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Knowledge Exchange Programme of
Ngā Pae o te Māramatanga
New Zealand's Māori Centre of Research Excellence

www.maramatanga.co.nz

Contact Details
Waipapa Marae Complex
16 Wynyard Street
Private Bag 92019
The University of Auckland
New Zealand

info@maramatanga.co.nz

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Cover design by Len Hetet (Ocean 64 Ltd)

Editorial Team
Joseph Te Rito, Susan Healy, Lee Ann Thomas, Margaret Wilkie (transcription)

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Te Ara Pūtaiao: Māori Insights in Science

A monograph produced in the Tihei Oreore Series

This monograph is a compilation of papers presented by four Māori scientists as part of the Ngā Pae o te Māramatanga Policy Seminar Series, 3–4 November 2005, Wellington, New Zealand. The seminar was convened by Ngā Pae o te Māramatanga/New Zealand's Māori Centre of Research Excellence. The papers were edited and prepared for publication in 2007–2008.

Academic Convenor of the Policy Seminar Series
Professor L. T. Smith

Seminar Organiser
Knowledge Exchange Programme Leader
Dr J. S. Te Rito

Co-Editors
Dr J. S. Te Rito & Dr S. M. Healy

Ngā Pae o te Māramatanga

Ngā Pae o te Māramatanga is one of seven Centres of Research Excellence that were funded by the New Zealand Government in 2002. It was established as The National Institute of Research Excellence for Māori Development and Advancement and has recently been renamed as New Zealand's Māori Centre of Research Excellence. The Centre is hosted by The University of Auckland. Its participating entities are spread throughout New Zealand. The Centre offers three distinct but intersecting programmes: Research, Capability Building and Knowledge Exchange.

Whakataukī (Proverb)

Ko te pae tawhiti arumia kia tata	Seek to bring the distant horizon nearer
Ko te pae tata whakamaua	Grasp it firmly once near
Kia puta i te wheiao ki te ao mārama	And so emerge from darkness into enlightenment

Joint Directors

Professor Michael Walker

Dr Tracey McIntosh

Explanation of Series Title 'Tihei Oreore'

The title 'Tihei Oreore' signifies the heralding of the awakening of indigenous peoples. The monograph series provides a forum for the publication of some of the research and writings of indigenous peoples.

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Foreword

Professor Linda Tuhiwai Smith

This monograph of papers by four Māori scientists brings together three elements that are not commonly associated with one other: Māori, insight and science. And yet it is important for the future of Māori and all in Aotearoa/New Zealand that these links are made – and strongly. Through these papers are shown Māori who are committed to their people, to science and to the environment which sustains us all.

Today's Māori come from communities who traditionally were close observers of the natural world and who had an intimate knowledge of the ecological systems they lived in. The European immigrants who arrived some hundreds of years later than the Māori were able to introduce plants and animals from temperate regions that flourished in the New Zealand land and climate. By contrast, Māori had tropical plants available for introduction, most of which could not survive or survived only with great difficulty in New Zealand. Māori introduced the dog and rat but appear not to have attempted to introduce either the chicken or the pig, which were present in tropical Polynesia at the time of settlement. As a consequence, Māori had to be adaptable and innovative in their use and management of a wide range of native plants and animals and in their adaptation to the physical terrain and climate. These qualities of observation and innovation can be seen in the work carried out by the four scientists who regard themselves as inheritors of a unique tradition and with responsibilities to future generations.

A characteristic each of these scientists brings to their work is a questioning stance to conventional scientific views and practice. In varying ways they stand as outsiders to the mainstream and this they attribute to their Māori identity. Having confidence in the uniqueness of insight that this distinctive position allows is not always easy but their combined efforts highlight the potential for future contributions by Māori to science – locally, nationally and internationally.

Introduction

Joseph Te Rito & Susan Healy

This monograph is a compilation of four papers presented by Māori scientists at Turnbull House, Wellington, in November 2005. The papers were delivered as part of the Ngā Pae o Te Māramatanga Policy Seminar Series ‘Progressing Māori Development through Research’. Each of the scientists – namely James Ātaria, Elizabeth McKinley, Michael Walker and Shane Wright – has carried out pioneering work in her or his field and contributed to wider Māori enterprise and development. The papers give an overview of their research and address issues such as being a Māori scientist, doing scientific research, barriers to Māori in science and science education and the development of policy to overcome barriers and promote Māori involvement in science.

The work of these scientists has been supported by Ngā Pae o Te Māramatanga/New Zealand’s Māori Centre of Research Excellence. When opening the seminar series Professor Linda Smith, as Joint Director, outlined the context in which the Centre works. Over the last few years Ngā Pae o Te Māramatanga has been funding a wide range of research led by Māori that addresses a number of interdisciplinary issues and questions. An important consideration for the Centre and its researchers is the environment Māori research has to work through in order to make a difference for Māori and their communities. This concern is reflected in the papers presented by the scientists.

Professor Smith gave the following reasons for the Policy Seminar Series. In the main policy today uses an evidence-based approach. Until recently there was little evidence in the Māori area that explained and gave validity to what Māori were actually saying in the community or what they were experiencing. Ngā Pae o Te Māramatanga’s unique contribution, with the potential to make a huge difference, is the building of a body of scholarship and research that attempts to provide that evidence. While recognising that research has significant policy implications the Centre has found that researchers do not necessarily understand policy and the way policy makers’ minds think and that policy people do not necessarily understand researchers and their way of thinking. They are not trained in the same way. The *kaupapa* (agenda) of the Policy Seminar Series is to provide a forum for interaction between researchers and policy makers – through the presentation of some concrete research that the group can then dialogue about.

The papers in this book are presentations of recent research by the four scientists. They contain an interesting mix of personal reflection, detail concerning the research they have carried out and insight into policy that could lead to the involvement and advancement of Māori in science and environmental management.

The first paper is one on environmental research by Doctor James Ātaria, an environmental toxicologist. It opens with a summary of two research projects that James has headed. Both are investigations into situations where environmental issues are of immediate concern to local Māori communities. The body of the paper looks in detail at the second project which is centred on the Ahuriri/Napier estuary. Entitled ‘He Moemoeā mō Ahuriri: A Vision Plan and Health Assessment for the Ahuriri Estuary’ the study incorporates both a biophysical enquiry and cultural research. James details how he went about this complex project and the challenges that he faced. These challenges included the practical research, building relationships with the *tangata whenua* (people of the land) and other parties with interests in the estuary, the fostering of communication between these different groups, support for policy that takes into account *tangata whenua* and their concerns and the setting in place of mechanisms so the project would be of ongoing benefit for the people of the area. This paper shows how a Māori scientist has worked in a demanding situation in ways that hold together his integrity as a scientist, his

inherent skills in relationship-building and his concerns for the development and advancement of his people.

Professor Elizabeth McKinley's paper is entitled 'Māori in Science and Mathematics Education'. Elizabeth has made a significant contribution to science education in this country and her research has focused on Māori in science. She sees the involvement of Māori in science as vital to the wellbeing of Māori and the whole country. In this paper she gives feedback on two research projects that have been funded by Ngā Pae o Te Māramatanga. The first project looked at Māori knowledge, language and participation in secondary school science and mathematics education. The findings from the project are important because as Elizabeth points out little has been done to identify Māori involvement in and responses to science education. Elizabeth's second project called 'Science, Mātauranga Māori and Schools' was based on the questions: Can collaborative partnerships between science and *iwi/hapū* (tribe/clan) inform school science? And if so, in what ways? This research was seen as opening up possibilities for a positive engagement between Māori and science educators and as a counter to the negative stereotyping of Māori in much science education. Elizabeth's paper concludes with recommendations regarding policy and future research priorities.

In his paper Professor Michael Walker reflects on the significance of identity to the Māori scientist and shares understandings gained from his own scientific research. He also considers some of the obstacles to Māori participation in science and outlines measures for the advancing of Māori involvement in and contribution to science. His observations are usefully illustrated with practical examples from his experience. For many years Michael has worked to increase the participation of Māori and Pacific people in all aspects of science and has helped lead initiatives to improve their recruitment and retention as students in the sciences at university level. Some of these initiatives are outlined in his paper. Besides this Michael is an outstanding academic, being one of the world's leading scientists in the study of 'magnetoreception', the magnetic sense in animals. It is particularly interesting to read in his paper how he traces the connections between his success as a scientist and the fact that as a Māori he brings to his research a uniqueness of approach and 'a different set of operating assumptions'.

Doctor Shane Wright is another Māori scientist who is making a significant contribution at an international level. Working as a biologist he has carried out groundbreaking research leading to a rethinking of some long held assumptions about evolution. His paper is called 'Energy and Evolution' and traces the development of his research over twenty years, with emphasis on his more recent research. This account gives insight into Shane's work in tropical and temperate forests, his formulation of theory to explain what he has found and the development of experimental design to test the theory – all placed in the context of the experimentation and theory of others in the field. It is a fascinating story, not only of an academic journey but of a personal one as well. In a similar way to Michael Walker Shane believes that his Māori identity has kept him open to different ways of approaching the questions and issues of his discipline.

Glossary

kaupapa	fundamental principles; plan; agenda
hapū	clan; group of families
iwi	tribe; federation of clans
tangata whenua	people of the land; those who hold the authority of the land in an area

Editors' Notes

Initially the papers in this monograph were oral presentations. The presentations were tape-recorded and later transcribed. More recently the transcribed texts have been edited for publication. The conversational style of the original presentations has largely been retained in the published papers.

In this publication the convention in regard to the Māori language is that Māori words are italicised. This practice does not apply to proper nouns or names of organisations. When a Māori word is used for the first time within a paper its English translation follows directly after it in brackets. This translation appears again in the Glossary of Māori words at the end of the paper.

The macron symbol, a dash placed above vowels, is used to indicate a double-length vowel sound. These macrons are provided to assist the reader to pronounce Māori words correctly and to avoid ambiguity, for example, to distinguish between *mana* (authority) and *māna* (for him/her). We have chosen not to adopt the practice of inserting two vowels used by some Māori writers for these same purposes, that is, we would use *māna* rather than *maana*.

In terms of the English language the conventions of New Zealand based upon British English have been the preference. A particular feature is the use of the letter 's' rather than 'z' in such words as 'emphasise'. Another is the use of '-our' rather than '-or' at the end of words like 'favour'.

PowerPoint slides were used by each of the authors in their oral presentations. The information from the slides is included in the text as Figures. These Figures are based on the original slides.

CHAPTER ONE

Environmental Research

James Ātaria

Doctor James Ātaria (Rongomaiwahine, Ngāti Kahungunu, Ngāti Tūwharetoa) has a doctorate in environmental toxicology from Lincoln University and is currently a researcher in the Pest Control and Wildlife Toxicology Team at Manaaki Whenua (Landcare Research). He specialises in mechanisms of chemical toxicity in vertebrate wildlife species and the development and implementation of biochemical and physiological processes as tools for assessing chemical impacts on wildlife. James is also involved in initiatives to increase Māori capability in environmental research.

Doctor Ātaria was presented with the Te Tohu Pūtaiao Toiora award for biological sciences at the inaugural Te Amorangi Māori Academic Excellence Awards in Hamilton in 2002. In 2005 he was appointed to Ngā Kaihautū Tikanga Taiao, the Māori advisory group to the Environmental Risk Management Authority of New Zealand (ERMA).

Doctor Ātaria has spearheaded two projects in association with Ngā Pae o te Māramatanga. These environmental research projects have been carried out in close liaison with local Māori communities.

The following is an edited transcription of the seminar delivered by James Ātaria. The Figures are based on the PowerPoint slides he used.

Introduction

Current Ngā Pae o Te Māramatanga Projects

- Ko te Huarahi ki Mua: Roads for Change
- He Moemoeā mō Ahuriri: A Vision Plan and Health Assessment for the Ahuriri Estuary

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Figure 1. Current Ngā Pae o te Māramatanga projects

I have two research projects going with Ngā Pae o te Māramatanga. The first project is ‘Ko te Huarahi ki Mua: Roads for Change’ and involves working with Awataha Marae on the North Shore in Auckland. Essentially it is a biophysical enquiry looking at two streams, the road runoff and the impact of the runoff on the streams. The second is ‘He Moemoeā mō Ahuriri: A Vision Plan and Health Assessment for the Ahuriri Estuary’. I will be saying more about what is encapsulated in that title.

The roading project on the North Shore is a 19 month project and the first objective is a literature review looking at the issue of roading runoff and at ways that you can mediate and mitigate road runoff. The second major objective is a biophysical look at chemical contaminant impacts and the third is a cultural objective, looking at some of the views and values of the people at Awataha Marae as well as the *tangata whenua* (people of the land). Because Awataha Marae is a *Ngā Hau e Whā* or urban marae it has its own set of values and there are also the *tangata whenua* values overlaid on that. It is actually a very interesting site. The principal partnerships we have got going there are obviously Awataha Marae; Bill Kapea (Ngāti Whātua) who also has his own consultancy; Fletcher Construction; and Transit New Zealand who are not really partners and who have been difficult to work with.

‘He Moemoeā mō Ahuriri’ is a two year project and follows a similar pattern: literature review, a biophysical component and a planning document. Out of this we want to develop a way forward, and that is very much rooted with the *tangata whenua* there. Te Whanganui-ā-Orotū is commonly called the Napier Estuary. The major partners are: Te Taiwhenua o te Whanganui-ā-Orotū which is one of the governance bodies set up by Ngāti Kahungunu and so has a *rohe* (territory) associated with it, inclusive of which is Te Whanganui-ā-Orotū; the Mauri Protection Agency which is essentially a ‘one man band’, Morry Black, who has been integral in that work; and also SCION (New Zealand Forest Research Institute Limited) who are helping us with some of the analysis.

He Moemoeā mō Ahuriri

Today we are going to focus on ‘He Moemoeā mō Ahuriri’.

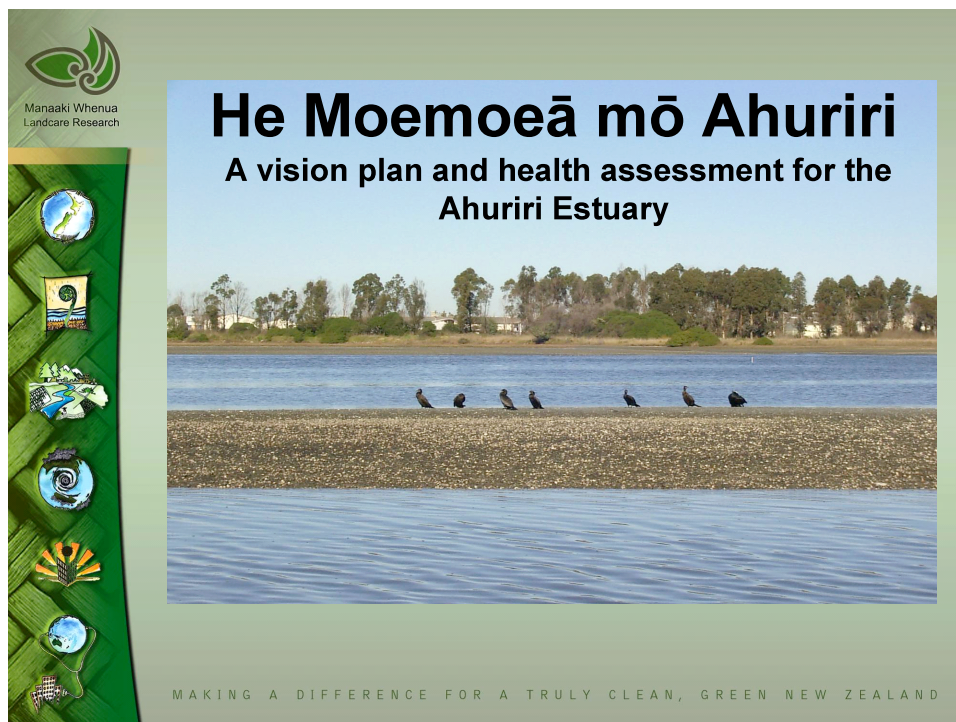


Figure 2. He Moemoeā mō Ahuriri

The Ahuriri Estuary/Te Whanganui-ā-Orotū



Figure 3. The Ahuriri Estuary/Te Whanganui-ā-Orotū and Napier City

Prior to the 1931 Napier earthquake the highlighted area was largely covered with water. The earthquake was an upheaval of three metres and as a result a lot of land came up. In fact, there was a story that was relayed to me of an old *kuia* (older woman) who was adamant that ‘Tangaroa [God of the seas] is coming back to claim his place’. This is consistent with scientific evidence which indicates that the predominant movement of land in this area is in a downward direction. The upheaval was actually something unusual. The old *kuia* has got something; that is, if you buy a house in Napier make sure it is on a hill.

Important in all this work is finding something that is relevant; certainly the context within this area is very interesting. We are taking this four-sided approach.

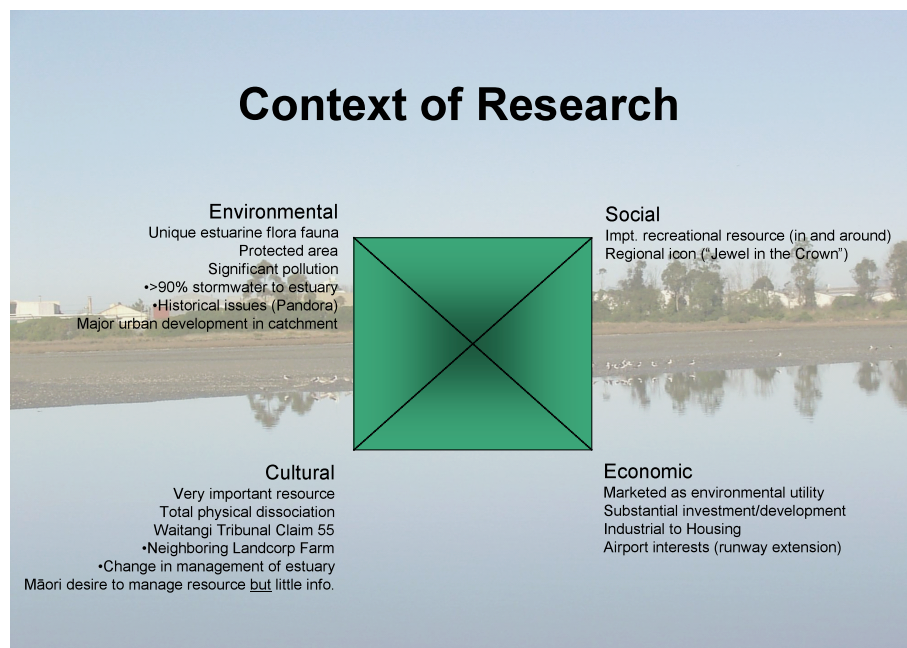


Figure 4. Context of research

We are looking at the Environment with its unique estuarine flora and fauna, animals and plant life. The Department of Conservation has a protected area or reserve in there; however, there is significant pollution going on. I have just been talking to the Napier City Council and they have confirmed that more than 90% of the storm water is going into the estuary. There are also historical issues around the estuary. All of this is an industrial estate. In the past they have had three tanneries that have emitted some very nasty things. Presently there is a galvanising plant and fertiliser storage units. Essentially there is still predominantly industrial activity going on in this area although the land-use is changing. Certainly from an environmental point of view or perspective there are lots of chemical issues there.

