converted to an equivalent volume per event.
- Water for human consumption is set at 250L/day per person.
- No change is expected in the distribution of sources of *E. coli* (i.e. birds, possums, rats) with climate change.

Consequently, climate change impact on *E. coli* in water supply (using an assumed 1mm first flush diversion) is expected to be as follow for each community in comparison with current situation:

- For all three communities, *E. coli* concentration in roof water tank is expected to increase with climate change across time and radiative emission scenarios. This increase is expected to be between 200 and 300%.

Given low levels of *E. coli* at Te Kao and Pawarenga these predictions still leave contamination at 'acceptably' low levels. At Motukaraka, particularly for the homes where contamination levels are already showing high readings, the predictions suggest the need for system upgrades that reduce current levels of contamination.

Seasonal patterns are expected to reflect current seasonal pattern with a large increase in *E. coli* in summer months (reflecting current sampling strategy).

Household water infrastructure survey

The community household surveys provided useful quantitative data relating to drinking water supply and storage. Collation of the surveys across the three communities revealed that roof water was supplemented by puna and commercially purchased drinking water by many households. That there was no certainty around a sustainable supply of drinking water was of concern to many. Outstanding maintenance of water supply infrastructure was a major issue across the three communities; cost and access was cited as the main problem for these rurally isolated communities. A significant amount of infrastructure needed urgent repair or even replacement (tanks, roofs, guttering, pipes), and there was also a need for additional water storage.

Contamination of roof water supplies from road dust, pine plantations pollen and debris, pest fouling (possums, rodents, birds), agricultural fertilizer, pesticide and weed control sprays, and the 1080 drop in one community was raised often. In some instances, water was described as discoloured, smelly, or muddy during particular climatic conditions or weather events.

Responses demonstrated the resourcefulness of people who had made the best of what they had – people who never ran out of water because they managed their supply so well despite droughts, installing small additional tanks for gardens and implementing grey water use for gardens. Whanau conserved and managed their supply well, and about half were boiling or filtering their drinking water as a precaution.

Community experiences of climate change

The following section provides some insight into the experiences and knowledge of local kaumatua who shared their stories for the project. They had lived on the land in these communities most of their lives; one for 94 years and had never lived anywhere else. They had always observed and lived by the weather and acknowledged the vital connection between it and the environment whether it be in regard to farming, gardens, orchards or fishing. They were acutely aware of weather patterns and their impact on water; that seasons were very indistinct and unpredictable now compared to what they grew up with, that lifestyles and livelihoods would be influenced by the availability of a sustainable supply in the future. None were fazed by the impact of climate change – they had grown up valuing water, they had the necessary knowledge and life skills to adapt to changing situations and realities as required. This stemmed from lifetime of working with the weather and looking after the resources available to them.

Water was viewed holistically. It was a taonga "*Water was a commodity that was precious and it still is precious.*" Although the climate change project was focused on household drinking water it could not be viewed in isolation; it was part of the environment, the land, the people and had whakapapa to Rangi and Papa. Water was the basis for land-use decisions (farming, gardens, orchards), and lifestyles revolved around water, both fresh and salt-water.

Changing weather patterns and seasons

The biggest change Kaumātua had seen was that the seasons were now unpredictable and no longer distinct. "*Clear seasons - summer is summer, winter is winter, then autumn, like that. But not now … it's all over the place.*

> *At one time, you could say okay, winter starts in June and finish in September. Nowadays it's totally different. You can have wintery days in November.*
>
> *You can have a very, heavy frost now and [then it] rains directly afterwards … that is unusual from the time when I was small.*

Stronger winds than usual were observed by a 94 year-old at the property he had lived on all his life: "*I think last year we had the strongest winds we've ever seen here. Yes, the tide came right up over the flats …*

Flooding events had become random, rather than the usual winter:

> *"The winter floods we had was quite normal. We [now] can have floods anytime and big floods. So, that is a dramatic change. … we got done in 1986 with Cyclone Bola … again 14-years later in 1999. So, it isn't a cycle that you can say it's a 100-year event it's now anytime event. … must have some effect of climate change.*

Species indicating change

Fisher people were acutely aware of change and were concerned about the impact for whanau who rely on the sea to feed their families. Seasons determined local kaitiakitanga practices and harvest times; environmental indicators guided them ".. *they all had their seasons … Everything has it's time."*

> *… there's time for fish, there was time for oysters, time for mussels. And it never altered until recently. I realised about two years ago things are changing. Things [plants] are blooming out of season.*
>
> *Fishing is all out of kilter. Mullet never came till winter and now you've got mullet coming any old, time sort of thing. It's really changed.*

White-baiters had noticed seasonal changes affecting the cycle for that species. The season that used to be June and July in one community, now seemed to be late August/September. Siltation caused by run-off from significant storms and landslides were seen to be contributing factors.