There is also major urban development around the estuary. Most of the land use has been farming; they grazed cows and sheep but now it is beginning to change; there are a lot of new subdivisions happening around the estuary. It is very interesting from an urbanisation perspective. Essentially the estuary is receiving all of these different impacts, so creation of this research was quite timely in terms of coming up with some sort of management document.

Culturally, *kai* (food) is obviously a very important resource to the *tangata whenua* and in the past a major *kāpata kai* (food cupboard), *mahinga kai* (food resource) area. However, interestingly enough, the *tangata whenua* have discouraged their own tribal members from harvesting shellfish from the estuary; they established a *rāhui* (prohibition) quite a few years ago now, so there is a total physical dissociation. You can actually feel the *aroha* in the mind of the people because they love this area but they tell their own people not to go there and harvest. Why? Because of the chemicals.

Politically, the Waitangi Tribunal Claim Wai 55 covers the whole area where the airport is and the neighbouring Landcorp Farm. It is our understanding that the *tangata whenua* are negotiating with the government to have those resources returned and also to have a greater role in the management of the estuary itself. It is one of those interesting situations where you have got one authority managing this area, another authority managing the piece above the bridge and then another managing yet another piece. What is likely to happen is that there will be a change in the management of the estuary towards a more co-management arrangement with the *tangata whenua*. Along with the desire 'to get everything back' is an acknowledgement by the *tangata whenua* that they have a lack of information that will assist them to manage and make decisions for the estuary. They say, 'We are really keen to get it back but when we get it back, what information do we have to help manage it?' They want to harvest *kai moana* (sea food) there but they just do not have any information about the safety of eating *kai* from the estuary. Certainly from a cultural point of view they want this research done for their own information.

The estuary is a very important recreational resource – the 'jewel in the crown' of Hawke's Bay as it has been called. It is a regional icon.

Economically, as I mentioned before, there are all these different activities going on around the estuary, putting a lot of pressure on the estuary itself. It is an interesting resource because generally not a lot is known about the estuary compared to some of the estuaries in Auckland where there are volumes of scientific data about particular resources. Here there is not too much. Yet, there is quite a lot of activity. Shown in Figure 4 is a picture of the Pandora Estate and a big waterway that drains this area.

All of this is starting to change. The developers are building new apartments, a change in land use that is fuelled by economic opportunities and the marketing of the estuary as an environmental utility. Generally the developers know little about the state of this utility which is interesting. Also there is the other new development that is going on. The airport wants to extend to have an international facility, so potentially there will be further pressure on the estuary.

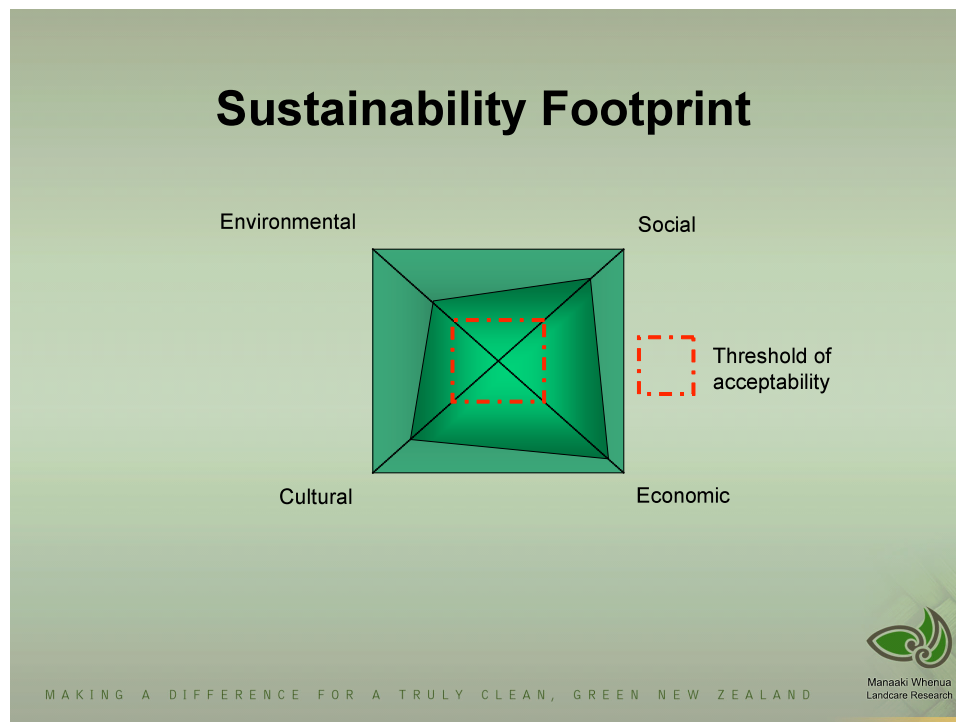


Figure 5. Sustainability footprint

If we look back at some of the issues there is a quadruple bottom line, essentially a sustainability footprint associated with that resource. We can argue that the lines along some of these axes are above the acceptability threshold that many groups and organisations have. It is the desire of the Taiwhenua o Te Whanganui-ā-Orotū (the local tribal authority) to reduce that footprint to an acceptable level. It is only through research that we are able to get a gauge on a) where the threshold is because everyone has a different threshold and b) the state of the Estuary, how healthy is it. Certainly, environmentally, as toxicologists we have a good understanding of where the footprint lies on this axis. That is the sort of vision Taiwhenua has as well.

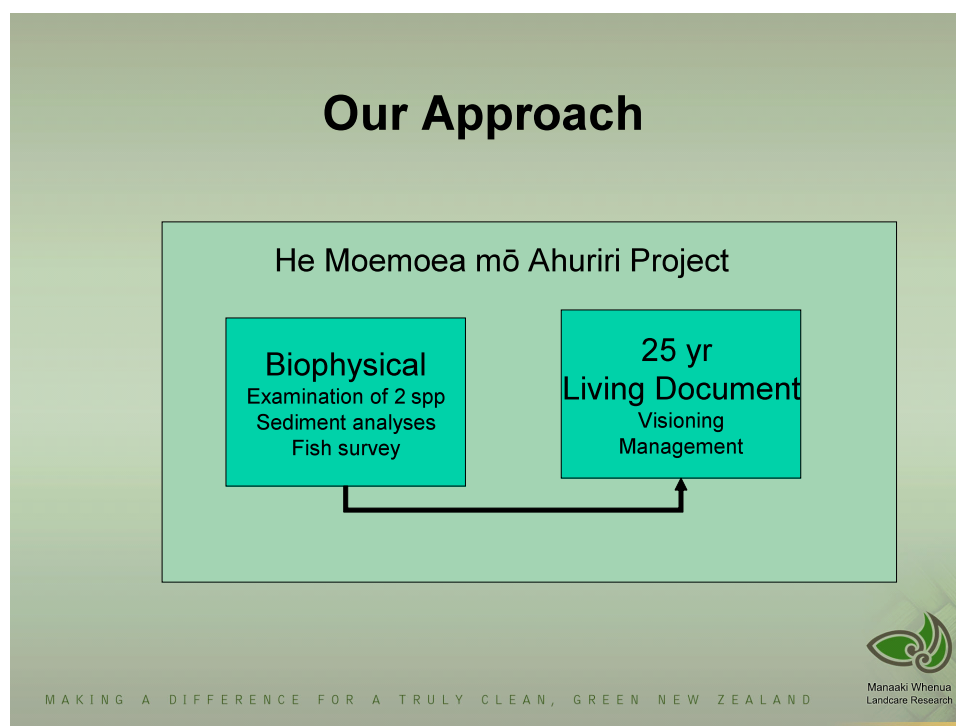


Figure 6. Our approach

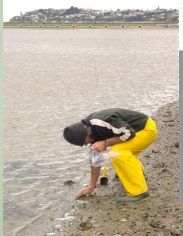


In the project itself there are three objectives; but the goal is really a two-pronged approach. One is a biophysical approach, so we are using some of our analyses at work and also a fish survey looking at two species. The species were not randomly chosen; they were identified from a criterion that we developed. The two species selected were the ones that appeared most when talking with *kaumātua* (elders) and local people including fishermen. What are the main fish species in the estuary? Flounder and cockles were the two most often mentioned. There were others; the *whetiko* or mud snail was also ranked.

Also, looking at sediment analyses, the sediment in the Ahuriri estuary is quite unique because it is a very shallow estuary; you have contaminants binding closely to sediment since they associate with small particles. When there is runoff or chemicals coming from the stormwater, the sediment in there or from the estuary binds to it. Because the estuary is so shallow you do not get a tidal influence where the sediment is drawn in and out with the tide; instead the sediment settles in the estuary. In this situation the sediment can tell us a thousand words. If you examine the sediment you can be provided with a lot of good information because of the nature of the estuary.


We are also looking to do a fish survey as a part of the biophysical work and that aligns with finding out what is in there now. There was a large survey done in the 1970s which was quite in depth. We are not looking to repeat that; our work is lot smaller but we want to provide an update on what is in there now.

The second thing is an important detail related to the direction of the arrow in Figure 6. Rather than the biophysical work determining where the cultural research fits in it is the other way round; we are looking to feed the information from the biophysical work into the cultural research. In this way we are looking to feed this information into the development of a 25 Year Living Document. And it is the Taiwhenua who want to produce this as a document. We are trying to create a balanced view through this process, not only that of the Taiwhenua. While it is rooted in the concerns and the values of *tangata whenua* we are looking to branch out and interview and talk with the Hawke’s Bay Regional Council, the Napier City Council, the Department of Conservation and other end users associated with the estuary.

**The Research Project: Part II
Biophysical Research-Contamination**

<p>sediment</p>  <p>Residues (metals, organics) copepod toxicity</p>	<p>pātikitōtara yellowbelly flounder <i>Rhombosolea leporina</i></p>  <p>Tissue residue levels (metals) Measure overall and reproductive fitness Measure several biomarkers</p>	<p>tuangi common cockle <i>Chione stutchburyi</i></p>  <p>Tissue residue levels (metals)</p>
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**Figure 7. The research project: Part II
Biophysical Research – Contamination**

The yellow-belly flounder (*pātiki*), the *tuangi* (cockle) and the sediment samples are a focus for the biophysical research. With the sediment, for example, we are looking at doing a suite of metal analyses and also looking at a range of organic contaminants. We have a student in Auckland who is going to investigate the toxicity of the sediments. She is developing a toxicity test in copepods which are little creepy crawlies that live in the estuarine sediment and are distributed throughout New Zealand.

For the *pātiki* (flounder) we are looking at tissue residues and again metals because the *tangata whenua* had concerns about the metals in stormwater. We are also looking to measure some overall reproductive and general animal fitness type measurements – and they are quite easy to do – so developing a number of body indices which are a rule on a scale. They give out some good information. We are also looking to measure some biomarkers, that is, indicators. The indicators that we are using are biochemical markers. These are enzymes that are quite responsive to certain classes of chemicals. By using and measuring these we can actually get an indication of exposure to certain classes of compounds. We look to back that up with bile measurements. The bile contains a lot of breakdown products from the liver, which basically decontaminates everything. Many of the breakdown products, including the contaminants, end up in the bile. There is a simple test you can use to analyse those – a test for organic compounds.

With the *tuangi* (cockles), metals were again a major issue for *tangata whenua*; within the budget we can certainly look at that as well.

My co-worker, Morry Black, is shown in Figure 7. He has been essential for this project. One of the things I have found when you are doing things away from home it is really essential to have a person on the ground where you are doing the work. Morry is fulfilling that function very well; I acknowledge him for his great efforts.

The second part of that biophysical research is to carry out a fish audit.



Figure 8. The research project: Part II: Biophysical Research – Fish Audit

Essentially this consists of going out into the estuary and catching as much as we can; it is a capture and release type exercise so we are not killing them. We trialled the net shown in Figure 8. It looks like a monstrosity and it is; we did not catch a thing so I am not too sure what we are going to do about that. The theory was all there but maybe it was the actual practice that we did not go well with; it demonstrates that field work does not always go to plan. The other picture is of a gill net for catching the flounder.

The Research Project: Part III Visioning Document

- Interviews (aspirations for future management)
 - Elders Māori organisations
 - End-users other stakeholders to provide balanced document
- Science to input into this

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Figure 9. The research project: Part III: Visioning Document

The Visioning document, as I alluded to before, is deeply rooted with the Taiwhenua and *tangata whenua* and focuses on their aspirations for the future management of the estuary. A number of elders and Māori organisations have been approached; we have a list and we are identifying some key individuals to interview. As I mentioned I have been given a lesson in Project Politics 101 because I have been rapidly coming up to speed to find out how their aspirations can be taken into account by local policies and plans. I have been interviewing other non-Māori end-users to provide a balanced document. Balance is important if all of the community is going to pick up and use this document. It is about providing a vehicle that they feel comfortable enough to come on board and they actually take over some of the ownership. It is all those sorts of things. As a scientist you have your lab bench and your test tubes, or I do anyway, so this is all new stuff to me; it is certainly a steep learning curve. This will be an integral part of this document. We are hoping that amongst the whole array of issues that will come out in this process science will feed into that issue of contamination which is a pretty big one for everyone concerned.

Project was launched with blessing



Figure 10. Project was launched with a blessing

So we started in June. There were two *kaumātua* (elders): Heitia Hihā whom many of you will know and Bevan Taylor. Also present was Tipu Tārehā; he is the Executive Officer of the Taiwhenua whom we are dealing with. This was amazing: we had a blessing early in the morning and the sun was up. Prior to the day I flew in I was told that the weather was terrible; it was stormy and they had had flooding for the previous week. When we arrived on a Sunday it was starting to clear up but there were still a lot of clouds in the sky and I thought that we might have to cancel the research planned for that week. However, organising for this field work is a bit of a logistical nightmare so we kept our fingers crossed that the weather was going to be good. Anyway, we got up in the morning and there was not a cloud in the sky; it was amazing; and these *kaumātua* were conducting their *karakia* (invocations). You can see the water is like a mirror. Whatever they said they got it right because we had beautiful weather that whole week and once our research finished the weather closed in again.

We started the work by looking at contamination. That involved collecting *tuangi* and *pātiki* from the estuary.



Figure 11. Biophysical research: contamination initiated

Shown in Figure 11 are some of the key players: Jenny Mauger; Louis Tremblay, a French-Canadian who the Taiwhenua have taken under their wing and classify as a pseudo-Māori; Mere Tīpene who is a secondary school student (later I will talk a little more about the relationship we fostered here); Tipu Tārehā; Morry Black; and the researcher from SCION who has gone back home to Canada.

Here are some of us in action doing the sampling:



Figure 12. Fish and cockle sampling

Figure 12 is included because I wanted to highlight the local enthusiasm for the project. The amount of support we have had has been phenomenal. We went down to Pōrangahau, our reference site. We had scanned up and down the coast for a reference estuary but it was hard to identify an appropriate site. However, Pōrangahau fitted most of the criteria so we went with that. We approached the Ngāti Kere Rohe Trust and got clearance at that level. We went to do some sampling at Pōrangahau. The floods I mentioned before had also affected this area. The slipway was mud and we could not get our boat in to the water – basically bringing our whole research to a grinding halt – but Mere’s father, Raymond Tipene, came to the rescue spurred on by the fact that his daughter was involved in this research. He used his 4 wheel drive vehicle to help us get the boat afloat. Things were also made difficult for us because of the very high and low Spring tides so it was getting late when we started sampling. As a result we were just going to do the sampling on the back of a truck. But Raymond kindly opened up his shed and we were in there until about 10.30 at night. The left-hand photograph in Figure 12 shows us at work in the shed. Raymond also fed us – it was amazing – and he wants us to go back. This is an example of the support that can happen when research projects engage appropriately with communities and people who are really keen on getting in and finding out more.

The right-hand photograph in Figure 12 shows us at work in Napier. Again we were originally going to do the sampling in the back of a truck but Hawke’s Bay Seafoods offered us the use of their seafood processing plant so we set up there. It was through people we knew who were really interested that much of our research was supported. In this instance there is a Māori connection. Ngāti Kahungunu connects into Hawke’s Bay Seafoods. People at the factory were keen to see what we were doing and what was being dissected out of the flounders – it was a great experience.

As part of my approach I have targeted policy-makers and, so, have drawn up predicted outcomes, both short-term and medium to long-term.

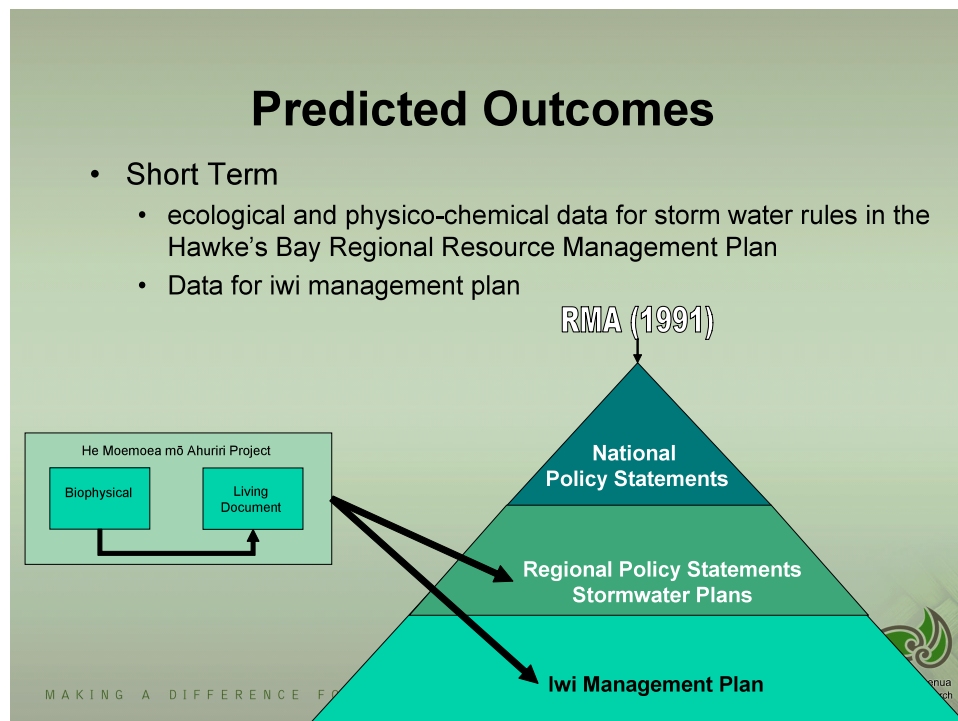


Figure 13. Predicted Outcomes: short-term

In the short-term there are the ecological and physico-chemical data for storm-water rules. Morry Black does a lot of work in the Hawke’s Bay area on resource management and he had negotiated with the Hawke’s Bay Regional Council in order to get some leeway in the

development of the proposed Hawke’s Bay Resource Management Act. This was so as to have in the plan that the Council would give effect to Māori values and their associations with the environment. In this case because it was the storm-water rules it was water-based, so that was Māori and water hand-in-hand really. That was one way in which we were going to try to get the information fed into the policy statement at this level. There is also another initiative that Taiwhenua wants to undertake and that is to develop an Iwi Management Plan. Taiwhenua is really keen to see what comes out of this. Also they see the things that come out of the Living Document as very much part of information for their Iwi Management Plan. These are two of the ways we see at the moment of getting this research to gain some traction rather than just sitting around as a report on someone’s bookshelf.

Predicted Outcomes

Med-Long Term

- Development of holistic management paradigm (WAI 55 sustainable development)
- Closer working relationships between iwi, regional district authorities and other organisations, particularly with respect to information to assist future development strategies for estuary
(This is already beginning to happen e.g. through bringing scattered data together)

*Manaaki Whenua Landcare Research
Making a Difference for a Truly Green New Zealand*

Figure 14. Predicted Outcomes: medium to long-term

The other medium to long-term impact of this research is the development of a holistic management paradigm. Again, the Waitangi Tribunal report Wai 055 is likely to have some management implications for the estuary and also for trying to get sustainable development established in this area. Another interesting observation with this applied research, we have found that when working with authorities and organisations people see research almost as an independent vehicle that they can readily climb on board – even when there are people or organisations involved with whom they might have had issues in the past. There is some antagonism on issues surrounding the Napier Estuary. We first went to the Taiwhenua and they were saying that they wanted to be able to ‘hit others over the head’ with our report. We said, ‘No, research is supposed to be objective and what the results show is what we get; if you can use it that’s fine’ – in other words, the whole idea of researchers not being on anyone’s side. ‘We certainly will not provide you with data that is angled towards anything’ – although the data is part of what they want, which is fine. Certainly, the chemical issue is a number one priority so we will use our tools to see what comes out of that. The whole thing is interesting because we have these different groups: City Council, Regional Council, Taiwhenua; they have their own relationships but this sort of research has been a way for people to come on board and start to get to know each other, so that has been quite interesting. It is a sort of ‘fuzzy’ outcome but I think it is an important step towards starting those linkages going. It is starting to happen.

I have data for the beginning of the literature review. Already, it is pulling together a lot of the literature. Some work that has been done on the estuary sits in people’s offices but is unknown to others. I went through finding out from people what had been done; that is part of the relationship

building. People have been saying to us, 'Oh, I've got a report from 1986. This might be useful for your work'. So that has been a really informative process.

This is an example of sediment quality surveys that have been done:



Figure 15. Sediment quality surveys

Here are water quality surveys:

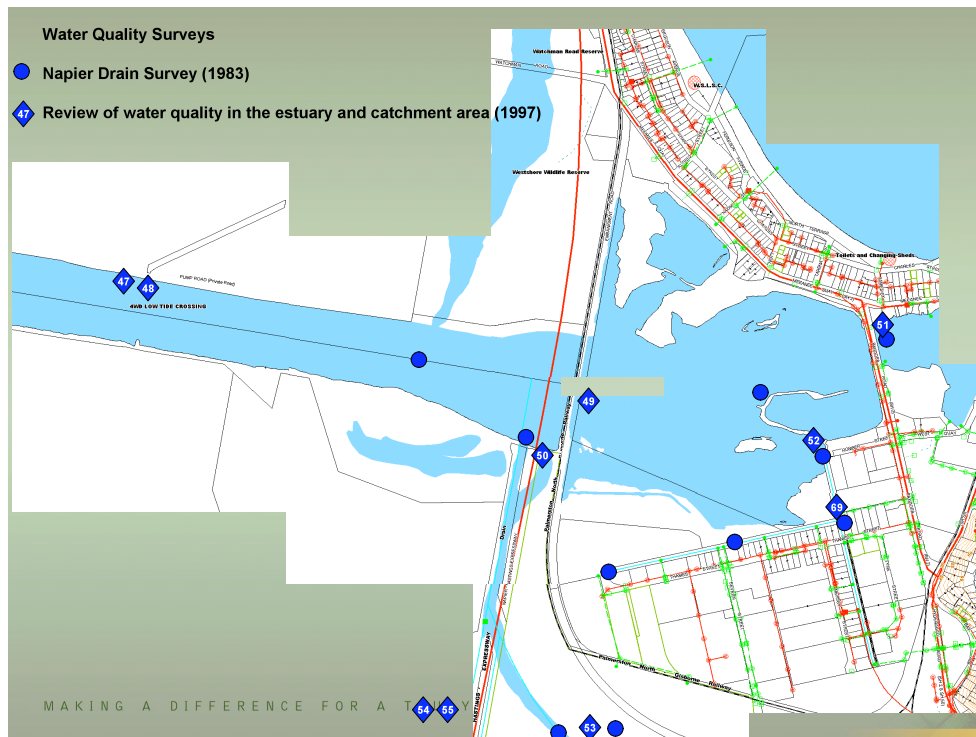


Figure 16. Water quality surveys

The Napier Harbourmaster provided the following about unauthorised discharges:

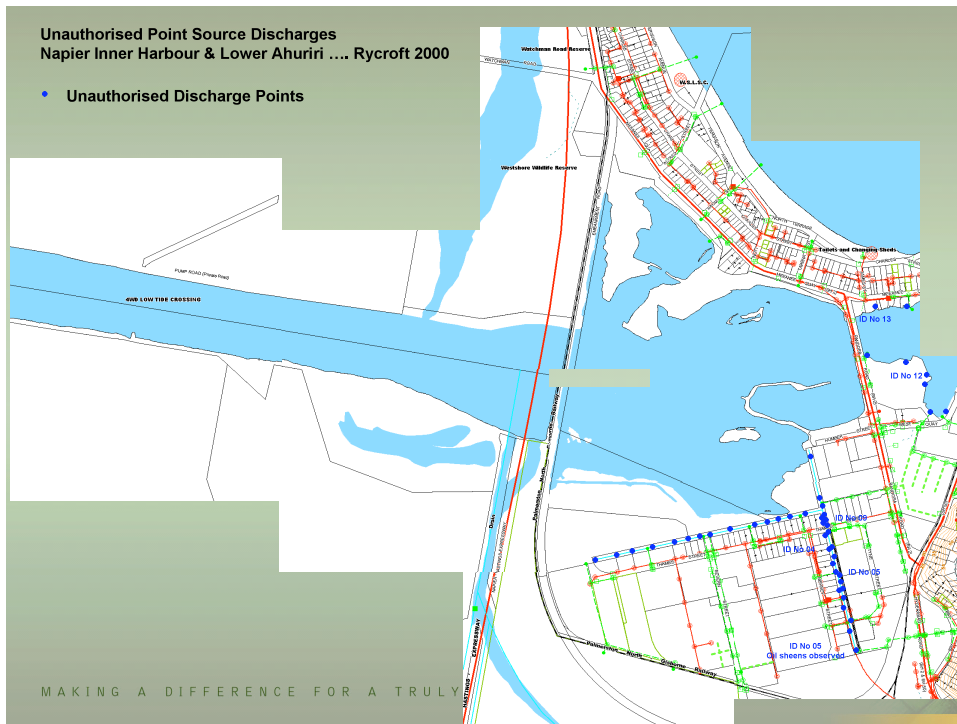
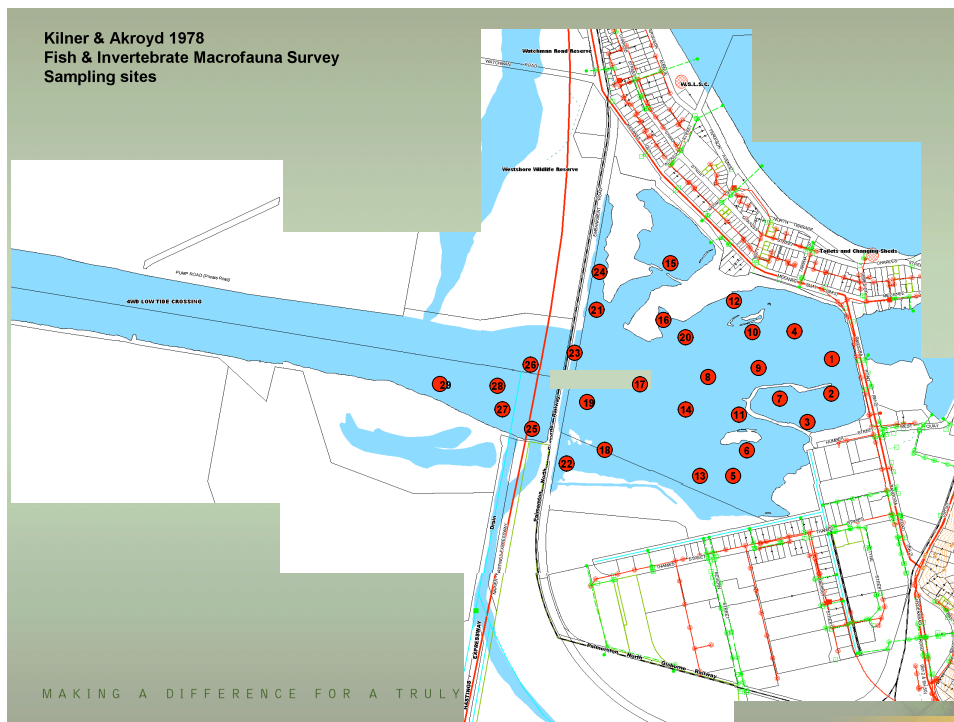


Figure 17. Unauthorised point source discharges

There is a large macrofauna and flora survey that was done. It was quite intensive.



**Figure 18. Kilner & Akroyd 1978
Fish & invertebrate macrofauna survey**

A more recent biological survey was done by bio-research consultants.

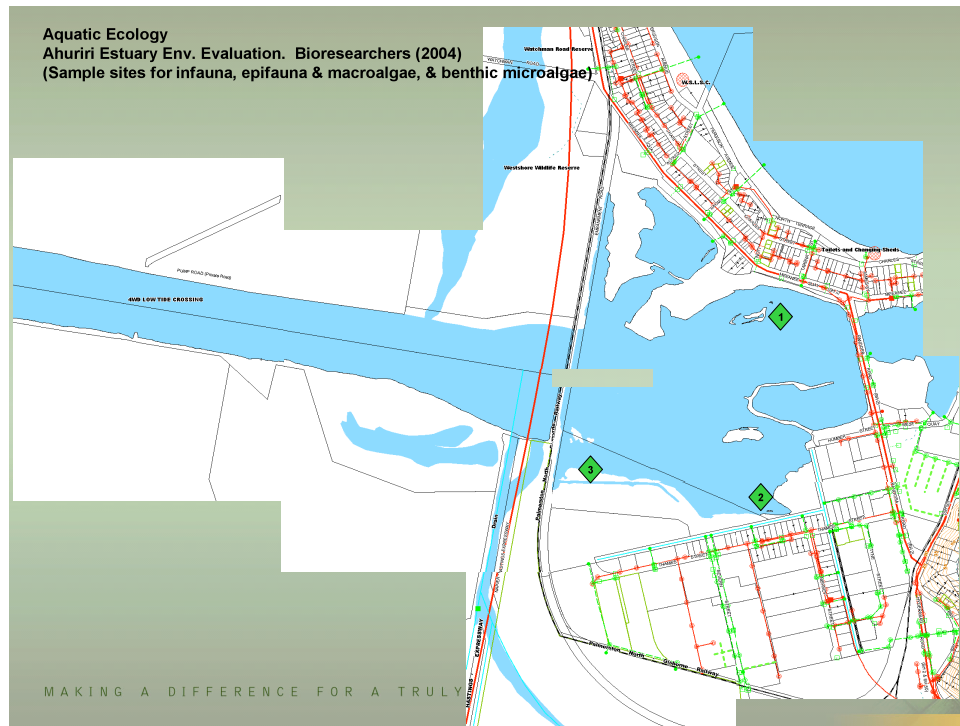


Figure 19. Aquatic ecology

And then there is the work we started to get into, which was looking at significantly important areas relating to *kai*; and certainly in the estuary itself there is the *whetiko*, the mud snail harvested from *mahinga kai* there. There is the *kohanga* or nursery for the *pātiki*; and there's a cockle *mahinga kai*. That area there is very famous for cockles. Incidentally Transit NZ just put their new back road right through the middle of the *mahinga kai*.

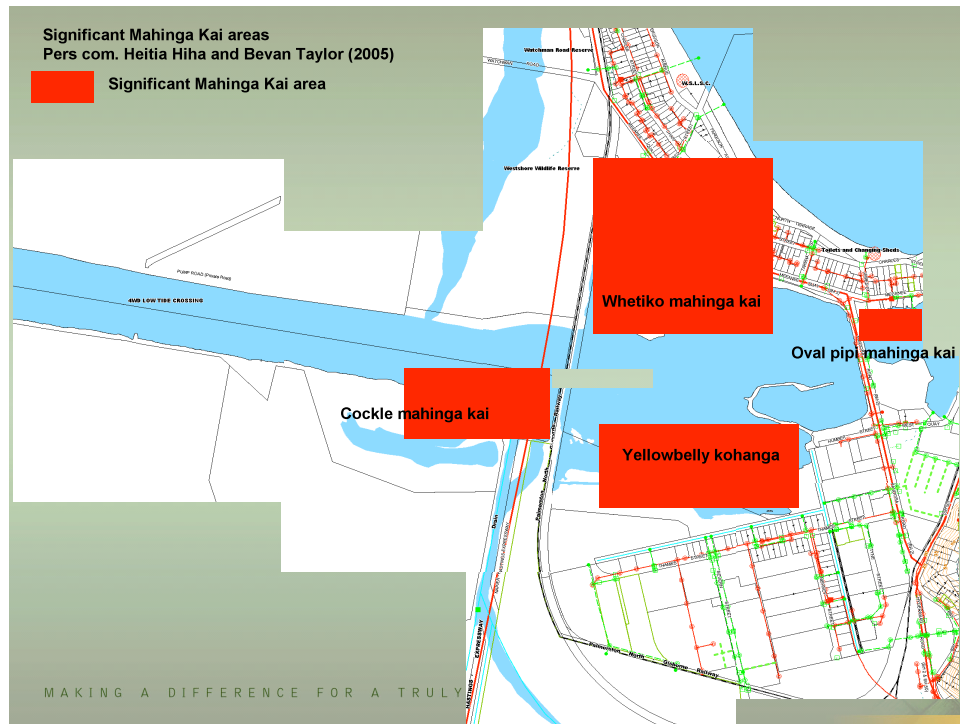


Figure 20. Significant mahinga kai areas

There is also the work that we did: sediment sampling, cockle sampling and where we set our nets.

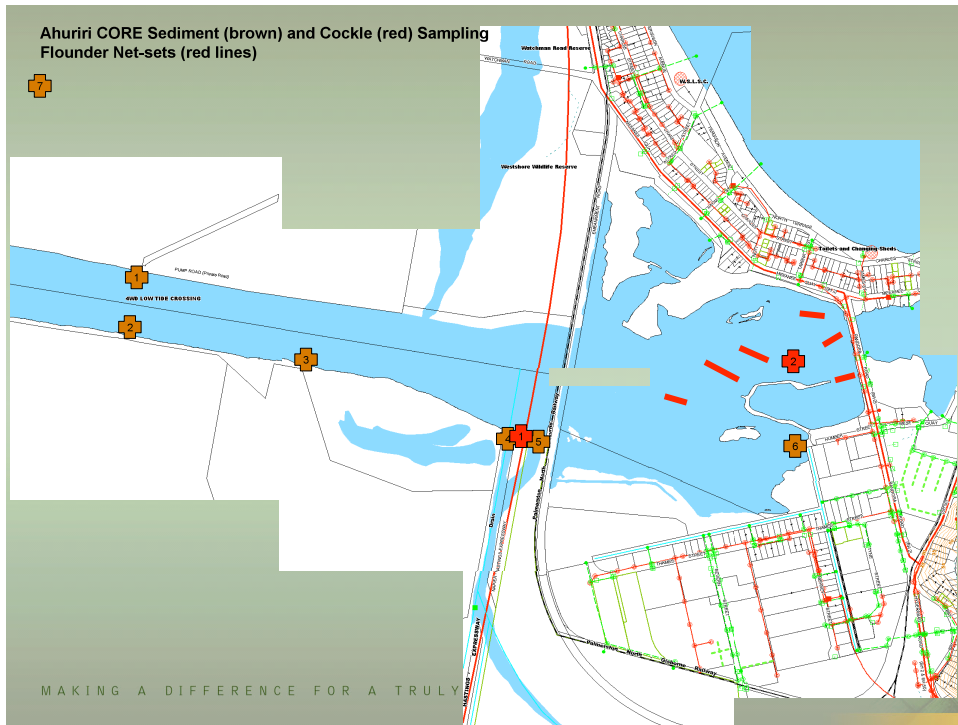


Figure 21. Ahuriri core sediment and cockle sampling net-sets

The whole idea was: How do we bring it all together? This diagram showing all the information combined is pretty rough but it gives a good idea that there is quite a bit of information available on the estuary.