The timing of gardening and farming routines had also changed and this was beginning to impact on the ability of whanau to be self-sufficient.

> *We were self-sufficient ... in a way that you could bring up a big family on ten acres. … now, from July to late October, November, the ground's saturated. One time we could make our gardens, we would start ploughing our gardens and everything in July, August just to turn it over. We would*

> *consider June, July, August, those are winter months. September, October we'd be planting. Not very often you can get into your garden these days in October.*

Increasing and different pest species

The current climatic conditions had seen an increase in new pest species (flora and fauna) and diseases. A sea shrimp for example was thriving in one area and reducing the usual fish catch.

> *… once upon a time you could just … rush down and spear half a dozen great, big flounders … Now you could walk the whole beach and lucky if you get one or two. It's got a mantis shrimp. It eats into the wee flounder, about the size of your finger. They never used to be around before. Just [noticed in] the last four or five years they've been in the harbour. When we were kids we used to see these little, wee flounders in the rock pools by the water. … now you never see one.*

The storage-life of vegetables such as potato and kumara crops which need dry summer conditions leading up to harvest had also changed. "*… they don't last. You can't store them like how we, I'm certain of that. It is most definitely the weather has affected."*

Catchments and siltation

The nature of local water catchments was identified as having a major influence of both water supply and quality. Water that came from large mountain and native bush catchment areas provided a level of security "*I get mine from the mountain and that water supply will always be there. That never runs out, no, no, never runs out."*

Unseasonal weather, particularly torrential rain, was blamed for siltation that impacted on the rivers, harbours and the sea of the three communities.

> *So, our riverbeds have risen dramatically because of the debris that comes down through the hills and has built up silt terribly in our inlet for a start. … the seabed's risen dramatically. The reason I can say this is that … 1987 I think it was or 1986, when we started canoe paddling, we used to hold [waka] regattas in Pawarenga and from about 1991 onwards we had to change our training area to Lake Ngātu because of the seabed and where we actually used to practise had risen that much, it got too shallow. … you've got 23 kms of siltation coming through and it all ends up at our backdoor.*

Water sources and storage

Kaumātua recalled a sustainable system of water supply from various sources. Water was drawn from puna (natural wells) for specific purposes such as the cowshed, household, and gardens). "*… the puna was always there for drinking. … we had other puna for our cowshed. We had wells here and there that you could go too.*

Maintenance of household water supply infrastructure was not a priority for some households that were struggling to survive in the low socio-economic conditions. It tended to be in response to a crisis situation rather than as a preventative measure. The increasing impact of climate change on existing poor infrastructure servicing small isolated rural communities was also highlighted and had huge implications when trying to encourage whanau to return home to live.

> *… you must remember too, the damage the climate has on our infrastructure, the roads … Slips … I have never seen places just to fall away as much as I've seen in the last few years, that's been there [stable] for years.*

Working with the weather, finding solutions

While climate change and the part that people had played in it were acknowledged, kaumātua had grown up working with the natural environment and had local knowledge/matauranga to guide and prepare for any adaptations required. Kaumātua saw climate change as natures response to man-made change and therefore had an obligation to work with it – tiakina te taiao, tiakina te iwi - caring for the environment so that it can care for the people. Water was regarded as a finite resource that must be looked after. "*… I'm saying nature's a great leveller when you think about the change. … I can always get another one [feed], but … not to water."*

Looking after the land did pose some challenges for communities trying to encourage whanau to return 'home' They would need employment and as land was the main resource in these communities it was important to ensure that any activity would enhance the environment and mitigate climate change. One suggested that for their community it was about nurturing the environment in its natural state.