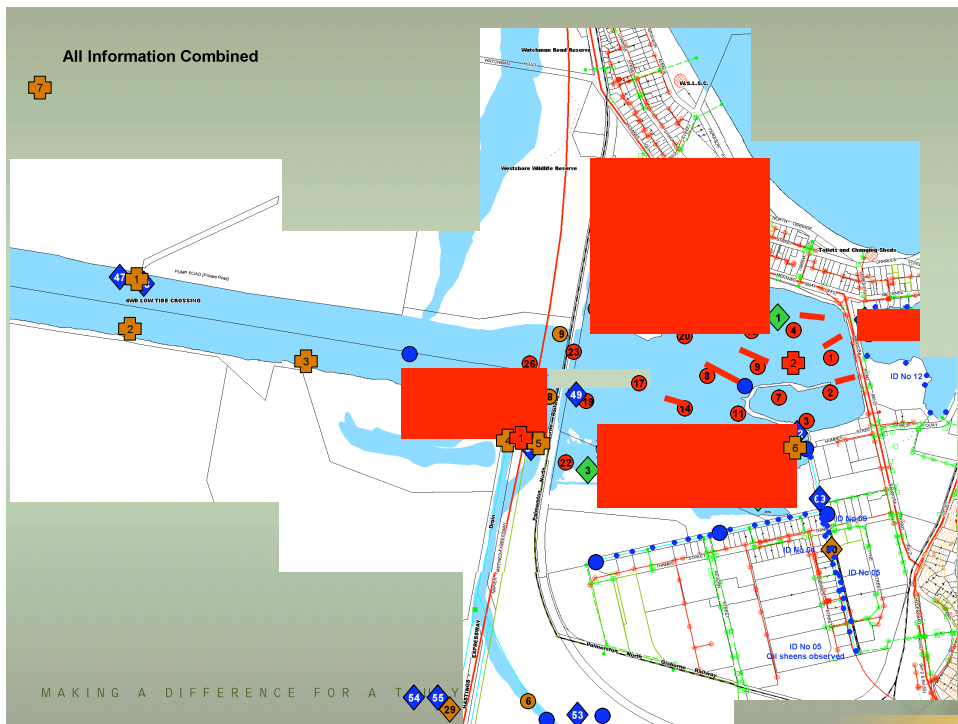


Figure 22. All information combined

So how do you bring all this information together in some sort of coherent fashion? All I have done is to represent these as layers on top of each other. But I have gone further: I have taken this – as part of the whole relationship building exercise – to the Napier City Council who hold and maintain the GIS (Geographical Information System) database system for the Hawke’s Bay region. I have asked them: a) Do you think bringing this information together is a good idea? and b) Is it possible that you can pick the idea up and run with it? I included the Hawke’s Bay Regional Council and DoC (Department of Conservation). Out of that came the acknowledgement that, yes, there is lots of data out there and a lot of data still being collected. So out of this a long and medium-term goal is to develop a database where historical data can go into it but also inform the core for all current monitoring that is going on so you can start to add more and more on to it. The advantage of GIS is that you can add different layers and can manipulate the data to show different aspects. They are just getting clearance from their bosses to go ahead with this. I have been surprised; there are a lot of reports out but it is the first time they have even considered bringing the information together or working with the Regional Council that holds a lot of environmental monitoring data. So that is a really important outcome, not only for those organisations but also for the *iwi* who are going through the process of marking *wāhi tapu* (sacred places) as well. That is not part of the project’s core work but it is one of those things that has evolved and could be quite useful.



Figure 23. Association with students

Just talking about making connections, there is the association with the students – highlighting some of the relationship-building that is taking place. Early on we wanted to get a post graduate student on this work but getting them is nearly impossible. So we thought outside the box and came up with the idea: Why not get a senior school student? Māori students have to go to school and some of them will be doing science. We approached Te Aute College and Hukarere but neither could help us at that time. So we tried Napier Girls’ High School and got a positive response from the teacher; she said, yes, we have a student who would be ideal for this’.

That is Merehera in the shadows, in the left-hand photograph above. Her father is the person in Pōrangahau who gave us the use of his shed to carry out our sampling in, so again there are lots of linkages. We set up the student association as part of the project and Merehera has been coming along and helping out. She has been great, first becoming involved in the project at a

time when we really needed it. All I said was, ‘There is a scalpel over there. Grab it. Put some gloves on and come over here, this is what we are taking out’. She just got to work and was great; she loved it. Her teacher (Anne Herbert) got back to us and said that the experience had had quite a profound influence on Merehera because her idea of what scientists do had been completely turned round. ‘Māori scientists as well,’ she said. Before that she had found it difficult to find a link between Māori and science. In talking with us she told us she now saw the link. It was awesome to hear that.

We have since been back at the school looking at developing a sort of ‘care for the estuary’, ‘adopt an estuary’ project. We went back and asked the teachers to look at that as part of their curriculum. There are a number of avenues we can go down. They had already been doing some thinking about it so they are quite keen to progress things so that the school and particularly the science students can be involved. What is more, Jenny Cracknell who is the head of Māori Studies at Napier Girls High School is keen to include Māori students – again because the estuary involves more than the monitoring, there are also the cultural values that go with it. There are a number of things coming to a head and now, hopefully, we are going to get the Hawke’s Bay Council to help them out as well, as they are keen to get involved. So you can see it is about forming relationships in this project; we are really hopeful that something will come out of that. The teenagers in the right-hand photograph in Figure 23 are from the Taiwhenua. They are exposing them to a lot of things; one of them was our research so they brought them down and we interacted with those teenagers as well.

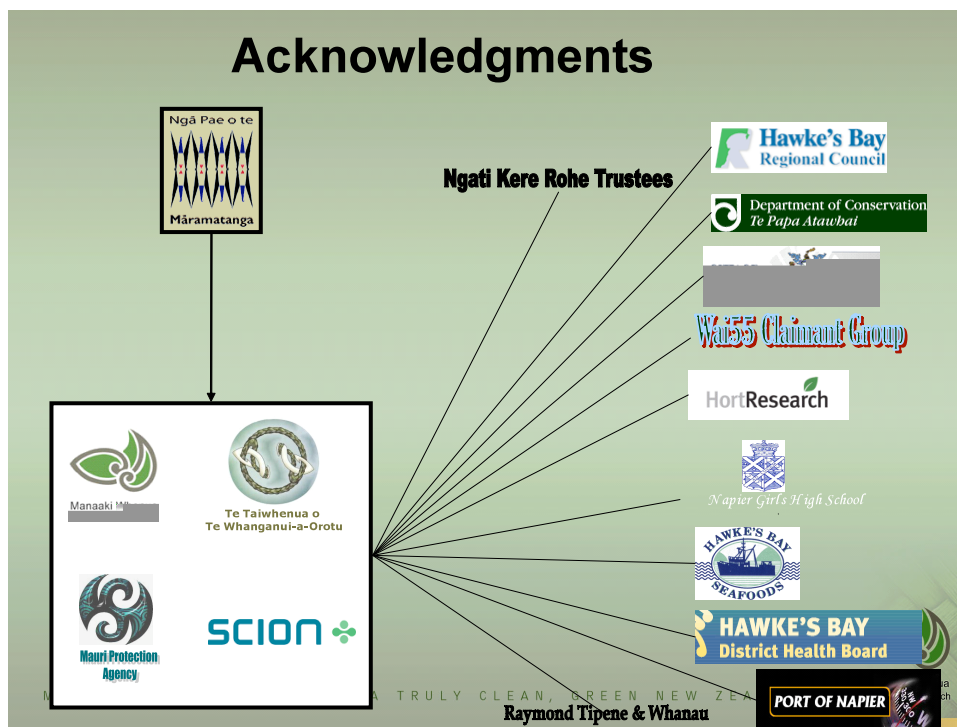


Figure 24. Acknowledgements

This Acknowledgements page serves to show the huge amount of support that has come to our project. The key programme is on the left; we have certainly got a load of encouragement for that. Also, things are starting to spin off out of there. Because the core project is only for two years we have tried to implement a few things that will continue on after we report. I think that is another way you can start to get things happening. Certainly a criticism that scientists face sometimes, particularly when doing applied research, is that you are there one day and gone the next. So we tried to get things going that may become self-fulfilling in the future; and, again, that is where the relationships come in.

Glossary

aroha	compassion; love; yearning
hapū	clan; group of families
iwi	tribe; federation of clans
kai	food
kai moana	sea food
kāpata kai	food cupboard
karakia	invocation; prayer
kaumātua	elders
kohanga	nursery
kuia	older woman
mana	authority; influence; dignity
mahinga kai	food resource
pā	occupation site
pātiki	flounder
pātikitōtara	yellow-belly flounder
rāhui	protection of a place or resources by forbidding access or harvest
rohe	territories of an iwi or hapū
tangata whenua	people of the land; those who hold mana whenua in an area
tikanga	customary; correct ways of doing things, protocols
tuangi	cockle
whānau	extended family group
whanga	bay
whetiko	mud snail

CHAPTER TWO

Māori in Science and Mathematics Education

Elizabeth McKinley

About the author

Associate Professor Elizabeth McKinley (Ngāti Kahungunu ki Wairarapa, Ngāi Tahu) taught science for 12 years in the greater Waikato area and held the position of Head of Science at Rotorua Girls' High School. She then joined the staff of Hamilton Teachers' College which later became the School of Education at Waikato University. While there she taught science education and foundation studies, did post graduate science and technology and mathematics work and was involved in the early national science curriculum developments. She co-directed the writing of the Pūtaiao documents with Pauline Waiti and contributed to the Māori medium document for schools as well as the English science documents. She had the benefit of being one of the few people in that development in the early 1990s who worked on both the Māori and English documents.

Associate Professor McKinley based her Masters thesis on the writing of the Pūtaiao curriculum document. Her doctoral thesis entitled 'Brown Bodies White Coats' is about the identity of Māori women scientists. This thesis investigated how stereotypical ideas regarding Māori and science have persisted across time – particularly the notions that Māori cannot do science and do not do science – and how these ideas become internalised for Māori. The research shows that the Māori women who have become research scientists have struggled to do so while still maintaining a sense of Māori identity. This research informs schools because many of these ideas continue to influence the teaching of Māori students in science and to affect their achievement.

Working as a science education specialist at The University of Auckland Associate Professor McKinley carried out two research projects for Ngā Pae o te Māramatanga. These look at what is happening for Māori in science education and the issues there for Māori.

The following is an edited transcription of the seminar delivered by Elizabeth McKinley. The information from the PowerPoint slides she used is shown in bold print and centred.

Introduction

My subject is Māori in science and mathematics education. In this presentation I will give an overview of what our research team has been doing in the two projects funded by Ngā Pae o te Māramatanga. I will also offer some ideas on what I think policy makers need to think about in this field.

Science does not stand out in terms of education generally and it does not stand out in terms of Māori education. Many Māori have found difficulty with science and dropped science subjects at Fourth Form level, Years 10 or 11; they are not very comfortable in doing science. It has been a field that has not been considered a priority. I am trying to convince you today that it should be a priority. I know that there are so many issues that beg for our attention and real crisis issues but I suggest to you that this is going to be a crisis issue in the near future. It is going to be a crisis issue for the whole country if we cannot get Māori students interested in this field in a big way.

In giving this presentation I will refer to some quotes from the research with the students.

**I don't think there is anything wrong with *my* science except
my science teacher.**

Year 10 Student

**They think that we're dumb ... they think that Māori people
do not have the same understanding for things.**

Year 10 student

The students interviewed spoke about their teachers more than any other aspect and this was particularly true for the younger children. Russell Bishop's initial research shows this quite well: that the students are very focused on themselves and how they get on depends a good deal on whether they like their teacher or not. This happens especially with the younger students. The older students start to talk more about the quality of teaching. Somehow the students make a transition between Years 9–10 and Years 12–13. When the older students talk about teaching it is still about how they get on with their teachers but they are also looking at how they can have an effect on their own learning. They realise they have a large degree of control over their own learning and learn what they can do themselves.

When we spoke to the teachers about their learning with Māori students in their classrooms they focused on pedagogy. While they talked a little about relationships they focused more on pedagogy, learning styles, context and what they try to do in their classrooms. They also focused on student under-achievement and student backgrounds – so the deficit issue is still evident, which is demonstrated by the second quote. The students know how their teachers see them; they pick it up really easily.

In Aotearoa we have had the Learning in Science Project (LISP) for science education. It was started in the 1980s. It was one of the most sustained pieces of research that was ever funded in this country but at no stage did the researchers include ethnicity or see the science learning of Māori students as an issue. The research involved 12–15 years of study over a number of projects funded together but Māori were never considered as a focus in any way. While the research contributed a lot to our understanding about interactive teaching and the generative teaching approach as outlined in their publications, it did not contribute much to our understanding about Māori students and their engagement with science education. If you talk to the researchers you find they were interested in trying to get the students closer to a scientific understanding. This is fine in some ways but they always dumped those students' answers that they could not understand (and these may have been 'cultural answers') because they could not perceive them as being on a shift towards a scientific understanding of a scientific phenomenon. So if they had students talking about anything cultural they cut it out and put it into the 'anomalies basket'. For the researchers that was not an issue. Unless they could fit the students' observations onto a continuum about how they thought children should understand a particular phenomenon the observations just got cut out.

We have really no research on whether teachers can combine their pedagogical knowledge and their subject knowledge in culturally relevant ways. While we have research on pedagogical knowledge in science we have not got any research into subject pedagogy or subject content knowledge in science in terms of cultural understandings. So the projects I am talking about today are like diving into a policy vacuum in terms of pedagogy. I want to talk about the two projects carried out for Ngā Pae o te Māramatanga. The first one, funded for the 2003–2004 period, has been completed and there is still quite a bit of publishing to come from it. I then thought about exploring an area that looked at contemporary contexts for science, so we did a side project which was a development from the first one.

The types of projects we are doing fit into a general aim that keeps in mind Mason Durie's ideas. That aim is to find answers to the question of what it means: to live as Māori, to participate as citizens of the world, to enjoy good health and a high standard of living? Within that context this is what we are looking at:

What constitutes effective mathematics and science curricula (including knowledge, language and pedagogy) for improving the educational achievement of Māori students at secondary school?

The students are very well aware of the challenge to be involved as citizens of the world. In the words of one of the Year 12 students, 'Māori need to learn these two areas because they are worldwide known. What Māori have to do to prepare themselves is for the future ... although it's good to hold on to our tikanga and everything you have, to add other things onto'.

Science and mathematics appear to be a-cultural. In many ways we have come to believe that. Our teachers believe it. Because there are laws of physics, et cetera, which we regard as being trans-national and trans-cultural we tend to see the whole field of science like that. The students are well aware of how science and maths travel with them and that they can take these things further afield and speak the same language somewhere else. In our research project we found good recognition, especially from our Kura Kaupapa Māori (Māori total immersion schools) students, about the notion of going out as global citizens.

Project 1: 'Māori Knowledge, Language and Participation'

Our research 'Māori knowledge, language and participation (MKLP)' was an exploratory scoping project. We looked at literature reviews, statistics and the Numeracy Project analysis. We also gathered a lot of interview data. We included four schools and tried to get another one involved. Despite the fact that science does not have a high profile, there were debates amongst the Kura Kaupapa Māori community about science and what language should be used at the senior level. So in the end we got three state schools and one Kura Kaupapa Māori. We also talked with the staff from one Iwi Education Project who were very interested in our research; this was Tūwharetoa who have 23 schools on board and seem to have a good, structured relationship with the schools. I am interested in looking at a group of schools that have a connection with a local *iwi* (tribe), would support what we are doing and be willing to co-operate with us. I think that there is potential for that further down the track.

It would be good for Māori students, not many Māoris are educated. They're all dropouts so we've got to get a few more Māori people up there.

Year 10 Student

We talked with 42 students both junior and senior, 18 teachers and 16 parents or caregivers. We wanted triangulation. We wanted to look at the students' experiences, especially those who had succeeded with science or maths at least at Year 11 and carried on with it. We did not interview a Māori senior student in chemistry or mathematics because there were none in our schools. We interviewed a few students doing mathematics with statistics; only one was doing calculus; and there were students involved in biology. We could not find anyone in the schools at senior secondary level who had got into what we call the 'hard' sciences of physics and chemistry and there was only one doing mathematics with calculus.

We talked to both mathematics and science teachers across all the schools. Although there were a number of Māori teachers interviewed it was mainly Pākehā teachers. It was easy to see that one school in particular had some Māori teachers in the science/maths area. Out of the three

state schools two had 45% Māori students, both of these schools being Decile 4. The other state school had about 30% Māori with a large immigrant population as well.

In our interviews with the adults we talked about students in terms of their experiences. We talked with the teachers about how they catered for Māori students in the classroom and particularly with the curriculum documents and contexts. We talked with the parents as to how they understood the positioning of mathematics and science as subjects and their aspirations for their students and their careers. Most of those parents were Māori but not all.

We gathered some statistics and wrote a report. It was difficult to access and obtain the statistics we needed to give us a picture of Māori student achievement in the sciences; the data that the Ministry of Education collects is problematic in this regard. We looked at School Certificate. Although it is now National Certificate of Educational Achievement (NCEA) there were generalised patterns happening before that. We got data from 1993, 1995, 1997, 1999 and 2001. In all the data on mathematics and science we were looking at qualifications from the last three years of school: School Certificate (SC), Sixth Form Certificate (SFC), University Entrance (UE), Bursary (B) and Scholarship (S). While the data on ethnicity by age was available from about 1996 onwards the data on student ethnicity by year was not. This made it too difficult to work out how many were entering in terms of the number of Māori students passing; we could only do it for the cohort so the data we have here is from the overall participation and achievement rates (where UEBS stands for University Entrance, Bursary and Scholarship).

Secondary School Statistics: entry patterns (pre NCEA)

- **Decline in all mathematics and science subjects 1993–2001 (except UEBS Chemistry)**
- **Māori participation gap grows between SC and UEBS**
- **The achievement gap is constant between SFC and UEBS (compared to the rest of the population)**
- **SC pass rate is approximately 60% of overall pass rate**
- **SFC Grades 1–4 is approximately 60% of overall**
- **UEBS consistently 10–20% lower**

The overall School Certificate pass rate is approximately 60% of the overall pass rate which is pretty low; Sixth Form Certificate is also around 60% and Bursary even lower. We had a big decline in those going into these subjects from about 1999. We thought it was when the Unit Standards came into schools. Unit Standards were what you did with lower ability classes instead of School Certificate or University Entrance; a lot of Māori students went into these. Before that they were being pushed into Sixth Form Certificate classes, for example; but now there was an alternative route – ‘streaming’ by another name – which carries on today through NCEA standards. We need to really monitor this sort of thing. The first year of qualifications, Year 11, is the most important with regard to students getting qualifications. This first year is the most important transition. After that they succeed at the same sorts of rates and it is not too bad.

We could only get the first level of NCEA results at the time.

Secondary School Statistics (NCEA)

- **Participation for Level 1 around 60%**
- **Achievement was at about 85% that of overall population for internal standards and 75% for external**
- **High achievement ran at less than 50% for internal mathematics to just 25% for external science (compared to the rest of the population)**

Participation at NCEA Level 1 was around about 60%, achievement at 85% for internal standards and 75% for external. This gave us some hope at least from surface appearances that it is better for Māori students. We do not know if this is the case at Level 2 as we do not have any information for that level. I do not know whether following from this there is anything else we need to look at with regard to Māori students' progress because it is a proven issue. In terms of Māori students we need to follow through on whether Māori students do better with NCEA or if the lower achievement is displaced to another level. We think it is easier to get grades for NCEA Level 1 and we need to check whether the lower achievement is displaced to Level 2.

As soon as we get into external examinations our students go down again. Look at those pass rates for internal and external and the percentages for high achievement. Those getting the top grades are few and far between. I think that in biology only a really small percentage, about 3%, of the top grades went to Māori. Even if we get participation up we are not getting good grades in mathematics and science so we have to watch all those things happening there. We have not had time to look at the years coming through but that needs to be done. I think we need to keep monitoring it for a while.

Factors in Science and Mathematics Education for Māori

- **Teachers struggle with curriculum suggestions regarding Māori language, knowledge and culture and pedagogy**
- **Strong belief Māori students take longer to be 'ready' for mathematics and science study**
- **Most Māori students in lower ability classes**
- **Relationships and expectations are important to younger students and parents**

That first factor is the biggest one, regardless of whether they were Māori teachers or not. Of the 18 teachers interviewed only three were really good at using the curriculum suggestions regarding Māori language, knowledge and culture and pedagogy. Two were *kura* (Māori immersion school) teachers and the other was in a state school. So there is an issue about teacher training and science training in that area. Teachers reported that they shared boxes of resources, often made up by another teacher; and the Māori component is being taught in such a way that it has turned into a caricature of Māori culture. Some teachers are really struggling with the perceptions.

Then there is the issue of stereotypical information about Māori. For example, there is a common belief that Māori students are only able to cope with learning in small bites. The teachers say that the students like to talk too much and that behaviour in classes stops them learning. We did have one teacher in a state school who took the notion of these students liking

to talk to each other into a form of pedagogy to enhance learning but that is difficult to do for most teachers. This teacher said, 'I can tell one kid something and it is around the class in two seconds'. He was a very good maths teacher who used the idea that students like to share information; he got them into groups working co-operatively. He was able to reorganise his teaching on the spot and take this new approach.

Another stereotype is that Māori students mature early physically but are immature for their age intellectually, which relates to the whole thing about Māori being not very bright (but good at sports, dance, et cetera).

Most Māori students are put into lower ability classes. The majority of schools openly 'stream' for maths, and in science it appears they are channelled through the lesser value Unit Standards. I do not agree with this myself but it is common practice. You talk to teachers who say 'this child is better than this' and then they add 'but her behaviour drags her down', thus justifying her placement in a lower ability class. You are still hearing teachers rationalise their decisions in this manner.

Relationships and expectations are really important with younger students and parents; we found quite a bit of talk about that. In terms of fieldwork I do not think there is anything here that you do not already know in terms of going out and talking to our parents.

While the senior students come to a realisation about the importance of the quality of teaching and their own self-motivation an important issue is to get them over the first qualification hurdle. This means that the first year is most important. It seems that some schools have had quite good programmes but it was difficult sustaining funding and teachers' energy levels. The parents and students spoke highly of the programmes but the schools had to let them go as they could not get them funded to the level required. However, bilingual programmes have often been used by schools to 'dump' the problem Māori students. There is a whole issue about how to get the necessary funding. Where do you go in terms of funding a bilingual science programme and things like that? At one stage there were a lot of bilingual programmes.

One school which gave up its bilingual programme moved students into a top Māori class. They decided to try something else and invited some students into a top ability class. We did not follow that up and maybe we should. While this can be seen as a sort of 'streaming' it means that instead of all the Māori students ending up in the bottom class this is an intervention that takes Māori students and tries to motivate them by telling them that they are in a top class. Maybe it is about the rhetoric and supporting Māori children's beliefs. This intervention was taken by a very supportive and respected Principal who was at her wits end about what the school could do to intervene and get students reaching their potential.

One of the schools had a senior programme that was working on inspirations and motivation. They took the senior Māori students out of class and put high profile people in front of them to speak with them. The students took to this. It was the only school that did this; another school could not even tell us who the Māori students were in the Seventh Form (Year 13).

Schools need to do more work with parents around achieving academic success. Subject choice is really important. While most of the parents were happy to leave it up to the students I got the impression that the parents were not always clear about the down-the-road implications of subject choice in secondary schools. It seems that quite a bit of work needs to be done in that area.

Issues for the Kura Kaupapa Māori School

- **Struggled to find a kaiako Pūtaiao**
- **Compulsory curriculum at wharekura (two senior science subjects not available)**
- **Academic success has a very high priority**
- **Discourse on being a 'global citizen' is very visible**
- **Students have issues around learning science in Māori at senior levels**

In the Kura Kaupapa Māori school they struggled to find a *kaiako pūtaiao* (science teacher). They also had a compulsory curriculum which affected what the students could do at the *wharekura* (Māori total immersion school). They did not offer senior physics or chemistry, not even by correspondence. We spoke with one parent whose child wanted to become a vet. He would have to attend another school to find the subjects he needed. There was no other way. He and his parents understood that and accepted it as part of being at a *kura* (school).

Academic success had a very high priority in the Kura Kaupapa. The Principal would not let the students sit Unit Standards for NCEA. We are talking about a small *wharekura* group; he takes whoever wants to stay on at the school. They entered the science and mathematics competitions in the local town. The Principal (who was also the maths teacher) translated all the questions so the students could answer them in *te reo Māori* (the Māori language). The thinking behind entering the competitions was so that people could see a Māori team there. The teams chosen by the other schools had no Māori students at all. These days they probably have more Asian than Pākehā students but it is that notion of 'here is a whole team of Māori students who are doing it at the Kura'. This sort of initiative is dependent on the *kaiako* (teacher).

The discourse on being a global citizen was very visible at the Kura Kaupapa. The students were very open to politics and other issues. They were a wonderful group of students and the best group to talk to in many ways. They were very articulate and very, very worldly-wise about politics and global issues generally. I have to say the Principal has done a very good job there for the students, he is very open.

Students do have issues around learning science in Māori at senior levels. Some of the students brought it up and the teachers have questions as well. A part of that is the difficulty of learning science in Māori. They know science is done in English around the rest of the world at those levels and it is taught in English in the universities.

Project 2: 'Science, Mātauranga Māori and Schools'

The second project was called 'Science, Mātauranga Māori and Schools' and was based on two questions:

- Can collaborative partnerships between science and *iwi /hapū* inform school science?
- If so, in what ways?

This was a side project. My idea was that we do a contemporary issue. We could see caricatures of Māori culture turning up in classrooms and I was saying: Where can we find a way forward to change this? That was the thinking behind this project. It was through a conversation with a friend who was working for Manaaki Whenua (Landcare Research) at the Waikato campus that I was inspired about what we could look at in our research. This friend is a scientist and while talking about some of the projects they were doing she said they had quite a few projects that involved working with *iwi* and *mana whenua* (the people with authority over the land). In listening to her several questions came to mind. I asked: Where are the schools in these projects? If this is a *whānau* (extended family group), *hapū*, *iwi* project, are the schools being brought in?

Isn't this an ideal site for teachers and our students to learn from? I could see possibilities for professional development (PD) for teachers or even actual classes; these projects were cases of science organisations working with local communities and this is where contemporary subjects for the curriculum could come from.

Science, Mātauranga Māori and Schools (SMMS)

- **Gathered projects from Manaaki Whenua**
- **Spoke with scientists and Māori organisations involved and visited projects**
- **Discussed appropriateness for school science (PD, curriculum application, resources, et cetera)**

We employed someone to go out and start looking at these projects. We did not go in and try to get schools involved. That would be the next step: trying to get a school involved in one of these programmes with a view to getting changes in the curriculum. We looked to see if the projects would be appropriate for school involvement because not every science project is appropriate for schools. There are a lot of criteria in terms of a science project fitting in. We found that there are huge amounts of information available and some of it in two languages. Sometimes Manaaki Whenua projects put up bilingual information on a website that our teachers could easily access. In fact all teachers could access the information but it would be particularly useful for Māori language teachers or those in *kura*. However, teachers were not being made aware that they could access such resources.

The scientists and organisations were largely willing to interact with the schools and a couple of them had tried. However, they had no idea about how to communicate well with the schools and get them involved. There is a huge gap. The goodwill is there but also a big chasm on all sides, with questions about how to do it, what is appropriate, where is the funding coming from, et cetera? They need to be led through that. I believe there is funding available. Organisations such as the Royal Society put up funds: teachers can apply for a scholarship to go out into the science community to be involved, updated and get knowledge. I think that a proposal for a project by a teacher under this scheme would be entertained – a project such as this where students are being brought into interaction with a scientific project and where someone is doing research in terms of change for the classroom. There is a way of doing this; we need to target a project and a local school. Contemporary topics are available; it is just a matter of finding them. The gap lies in having them identified. Some work was identified as being useful and the information sent out to schools.

Is being Māori important in learning science?

I'm proud to be Māori.

Year 10 Student

In one way it seems that the student is not answering the question but in another way she is saying that being Māori is really important, regardless of science or maths or anything else.

Conclusions re policy and research priorities

I have tried to think through the policy around this work we have been doing over the years. I am convinced that we have to look at research priorities if things are going to change. If we are going to change science education in this country for Māori students we have to make research a priority.

Research priorities

- **Classroom/school projects based on bringing together pedagogical knowledge and Māori knowledge**
- **Issues of cultural stereotypes in mathematics and science education and the extent of their effect on Māori achievement in these subject areas**
- **Second language acquisition and conceptual development in science and mathematics**
- **Initial teacher education and our ability to make changes**

There are a number of projects we can look at to get things moving with regard to school-based projects that bring together pedagogical knowledge and Māori knowledge. One of them is to change the science curriculum in schools for all students and for Māori students in particular. Getting these contemporary, culturally relevant pedagogies and content/knowledge going in classrooms is something that has to happen. To some extent this is even true in our *kura* although they were doing better at this. The *kura*'s struggle is with the resourcing.

The issue of bringing together pedagogical and Māori knowledge in school-based programmes is a really difficult one but we have to work out how to do this. We need more classroom and school-based projects reported on. There is very little in the international literature and it is so hard to find anything in terms of research in this area. There is a lot that has been tried but not a lot followed up – as in going through a trial project to see what difference it is making and then reporting on it. It is the recording, evaluation and reporting that is hard to find. There is quite a lot happening in various communities.

As regards the issue of cultural stereotypes in mathematics and science education it is essential we do something about this in classrooms. There is still a large belief that Māori are not good enough to do science programmes. Despite Māori students showing ability and the teachers knowing they have the ability the teachers cannot get them to where they should be in terms of achievement. This is a really hard issue to tackle as teachers do not like to see themselves as not doing the best by their students. The extent to which this plays out for the students comes through.

Second language acquisition and conceptual development in science and mathematics are really important, too, as in getting the Māori language going along with the scientific and mathematical concepts. Even the students in the *kura* are saying the best teachers are those who can do both, get the language going as well as the concepts. We do not have many teachers who can do that. A lot of the *kura* teachers are good but when they get to maths and science they say, 'I can't do maths and science'. While that could be an obstacle in itself it does not necessarily have to be so. When you get a person who gets the language and the concepts going together and does it well it is excellently done – and the students do excellently as well. But half-baked efforts do not work so we need to find the ways to make it happen.

Teacher education institutes need to do something about this and be prepared to take on new approaches. If they are not getting science and maths teachers in for teacher education and not running short courses to cover what is needed we have to find other ways of training or up-skilling teachers in these areas. One way might be by running some subject area education courses. And something has got to be done about initial teacher education.

As for Māori language policy in schools, I know there is some work being done on it but how far is it getting into the schools? We have got to have something in there in terms of building positive attitudes towards using Māori language in schools. Maybe we need to look at some

current programmes although I am not sure where they are to be found. We may be able to get to it through the numeracy project; there is some data from that.

There is also work to be done in exploring some of the current successful programmes, for example, the partnership programme between Tūwharetoa and the National Institute of Water and Atmosphere (NIWA). The research could be carried out collaboratively with the Iwi Education Partnerships (IEPs). This research needs to be done.

I believe a Māori scientist is somebody who can take on board all of the Pākehā knowledge but still maintain his taha Māori and his taha wairua and get the two finely balanced ...
Father

In conclusion I have to say that in our research we spoke to some articulate students who were bright and had lots of aspirations and we found some very good understandings of science.

Glossary

hapū	clan; group of families
iwi	federation of hapū; tribe
kaiako	teacher
kura	school
Kura Kaupapa Māori	Māori total immersion schools
mana	authority; influence, dignity
mana whenua	the people with authority over the land
Manaaki Whenua	Landcare Research
Mātauranga Māori	Māori knowledge
Pākehā	Non-Māori New Zealander of European descent
pūtaiao	science
taha Māori	Māori side; Māori dimension
taha wairua	spiritual side; spiritual dimension
te reo Māori	the Māori language
tikanga	customary correct ways of doing things; protocols
whānau	extended family group
wharekura	Māori total immersion high school

CHAPTER THREE

He Whāinga Māramatanga, He Kimihanga Tūrangawaewae

Michael Walker

About the author

Professor Michael Walker (Whakatōhea) is a Fellow of the Royal Society of New Zealand and one of the world's leading scientists in the study of 'magnetoreception', the magnetic sense in animals. He has discovered the cells that vertebrates almost certainly use to detect magnetic fields, the first new type of sensory cell to be identified in decades. From this and related research he has developed a coherent picture of the magnetic sense from the cell that detects magnetic fields through the nervous system and behaviour in the laboratory to the use by animals of the Earth's magnetic field for navigation. His work, which is now being extended to include biological rhythms, combines theory and experiment and bridges the biophysics, anatomy, neurobiology and behaviour of animals.

Professor Walker also combines his world-leading scientific research with an outstanding leadership role as an advocate to science on behalf of Māori and to Māori on behalf of science. He is Joint Director of Ngā Pae o te Māramatanga and brings extensive teaching, research and service provision experience to this role. Throughout his career he has worked to increase participation by Māori and Pacific Island people in all aspects of science and has helped lead initiatives to improve their recruitment and retention as students entering the sciences at university level. This work has included the establishment of the Tuakana Programme to ensure Māori and Pacific Island students in biology succeed in their first year at university and the whole of their degree course. He is also active in advocacy for science and science education to Māori and Pacific Island people.

The following is an edited transcription of the seminar delivered by Michael Walker. The Figures are based on the PowerPoint slides he used.

Introduction: research and identity

The title of this presentation *He whāinga māramatanga, He kimihanga tūrangawaewae* (A search for understanding, A search for a place to stand) is deliberate because it reflects where we are as Māori who are also scientists. Not only must we pursue understanding just as our colleagues do we also have to create a space in which to operate, by which I mean an intellectual space that reflects our difference and uniqueness. That is, we have to be aware we are coming from a very, very different set of operating assumptions and recognise that our identity is important in our research. We need to persuade others that our identity is important and that it drives our research. We also have to grow our successes and grow them rapidly both in time and in numbers. As a consequence of our research and the people we train we need to change the attitude of the dominant society so that our contributions can be received in an appropriate environment and expand the intellectual scope of the nation.

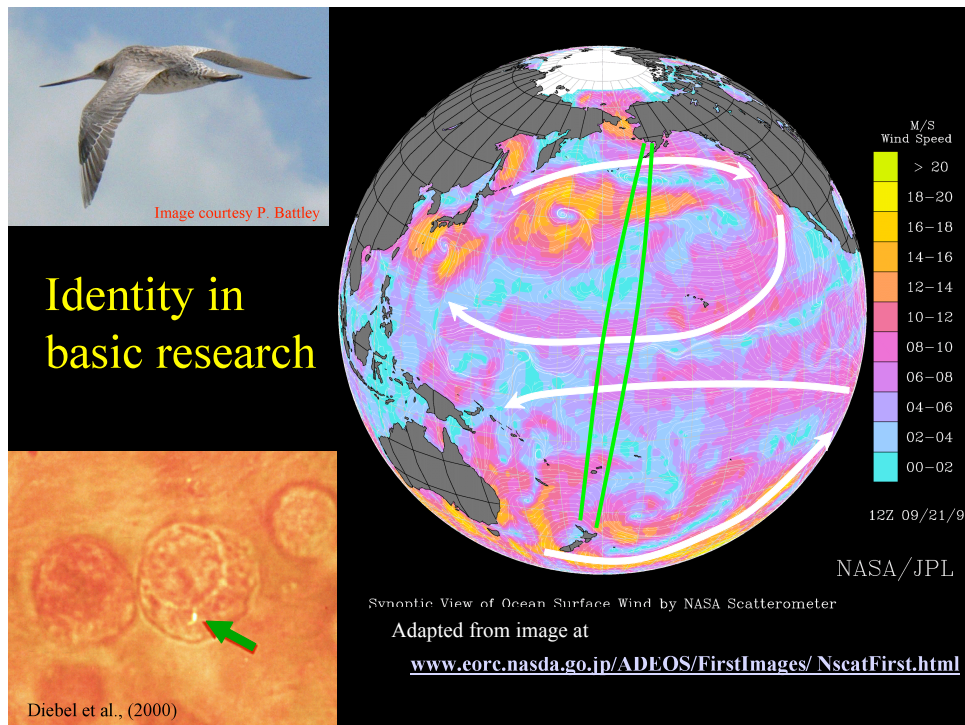


Figure 1: Identity in basic research

I will begin with a story. New Zealand, our home, appears at the bottom of this image of the hemisphere which is centred on the North Pacific Ocean. The image displays synoptic weather data for 21 September 1996 (the September equinox). The circular feature to the east of Japan in the weather image is a typhoon in the North Pacific. The bird in the picture to the left of the weather image of the Pacific Ocean is a bar-tailed godwit. These birds leave Alaska at about the time the weather image was taken. As the birds fly southwards across the Pacific they initially fly through a belt of westerly winds, then on through a set of variable winds, then through the north-east trade wind belt (north-easterly to easterly winds), the doldrums, the south-easterly trade winds, another belt of variable winds and finally they enter a new belt of westerlies as they approach New Zealand.