> *… I think if we left all the land in its natural state and worked within the environment of trying to grow a few things or do a few things that don't damage the land, yeah. I think that's the key factor.*
>
> *… all our lives we've been chopping tea-tree, now it is precious. … we've got to educate our young people … But because of climate change and past [practices], [we need to] do what we can do best with what can get out of the land without disturbing it.*
>
> *Kaumātua made the connection between climate change and detrimental land-use practices of the past. They were confident that they had the knowledge to work with the changing climate patterns; they were resourceful people and had always valued water. They would be looking to local puna for supply, drawing on the understandings passed down to them about the way in which their catchments worked, and maintaining rangatiratanga over the land.*
>
> *… we've got a huge catchment, we don't have to have rain here and yet we can have a flood … I think we're blessed myself. But if there was any development [we] should actually determine that. ... that's how I feel and I promote that. ... that would be a priority ... having control. We know where all our puna are. We know where all our water supply is. … if we can control our own destiny in terms of how slow we move or how fast we move, we're okay.*

Other outputs

Several areas were identified as the basis for ongoing community action. They included: strategies to overcome barriers to household water systems maintenance, improved water storage to provide capacity during drought periods, practical ways to ensure safe drinking water, investigating puna and other community water sources to meet some water needs.

The communities, all in close proximity to the sea, were very concerned about sea-level rise and the need to take a holistic approach to climate change that included all possible impacts on the community. At one Marae adjoining a harbour foreshore, the sea had already breached the grounds putting the sewerage system at risk and the long-term viability of the marae site. Another had built a retaining wall 12 years ago to stop the marae atea eroding further into the harbour.

Communities demonstrated that they have their own processes and systems to respond and cope with situations. They are resourceful and well used to developing solutions to suit their needs. The project has added a range of relevant networks and support for communities to access.

GIS maps

As we refined the research design it was realised that with just three sampling locations spread over some 100km north to south that there would be insufficient data continuity to meaningfully map measurements of temperature and precipitation on GIS. It is possible that appropriate quantification could be developed from the VRSN but that would be a NIWA project beyond what was proposed for the current project and would require a further tranch of funding to support community temperature and precipitation measurements as well as the location adjusted modelling. If such a project were to be considered and perhaps it should be given the differences between manual and automated data seen in the current work then adding in further locations (eg Mitimiti, Broadwood, Panguru, Kohukohu, Awanui, Te Hapua) would enhance what could be learned.

Dissemination

Two papers based on the project have been prepared:

- Temperature, Precipitation and Microorganisms; the importance of local data for drinking water quality in remote Maori communities, will be submitted to either EcoHealth or AlterNative.

- Field trial of Compartment Bag Test for *E. coli* in drinking water in remote Maori communities, will be submitted to MAI Journal.

A Summary report of the project has been compiled for distribution to communities.

The planned 'community open-day' was not held. Such an event was difficult for our small communities to schedule within the full calendar of local activities and commitments, and we were confident that the involvement of local Community Researchers had provided ongoing opportunities to learn about the project.

Conclusion

With more knowledge and networks with other agencies and community groups, communities were now confident to champion their local climate change issues. The project supported communities to consider and explore issues of climate change to prepare for community specific impacts. This included understanding local water supply systems, the pressures and threats and drew on mātauranga Māori and kaitiakitanga practices, and knowledge of local weather patterns in thinking about how best to manage drinking water and prepare for climate change impacts.

The *E. coli* Compartment Bag Test that was trialled throughout the project proved to be an efficient and practical method for remote communities to identify very quickly and economically, if water was safe to drink. The user-friendly CBT equipment will enable local whanau to continue their monitoring programme and to take control of any suspected unsafe drinking water as required. When in doubt the key message was to boil water before consumption to remove all bacteria.

A number of practical tips, strategies and innovations were shared about minimising water contamination including the placement of septic tanks, protecting water sources, the need for possum and rat trapping programmes. Also stressed were the importance of regular ongoing repairs and maintenance, upgrading of pipes as required and de-sludging tanks. First flush diverters, UV treatment, and filters were seen as solutions to improving water quality in some situations. Communities were acutely aware of the need to store more water and this as well as the need for infrastructure upgrades at a number of households all involve cost. This is an area that needs to be explored further with government agencies and iwi.

The awareness raised through the project has included an interest by Iwi to raise community climate change concerns at a national iwi level, and to access related information held by local authorities so that a regional coordinated approach can be taken. The project is now in communication with the Far North District Council regarding local data and climate change strategies in the region. There are opportunities to share data and see how best communities can be supported to prepare and mitigate for the impacts of climate change throughout Te Hiku. Project presentations and Vision Matauranga news and reports have sparked interest in this project from other small rural communities also.

Change was not seen as something new in Te Hiku; the people are resourceful and had always worked with the weather.