In sum, the journey of the godwits is a tremendous navigational achievement. The birds fly roughly 11,000 kilometres and at that distance New Zealand represents a target two to three degrees wide. During the journey the birds are being pushed sideways by the winds in the big easterly and westerly wind belts and in relatively random directions in the areas of variable winds and in the doldrums. The journey takes about six to ten days, during which the birds fly non-stop. The birds are waders not swimmers and so they would not normally come down to rest on the surface of the water. Generally they do not land during the journey and, in fact, there is not much for them to land on along their route.

To understand how the godwits make this journey we would like to be able to provide an explanation in terms of the processes going on inside a single sensory cell which collects the key navigational information used by the birds. We are pretty confident that the cell shown at the bottom left of Figure 1 is the cell that detects the Earth's magnetic field which is the only information available from the environment that would be actually useful for guiding movement by the birds over such vast distances.

This is the field I have been working in for the last 25 years and in which I have had more than my fair share of success. I would attribute that success essentially to identity. The reason I say this is that we are a maritime nation. I have had a lot of time at sea around the north-east coast of the North Island and I have spent a little time sailing among the Hawaiian islands. I have read the

accounts by David Lewis and Dava Sobell respectively of how the Pacific Island navigators find their way around the Pacific, how oceanic navigation was developed in England and Europe and how its effectiveness was demonstrated by Captain Cook. So I have been able to understand the theory of both systems and been able to satisfy myself during my experiences at sea that both systems work. What that gives me, I believe, is intellectual flexibility through the understanding of the theory and experience at sea and that, in turn, permits recognition that both navigation systems work very well.

Out of this work comes a spin-off that also reflects identity. We have been working with homing pigeons to study navigation using the Earth's magnetic field. We use a little device based on the Global Positioning System (GPS) that the pigeon carries. As the pigeon flies home the device records fixes on the position of the animal. We set it to take a position fix every second while the pigeons are flying home. The positions recorded by the device are recorded with a resolution of about three metres so we can reconstruct the paths of the pigeons second by second to within about three metres as they fly home, usually within about an hour, from locations up to 30km away from their loft.

Now we have adapted the same device and put it on possums and by taking fixes at longer intervals recorded their movements over the course of up to several weeks. This next screen shows work done in the Dart Valley by one of our MSc students, Helen Blackie. A possum wearing the GPS-device as a collar is shown on the right hand side of the screen.

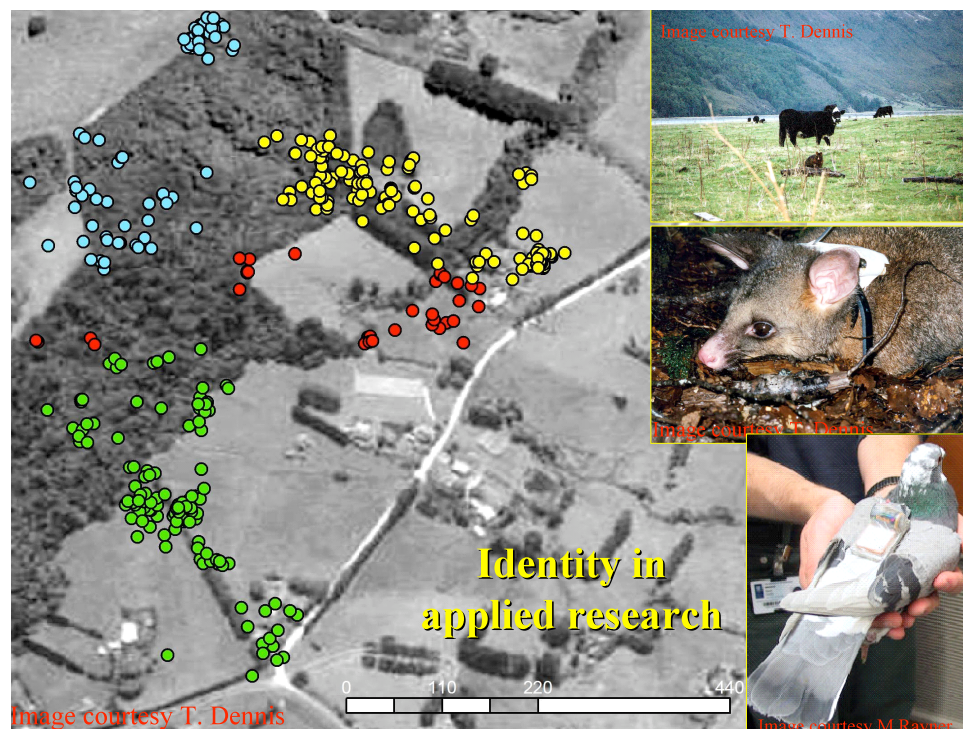


Figure 2: Identity in applied research

The photograph at the top right of Figure 2 shows a possum out amongst a group of cows as dusk was approaching. The possum is feeding in winter in improved pasture (that is, fertilised to stimulate grass growth). The possums live in dens on the edge of the forest and will walk up to a kilometre to feed in the improved pasture. The coloured dots superimposed on the black and white photograph on the left are actual fixes on a possum tracked over several nights at Dairy Flat just north of Auckland. The position fixes for each night are represented by a different colour. You can see where the animal has travelled to an orchard, people's backyards and so on. This demonstrates the technology and where we are going with it now. We are starting to take this technology and ask the questions: What are these possums doing in space and time? Can we

understand their movement patterns better? We are doing this with a view to providing better information for decision-making about the management and control of the possums.


I became interested in the issue of possums not long after returning to New Zealand when up in the Hokianga the Department of Conservation (DoC) started dropping 1080 poison into the forest. Hokianga folk began complaining about the collateral kills of pigs, deer and other animals. At the time I thought to myself that as a scientist I wanted to make a positive contribution to the resolution of this conflict. In the end I stored the idea away as I could not do anything about it at the time. Now, however, we have developed this spin-off technology which makes it possible for us to collect far more detailed and accurate information about possums than has ever been possible before. Our hope is to provide better information about the behaviour of possums which, in turn, will help to support better decision-making about their management and control.

The reason I have given these examples from my own research is to illustrate the point that identity helps drive us in our research. There is also another area that, I believe, the intellectual flexibility which comes with the dual identity of Māori scientists helps – but I will discuss that later.

Capability building

If we as Māori are going to get ourselves better represented amongst scientists, we need to grow people (that is, the number of Māori involved in science). Figure 3 is put here to illustrate one of the outcomes of our Capability Building work at Ngā Pae o te Māramatanga. It shows the participants at the first PhD Writing Retreat for Māori that we held at Hopuhopu in 2004.

Shortening timeframes through vertically integrated **Capability Building:**



PhD writing retreat

- 30 PhD candidates
- Median age 45
- Many in senior positions
- Major pieces of writing completed
- Significant reduction of isolation
- Mentor summer interns

Figure 3. Shortening time frames through vertically integrated Capability Building

There were 30 PhD candidates and their median age was 45. Many of them were in senior positions. They had major responsibilities within their disciplines, within their institutions, as well as within their families and *iwi*; so it is very difficult for them to focus on writing a PhD thesis. Hence the strategy is to take them away from these complex, demanding situations, away from the phone and email and get them to write. I believe one PhD was handed in following this first retreat and there are a number of others that have been completed since. People came from

all disciplines: education, arts and social sciences, out to astrophysics. Another thing that we do is to vertically integrate the PhD candidates with senior academics and also with Summer Interns who are undergraduate students. We are building up the Tuakana model discussed below and applying it across all transitions and the development of academic careers.

Because historically science has been one of the more hostile academic environments for Māori it has not done a good job in producing Māori (or Pacific Island) graduates. The strategy for response to this challenge was to take advantage of the concepts of *tuakana* and *teina* (elder and younger sibling) in Māori society. Briefly, the *tuakana* has a responsibility for ensuring the success of the *teina*, the *teina* has a responsibility to learn from the *tuakana* and both have a responsibility to contribute to the success of the wider group. The programme then sought to multiply off the successes achieved by the Tuakana students by ensuring they assisted those following them to succeed. The photograph in this screen shows the two Tuakana students (both coincidentally wearing sunglasses on top of their heads) working with groups of students in one of the first year papers in the School of Biological Sciences. These tutorials are optional and an extra for the Teina students. We therefore depend heavily on the Tuakana being very effective in order to keep the Teina interested and active in the programme.



Figure 4. The Tuakana approach

When we started intervening at first year level in 1991, the 1991 cohort substantially increased their pass rate. Those who participated in the intervention doubled their pass rate compared to those who did not. As a consequence overall representation of Māori students in our undergraduate population increased as this cohort came into the second year in 1992. It increased again the next year as they went into their senior undergraduate year and the 1992 cohort entered their second year. Overall representation of Māori students at undergraduate level then stabilised and we saw a similar pattern occur, although slightly delayed, with Pacific Island students. In essence we were retaining students to graduation at the same rates we were recruiting them. Further growth was then hindered because the recruitment rate from secondary schools was low.

A follow-on intervention was initiated by Shane Wright (whose paper appears in the next chapter) that addressed the issue of getting students to stay on for post-graduate study in biology. Shane started by persuading the School of Biological Sciences to use some of their annual Summer

Studentships to target Māori and Pacific Island students at the upper level of the undergraduate degree. These awards give promising senior undergraduate students a stipend to work over the summer in a research group so they can gain research experience first-hand. The impact of the first year of the targeted intervention was dramatic. It delivered a step increase in the number of Māori and Pacific Island students enrolling in post-graduate study in the following year. In summary, we were now confident that we could deliver success to Māori and Pacific Island students in the biological sciences at the university. This put us in a position to go out and sell it to students in schools to address the low recruitment of Māori and Pacific Island students from the schools.

In collaborations with schools, the Tuakana approach improves recruitment of Māori and Pacific Island students to university



Figure 5. Improved retention through collaboration with schools

The photograph in Figure 5 is of secondary school pupils taking part in the ‘STEAM AHEAD’ programme. The programme is run by the University but was developed from an initiative led by undergraduate students. In 1991 we were asked to supply some students to act as role models for Year 10 Māori pupils in Western Springs College which had a bilingual unit in which students were taught in Māori in every subject except science. The school asked for Māori students to act as Tuakana for their pupils so that they could know that they could pursue science even though the school could not recruit a science teacher who could teach them science in Māori.

Our students very quickly came back and said that we should be doing this for Māori and Pacific Island pupils in all schools. For two years and on a voluntary basis they ran an open day targeting Māori and Pacific Island pupils in Year 10 from all over Auckland. For the university students this was exhausting work done in their own time and at risk to their own studies. I was therefore delighted when the University adopted the approach and provided the skills and resources to get the school pupils to the University. This permitted the students to do what they did best, which was to show the pupils in the secondary schools the way forward and to show them that good things could happen if they persisted with their studies. The University has continued the effort as the STEAM (for Year 10 pupils) and STEAM AHEAD (for pupils in Years 12 and 13) The programmes have continued until now, long after the students who initiated them have graduated and left the University.

Although the STEAM programmes continue they do not allow tracking that will give direct measurement of their impact and they occur only once a year when sustained engagement would be more valuable. The problem is that funding ran out for the work at Western Springs College and the work fell by the wayside.

What we did learn from the work with Western Springs was that if you work with schools that know what they are doing with Māori and Pacific Island pupils good things can happen quickly. We later obtained further funding for intervention in schools in 2000 and so were able to link with another school, Tangaroa College, which is a Decile 1A school (in the most impoverished 10% of schools in the country). During the 1980s and 1990s Tangaroa College averaged less than one pupil per year coming to the University of Auckland. 2001 saw the beginning of a sustained interaction with the pupils from Tangaroa through our Tuakana programme, bringing university science students in to act as role models and mentors. From 2002 the numbers of pupils coming to the University increased year on year so that by 2005 the number coming from Tangaroa had reached eight and appeared to be growing exponentially. We replicated this at another school, Tāmaki College, so it is not an isolated incident. It is quite possible to align with a school that is committed to change and for change to occur quickly.

Changing attitudes through Knowledge Exchange

I said earlier that we need to be changing attitudes on the outside as well. This is challenging because it takes us into a whole bunch of cultural assumptions that are very deeply rooted and very hard to expose. One of the ways you can expose them is to demonstrate the impacts of people’s operating assumptions and reference points and how these can affect outcomes in society. I use a couple of examples which are very well-documented in terms of process, information and reference points. A simple, clear case of flawed information arising from a flawed process is the Arthur Allan Thomas trials. Both trials had the same jury criterion, the same operating assumptions, the makeup of the juries was essentially identical (the trials took place in the 1960s and 1970s, before the wave of immigration over the last 15–20 years) and the same result. In each trial there was also identical information but it was flawed because the police planted evidence. This example illustrates how critical it is to have good quality information.

Changing Attitudes though Knowledge Exchange				
Contributions of Cultural Assumptions (knowledge, reference points and process) to outcomes in society				
	Jury criterion	Jury verdict	Information to juries	Composition of juries
Arthur Allan Thomas	BRD	Guilty	} Identical, flawed	Very similar
	BRD	Guilty		
O.J. Simpson	BRD	Not Guilty	} Identical	Different
	Blame	Culpable		

Figure 6. Contributions of cultural assumptions

O. J. Simpson had two trials as well. The first one was the criminal trial; beyond reasonable doubt (BRD) was the criterion for guilt and he was found not guilty. In the second trial he was found culpable. The information for the two trials was identical but the compositions of the juries were different. The first trial took place in downtown Los Angeles and the second in Orange County. The compositions of the juries were very different: basically the first was black and the second was white. So operating assumptions and approaches can have dramatic impacts on outcomes – it is not enough just to have good process and good quality information.

In science in New Zealand there is a dominant set of operating assumptions rooted in culture, history and language; and there is another set which is seen as different and, therefore, potentially a threat. What we have to try and demonstrate is that difference is not a threat but an opportunity.

**‘Maori knowledge system’ as viewed from
‘scientific perspective’**

- Tāne-nui-a-Rangi brought the three baskets of knowledge back from the highest heaven.
- Implies knowledge is sacred as it is derived from the Gods
- Gods are not verifiable from a scientific perspective

Such knowledge is unlikely to be verifiable or rational

Figure 7. ‘Maori knowledge system’

If we consider the ‘Māori knowledge system’ through the ways scientists operate in the dominant mode we are faced with the following. The foundational belief that Tāne-nui-ā-Rangi brought three baskets of knowledge back from Te Rangi-Tūhāhā implies that knowledge is sacred because it is derived from the gods. Gods, as a result of the political history of science, are excluded from scientific discussion and are not verifiable from a scientific perspective. Ergo, Māori knowledge systems are not verifiable or rational. That is a minimally exaggerated position.

Now we can see how that plays out in environmental debates between Māori and scientists or other related professionals such as engineers. We are all old enough to know the following story. In the 1970s Lake Rotorua was rapidly becoming eutrophic as a result of minimally treated sewage going into the lake and huge amounts of subsidised fertiliser going onto the land around it. The fertiliser that was going on the land was *tapu* in the sense that the sacred cow of the economy was not to be touched. So to stop or slow down the eutrophication of the lake the Ministry of Works proposed that the sewage be piped out to the Kaituna River and flushed downstream. We were lucky to have the Waitangi Tribunal by then as it provided the opportunity for local Māori to express their opposition to the proposal by taking a claim to the Waitangi Tribunal. In debates such as this scientists and engineers tend to say things like *mauri* (essential life force) is not verifiable whereas you can actually measure the concentration of coliform bacteria in water; as long as these bacteria are present below a particular level you don’t have a pollution problem. Another argument is that it is too costly to change what is being done or proposed to be done.

As a result of the claim over the Kaituna River the Tribunal's recommendation to the Government was taken up: that the sewage should be treated and put on to the land. There have been a number of positive outcomes that have followed on from that recommendation: new ways of managing human waste have been developed; when application of treated sewage to the land is well managed the productivity of the land increases; it turned out that in the area around Rotorua forests could take a higher loading than any other environment in the area; trees in the forest also grew faster than elsewhere; and we have a greater understanding of ecosystem services. A little side text is this: the credit for achieving these outcomes is claimed by Forestry Research Institute. If you go to the land treatment collective page of their website you will find that they do not acknowledge the reason they looked at the issue of sewage disposal was because of the claim by local Maori to the Waitangi Tribunal. So in our society we have this ongoing problem with 'historical amnesia' which helps to shut down these kinds of contributions.

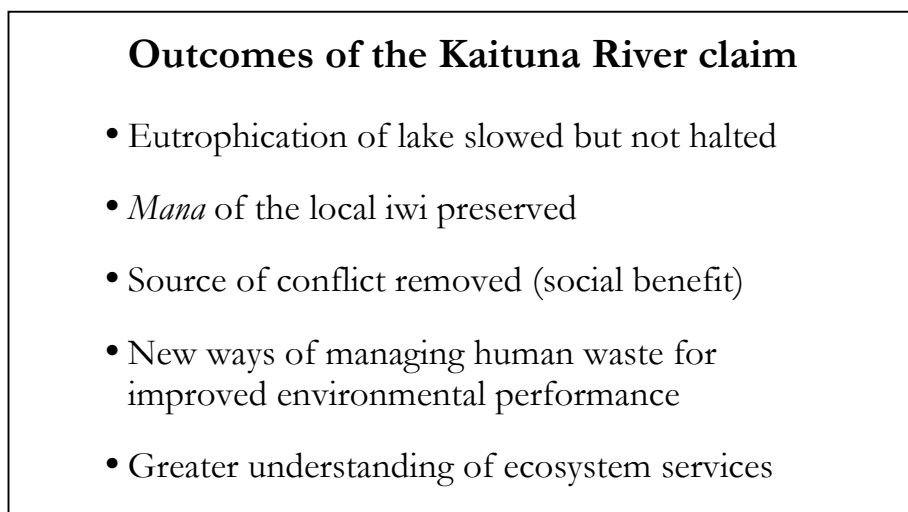


Figure 8. Outcomes of the Kaituna River claim

The cleaning up of the Kaituna River brings a range of potential economic benefits. Water is recovered for eating, drinking and recreational purposes. Obviously people would not want to go white water rafting in a sewage creek! To me the disposal of sewage on the land instead of into the river seems to be a major infrastructural benefit. What is more, besides the benefit to the river you get the enhanced performance of an economic crop, namely the trees. Admittedly the benefit to the forest is not without its problems. The workers in the forest are exposed to a bit more of a health risk. Also there are other problems you get with putting waste water (including sewage) on lands like this, for example, the heavy metals that are used in deodorants. In recognising these secondary effects of sewage pollution, however, we also recognise that such problems are of our creation and solutions to them should not be beyond our imagination.

Conclusion

For those of us who are scientists being accepted into science involves various forms of cultural surrender and retaining confidence in your identity under those circumstances is very difficult. For scientists who are not Māori the issue of identity is not normally a problem as such scientists usually operate under the cultural assumptions of the dominant society.

Another factor to be dealt with is the long time-frames for training. It takes 13 years in the school system, 10–12 years minimum to PhD, at least another 5, 10 or even 15 years to get international recognition, meaning your research will find its way into textbooks, and another 5–10 years to get information into undergraduate and school textbooks. This is a very long time-frame. What we need to do actively in order to grow our population and our uniqueness in the scientific community is to short-cut training. So that is where the MAI doctoral programme, for example, comes in. We also need to change attitudes in the system and one of the most important ways of

doing that is through producing graduates who become the system. That is also explicitly a long-term project.

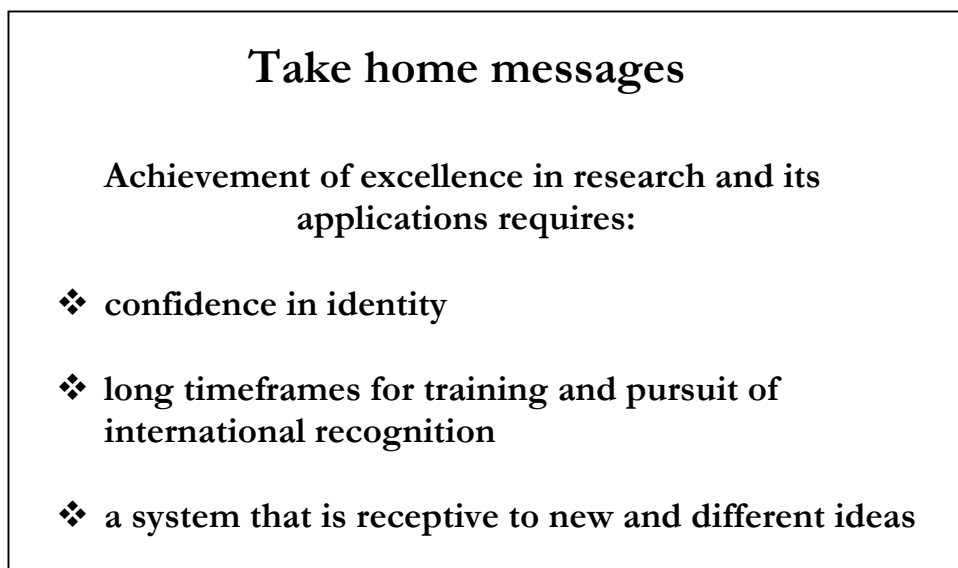


Figure 9. Take home messages

Glossary

iwi	tribe; federation of hapū/clans
marae	local community meeting place and buildings
mauri	essential life force
tapu	sacredness; spiritual power or protective force
teina	younger sibling
tuakana	older sibling

CHAPTER FOUR

Energy and Evolution

Shane Wright

About the author

Doctor Shane Wright (Ngāti Tūwharetoa – Te Ati Hau) is a lecturer in biological science at the University of Auckland with Pacific Biogeography as his main teaching area. His research has focused on tropical evolution and has several strands that include: (a) quantifying rates of tropical evolution, (b) quantifying the effect of population size and land area on rates of evolution, (c) phylogeographic studies with woody plants across Oceania and (d) the ecology of Pacific plants.

Doctor Wright has a strong record of publication in scientific journals. This includes two publications, both as first author, in the *Proceedings of the National Academy of Sciences*, the United States' leading scientific journal. His 2006 article in this journal sets forth new findings on evolution and was widely reported in general media such as *The Economist* and the *Guardian* in the United Kingdom.

Doctor Wright has initiated support for Māori and Pacific students in science at the University and been involved in the promotion of wider Māori and Pacific participation in the sciences.

Doctor Wright's research has been supported by Ngā Pae o te Māramatanga.

The following is an edited transcription of the seminar delivered by Shane Wright. The Figures are based on the PowerPoint slides he used.

Introduction



Figure 1. Is the rate of evolution faster in the tropics?

Pictured on the previous page is the Congo River and the rainforest surrounding it. Every tree you touch is a different species. There are so many species packed in here that the relationship in biology is described as megadiversity. If we moved away from the equator to 45 degrees North or South, to Dunedin say, and looked at another forest that is climatically similar in every way except for temperature, we would be lucky to find two or three distinct species in the canopy and they would be repeated over and over again. So there is something unusual going on in the tropics. My approach to my research into tropical diversity and tropical evolution comes from a different way of approaching things, as Michael Walker has discussed, a difference that comes from being Māori. I call that difference ‘a bit of fuzzy logic’; it is something I bring to bear in the approach I use in tackling these questions.

Evolution and spatial polarity

My first thoughts revolved around the question: Is the rate of evolution faster in the tropics? If the rate of evolution is faster then more species are going to be produced and more species will thus be packed into a given area. I have to say very humbly that many people have been addressing this question over the years going all the way back to Charles Darwin and even earlier to von Humboldt in the early nineteenth century.

There was, however, a second question to be asked: Does evolution have spatial polarity? That is where I came in, 20 or so years ago now, through looking at the world and asking questions that I hoped I could find answers to.

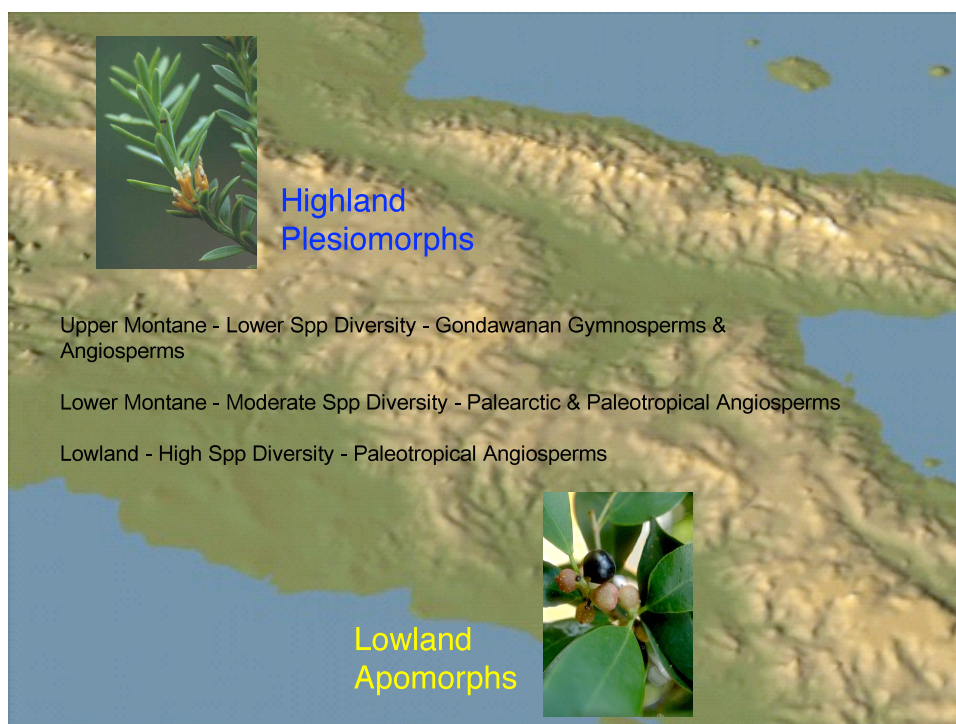


Figure 2. Highland plesiomorphs

This map shows a slice of Papua New Guinea. It is the largest tropical island, four times the size of Aotearoa (New Zealand). Most of the plant species are squeezed down in the lowlands and there would be perhaps 15,000 species there. While it has lowland areas much of New Guinea is highland; it is the leading deformed edge of the Australian plate which has been thrusting its way up for many years and New Guinea is the ruffled blanket that has been thrown up higher and higher as a result of that movement. This means that in New Guinea you have the opportunity to go right up into mountains as high as 5,000 metres. Geographically, it is possible to distinguish three different levels: the lowlands, the lower montane starting at about 1200 metres and the upper montane that starts at about 2000 metres.

As a 25–26 year old I thought I could see a pattern in the New Guinea rainforest which I had not found described anywhere in biology. What I observed was that the ‘modern’ plant species that seemed to be more recently derived in terms of the sequence of evolution were all down in the lowlands. For example, there is a *Ficus* there, a fruit bearing tree with phenomenal reproductive evolution going on. When you move up the mountainside and reach the cold subalpine you do not see any of those modern families that are down there in the lowlands. When you get to the top you find the old lineages, those described as plesiomorphs. Plesio means old and morph means a form.

It was not just that there was that vast stretch of difference between the very new at the bottom and the very old at the top. With that kind of ‘fuzzy logic’ I thought I could see a progression, as you moved from the lowlands up to the top, between the declining species diversity and the increasingly old life forms. So the paleotropical angiosperms, the modern guys, were down the bottom. In the lower montane there were still angiosperms but they were now palearctic as well as much older plants – the conifers (gymnosperms) such as the Klinki Pine – showing their faces on the lower montane, whereas down in the lower level there were no gymnosperms to see. As you go higher and higher the species diversity collapses. The forest in the upper montane actually looks like Aotearoa forest; there are species related to our old Southern Beeches and Rimu. All of these ancient species come from that great southern continent of Gondwanaland; they do not come from southern Asia, they come from way back in evolutionary time. They are the ‘pensioners’, the ancient life forms. There were angiosperms but angiosperms that contain elements of their morphology – such as in their water-conducting tissue – which are in the older states that they inherited from cone bearing plants. And there were the gymnosperms. When you went higher still, through the upper montane, by the time you reached the tree-line there were no angiosperms only gymnosperms.

I started scratching my head, trying to see what this pattern was about. Let me go back a step! When you talk to the botanists working in these forests you find they are very able and they need to be because they have to be able to differentiate at a very fine level between very closely related life forms. I did not have that specialised ability but in fact that helped me because I was able ‘to see the wood for the trees’. I could see this pattern of the plesiomorphs stacked on top of the apomorphs in increasingly older forms as you went higher. When I was 28 I went to South America and saw exactly the same thing, with different species and plants, of course, but the pattern was still there. So in my then youthful way I was rather excited by all this.

I started to look at the ideas in biology around this concept of evolution. The one that really dominated and I have to say was the ‘party-line’ was the idea that this pattern of species distribution is just an expression of different adaptive potentials between lineages. In other words the plesiomorph plants are at the top of the altitudinal column because that is where they best fit in the world. I could imagine people saying to me in reaction to my ideas, ‘Get a life, get real! There’s nothing going on except that everything is perfectly placed and arrayed in the world according to its particular morphology and therefore its particular adaptive potential’. Then I said to myself, ‘Hold on a minute! Gymnosperms, those old guys once dominated all terrestrial biomes’. I knew that because 150 million years ago there were no angiosperms. If you went to the floor of the Amazon Basin back then, what were there? There were conifers.

Also there are common notions around winners and losers. In particular there are these contrasting ideas. The first is that angiosperms are somehow not able to occupy any situation they like and so there are areas in which they are the losers and where conifers will prevail. This, however, can be contrasted with the fact that there are now 250,000 angiosperm species and only 700 gymnosperm species in which case the latter are the overall losers. In fact those quarter million angiosperm species are found in every corner of the earth. They can evolve when and where they wish and they have the ability to adapt to a wide range of physical challenges, some even having returned to the oceans. So this had me thinking that maybe evolution is organised

across gradients of available energy and the gymnosperms are now the remnant survivors – ‘refugees’ if you like – that are parked on the edges of an otherwise overwhelming angiosperm presence. This caused me to speculate that maybe there is a spatial polarity or a direction to it all and that the newer life forms such as angiosperms are most likely to arise where energy levels are highest; and for the older forms the only choice to survive is to beat a hasty retreat into some cold, dry or otherwise lousy position where the rate of evolution is somehow depressed.

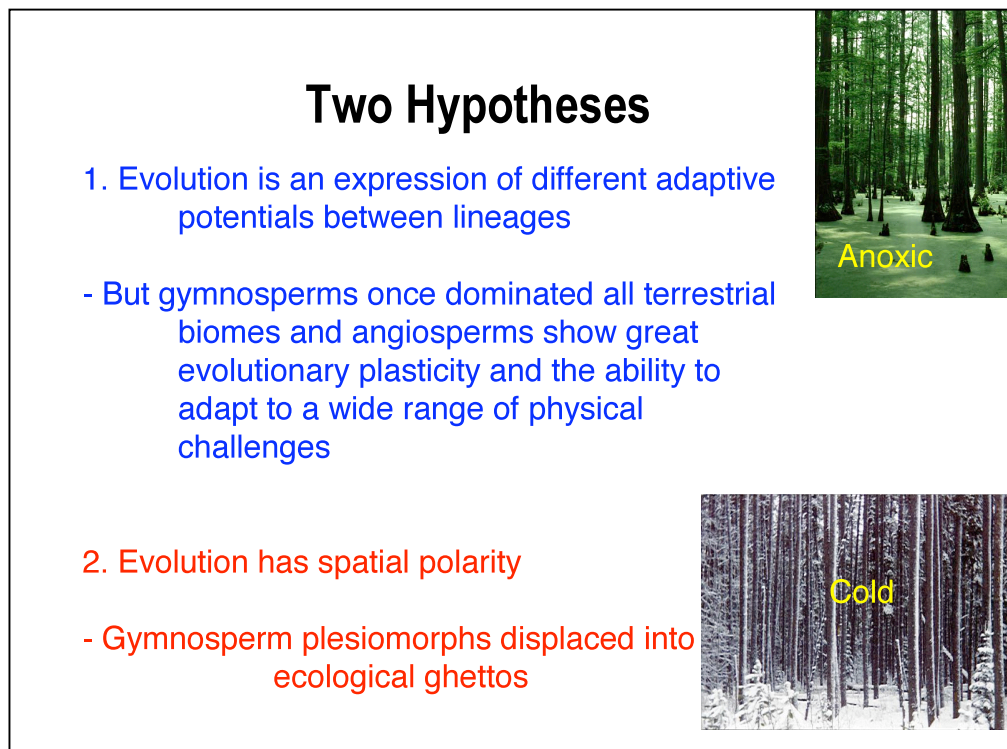


Figure 3. Two hypotheses

Gymnosperms thus occur anywhere there is a problem in terms of available energy. It might be in Southern Louisiana which is nice and warm but the soil is anaerobic; there is no oxygen in the soil so the productivity of the plants there is much reduced compared to plants in adjacent dryer soils. The lower photograph in Figure 3 shows another margin but one that is very different. This margin is due to cold which is what everyone associates with Pine, Spruce and so on. These plants are living six, seven or eight months of the year in a state of physiological drought because the soil is frozen solid which means they are prevented from producing biomass during that time. In the dry centre of Australia gymnosperms have also found viable niche space and again this persistence seems to relate to rather appalling conditions for plant life brought about by the dearth of rain. As far as I could see what all these three circumstances had in common was that they were the ‘junk sites’, the hard places in the world. So these older species were being thrust out into those circumstances by the wave of evolution emanating from high-energy centres; these centres produce new life forms more rapidly and therefore represent the places of high evolutionary intensity and rapid change which older life forms must vacate if they are to survive.

Centrifugal speciation

Directional component to evolution?

- Darwin's (1859) centre of origin concept
- Centrifugal speciation (Brown 1957/Briggs 2000)
- Briggs (2000): gradient from tropical marine Indo-West Pacific into adjacent temperate latitudes with apomorphs tending to occur at centre
- Jablonski (1992): Tropics as cradle of marine evolution from examination of first appearance of morphological novelties in fossil record

Figure 4. Centrifugal speciation

When I was 25 or 26 I started thinking, 'Wow! I think I can see something here that I haven't found written about by anyone else. Maybe I am the first to see this; maybe I'm going to be famous and rich!' Then, Charles Darwin hauls you up. He always does. In that ponderous and accurate way the old guy was thinking late in life he said, 'Yes, I think evolution has spatial polarity'. In fact, he called it something different. He said that evolution is oriented to centres of origin and that speciation sweeps out away from those centres. He did not identify the centres in terms of energy but another one of the great founding fathers, von Humboldt, did. When von Humboldt first went to Amazonia in the early nineteenth century he said to himself, 'Damn, I'm hot' and then, 'There is something in the numbers of species here. I wonder if it is to do with energy'. He wrote about that in German in 1808. So we had these concepts actually starting out with the beginnings of biology.

The idea of centripetal speciation, which again is that concept of polarity and direction, was first presented by William Brown, Jr. (1957), a researcher in comparative zoology. Latterly he has been championed by the zoologist, John Briggs. Doubtless, Briggs has seen something. Briggs (2000) describes the gradient from tropical marine Indo-West Pacific into adjacent temperate latitudes with apomorphs tending to occur at the centre. When I read that I thought, 'He's blurted it out'. But of course others had seen it. In 1992 David Jablonski, geophysical scientist, wrote a Nature paper looking at fossil records. He identified the tropics as the cradle of marine evolution from his examination of the first appearance of morphological novelties in the fossil record. According to Jablonski the fossil record was holding this pattern for all of us to see.

Energy

What could be the cause of faster rates of evolution in the tropics?

10°C rise in MAT = Doubling of 1° Productivity

• Rohde (1992) - Higher temperatures increase the rate of evolution by:

- increasing metabolic rate and cellular output of mutagenic byproducts = faster mutation
- shortening generation times and increasing rates of natural selection



Combination leading to greater effective evolutionary rates at lower latitudes

• Gillooly *et al* (2005) Metabolism governs the two processes generally thought to control mutation rate:

- production of free radicals
- DNA replication errors during cell division

Figure 5. Energy

So what could be the cause of the faster rates of evolution in the tropics? Well, here is a good steer: a 10 degrees Celsius rise in the Mean Annual Temperature produces a doubling in primary productivity. A doubling in primary productivity is a doubling of the biomass that has been produced for each unit area. That double productivity only happens because the cells inside are more active. The rate of business of the biological processes is being thrust forward at a faster rate.

In 1992 a novel explanation was put forward by the biologist, Klaus Rohde, who worked in the University of New England in Armidale, Australia. Rohde said that the increasing metabolic rate and cellular output of mutagenic by-products in the form of free radicals (or whatever the cell is producing) is damaging to the DNA cells and as a result you have got faster mutation. Hence the basic stuff of evolution is being produced here: difference is being produced, mutations are being produced. Of course most of those mutations are useless and produce an organism that is dysfunctional and probably will die. But a small subset of those mutations will be mutations which produce novel adaptations that will allow it to evolve and change.

Rohde also said that the driving of energy through biological systems tends to shorten generation times and increase rates of natural selection. Ectotherms or cold-bodied organisms will get to fruition much more rapidly, so you will have more generations in a given period of time. If you are increasing the numbers per unit time in the species you are then increasing the rates of natural selection and this increase also leads to more rapid evolution and so you get a 'double whammy'. You are producing more mutations and you are acting on those mutations more rapidly, thereby selecting in favour of your better-endowed successors at a higher rate. So the combination of these two factors may be leading to greater effective evolutionary rates at the lower latitudes. However, there was a real difficulty with Rohde's explanation as he himself lamented, 'I can't measure this'. And I thought, 'Oh, I have an opportunity!'

Hypothesis Testing

1. Bromham & Cardillo (2003) - mtDNA

45 pairs of avian congeners = 1 tropical vs 1 temperate

Result - no significant difference

But

- Used migratory assemblage of birds from N America with summer range applied for latitudinal position
- Confounded latitude and altitude so used high altitude tropical spp from low energy ecosystems

Figure 6. Hypothesis testing: 1. Bromham & Cardillo

Following Rohde, the evolutionary biologists Marcel Bromham and Lindell Cardillo (2003) got busy and said, 'Well, we can use mitochondrial DNA as a source of measurements'. They took 45 pairs of birds that are congeneric, avian congeners, meaning birds that are close relatives to each other. One of the species was in the tropics and the other in a temperate region. They measured branch lengths in the tropics and in the temperate habitats and got no significant difference. They debunked Rohde.

When I read Bromham & Cardillo I said to myself, 'These guys are very much senior to me in every possible way. Yet in their evidence for their temperate positioning (there is temperate and tropical positioning in terms of latitude) they have taken the birds of North America, the vast majority of which are migratory and they have used the summer range to represent their general position'. Now why does a bird fly south for the winter? The answer is that they do not want to die; and so, of course, the summer range during the northern summer is tropical. These are actually tropical birds but Bromham & Cardillo were calling them temperate birds. You cannot do that. That is not an adequate experiment to test the climate experienced per annum. They went further; they also confounded latitude and altitude. They were using the high altitude tropical species that were essentially temperate. If you crawl up the side of a mountain it gets colder by 0.6 degrees Celsius with every 100 metres that you go up. So again they were not structuring their work in the right way. Inevitably they got no significant difference.

Back in 2000 I had been working with some wonderful plants from the Māori world in the genus *Metrosideros* including Aka, Akakura and Akatea. I had been using their DNA to do much more simple stuff: a 'whodunit' and a tracking of the patterns of their dispersal across Oceania. However, it was notable that the branch lengths showing mutations per species in New Caledonia and Aotearoa (New Zealand) were short compared to the branch lengths in Papua New Guinea which were huge. This then was the beginnings of the data-based research into rates of tropical and temperate evolution.

Hypothesis Testing

4. Wright *et al* (2003) ITS+ETS

- *Mearnsia* spp in equatorial tropics have 3x higher substitution rate compared to spp in cooler New Zealand & New Caledonia

But

- One taxon only
- Non-independent branch lengths



Figure 7. Hypothesis testing: 4. Wright et al.

Statistical examination of this dataset showed a three times higher substitution rate in the tropics. This was published in *Evolution* in 2003 and was promptly criticised. It probably deserved this because as everybody said, ‘One taxon does not a whole of nature make’. The research was also criticised because the branch lengths were not independent. In other words, when you tracked your way through the phylogeny or tree of relationships constructed by the computer, parts of the branch lengths were shared between what should have been independent, paired comparisons. So there was a problem with part of the experimental design and the limitation of only one taxon. Nevertheless, the fact of the substitution rate being three times higher was sufficient for this to make its way into *Evolution*; it was regarded as being of interest.

The new research

So what are we going to do for the new research? Before looking at this I want to thank Ngā Pae o te Māramatanga. The reason this research has gone ahead is because of their support.

The first question was: What experimental design to use? We thought, ‘Let’s go to Bromham and Cardillo! Let’s not reinvent or come up with a new design! Let’s get Bromham and Cardillo and do it the way they did it but apply a bit more rigour!’ One of our decisions that altered their approach was to use plants and not birds. The difficulty with birds is that they are flying around and constantly changing the thermal regime they live in, whereas there are no problems with plants being migratory. Plants are stuck in one place, come rain or shine; the temperature goes up or down and their metabolic response is set by the mean of the ambient temperatures that they experience at that locality.


We used a piece of DNA called ITS (Internal Transcribed Spacer of ribosomal DNA) which is typically used in the study of plant phylogenetics. We used 45 pairs, the same as Bromham and Cardillo did with birds. In fact 45 is the upper limit that we could have examined because it is very hard to find plants that are tropical and also have close relatives living in the temperate world. Most plants are specialists; they are either tropical or temperate but not both. We examined the 45 congeneric/conspecific pairs where one was tropical and one was temperate. The tropical species were from warmer lowland/lower montane bioclimatic zones. The temperate

species were from the highest latitude and highest altitude possible but remaining within the same biome (rainforest). The targeted variable that might affect rates of evolution was temperature and the controlling of other climatic variables such as water, et cetera, allowed us to focus our experimental design on the effect of that single variable. We thus could not go shifting between habitats that might, for example, have different rainfall regimes – all of these plants are from one, very wet biome although from very different temperature regimes.

We also controlled for body size and population size. There is a problem if you vary body size because the large plants have had a longer generation time and that could affect the results. Population size is problematic because the argument amongst the luminaries in biology, at the moment anyway, is that a smaller population has a more rapid rate of molecular evolution.

New Research

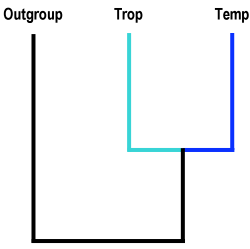
What experimental design?



Bromham & Cardillo (2003) but with plants whose metabolic rate is set by ambient temperature (ITS of rDNA)

45 Congeneric/Conspecific Pairs - 1 Tropical vs. 1 Temperate

- Tropical spp from warmer lowland/lower montane bioclimatic zones
- Temperate spp from highest latitude and highest altitude possible but remaining within same biome (rainforest)
- Also control for body size and population size



The amount of mutational change can be measured from the node of common divergence for each pairing

Confamilial outgroup acts as proxy for most recent common ancestor

Long branch = much change
Short branch = little change

Figure 8. New research

The question was: What do we do with the trees of relationships as exemplified in the diagram above? In these trees there is the tropical lineage; the length of that branch is proportionate to the amount of mutation that has gone on in that lineage since it separated from its temperate counterpart and, likewise, for the temperate lineage relative to its tropical counterpart. A long branch for a particular lineage represents much change and a short branch denotes less change. To produce the node of divergence for the measurement of change in each lineage you need a common ancestor to both. Unfortunately, you do not have the common ancestor anymore; it is typically extinct. In its place what is used as the proxy is the next nearest relative of the two being compared, called the outgroup. Thus we had the three elements to the phylogeny or tree of relationships that the computer builds using the DNA data: the outgroup and the two members of the ingroup, one tropical and one temperate.

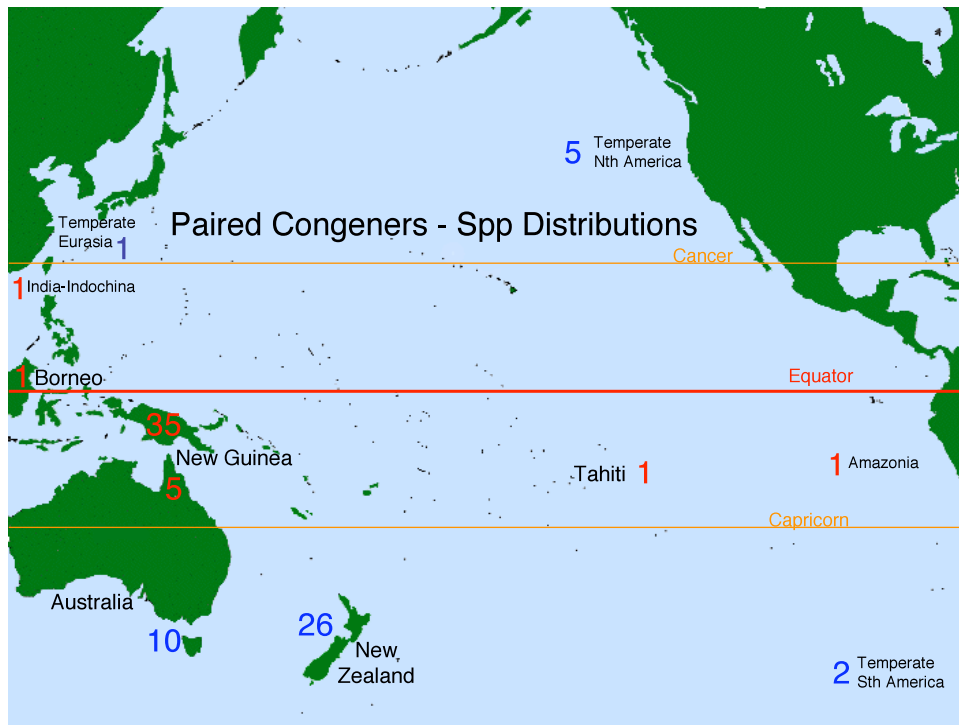


Figure 9. Paired congeners – Spp distributions

Where did the 45 pairs come from? For the reds, the tropical group, we concentrated on lowland Papua New Guinea (PNG) because we could get access to it; I knew people there and I was comfortable working there. So 35 species came from PNG, five from Queensland, one out of India and a few from other places like Tahiti and Amazonia. For the blues, the temperate group, 26 came from Aotearoa/New Zealand, ten from southern Australia, five from temperate North America and five from South America. Because it is surrounded by water and climates are ameliorated it seems that Aotearoa carries into the temperate zone the highest number of plant genera from tropical lowlands anywhere. Again it was a serendipitous location to go for tropical plants behaving as if they were in drag – in other words being located in the temperate latitudes.

Data from where

- Highly constrained selection criteria rule out data mining of Genbank
- Collections from field and from herbaria with <20% from Genbank (mostly outgroups)
- Sequencing task made complex by diversity of genotypes
- ITS length ranges from 550bp - 2000bp, new primers and repeated experimentation with PCR conditions required - 3 yr logistical task

Why only 45 pairs

- Plant genera are conservative vis a vis latitudinal distributions - either tropical or temperate but rarely both

Why so many from New Zealand

- Isolated and floristically depauperate NZ, nevertheless carries possibly largest number of lowland tropical rainforest genera into high latitudes of any landmass

Figure 10. Where to get data from

There were several factors that affected where we were to get our data from. We were highly constrained by selection criteria that ruled out data mining of the Genbank database on the internet. This is the way most people do it these days; they just go and download everything and make a paper out of that. We could not do that because we had constrained ourselves by our selection criteria. Our collections were from the field and herbaria with less than 20% from Genbank and those were mostly outgroups.

The sequencing task was also made complex by the diversity of genotypes. ITS is different for all these different plants. For example, ITS in *Totara* is 2,000 bases long; ITS in *Acacia* is only 500 bases. These differences mean that each pair is often a new challenge to extract what may be quite unique DNA. It therefore took years of struggle to complete this dataset. Working within one genus you have learnt previously how to work with that genus and that species. For this research every pair was a novel task.

The question might be asked: Why only 45 pairs, why not 450 pairs? The reason is that plant genera are conservative vis-a-vis latitudinal distributions; they are either tropical or temperate but rarely both. Pairing cold and hot climate near relatives was thus difficult to do. We also sampled only woody species. We did not sample herbs (herbaceous plants) because some of them are annuals and some are perennials – this means that generation times are all over the place. That is why we chose to work with woody species; it takes decades to produce a decent sized plant body so, other things being equal, the generation times for woody near relatives should be similar if climate is not affecting that period. We compared plants from different strata: vines against vines, trees against trees, shrubs against shrubs and from a wide phylogenetic range. The sample included araucarians which are the oldest of the old as in the oldest cone-bearing plants; magnoliids, the oldest of the flowering plants; the basal eudicots; and then all the way through to the core eudicots, the modern flowering plants, the rosids and asterids. Thus the sample was taken from a broad range of plant evolution, ranging from species originating 200 million years ago through to plant families that probably only differentiated in the last 40 or 50 million years.

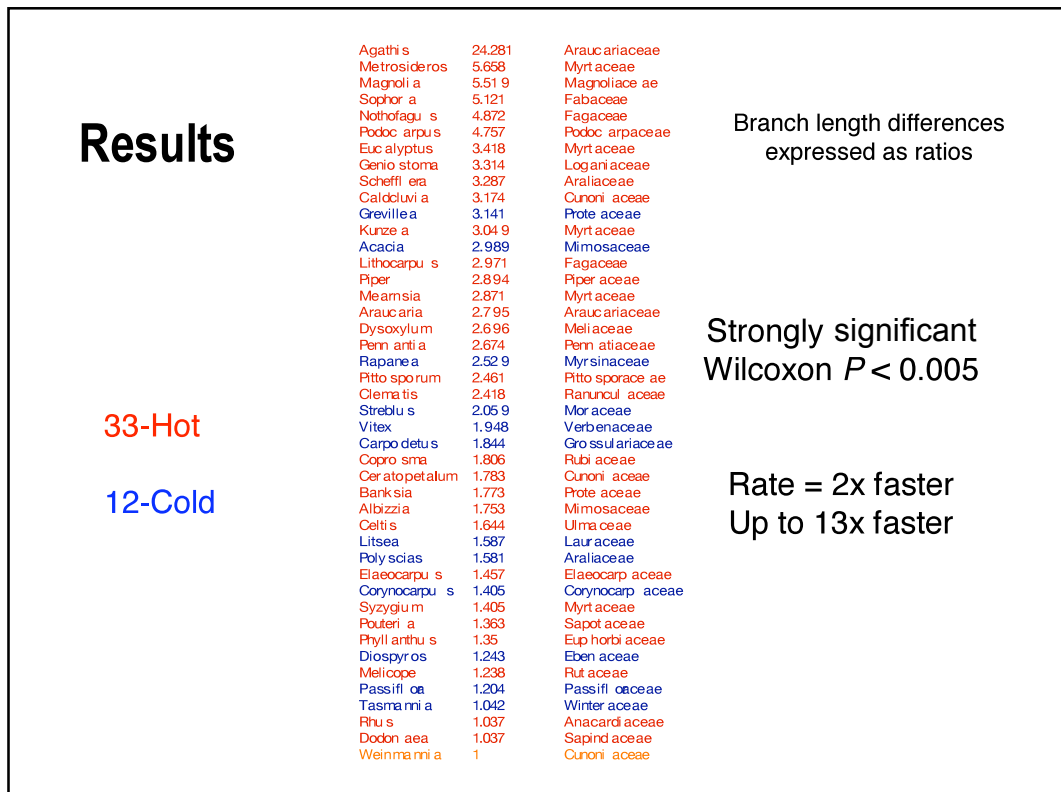


Figure 11. Results

The results are shown in the diagram above which shows the branch length differences expressed as ratios. We thus compare the two branch lengths, one tropical and one temperate, with one expressed as a ratio of the other. The branch length differences are then ranked with the biggest difference at the top right down to the smallest at the bottom. The red (hot) ratios denote a comparison where the tropical species has the longer branch (more mutations) and the blue (cold) where the temperate has the longer branch. Thirty three of the comparisons have a longer branch length – a faster mutation rate – in the tropics. Twelve of them had longer temperate branches. In the case of the blue ones the branch lengths are therefore longer in the temperate world and so the blue ratios can be treated as negatives. The statistical test we used powerfully affirms this as a significant relationship in favour of enhanced rates of tropical evolution.

But - can the results from largely non-coding ITS be extrapolated to the whole genome?

- Barraclough & Savolainen (2001) - found rates of protein and morphological evolution correlate with neutral substitution rate in a large sample of angiosperms
- Sampling replicated between ecologically diverse pairings and across great phylogenetic distances (gymnosperms and full range of angiosperm diversity)
- Reasonable to infer that a significant result using such a diverse sample base is indicative of a comprehensive genetic effect

Figure 12: Can the results be extrapolated to the whole genome?

Questions that evolutionary biologists might ask to challenge this result include: Can the result from just one piece of non-coding DNA be extrapolated to the whole genome? However in 2001 the evolutionary biologists, Tim Barraclough & Vincent Savolainen, found that rates of protein and morphological evolution correlate with rates of change for non-coding DNA in a large sample of angiosperms. Hence it is reasonable to infer that a significant result using such a diverse sample base is indicative of a comprehensive genetic effect.

Other work?

Population Size and Rate of Evolution

Birds on Islands

49 Pairs Contrasted with mtDNA

Insular Evolution Slower

Nearly Neutral Theory

Unconstrained = no effect

Constrained = small faster

Natural Selection

Big pop = more mutations = more
beneficial mutations = more fixation
+ve selection *and* more fixation by
hitch-hiking



Figure 13. Other work?

Following that result: What other work needed to be done? In fact, energy is only half the story. The other key question is this: How does the size of the population affect the rate of mutation? The size of a population should also have an effect on the rate of mutation because a larger population will capture more energy and therefore produce a greater total number of mutations – that is, it should have a faster rate of evolution. Without an understanding of this relationship only half the issue is being addressed. We have now completed a comparison of this relationship for birds, contrasting island forms (with small populations) to mainland forms (with large populations) to examine this relationship.

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